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Project portfolio management considering the commitment of agents: a bi-objective model applied to administrative services

Jorge Noro[1,2], Luís C. Dias[1]

1 - University of Coimbra, Centre for Business and Economics Research (CeBER), Faculty of Economics, Portugal

2 - University of Coimbra, Institute for Interdisciplinary Research, Portugal

Abstract

This article presents a new bi-objective optimization model for project portfolio management. The model formulation selects which projects will be implemented and by whom. The objective functions seek to maximize the economic gains of the project portfolio selected and to maximize the skills development of the agents allocated to these projects, thus promoting the improvement of the team's performance over time. The constraints to the choice and allocation of projects take into account the workload of the agents and the way the distribution of work affects their employment commitment, considering the dimensions of Absorption, Dedication and Strength of the UWES (Utrecht Work Engagement Scale), in its reduced form. Experimental results are presented, for a scenario based on the experience of administration offices for the management of research and innovation projects at a higher education institution.

Key words: project portfolio management, work engagement, agent commitment, multi-objective optimization, project allocation

1. Introduction

In a socio-economic context of regulatory uncertainty, increasing competitiveness and rapid cyclical changes, public institutions face structural challenges impacting their mission and organization. In the case of Portuguese public Higher Education Institutions (HEIs), strategies and organizational design for the enhancement of their operation and the optimization of their institutional performance result from the decisions of different entities, and Decision Makers (DMs) are often limited by budget constraints and lack of capable human resources. This hinders the management results of organizations, in the economic-financial, teaching, research and knowledge transfer domains. These restrictions can also hinder the individual progress of its agents, the reinforcement of knowledge and the professional experience of its teams. Thus, the adoption of good practices and continuous improvement measures are needed for the development and affirmation of the organization. In HEIs, these goals are often pursued through project-based management (Mano & Marques, 2012) and engagement strategies.

The use of mathematical programming in portfolio management has received increasing attention. Several decision support models have been proposed for dealing with conflicting objectives, as usually occurs when maximizing both the (financial) value of the organization's project portfolio and other less tangible benefits, such as recognizing or increasing the skills of staff members (Chen et al., 2017; Gutjahr et al., 2008, 2010; Stummer et al., 2009). In addition to conventional components of uncertainty and risk or financial gains, the consideration of other dimensions can promote solutions that promote collaboration, the development of skills of the staff, their professional satisfaction and fulfilment or the reinforcement of the teams' commitment to the organization (Barbati et al., 2018; Gutjahr et al., 2008, 2010; Jeng & Huang, 2015; Liesio, 2008; Tervonen et al., 2017; Vilkkumaa et al., 2014). However, to our knowledge, the possibility of considering the dimensions of Vigour, Absorption and Dedication, which support the agents' commitment to the service, as has been tested in multiple surveys, according to UWES - Utrecht Work Engagement Scale (Attridge, 2009; Bakker et al., 2008), has not been exploited so far.

This work integrates new restrictions based on work engagement theory to obtain Pareto efficient solutions for the problem of choosing which projects to implement and who will be assigned to them. Formulating this as a bi-objective optimization problem allows DMs to choose a compromise in-between the maximum financial value that results from the execution of the projects in the portfolio and the maximum potential development of skills of its staff, examining the available trade-offs.

This study contributes to the literature on project portfolio management, by introducing a decision model to apply as a decision support tool when allocating new projects to a team, based on well-established concepts from Industrial-Organizational Psychology. The model allows DMs to consider the development of employees' skills and their commitment to the service, while maximizing gains from implementing new projects. The benefits obtained from implementing a portfolio of projects, distributed by a team, include the increase of individual and global performances, while ensuring the employees' commitment to the service, which can, thus, extend the global service capacity. This study was motivated by its application in national public entities, particularly in HEIs, where project-based management and strategic planning for human resources play a critical role, but the field of potential applications is broader.

This article is structured as follows. After this introduction, section 2 focuses on previous approaches in the literature, listing the main groups related to the topic. In section 3, the mathematical model formulation is provided. Sections 4 and 5, respectively, present an illustrative case based on the experience of a HEI and its results. Section 6 gathers the main conclusions that arise from the discussion, including next steps and further research.

2. Previous Approaches

Among other classifications (e.g., (Saiz et al., 2021)), the literature on portfolio management can be organized according to the following groups:

a) Financial portfolio management, addressing the choice of financial assets or investment projects considering their returns and risks. Examples in this group include investment portfolio selection and management (Reilly & Brown, 2011) attending to the portfolio management foundations and alternative risk measures (mean-variance) (Henriques & Neves, 2019; Markowitz, 1952, 1990, 2014). Besides financial aspects, this type of problems may also incorporate criteria that reflect social responsibility and sustainability aspects (Bilbao-Terol et al., 2016, 2018; Dobrovolskien & Tamo, 2016) or other criteria (Aouni et al., 2018).

b) Multicriteria resource allocation problems and portfolio decision analysis, dealing with the choice of projects to be implemented, usually under a budget constraint. The benefits of implementing each project are assessed by a multicriteria aggregation model, typically a multiattribute value function (Salo et al., 2011b). As such, these models usually incorporate other evaluation criteria besides financial gain and financial risk. Examples in this group include: multicriteria decision support systems for portfolio robustness evaluation (Lourenço et al., 2012); models to support the selection of a portfolio of stocks (Bana-e-Costa & Soares, 2006; Phillips & Bana-e-Costa, 2007); Bayesian modelling of uncertainties to increase the expected future value of the selected portfolio, raise the expected number of selected actions that belong to the optimal portfolio and eliminate the expected gap between the realized ex post portfolio value and the estimated ex-ante portfolio value (Salo et al., 2011a; Vilkkumaa et al., 2015; Vilkkumaa, Liesiö, et al., 2014) and other models combining strategies to tackle uncertainty on R&D project portfolio selection (Jeng & Huang, 2015; Mavrotas & Makryvelios, 2021). These methods are surveyed by (Morton et al., 2016) and (Liesiö et al., 2021).

c) Portfolio assignment problems in which DMs need to decide not only which projects will be implemented, but also who will be assigned to their implementation. This line of research proposes multicriteria decision support system models based on competence-driven project portfolio selection, scheduling and staffing (Chen et al., 2017, 2020; Gutjahr, 2015; Gutjahr et al., 2008, 2010; Gutjahr & Froeschl, 2013; Stummer et al., 2009; Xu et al., 2017; Zaraket et al., 2014).

d) Models for project portfolio selection and scheduling with multiple time periods, allowing project to be interrupted (Tian et al., 2016), time profile factors and other constraints (Li et al., 2015, 2016; RezaHoseini et al., 2020).

