A Novel Approach Based on Staff Scheduling Optimization in Information Technology Projects

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Abstract

In an organization that develops Information Technology projects, often exists staff scheduling demands. In most of these organizations the resources are simultaneously shared between many projects. The organization has the responsibility of doing this optimized staff scheduling attending the projects demands. But, this is not a simple task to do and it turns more complex as the number of projects and professional increases. This paper proposes a mathematical programming model supported by multicriteria that will assist the Information Technology organization during the staff scheduling activity. The proposed model aims to optimize the demands of the professionals to the Information Technology projects.

Keywords:

*Linear Programming, Multicriteria, Project Management***.**

1. Introduction

In the development of Information Technology (IT) projects, there are a lot of difficulties involved. The biggest one is to identify all the resources that will be necessary to the project and select them in a way that they will be available to perform the projects activities [13]. The staff scheduling is, therefore, an important and complex activity, known as a non systematic process, since that is typically based on professional experience.

Considering that the staff scheduling represents a main factor for the IT projects success, it is important to choose the appropriate professionals to the projects so that they can achieve the desired levels of costs, time, and quality.

The linear programming models defined in Bazaraa [8] presents optimized solutions in the staff scheduling. Among the different applications of scheduling models, some works should be evidenced. Baker [3] developed an efficient technique (that is not based on integer linear programming), to determine the lowest number of workers considering that each worker has a two days rest.

The staff scheduling transformation into net flow problems was related in Bartholdi [7]. The knowledge acquisition in modeling a staff scheduling problem was presented by Lee [10]. Metaheuristics were applied to solve the scheduling problem in Brusco [9]. The use of interfaces in linear integer programming to spreadsheets, were presented by Asley [1] and finally, the solution of big scale problems involving multiple break windows were related in Aykin [2].

The multicriteria methodology takes in consideration the importance of subjectivity in a decision environment. In this case, the impossibility of exclude the subjective aspects like, values, culture, intuition, objectives and personal concepts is defended. According to Bana e Costa [4] the growth of multicriteria decision support methodology is related with the capacity of supplying subsidies to the group involved in the decision making process to obtain a better solution to the group needs.

Gilberto et. al [5]defends that the decision support provides a better understanding to the environment's manager, asserting that the proposed solution can be considered adequate inside the analyzed context.

In this context, this work presents a linear mathematical programming model that is supported by multicriteria that optimizes the staff scheduling in IT projects. Specifically, the model supplies the organization with a decision support mechanism that provides staff scheduling considering subjective criterias.

2. The Staff Scheduling Problem in Information Technology Projects

A lot of improvements have been identified with the objective of maximizing the IT projects success, but there is still a lot to be done to increase the number of successful projects, that is, conclude them in time, with the planned costs, with the desired functionalities and qualities.

The construction of the team that will compose the project involves that the needed human resources will be

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scheduled to the projects. The project has its team formed when the people are assigned to work on it. The scheduling can be realized in three different ways: full time, partial time, or variable, depending on the projects needs [11].

During the activity of staff scheduling some decisions need to be taken. According to PMBOK [11], the functional managers should assert that the project receives the appropriate people at the right time. For that, there is a need to find in the organization the professionals with the necessary knowledge and profile that are available, and finally, assign in the best way, the professionals to the projects that are being executed.

But this is not a simple task to do, once it is common to have a series of different scheduling possibilities. Besides that, not all the combinations turns possible that, for the higher number of projects, the professionals with the required profile and knowledge will be scheduled, minimizing the scheduling gaps inside the organization.

2.1. The Organizational Structures

The structure of the organization often restricts the availability or the conditions where the resources become available for the project, PMBOK [11].

In general, organizations use different structures. The main ones are:

• **Organization with functional structure:** each employee has a well defined superior, and the teams are organized by function (ex. finance, production, etc.) or by following the company's internal structures.

• **Organization by projects:** the company is organized into departments, each of which responds to a project manager. Some areas give support to all projects.