e) Multi-criteria evaluation of projects not based on mathematical programming, e.g., decision support tools for collaborative group decision making (Costa et al., 2003)

The present work belongs to group c), combining the selection of projects with their assignment to the agents who will implement them. This group is related to a rich literature on the problem of project staffing and scheduling, see e.g., the review by (De Bruecker et al., 2015). These works consider a set of projects that must be carried out and define who will implement these projects and when. Some of the works on staffing and scheduling allow modelling the skills improvement by carrying out some tasks, as well as the skills deterioration when staff are idle (a recent example is Chen et al., 2020). The work of Gutjahr and coauthors (Gutjahr et al., 2008, 2010, 2015) is closer to portfolio management since it considers as well the selection of which projects will be implemented. In those works, skills increase linearly with time working on related tasks, and decay while idle. Gutjahr et al., (2008) considered a weighted sum of two objectives (economic gain and gain from increased competencies), with weights defined a priori; later Gutjahr et al. (2010) revisited this problem as a bi-objective problem, using a population-based genetic algorithm to approximate the set of Pareto optimal solutions that a DM can choose from. An interactive decision support system has also been developed for that model (Stummer et al., 2009), as well as extensions considering stochastic uncertainty (Gutjahr & Froeschl, 2013). Zaraket et al. (2014) also address project selection under a skills-based framework, formulated as a single-objective problem (maximize profit) and considering skills in the constrains. This group also includes the work of Xu et al. (2017), which combines the project portfolio selection with staff assignment. It does not address skills learning or decay, as it focuses on in dealing with uncertainty, under a fuzzy modelling framework. Another quite different approach can be found in the work of (Brummer et al., 2011), who describe a portfolio decision analysis that takes into account the agents implementing the projects not in terms of their skills, but in terms of their stated interests.

Similarly to other methods in group c) the current work considers simultaneously the problem of project selection and staff assignment. Moreover, it assumes that the implementation of the project is affected by the skills of who implements it, and that the implementing agent improves with experience. Unlike previous work, this work assumes multiple factors concerning the dependence between the allocation of projects and the performance of the agents, grounded on the theory of work engagement. According to (Attridge, 2009), high levels of work engagement exist when employees are involved with, committed to, enthusiastic, and passionate about their work. This provides desired levels of agents' commitment with the organization, through their satisfaction and self-fulfilment. Also, this theory, linked to occupational health Psychology (Bakker et al., 2008), contributes to estimate the costs of disengagement and the business benefits linked to positive engagement. The literature also indicates that work engagement can be improved through adopting certain workplace behavioural health practices that address supervisory communication, job design, resource support, working conditions, corporate culture, and leadership style. Several case studies provide accounts of employers who measured and used employee engagement data to improve their work culture, retain employees, and increase business financial success, focusing on three dimensions: Vigour, Absorption and Dedication (Schaufeli et al., 2006).

In this review of operations research and decision analysis literature, no studies were identified where the management of project portfolios considered work engagement.

Compared to previous literature on project portfolio management decision analysis, briefly reviewed here, the present work innovates mainly by considering the behavioural construct of work engagement. It recognizes that workload and skills development are not only important per se, but also in the way they interact with other aspects within this construct. According to this model, the assignment of projects of different complexity levels and to different agents allows reaching a balance between solutions for maximum profit and those that promote maximum team development, in a way that does not jeopardise work engagement.

3. Model

This section presents the mathematical formulation of the model to decide which projects should be implemented and who should manage these projects. A set of binary variables (y_j) represents whether a project will be implemented, assuming that not all projects need to be implemented. The chosen projects will be implemented and managed by a single staff member – the agent. A set of binary variables (y_{ij}) represents whether agent i is assigned to manage project j. The set of projects chosen, together with ongoing projects (chosen in an earlier period) become the organization's portfolio for the subsequent period. The current model does not allow ongoing projects to be cancelled to free up resources, or to reassign ongoing projects to a different agent, although the model formulation can easily be changed to drop these assumptions.

The proposed model introduces new restrictions and follows other models that are competence-driven, seeking compromises between potentially competing goals: the value of the project portfolio and the value that results from the individual development of skills. The model is therefore a bi-objective mathematical program. The skills entry values (before new projects allocation) are considered when assigning new projects to an agent, and can be developed by executing such new projects, contributing in this way to increase the work capacity and the team's overall performance in later periods. The distribution of new projects also considers the previous portfolio and the workload limits, in hours, which reflects the agent's effort. Work engagement will be considered in the form of constraints, by defining a limit for the disengagement of each agent in the organization.

The following assumptions and parameters were defined for the model:

i) the team (staff) is composed of a certain number of agents, given by n_s, who manage projects in a given service;

ii) before the decision/ allocation moment, the staff already has a portfolio with a number of ongoing projects given by n_o;

iii) n_a available new projects can be added to the portfolio, and therefore the maximum number of projects to be carried out during the next planning period is $n_p = n_o + n_a$;

iv) not all the n_a potential new projects need to be allocated, i.e., some projects may not be chosen at present;

v) no project is assigned to more than one agent;

vi) each agent can receive multiple projects;

vii) each agent has the capacity and skills, although differentiated, to manage any of the potential new projects to be distributed.

Before presenting the mathematical programming formulation in Section 3.2, the following section explains how the concepts of workload, engagement and skills development were modelled. For convenience, the notation is summarized in Table 1.

[Table 1 – Notation]

3.1 Workload, engagement, and skills development

In this article, workload is represented by the time that each agent is expected to dedicate to a specific project, in hours per period (typically, hours per week). These hours are estimated considering the categorization of projects by levels of difficulty, the corresponding volume of budget to be executed, and the previous professional experience or the knowledge of each agent, for these projects. A maximum workload (capacity) is considered for each agent, which should be set respecting labour regulations and specific conditions of the organization, such as working in shifts or overtime.

For the agents' commitment, the metric published by Utrecht for Work Engagement (Attridge, 2009; Schaufeli et al., 2006) was considered, which in the short version results from the answer to nine key questions, concerning the Vigour, Absorption and Dedication dimension on a 0-6 scale:

Vigour (VI) | Work capacity, mostly physical availability

VI1 – At my work, I feel bursting with energy.

VI2 – At my job, I feel strong and vigorous.

VI3 – When I get up in the morning, I feel like going to work.

Absorption (AB) | Ability to concentrate and feel happy at work

AB3 – I feel happy when I am working intensely.

AB4 – I am immersed in my work.

AB5 – I get carried away when I am working.

Dedication (DE) | (Strong) commitment to tasks, feeling they are relevant and useful

DE2 – I am enthusiastic about my job.