• **Organization Matrix:** a matrix structure is a combination of structures - functional and by projects. This can take on distinct characteristics that depend solely on the degree of importance that each end is considered. Can be divided into structural matrix weak, strong and balanced. The weak matrix structure maintains the functional manager to a higher level of authority seems to be more of a functional structure, the structure is seems very strong with a by projects and manager of projects has great authority, and can allocate resources to other areas or even hiring external resources to complete the project, and finally the structure balanced matrix represents a balance between the two extremes, the first functional and by projects.

Most modern companies involves all the organizational structures at the same time in their organization charts, having since sectors where the structure is fully functional even whole departments devoted entirely to the structure for projects, Vargas (2000). These structures are called composite structures, represented by Figure 1.

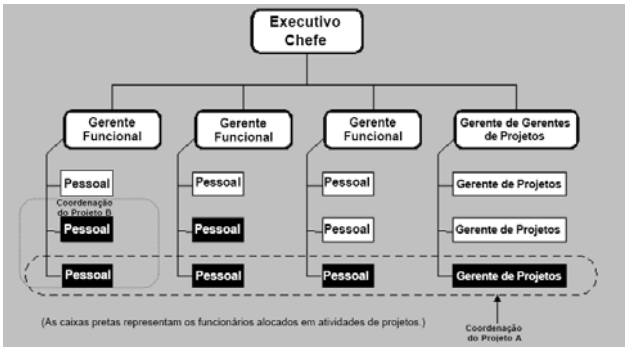

Figure 1 - Organization Structure With Composite, PMBOK [11]

In composite structures, the functional manager has the responsibility to meet the needs of the project indicating who will perform the service, performing that function, in that period and with what dedication.

3. The Information Technology Staff Scheduling Model

The proposed model has as objective to optimize the staff scheduling in IT projects. This scheduling can be realized in *m* projects, during *n* periods, with *q* professionals that can have *p* profiles. The model reaches the best composition of these professionals, attending the following restrictions:

a. **A professional can perform more than one profile**. As profile it is intended the functions that can be developed by a professional in an IT project. Some examples are: requirements analyst, project manager, software developer (coder) and tester.

b.**The professional can be scheduled only to the profiles that he can perform**. This restriction indicates the profiles that can be performed by a professional in a project. The profiles are defined according to the professional's knowledge, abilities and experiences.

c.**The professional can be scheduled to more than one project in the same period**. That means that a professional can integrate different projects at the same period.

d.**The maximal percentage of professional scheduling should not be higher than his weekly number of hours.** This restriction establishes that the professionals will not work more than the hours that he is assigned to work in the organization.

e.**The staff scheduling should attend the profiles demands of the projects**. The model proposed should consider the profiles needs defined for the projects in each scheduling period that is treated.

3.1. The model decision variables

The model decision variables represent the professionals combinations of scheduling in a project, performing a specific profile in the period established.

x_{ijkh} - the scheduling percentage, being the scheduling indexes:
i - project where the scheduling will be realized;
j - period (week) of the scheduling;
k - profile that will be performed by the professional;
h - professional that will be assigned.

In the objective function (1), each scheduling can have a higher weight in relation to the other (c_{ijkh}), that will be determined by a multicriteria approach, according to the scheduling priority of the professional to the project.

$$\text{Min} \quad \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \sum_{h \in H} c_{ijkh} x_{ijkh} \qquad (1)$$

c_{ijkh} - scheduling priority (defined by a multicriteria approach);
I = {1...m} the set of projects of the organization;
J = {1...n} the set of scheduling periods;
K = {1...p} the set of profiles that can be performed by the professionals;
H = {1...q} the set of organization's professionals.

It is considered that the professionals will only be scheduled to the profiles that they have competence to work, in more than one project (if necessary), not exceeding the time that he is suppose to work in the organization. The second restriction (2) is constituted by the possible staff scheduling to the profiles that they can perform in the different organization projects.

$$\sum_{i \in I} \sum_{k \in K_h} x_{ijkh} \leq a_h \qquad (2)$$

I = {1...m} the set of projects of the organization;
J = {1...n} the set of scheduling periods;
K_h - the set of profiles that can be performed by the professionals;
a_h - professionals availability according to the hours that he is assigned to work in the organization.
The scheduling demand of the professionals' profiles should be represented in the model by the third restriction (3).

$$\sum_{h \in H_k} x_{ijkh} \geq d_{ijk} \, (i \in I; j \in J; k \in K_h) \qquad (3)$$

d_{ijk} - the demand of profile k in the i project, and j period;
J - the set of scheduling periods;
$k \in K_h$ - the set of profiles that can be performed by a the professional h;
$h \in H_k$ - the set of professionals that can perform the profile k.