DE3 – My job inspires me.

DE4 – I am proud of the work that I do.

Work engagement, modelled as an average of these three dimensions, is therefore a rich construct that can be affected by the set of projects assigned to an agent. On the one hand, to be engaged, an agent should not be working too much, because of the Vigour dimension. On the other hand, to be engaged, an agent needs new and more challenging projects, and needs to feel he or she is evolving, due to the Absorption and Dedication dimensions. Limit values for the lack of engagement of the agents need to be set, and can be relaxed, or tightened, depending on the understanding of the DMs.

3.2 Mathematical programming formulation

The objectives are to maximize the value of a portfolio composed of potential new projects and projects already underway, while maximizing the development of individual skills. The latter also operates as a recognition, meeting the agent's potential, and preventing the departure of staff due to dissatisfaction or disinterest, i.e., Work Disengagement.

The initial portfolio consists of n_o ongoing projects. The final portfolio, after adding the new projects to be distributed, has a maximum number of projects given by n_p.

Decision variables

Let $y_{ij} \in \{0, 1\}$ be a binary variable indicating whether project *j* is implemented by agent *i*. It is a constant in the range j=1, …, n_o and a decision variable in the range: j = n_{o+1}, …, n_p.

Let $y_j = \sum_{j=1}^{n_p} y_{ij}$ indicate, for each project *j*, whether it is implemented ($y_j = 1$) or not ($y_j = 0$).

Objective functions

The value of the selected portfolio is the sum of the value attributed to each project included in it:

(1) $\sum_{j=1}^{n_p} V_j * y_j \rightarrow max$ *(Objective function #1 | Portfolio value)*

where,

V_j is the value of the project *j* to the organization.

It should be noted that

(2) $$\sum_{j=1}^{n_p} V_j * y_j = \sum_{j=1}^{n_o} V_j * y_j + \sum_{j=n_{a+1}}^{n_p} V_j * y_j,$$

where $\sum_{j=1}^{n_o} V_j * y_j$ is a constant value, regarding ongoing projects, whereas $\sum_{j=n_{o+1}}^{n_p} V_j * y_j$ results from the potential allocation of new projects.

The value for skills development results from the realization of each project and the related requirement levels:

(3) $\sum_{j=1}^{n_p} DC_j \rightarrow \max$ *(Objective function* #2 | *Skills Development)*

With DC_j given by:

(4) $$DC_j = \sum_{i=1}^{n_s} DC_{ij} * y_{ij}, \forall j \in \{1, \dots, n_p\}$$

The second objective function relies on the contribution of each project, j, assigned to agent i for his/her skills development, DC_{ij}, that in turn considers different requirement levels:

(5) $$DC_{ij} = \left(1 - C_{ij}^s\right) * L_j$$

where,

C_{ij}^{s} is the starting/entry (before new assignment) skills of agent i to manage project j

L_j is the requirement level of project j

Skills development for a given project, DC_{ij}, depends on the input value for the skills of each agent for the respective project, C_{ij}^{s}. Thus, the model allows a wide range of input values for skills, based on real values that can be collected through different methodologies, beyond those theoretically estimated. DC_{ij} then corresponds to an estimate of what would be the increase in the skills of agent i (expectation of progress) for carrying out project j. As an example, suggested values of starting skills, C_{ij}^{s}, considering training and experience profiles are provided in Table 2.

[Table 2 – Starting Skills considering training and experience profiles]

The requirement level of a project, L_j, considers the project budget, B_j, project type, TP_j and the organization's experience in carrying out related projects, XP_j. The different projects requirement levels ranges $L_j \in [0, 1]$ can be set as follows:

(6) $$L_j = \frac{B_j + TP_j - XP_j + 1}{3}$$

The budget's contribution, B_j, to the calculation of the project's requirement level is a score in the range [0, 1], such that 1 corresponds to projects with the highest budget and 0 corresponds to projects with the lowest budget.

The contribution of the type of project, TP_j, to the calculation of the project's requirement level is a score in the range [0, 1], such that 1 corresponds to projects with the highest complexity and 0 corresponds to projects with the lowest complexity.

Finally, the contribution of experience in carrying out related projects, XP_j, for the calculation of the level of demand is also a score in the range [0, 1], being 0 if less than a determined minimum number of projects was carried out, being 1 if more than a determined number in a set of projects were successfully managed before, and having intermediate values in between. This appears with a negative sign on equation (6) because the fewer the projects of the same type the organization has successfully managed, the more difficult it is for agents to have access to manuals and support to perform them.

Constraints

The objective functions maximization is subject to restrictions (7) to (10):

(7) $$\sum_{j=1}^{n_p} a_{ij} * y_{ij} \leq k_i \text{ , } \forall\ i \in \{1, \dots, n_s\}$$ | Work Capacity

where,

k_i is the upper limit of working hours per period for agent i.

a_{ij} is the time per period that agent i will consume, given its own skills, while managing project j. The parameter a_{ij} considers its own (starting) skills C_{ij}^s and the time per period required, T_j, according to requirement level of that project, L_j,

(8) $$WD_i^1 \leq MD_i,\ \forall\ i \in \{1, \dots, n_s\}$$ | Bounds concerning the agents' commitment to service

where,

MD_i represents the maximum Work Disengagement tolerated by agent i. If exceeded, the agent is likely to leave the organization. Work Disengagement, WD_i, results from the impact of the projects allocated to the agent, in light of the UWES dimensions of Vigour

(VI), Absorption (AB) and Dedication (DE). WD_i values result from the values assigned to these dimensions for each agent, considering the previous portfolio (ongoing projects) and the allocation of new projects to each agent's portfolio. To represent these different periods, before and after the allocation of new projects, WD_i^t was set, with index t representing each moment (t = 0, before allocation; t =1 after allocation).

The work disengagement, WD_i^t, corresponding to a lower individual commitment, is the difference to a full commitment. This commitment value, WE_i^t, is the work engagement value of each agent, i, to the organization. WE_i^t is determined by the average value of Vigour (VI_i^t), Absorption (AB_i^t) and Dedication (DE_i^t) dimensions. The initial values (VI_i^0, AB_i^0, DE_i^0) attend to the scale ([0, 6]) provided in the literature and the values after allocation (VI_i^1, AB_i^1, DE_i^1) are determined as a variable percentage of the former. These percentage values (k_{VI}, k_{AB}, k_{DE}) can be set by the DMs, one per dimension (VI, AB, DE). For each dimension (VI, AB, DE) a specific formulation was set considering dimension related issues and projects assigned y_{ij}, resulting in: $VI_i^1 = VI_i^0 * (1 - k_{VI} * \sum_{j=1}^{n_p} y_{ij})$ for Vigour, $AB_i^1 = AB_i^0 * \left(1 - k_{AB} * \sum_{j=1}^{n_p} y_{ij} + k_{AB} * \sum_{j=1}^{n_p} DC_{ij}\right)$ for Absorption, and $DE_i^1 = DE_i^0 * \left(1 - k_{DE} * \sum_{j=1}^{n_p} y_{ij} + k_{DE} * \sum_{j=1}^{n_p} L_j * (1 - C_{ij}^s)\right)$ for Dedication. The final value of Work Disengagement of each agent, WD_i^1, can now be set by the difference to full commitment, given by $WD_i^1 = 1 - WE_i^1$, where $WE_i^1 = \frac{VI_i^1 + AB_i^1 + DE_i^1}{3}$, as summarised in Table 3.

[Table 3 – Work Disengagement]

The decision variables, y_{ij}, are restricted to be binary (a project is completely executed or not executed):

(9) $$y_{ij} \in \{0, 1\}$$

Each project is allocated to at most one agent:

(10) $y_j \leq 1$

In summary, the 0-1 linear programming formulation is:

<u>Decision variables</u>

y_{ij} defines whether project j is assigned to agent i

y_j defines whether project j is implemented

<u>Objective functions</u>

$$f_1 = \sum_{\mathrm{j}=1}^{n_p} V_j * y_j \rightarrow max$$

$$f_2 = \sum_{\mathrm{j}=1}^{n_p} \mathrm{DCj} \rightarrow \mathrm{max}$$

<u>Constraints</u>

$\sum_{j=1}^{n_p} a_{ij} * y_{ij} \leq k_i$, $\forall\ i$ (availability of staff members in hours/period)

$$\mathrm{W}D_i^1 = 1 - \frac{VI_i^0 * \left(1 - k_{VI} * \sum_{\mathrm{j}=1}^{np} y_{ij}\right) + AB_i^0 * \left(1 - k_{AB} * \sum_{\mathrm{j}=1}^{np} y_{ij} + k_{AB} * \sum_{\mathrm{j}=1}^{np} DC_{ij}\right) + DE_i^0 * \left(1 - k_{DE} * \sum_{\mathrm{j}=1}^{np} y_{ij} + k_{DE} * \sum_{\mathrm{j}=1}^{np} L_j * \left(1 - C_{ij}^s\right)\right)}{3} \leq$$

MD_i, $\forall\ i$ (maximum disengagement)

$y_j = \sum_{i=1}^{n_s} y_{ij} \leq 1, \forall\ j$ (each project is allocated to at most one agent)

$y_{ij} \in \{0, 1\}\ \forall\ i, j$

The complete set of efficient solutions was obtained using the ε-constraint method (Mavrotas, 2009), due to its ability to find non-supported non-dominated solutions. The Pareto optimal (or efficient, non-dominated, non-inferior) solutions are the solutions that cannot be improved in one objective function without deteriorating their performance in at least one of the rest. In the ε-constraint method, one of the objective functions is optimized using the other objective functions as a constraint requiring a given level, e.g., in bi-objective problems, maximizing f_1 subject to $f_2 \geq l_2$. To verify the solution that maximizes f_1 subject to $f_2 \geq l_2$ is Pareto optimal, the roles of the objectives can be reversed maximizing f_2 subject to obtaining the maximum previously found for f_1. The set of the Pareto optimal solutions is the Pareto set.

4. Application in the context of a Higher Education Institution

This model aims to respond to the needs of organizations, in different contexts, namely, for application in project management offices, such as the Projects and Activities Division of the Research Promotion and Management Service, of the Administration of the University of Coimbra (UC) in Portugal, whose reality provided the basis for some assumptions, estimates and categorizations of the present work.

UC is one of the oldest European universities, encompassing units for Teaching, Research and Cultural Extension, as well as different Administration services. The latter include a Project Management Office, staffed with a team of project managers, coordinated by a Head of Division. In services and divisions such as this, from the UC Research and Promotion and Support Service, as well as within the 40 Research and Development Units that make up the UC Group, daily challenges arise in the scope of project portfolio management (including staffing), who need different answers, such as those presented in this work. For this work, the input values (e.g. VI, AB, DE) are based on internal professional experience in the direction of project management offices of the first author.

The model was tested by studying a case (Base Case), whose results are presented here, assigning new projects to a team of agents (staff), who already had ongoing projects assigned to them.

The type description and weight contributions are shown in Table 4.

[Table 4 – Type of project description and weight contribution]

This work considers $B_j = 1$, $B_j = 0.5$, and $B_j = 0$ for projects with a large, intermediate, and low budget, respectively. The workload associated with the project requirement level, L_j, was established considering weekly time periods and according to Table 5.

[Table 5 – Hours per week from requirement level ranges]

The following parameters were considered:

- The assigned and ongoing portfolio has $n_o = 10$ projects (2 projects per agent)

- $n_a = 20$ new projects are available to be selected, and therefore the final portfolio of projects will have at most $n_p = 30$ projects

- The requirement level of each project, $L_j \in [0, 1]$

- The time (h/week) each project requires, Tj $\in \{1, 2, 3, 4, 5\}$

- The weekly limit load, $k_i = 35\ h$

- The team with $n_s = 5$ agents

- The starting competencies (skills) of each agent, $C_{ij}^{s} \in [0, 1]$

- The maximum level of disengagement, $WD_i = 0.7$

- The entry values (as questions scores) for Work Engagement dimensions (VI, AB, DE) in Table 6. These values were assumed on the UWES scale, which need to be elicited, using interviews or surveys, in each specific future applications.

[Table 6 – Entry values for Vigour, Absorption and Dedication]

To simulate real, asymmetric, teams the model allows different sets of entry skills. The details of the projects, ongoing and new (to assign), are listed in Appendix A.

5. Results

Given the perspective of potentially conflicting objectives, the complete set of efficient solutions resulted from maximizing the objective function "Portfolio Value" while restricting, increasingly, the values of objective function "Skills development". The 0-1 linear programming solutions were obtained by using OpenSolver's COIN Branch and Cut Solver (Mason, 2012).

Maximizing objective function f_1, i.e., determining the value of the portfolio before any restriction is set for the second objective function, yields 4315 for the portfolio value and 7.28 for the opportunity of skills development. Then, maximizing objective function f_2 subject to $f_1 \geq 4315$ led to the same solution, allowing to conclude this solution is Pareto optimal. In this solution, not all new projects are selected, only 15, to be added to the 10 ongoing projects. These projects will consume similar time (hours/week) from each agent

(T_j=3), since similar management procedures were considered (kick off, closing, recruitment, accountability) to be accomplished. The model includes the possibility of freely adjusting these requirements, both in time (hours per week) and expertise level (skills), according to a table of values (L_j).