3.2. Defining the problem

In an institution that develops IT projects, there is a regular demand for allocation of professionals in its projects. The demands needs human resources for periods that are defined according to the projects plan[14].

The problem is determine the optimum allocation of staff considering demands for allocation of human resources for 3 (three) of software development projects running concurrently for 24 (twenty four) weeks, using 8 (eight) profiles to be attributed all or part of the 17 (seventeen) respecting the professional competence of each one doing the profile implementation.

The 8 (eight) profiles were defined according to the projects nature. As we are dealing with software development projects, the following profiles were found with their respective minimum allocations (Table 1).

Table 1 - Profiles professionals with their minimum allocations

Profile	Description	Minimum Allocation	
		%	Decimal
Project Manager (GP)	Responsible for planning and managing the project. PMBOK (2000)	25%	0,25
Requirements analyst (AR)	Responsible for leading and coordinating the achievement of the requirements and needs of the client, identifying features and limits of the system. RUP (2000)	25%	0,25
Designer (PROJ)	Responsible for modeling, responsibilities, operations, attributes and relationships between one or more components of software and determine how they should be implemented in the environment . RUP (2000)	25%	0,25
Encoder (COD)	Responsible for implementing and testing the components in accordance with the standards defined in the project, and integrate it into larger subsystems. RUP (2000)	50%	0,50
Tester (TS)	Responsible for planning, design, implementation and evaluation of tests, including the generation of test plan and model, implementing procedures for testing and evaluating the scope of testing, results and effectiveness.	10%	0,10
Graphic Designer (DG)	Responsible for designing the graphical interface of the products developed in the projects.	25%	0,25
Quality Engineer (EQ)	Responsible for ensuring compliance of the activities and artifacts with quality standards established by the organization. PROSCES (2002)	10%	0,10
Configuration Engineer (EC)	Responsible for controlling versions and track the updates of the project artifacts. PROSCES (2002)	10%	0,1

Table 2 - Mapping of professionals and their skills

Professionals	Abilities - Profile								Availability	
	GP	AR	PROJ	COD	TS	DG	EC	EQ	Carga horária semanal	Maximum Allocation
Professional 1	X								40 hours	100%
Professional 2	X								40 hours	100%
Professional 3		X							40 hours	100%
Professional 4		X							30 hours	75%
Professional 5		X		X					40 hours	100%
Professional 6			X						30 hours	75%
Professional 7		X	X	X					40 hours	100%
Professional 8		X	X	X					40 hours	100%
Professional 9		X	X						40 hours	100%
Professional 10				X					40 hours	100,00%
Professional 11			X	X					20 hours	50,00%
Professional 12			X	X					20 hours	50%
Professional 13								X	40 hours	100%
Professional 14							X		40 hours	100%
Professional 15					X			X	40 hours	100%
Professional 16					X	X			40 hours	100%
Professional 17						X			40 hours	100%

Table 2 shows the 17 (seventeen) who may be assigned to 3 (three) projects, indicating for each one the profiles that can be exercised (his abilities) and its maximum allocation (in 1 or more projects) of according to their hours of work weekly. It is important to note that the weekly working hours to 40 hours represents 100% of the maximum allocation. Load-time lower and higher were calculated proportionately.

The demands for allocation of human resources were developed from the planning of the activities of 3 (three) projects of software development. For each week the project was given the percentage of each profile that is required according to schedule of project activities.