The set of Pareto solutions, obtained by maximizing f_1 subject to successively increasing lower bounds for objective f_2, is depicted in figure 1. In order to check Pareto optimalty for these solutions, function f_2 was maximized subject to obtaining the maximum values found for f_1.

[Figure 1 – Outline of the efficient frontier]

The most interesting trade-off occurs on the third solution (f_1=4295; f_2=7.9), as the relatively small value loss (less 0.5%) compared with the solution with the highest value is compensated by an increase of 8.5% in terms of skills development. In this solution, the agent with the highest entry skills, S_2, receives more projects, but not all - not exhausting the workload. Agents S_1 to S_3 reach high levels of disinterest (60%) without, however, reaching the proposed limit (70%). Thus, they can also receive new projects.

Despite also receiving new projects and, in the end, keeping the same number of projects as agent S_1, agent S_4 maintains the high levels of interest and commitment to the team (disinterest of 20%). The same happens with the agent S_5, but in this case it results from the low workload. The allocation of projects in this solution is presented in Table 7.

[Table 7 – Staffing, Project Allocation for solution 3 (f_1=4295; f_2=7.9)]

The values for skills development of agents are shown in Table 8.

[Table 8 – Values for entry and final skills for solution 3 (f_1=4295; f_2=7.9)]

This model takes into account the dimensions of the Utrecht scale (Attridge, 2009; Bakker et al., 2008) Vigour, Absorption and Dedication, whose average values after attribution of the new portfolio are presented in Table 9.

[Table 9 - Values for work engagement, before and after allocation for solution 3 (f_1=4295; f_2=7.9)]

Consistently, efficient solutions were found in different adjustments to the model (e.g. changing the entry skills, requirement levels, total of working hours, etc.), and alternating the maximization of the objective functions. The solution values and graphs resulting from all these variants are presented in appendix B – instances B1 to B4.

6. Discussion and conclusions

From the results it can be concluded that the model enables the analysis of the conflict of objectives through Pareto optimal solutions, allowing DMs to select the most preferred compromise.

The solutions obtained with the ε-constraint method that led to the increase in the second objective function correspond to a decrease in the values of the first objective function, whose best balance, to be defined by the DMs, allows combining the potential development of individual skills, and therefore of the team, in relation to the value of the portfolio.

Thus, this decision support model allows DMs to choose the most balanced solution, in terms of these benefits, according to their preferences while ensuring the team commitment to the organization. The organization can aim to increase financial results, faster and in an easily perceived way (tangible), regardless the agents' commitment, or the organization can aim to promote teams' progress in order to increase the range (type, budget) of projects and the overall performance of the team, in future periods, while aiming at the best value at the desired portfolio.

The maximum value of lack of commitment to the service can be set with different values and allows to find a maximum portfolio value which corresponds to the largest number of new projects carried out. The illustrative solution in section 5 reached 15 out of 20 potential new projects. The solutions obtained show that increasing the work engagement values within the team can lead to a reduction in the number of projects selected. On the other hand, increasing the disinterest (thus decreasing the work engagement within the team) and not ensuring the same perceived opportunities for the agents skills development most probably leads to an increase of the intention of some agents to leave the organization (due to burnout, tiredness and other factors (Bakker et al., 2008)).

Unsurprisingly, according to the model, the work engagement on average decreases along with the increase of the workload (e.g. Vigour), but depending on the development of skills, that can be offset by an increase of the other dimensions (Absorption - focus on work, and Dedication – recognition), which is consistent with the behavioural domain literature (Attridge, 2009; Bakker et al., 2008). The maintenance or the increase of the agents' commitment levels will result from the assignment of projects, and from keeping the agent active. The reinforcement of one, or more, of the work engagement dimensions can contribute to agents' retention and prevent the degradation of competences due to non-assignment of projects (and their tasks, recognized as relevant to the organization).

The evolution of the agents' engagement to the service is based on the premise that they remain in the organization for a sufficient period of time (e.g., 2 years) for the organization to profit from it (regarding time and money invested in training and work conditions). The follow-up of engagement can contribute to the retention of agents in the organization, aiming for continuous performance improvement in factors such as the enthusiasm to receive work, to improve the focus or to increase their dedication. And, from this retention and the promoted collaboration, an increase in the team's performance and, consequently, in the organization's performance can be expected.

Intending to further validate the model, in the future, on different times and work environments, it seems useful to collect the input values through direct queries (e.g, surveys, interviews) with staff members and DMs of each specific service. Future research can also compare results anticipated by the model with the benefits obtained at later periods. Such an approach can also lead to the introduction of other criteria, such as the cost of not doing projects.

The future development of this model can also contribute to support the decision of the top management of the organizations, to assess their dynamic capabilities and to validate a relationship between the development of the team's competences, as a whole (sum of the individual and their synergies), with the successful achievement of strategic goals, through an internal, structural, and an external, competitive, alignment.

Also, it seems appropriate to analyse the issues of commitment and individual progress associated with intermediate decision-making levels, which are often faced with having to operationalize higher level decisions, while still maintaining the challenge of maintaining the commitment levels of their teams. This approach could contribute to develop new software applications useful for HEIs managers, while designing their strategic projects and plans, particularly on Human Resources management and regarding behavioural issues, where efficiency gains – increasing talent retention and continuous improvement proposals by the teams - can be achieved.

Although this approach was set to a public administrative service, at a HEI Administration central structure, the model can also be potentially useful in the private sector, where gains of efficiency play also a relevant role on a competing strategy environment. Besides the already mentioned retention factor and improvement suggestions coming from the bases of the organizations, gains on individual workload rates or the motivation for hard work by the agents, decreasing the level of staff turnovers and of absenteeism, will result from a highly committed team, becoming more productive. With this model, the projects, and tasks carried out per agent are individually perceived as relevant and the DMs are invited to allocate them beyond the obvious option of choosing the best rated agent for each purpose.

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All data are presented in the article and the appendices

[Appendices A and B]

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Portfolio Management considering the commitment of agents: a bi-objective model applied to administrative services

Jorge Noro[1,2], Luís C. Dias[1]

1 - University of Coimbra, Centre for Business and Economics Research (CEBER), Faculty of Economics

2 - University of Coimbra, Institute for Interdisciplinary Research

= FIGURES =

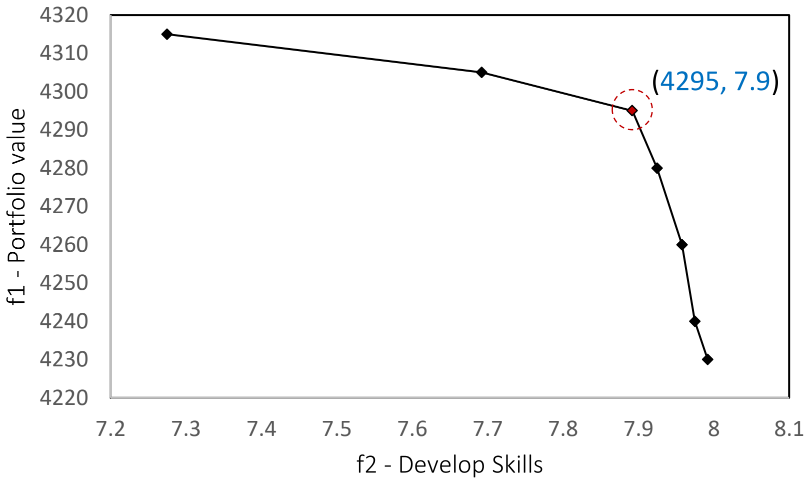
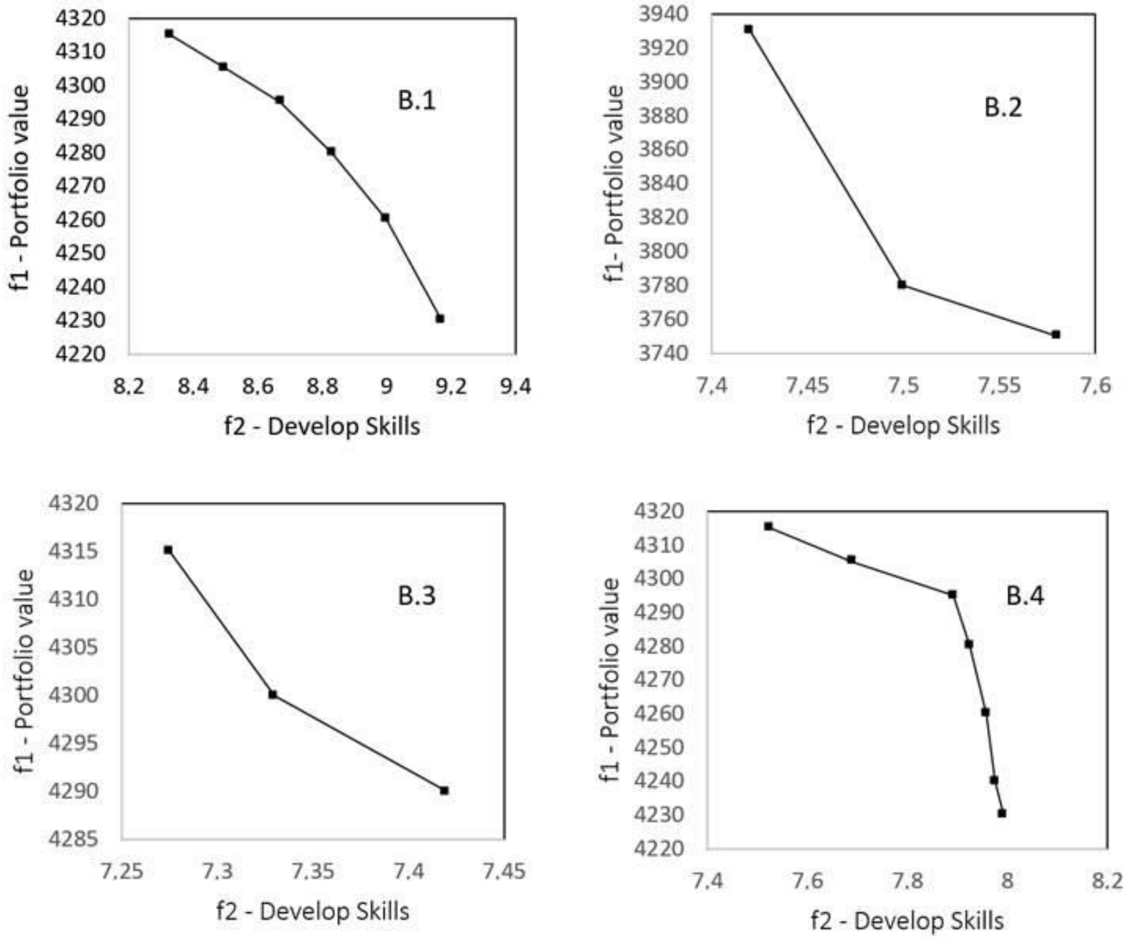


Figure 1
Efficient solutions (Pareto front) for the Base Case

Figure 2 - Efficient solutions for instances B.1 to B.4


B.1
f1 - Portfolio value
f2 - Develop Skills
4320
4310
4300
4290
4280
4270
4260
4250
4240
4230
4220
8,2
8,4
8,6
8,8
9
9,2
9,4
B.2
f1- Portfolio value
f2 - Develop Skills
3940
3920
3900
3880
3860
3840
3820
3800
3780
3760
3740
7,4
7,45
7,5
7,55
7,6
B.3
f1 - Portfolio value
f2 - Develop Skills
4320
4315
4310
4305
4300
4295
4290
4285
7,25
7,3
7,35
7,4
7,45
B.4
f1 - Portfolio value
f2 - Develop Skills
4320
4310
4300
4290
4280
4270
4260
4250
4240
4230
4220
7,4
7,6
7,8
8
8,2