Table 3 - Demand Project (first 12 weeks)

Projeto 1												
Perfil	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
GP	0,75	0,75	0,75	0,75	0,75	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,25	0,25	0,25
PROJ			1	1	1	1	1	1	1	0,5	0,5	0,5
COD				1	1	2	2	2	2	2	2	2
TS								1	1	1	1	1
EC			0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,25	0,25	0,25
EQ	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
DG			0,25	0,25	0,25	0,25		0,25	0,25	0,25	0,25	
Projeto 2												
Perfil	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
GP	0,75	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	2	2	2	2	2	2	2	2	2	2	2	2
PROJ	1	1	1	1	1	1	1	1	1	1	1	1
COD				1	1	1	1	2	2	2	2	2
TS								1	1	1	1	1
EC			0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,25	0,25	0,25
EQ	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
DG			0,25	0,25	0,25	0,25		0,25	0,25	0,25	0,25	
Projeto 3												
Perfil	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
GP	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	2	2	2	2	2	2	2	2	2	2	2	2
PROJ			1	1	1	1	1	1	1	1	1	1
COD			2	2	4	4	4	4	2	2	2	2
TS					2	2	2	2	1	1	1	1
EC	0,1	0,1	0,1	0,1	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
EQ	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
DG			0,5	0,5	0,5	0,5	0,25	0,25	0,25	0,25	0,25	0,25

Table 4 - Demands of the projects (last 12 weeks)

Projeto 1												
Perfil	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**
GP	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	0,25	0,25	0,25	0,25	0,25	0,25	0,5	0,35	0,35	0,35	0,3	0,3
PROJ	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5				
COD	2	2	2	2	2	2	1	1	1	1	1	1
TS	1	1	1	1	1	1	1	1	1	1	1	1
EC					0,25	0,25	0,25	0,25	0,25	0,25	0,5	0,5
EQ	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
DG			0,25	0,25	0,25	0,25			0,25	0,25		

Projeto 2												
Perfil	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**
GP	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	2	2	1	1	1	1	1	1	1	1	1	1
PROJ	1	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
COD	2	3	3	3	3	4	4	4	4	2	2	1
TS	1	1	1	1	2	2	2	2	2	1	1	1
EC	0,1	0,1	0,1	0,1	0,25	0,25	0,25	0,25	0,25	0,25	0,5	0,5
EQ	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
DG			0,25	0,25	0,25	0,25			0,25	0,25		
Projeto 3												
Perfil	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**
GP	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
AR	2	2	2	2	2	2	2	2	2	2	2	2
PROJ	1	1	1	1	1	1	1	0,5	0,5	0,5	0,5	0,5
COD	4	4	4	4	3	3	3	2	2	2	1	1
TS	2	2	2	2	1,5	1,5	1,5	1	1	1	1	1
EC	0,25	0,25	0,25	0,25	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1
EQ	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
DG	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25		

3.3. Criterias definition

To define the scheduling priority in the project it was used a multicriteria methodology, enclosing the evaluation phase, that is composed by three activities: (i) construction of a qualitative model of values; (ii) options evaluation, that consists in the application of the model for a particular set of options; and (iii) sensitive analysis, that tries to adequate the solution provided by the model.

The criterias that have influence in the staff scheduling choice to the TI projects were defined according to the authors work experience in the development of software projects. These criterias (Table 5) represent the factors that frequently are evaluated when the manager needs to choose what professionals will perform what activities in a specific period.

Criteria	***Description***
Technological Knowledge (CT)	Represents the professional's technological knowledge, including the knowledge over the tools, methodologies and the certifications obtained.
Experience (EXP)	Represents the professional experience in IT projects, including: time of work, participation in similar projects, which takes into account the professional's experience in a certain application domain.
Academic Formation (FAC)	It encloses the professional´s scholarship level, number of publications, complementary courses, knowledge over exchange languages.
Cost (R$)	Represents the direct and indirect professional´s cost to the organization.

Table 5- Criterias to the professional scheduling on IT projects

To assist the criterias analysis, it was defined a scale (Table 6) that classifies the professionals according to their abilities, knowledge and competences.

4. Model Application

4.1. Study of case

The implemented study of case considers the scheduling demands of human resources for three software development projects (Table 7) that are being developed at the same time, using eight profiles that are partially or totally assigned to the seventeen professionals, respecting their competences to assume a profile.