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= TABLES =

Table 1
Notation

Decision variables	Parameters	Description
y_j		Binary decision variable indicating if project *j* is implemented
y_{ij}		Binary decision variable indicating if project *j* is implemented by staff member *i*
	a_{ij}	**A**vailable time consumed by staff member i when managing project j, given its own skills, in hours/period (typically, hours/week)
	a_{Ti}	**A**vailability (**t**otal), of staff member i considering its project portfolio
	AB_i^t	**Ab**sorption, with t ∈ {0, 1} – index of values, before (0) and after (1) projects allocation, with i ϵ {1, …, n_s}
	B_j	**B**udget, project j financial volume, with j ϵ {1, …, n_p}
	C_{ij}^s	**C**ompetencies/skills (**s**tarting), of staff i, for project j, with i ϵ {1, …, n_s}; j ϵ {1, …, n_p}
	C_{ij}^e	**C**ompetencies/skills (**e**nding), of staff i, after project j, with i ϵ {1, …, n_s}; j ϵ {1, …, n_p}
	DC_{ij}	**D**evelopment of **c**ompetences/skills, of staff i by carrying project j
	DC_j	**D**evelopment (total) of **c**ompetences/skills (sum), of team by carrying project j
	DE_i^t	**De**dication, with t ∈ {0, 1} – index of values, before and after projects allocation, with i ϵ {1, …, n_s}
	MD_i	**M**aximum **D**issatisfaction (Leaving **i**ntent), of staff member i, with i=1,…, n_s
	k_i	Value (constant) of maximum working hours for each staff member i
	L_j	Requirement **L**evel, of project j, with j ϵ {1, …, n_p}
	n_o	**N**umber of **o**ngoing projects of the team, already allocated (historic portfolio)
	n_a	**N**umber of **a**vailable projects that can potentially be selected
	n_p	**N**umber (maximum) of **p**rojects (=$n_o + n_a$)
	n_s	**N**umber of staff members (team size)
	P_j	**P**roject j, with j = 1, …, n_p
	S_i	**S**taff i, with i = 1, …, n_s
	T_j	Management **T**ime, in hours/period, required to execute the project j, with jϵ{1, …, n_p}
	TP_j	**T**ype of **P**roject j, with j = {1, …, n_p}
	V_j	**V**alue of the project j, with j ϵ {1, …, n_p}

VI_i^t	**Vi**gor, with t ∈ {0, 1} – index value, before and after project allocation, with i ϵ {1, …, n_s}
XP_j	E**xp**erience (history), in carrying out related project, with j = {1, …, n_p}
WE_i^t	**W**ork **E**ngagement – value of work engagement with the organization, of staff i, with i = {1, …, n_s}, based on dimensions: Vigor, Absorption and Dedication before and after allocation, with t ϵ {0, 1}
WD_i	**W**ork **D**isengagement – value of work disengagement with the organization, of staff i, with i ϵ {1, …, n_s}, based on dimensions: Vigor, Absorption and Dedication
WD_i^t	**W**ork **D**isengagement – value of work disengagement before and after allocation, with t ϵ {0, 1}

Table 2
Starting Skills considering training and experience profiles

$C_{ij}^s \in [0, 1]$	Profile	BCT		PE		IT	
		Have	Not Have	Have	Not have	Have	Not have
0.00 – 0.24	Basic		X		X		X
0.25 – 0.49	Intermediate low	X			X		X
0.50 – 0.74	Intermediate high	X		X			X
0.75 – 1.00	Advanced	X		X		X	

Legend: BCT – Basic Curricular Training, courses and other suitable training; PE – Professional Experience, and accumulated service time in related functions; IT – Internal Tutoring, assignment on-the-job training

Table 3
Work Disengagement

WD_i^t $t \in \{0, 1\}$	Staff member, i $i \in \{1, \dots, n_s\}$	Moment in time	Values	
			Work Engagement	Work Disengagement
WD_i^0	T_i	Before allocation	WE_i^0 VI_i^0, AB_i^0, DE_i^0	$WD_i^0 = 1 - WE_i^0$
WD_i^1		After Allocation	WE_i^1 VI_i^1, AB_i^1, DE_i^1	$WD_i^1 = 1 - WE_i^1$

Table 4
Type of project description and weight contribution

Description	Weight contribution		
	Type of project, TP_j	Experience (historic), XP_j	Budget Execution, B_j
Research, Copromotion, Investment	1	$\begin{cases} 1, > 5\ proj \\ 0, < 2\ proj \\ 0.5, all\ other \end{cases}$	$\begin{cases} 1, > 50k[u] \\ 0, < 1k\ [u] \\ 0.5, all\ other \end{cases}$
Specialized Services, Administrative modernization	0.5		
Training, Dissemination	0.1		

Table 5
Hours per week from requirement level ranges

Hours per week, T_j	Ranges for project requirement level, L_j
1	$0.0 < L_1 \leq 0.2$
2	$0.2 < L_2 \leq 0.4$
3	$0.4 < L_3 \leq 0.6$
4	$0.6 < L_4 < 0.8$
5	$0.8 \leq L_5 \leq 1.0$

Table 6
Entry values for Vigor, Absorption and Dedication.

Staff, S_i	VIGOR			ABSORPTION			DEDICATION		
	VI1	VI2	VI3	AB3	AB4	AB5	DE2	DE3	DE4
S_1	2	3	4	0	1	3	3	3	3
S_2	1	3	3	5	3	4	5	4	4
S_3	4	5	6	3	0	1	3	2	2
S_4	5	5	5	5	5	5	6	6	6
S_5	3	5	4	6	5	5	5	5	5

Table 7
Staffing, Project allocation for solution 3 (f_1=4295; f_2=7.9)

Staff member, S_i	P_f	P_0	P_1
S_1	4	2	2
S_2	10	2	8
S_3	5	2	3
S_4	4	2	2
S_5	2	2	0

Legend: P_0 is the initial portfolio (ongoing projects before the allocation proposed by the model); P_1 is the portfolio of newly allocated projects; P_f is the new portfolio after allocation of new projects.

Table 8
Values for entry and final skills and for agent's workload for solution 3 (f_1=4295; f_2=7.9).

Staff member	Total Projects	Entry Skills, ∀ Proj	Opps Develop Skills		End Skills, ∀ Proj
S_i	P_f	C_i^s	*Ongoing*, C_{ij}	*New Proj*, C_{ij}	C_i^e
S_1	4	0.40	0.48	+0.40	0.88
S_2	10	0.90	0.60	+0.33	0.92
S_3	5	0.50	0.10	+0.50	0.60
S_4	4	0.40	0.42	+0.30	0.82
S_5	2	0.25	0.80	=0.00	0.80

Table 9

Values for work engagement, before and after allocation, for solution 3 (f_1=4295; f_2=7.9).

Staff member	Final portfl	Score of engagement dimensions, *Utrecht Work Engagement Scale, UWES*									Resulting Max Disengagement
S_i	P_f	$WE_i = f(VI, AB, DE)$						Delta Scores			$WD_i = 1 - WE_i$
		VI_0	AB_0	DE_0	VI_1	AB_1	DE_1	VI	AB	DE	
S_1	4	0.50	0.22	0.50	0.40	0.20	0.49	-10%	-2%	-	0.6
S_2	10	0.39	0.67	0.72	0.08	0.41	0.70	-31%	-26%	-1%	0.6
S_3	5	0.83	0.22	0.39	0.58	0.19	0.39	-25%	-3%	-1%	0.6
S_4	4	0.83	0.83	1.00	0.67	0.77	1.00	-16%	-7%	-1%	0.2
S_5	2	0.67	0.89	0.83	0.67	0.89	0.83	-	-	- -	0.2
Team	Avg	*64%*	*57%*	*69%*	*48%*	*49%*	*68%*	*-16%*	*-8%*	*-1%*	
	ΔWE_i		*63%*			*55%*					

Portfolio Management considering the commitment of agents: a bi-objective model applied to administrative services

Jorge Noro[1,2], Luís C. Dias[1]

= APPENDICES =

Appendix A

Project Index Pj	Project Value Vj	Budget Value €	Budget Category Bj	Type Project Description	Type Project TPj	Historic Experience N of Proj	Experience Project XP	Requirement Level Lj	Workload Time h/week
P1	150	50 000 €	1.0	R&D ScTech	1	0	0.0	1.0	3
P2	160	75 000 €	1.0	R&D Law	1	1	0.0	1.0	3
P3	155	25 000 €	0.5	Service Desk	1	3	0.5	0.7	3
P4	170	5 000 €	0.5	Team Work	0.5	2	0.0	0.7	3
P5	165	1 000 €	0.0	Mobility	1	0	0.0	0.7	3
P6	175	80 000 €	1.0	Mobility	1	1	0.0	1.0	3
P7	150	40 000 €	0.5	Investment	1	0	0.0	0.8	3
P8	155	50 000 €	1.0	i9Desk	0.5	0	0.0	0.8	3
P9	160	50 000 €	1.0	Strategic Study	0.5	1	0.0	0.8	3
P10	150	200 000 €	1.0	R&D Life Sc	1	2	0.0	1.0	3
P11	155	250 000 €	1.0	R&D Mng	1	2	0.0	1.0	3
P12	165	1 000 €	0.0	R&D tests	1	1	0.0	0.7	3
P13	180	35 000 €	0.5	R&D Health	1	10	1.0	0.5	3
P14	155	500 €	0.0	Training	0.5	1	0.0	0.5	3
P15	175	750 €	0.0	R&D Award	1	12	1.0	0.3	3
P16	160	500 000 €	1.0	Investment	1	6	1.0	0.7	3
P17	190	1 000€	0.0	BenchMark	0.5	5	0.5	0.3	3
P18	200	750 €	0.0	Special Serv	0.5	2	0.0	0.5	3
P19	160	12 500 €	1.0	Strategic Plan	0.5	3	0.5	0.7	3
P20	180	150 000 €	1.0	R&D	1	6	1.0	0.7	3
P21	180	250 000 €	1.0	R&D Mng	1	2	0.0	1.0	3
P22	180	1 000 €	0.0	R&D tests	1	1	0.0	0.7	3
P23	180	35 000 €	0.5	R&D Health	1	10	1.0	0.5	3
P24	180	500. 00 €	0.0	Training	0.5	1	0.0	0.5	3
P25	180	750 €	0.0	R&D Award	1	12	1.0	0.3	3
P26	180	150 000 €	1.0	Investment	1	6	1.0	0.7	3
P27	180	500€	0.0	BenchMark	0.5	5	0.5	0.3	3
P28	180	750 €	0.0	Special Serv	0.5	2	0.0	0.5	3
P29	180	12 500 €	1.0	Strategic Plan	0.5	3	0.5	0.7	3
P30	180	150 000 €	1.0	R&D	1	6	1.0	0.7	3

Appendix B

Besides the instance presented in Section 5, other instances were solved to test the model (B.1-B.4). The solutions presented in the following tables and in Figure 2, for each instance, result from maximizing f1 while successively increasing the minimum f2 requirement. In some of these instances (B.2-B.4) one finds non-supported non-dominated solutions (i.e. solutions that are dominated by a convex combination of other solutions), which is not uncommon when binary variables are used. Note that such solutions would not be found if a weighted sum was used as a scalarizing function, instead of using the ε-constraint method.

Instance Max f1 s. min f2	*Workload limit (hours/ week)*	*Precedent projects assigned (number per agent)*	*Entry skills (profile)*	*Project requirement (hours/ week)*
B.1	*35*	*2*	*0.5 (all)*	*3 (all)*
B.2	*35*	*2*	*0.5 (all)*	*1< x <5*
B.3	*35*	*2*	*0.5< x < 0.65*	*1< x <5*
B.4	*35*	*2*	*0.25< x < 0.9*	*3 (all)*

Solution ID	Projects not implemented	Number of projects assigned per agent	Skills Score	Skills Development	Portfolio Value
B.1	No. Projects	Si	∑	f2	f1
1	11-12-14-16-19	3-3-3-3-3	4.63	8.33	4315
2	11-14-15-16-19	3-3-3-3-3	4.71	8.5	4305
3	12-14-15-16-19	3-3-3-3-3	4.79	8.67	4295
4	14-15-16-19-27	3-3-3-3-3	4.88	8.83	4280
5	14-15-16-25-27	3-3-3-3-3	4.96	9	4260
6	14-15-17-25-27	3-3-3-3-3	5.04	9.17	4230
7	End				

Solution ID	Projects not implemented	Number of projects assigned per agent	Skills Score	Skills Development	Portfolio Value
B.2	No. Projects	Si	∑	f2	f1
1	11-12-16-19-20-21-26	2-3-2-3-3	4.17	7.42	3930
2	11-12-14-15-16-19-26-29	2-2-3-3-2	4.21	7.5	3780
3	12-14-16-19-20-23-29-30	2-2-3-2-3	4.25	7.58	3750
4	End				

Solution ID	Projects not implemented	Number of projects assigned per agent	Skills Score	Skills Development	Portfolio Value
B.3	No. Projects	Si	∑	f2	f1
1	11-12-14-16-19	2-3-3-3-4	4.38	7.275	4315
2	11-14-16-19-23	2-4-2-3-4	4.42	7.33	4300
3	12-14-16-19-30	2-3-2-4-4	4.46	7.42	4290
4	end				

Solution ID	Projects not implemented	Number of projects assigned per agent	Skills Score	Skills Development	Portfolio Value
B.4	No. Projects	Si	∑	f2	f1
1	11-12-14-16-19	2-8-3-2-0	3.85	7.525	4315
2	11-14-15-16-19	2-8-3-2-0	3.93	7.692	4305
3	12-14-15-16-19	2-8-3-2-0	4.01	7.892	4295
4	14-15-16-19-25	2-8-3-2-0	4.04	7.925	4280
5	14-15-16-25-27	2-8-3-2-0	4.07	7.958	4260
6	13-14-15-25-27	2-8-3-2-0	4.09	7.975	4240
7	14-15-17-25-27	2-8-3-2-0	4.1	7.992	4230
8	end				

Figure 2 - Efficient solutions for instances B.1 to B.4