Table 6 - Criterias scale

Criteria	*Scale*	*Description*
Technological Knowledge (CT)	Excellent	High knowledge over all the evaluated items.
	Good	High knowledge over a few evaluated items.
	Regular	Domain over one evaluated item.
	Low	Knows superficially the evaluated items.
Experience (EXP)	Excellent	More than 10 years
	Good	Between 5 and 10 years.
	Regular	Between 2 and 5 years.
	Low	Less than 2 years.
Academic Formation (FAC)	Excellent	Scholarship level ≥ Master of Science, more than 5 publications, complementary courses and fluency in English.
	Good	Scholarship level ≥ Specialist, with or without publications, complementary concluded courses and domain over the English language.
	Regular	Scholarship level ≥ Graduation, with or without publications, complementary concluded courses and domain over the English language.
	Low	Scholarship level = Graduating, with or without publications, complementary concluded or not concluded courses , and domain over the English language.
Cost (R$)	High	Senior
	Medium	Intermediate
	Low	Junior

As we are treating of software development projects, the profiles considered in the study of case were: software manager, requirements analyst, software architect, software developer (coder), tester, graphical designer, quality engineer, and configuration manager.

The staff scheduling demands were elaborated during the planning activities of the three projects. For each week of the project it was indicated a percentage of each professional profile that is required according to the project's activities.

Table 7 – Projects Characteristics

Project	*Characteristic*
Project 1 (P1)	Research project with a few budget restrictions.
Project 2 (P2)	Commercial project with medium budget restrictions
Project 3 (P3)	Commercial project with high budget restrictions

4.2. Appling Multicriteria

In face of the original problem extension, the scope defined to the multicriteria use in the proposed model was restrict to determine the professional's scheduling priority to the project. The application of multicriteria combined the three projects (characterized in the study of case), associated with two professionals that can perform the project manager profile.

Using real curriculum evaluation, some values were obtained for each one of the criterias associated to the professionals, like it is identified on Table 4.

Table 8 – Professionals Evaluation

Critéria	*Professional 1*	*Professional 2*
Technological Knowledge (CT)	Excellent	Good
Experience (EXP)	Good	Regular
Academic Formation (FAC)	Good	Excellent
Cost (R$)	High	Médium

4.2.1. Using M-MACBETH approach

To help the judgment, it was applied the M-MACBETH for MCDA*[6] approach. Initially it was constructed a tree that contains a subset of all the combinations between the projects and the professionals. For all the combinations it were assigned the criterias defined in Table 1 (Fundamental Point of View – FPV). The subset of combinations corresponds to the relation between the three projects and two professionals that responds to the project manager profile. The Figure 1 presents the tree that corresponds to the prioritization objectives of the two professionals to the three projects.

The judgment of the criterias by project/professional considered the characteristic of the three projects (Table 3) as the evaluation of each one of the professionals to the criterias. (Table 8).

The priorities of the professionals scheduling to the projects were evaluated to each one of the defined objectives (criterias). It is important to point out that the indicators were related in pairs for each criteria, like it is shown, in one of these analysis, on Figure 2.

Figure 3 shows the final result obtained from the applications of the M-MACBETH approach.

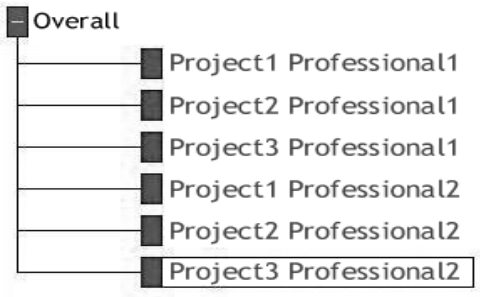

Figure 1 – Problem's value tree

Project1 Professional1

	upper	CT	EXP	FAC	R$	lower	Current scale
upper	no	positive	positive	positive	positive	positive	100.00
CT		no	mod-strg	moderate	weak-mod	positive	90.91
EXP			no	weak-mod	weak	positive	45.45
FAC				no	weak	positive	27.27
R$					no	positive	9.09
lower						no	0.00

extreme
v. strong
strong
moderate
weak
v. weak
no

Consistent judgements

Figure 2 – Judgment of the criterias in the scheduling prioritization of Professional 1 to the Project 1.

Table of Scores

Options	Overall	P1PM1	P2PM1	P3PM1	P1PM2	P2PM2	P3PM2
CT	85.25	90.91	87.50	60.00	90.91	90.91	46.15
EXP	53.77	45.45	62.50	30.00	63.64	63.64	23.08
FAC	21.49	27.27	12.50	10.00	36.36	9.09	7.69
R$	31.10	9.09	37.50	90.00	9.09	36.36	92.31
[all upper]	100.00	100.00	100.00	100.00	100.00	100.00	100.00
[all lower]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scaling constants		0.2353	0.1568	0.1373	0.2745	0.1765	0.0196

Figure 3 – Final judgment of scheduling prioritization of the Professionals to the Projects.

4.3. Computational Results

It was elaborated a linear programming model as defined in section 3. The model constructed was executed applying the data of the scheduling professional demands with LINDO, of LINDO Systems [12] in two in two distinct phases.

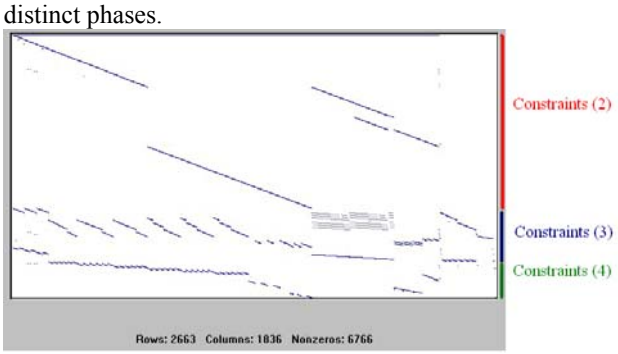

Figure 4 - Matrix of constraints generated by LINDO

At the first phase, the weights considered in the objective function were equals to one, allowing the model to take the scheduling decision. In this experiment, it was obtained a viable to the scheduling of the seventeen professionals to the three projects. However, the scheduling proposed by the model was done randomly and far away from an ideal situation, once the model takes in consideration only the mathematical restrictions, without counting with any subjective criterias that would influence the scheduling decision. Figure 5 shows the graphics of the scheduling of the two project managers to one project using only the mathematical model.

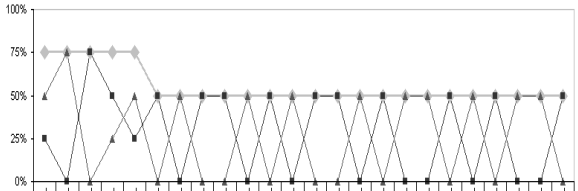

Figure 5 – Results of the project manager scheduling to the first project using only the mathematical model.

At the second phase, it were reflected the subjective concepts that are applied in practice by the organizations. The weights were defined based on the scale table of the final professional's prioritization scheduling (Figure 3). Figure 6 shows the results reached with this experiment.

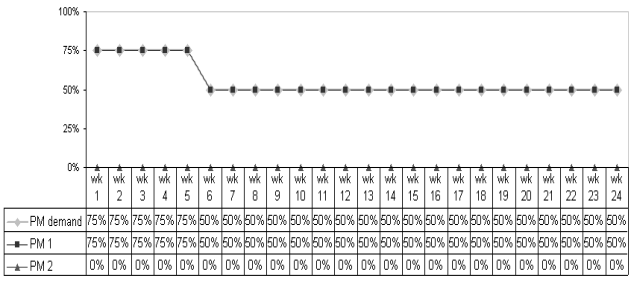

Figure 6 - Results of the project manager scheduling to the first project using the combination of mathematical model with a multicriteria approach.

Using the graphics to evaluate the results, it can be observed the clear scheduling difference between the two approaches. The usage of weights, defined by a multicriteria approach, in the objective function turns the scheduling process closer to the ideal, helping managers in an effective way during the professional's scheduling in IT projects.

5. Final Considerations

With the model application in the professional's scheduling planning, the distribution of professionals can be optimized and the time of idleness can be minimized, maximizing the attendance of the objectives and restrictions proposed. At this form, the conventional methods that are based on the professional experience were substituted to the use of formal explicit models.

The multicriteria application using M-MACBETH approach allowed the establishment of differential prioritization to the professional's scheduling, providing compatible results with ideal situations in IT project scheduling.

As a future work perspective, it is intended to develop a decision support system tool that contains a friendly interface, facilitating the model application for professionals who have less experience in optimization.

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