Multicriteria Model to Allocate Human Resources in Primary Health Care Programmes

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Abstract

Primary Health Care (PHC) is a key component of the Portuguese National Health System (NHS), representing the first level of contact between the individuals and the health system. In the scope of the PHC′s reform, which started in 2005, Family Health Units (FHU) were created and a contracting system was introduced. FHU with greater organisational maturity have the possibility to provide an additional portfolio of services, which complement the mandatory services already available in the FHU and add value to the organisation and to its users. This thesis aims to develop a methodology to support the FHU LoureSaudável in the choice of an additional portfolio of services. The developed methodology comprises a multicriteria model formulated with the MACBETH approach and a resource allocation model developed with the PROBE software. The model results supported the FHU LoureSaudável decision to allocate human resources in primary health care programmes in a way which maximized the benefits for the available resources in different future scenarios.

Keywords: Primary Health Care, Human Resource Allocation, Multicriteria Model, Portfolio Decision Analysis.

1 Introduction

Primary Health Care (PHC) is the first level of contact between the individuals and the health system in the Portuguese National Health System (NHS) [1]. It provides universal and essential care, which should be available for everyone, and aims not only to treat health problems, but also to promote health, prevent diseases and provide curative and rehabilitation care [1]. In 2005, a structural and organisational reform of Portuguese health sector began in order to make PHC the key component of NHS, which is consensually recognised to be more cost-effective [2]. Primary Care Centres (PCC) were reorganised in operative divisions with complementary missions [3]. The goal was to create more and better health care for citizens and to improve accessibility, proximity and quality of services [2]. Moreover, this reform intended to promote professional satisfaction, giving more autonomy to the organisations and rewarding good practices [3]. As an attempt to achieve these goals, Family Health Units (FHU) were created – small functional units with organisational and technical autonomy and subjected to an internal contracting system. All FHU must provide a set of core services, known as the basic portfolio of services [4]. Related to these services, FHU have to fulfil a set of contracted indicators of performance. Not all FHU have the same organisational model and contracting demand. Some FHU may settle in a lower level of complexity in terms of contracting demand (model A), while others, with greater organisational maturity and greater performance in fulfilling contracted goals, may evolve to model B or model C (although the last one has not been implemented yet) [4].

Besides the basic portfolio of services, FHU of model B may provide an additional portfolio of services, comprising a set of services which complement the core services and add significant value to the organization, to its professionals and to its users [5].

Within this context, FHU LoureSaudável is facing the challenge of providing more and better health care services, while dealing with scarce resources. This unit intends to build an additional portfolio of services but does not have resources to choose all possible services. There was a clear need to properly evaluate the benefit of all possible additional services in order to find the portfolio that maximizes the overall benefit for the resources available.

This work was developed to support FHU LoureSaudável in its decision to choose an additional portfolio of services. A decision support methodology was built with this FHU to assist the allocation of resources in additional programmes, comprising the following features: transparency, accountability for multiple objectives and a participative process involving key stakeholders.

2 Literature Review

Considering the problem at hand, an extensive literature review was conducted and it showed that literature is rare in this area and does not provide methods for supporting FHU′s decision in a transparent and rational way. Online databases were consulted using queries as *human resource allocation*, *priority setting*, *multicriteria decision analysis* and *portfolio selection*. Although economical and non-economical methods were found, this review focused on methodologies that considered the opportunity cost of alternatives and incremental changes in benefits and costs, since approaches which do not respect this principles have shown to lead to sub-optimal outcomes [6].

Conventional methodologies to prioritize health interventions, such as cost-benefit analysis, cost-utility analysis and cost-effectiveness analysis, lack features required to properly address the present resource allocation problem. The fact that they do not account for multiple criteria and they can lead to a misinterpretation of the results [7] limits their applicability and jeopardizes their credibility. Other methods, such as Programme Budgeting and Marginal Analysis (PBMA) and Multicriteria Decision Analysis (MCDA) have emerged in an attempt to fill the gaps present in conventional methodologies, while respecting the economic principles previously mentioned.

PBMA is a systematic and explicit approach for priority setting, which considers the concept of opportunity cost and margin [8]. This approach involves the definition of criteria according to which allocation alternatives are evaluated by an advisory panel. The alternatives are rated in each criteria and the scores are multiplied by the respective criteria weights [9]. Based on these scores, recommendations are elaborated regarding the prioritisation of allocation alternatives. Although PBMA uses a participatory process and contemplates multiple criteria, it does not provide guidelines on the elicitation of criteria, scoring of alternatives and determination of weights.

Given the features of the FHU LoureSaudável′s resource allocation problem, MCDA was considered the most appropriate method to assist this decision. MCDA comprises a methodology for evaluation of alternatives, assigning utility values to the alternatives in different evaluation criteria. The purpose of these value measures is to express attributes of criteria of different nature in a common unit, enabling comparison [10]. Through a participatory process, an explicit rational model is built, incorporating the values and judgments of the decision maker (DM) and creating a common language and understanding [11]. As a result of multicriteria models, the overall benefit of each alternative is obtained, given by aggregating the partial value of the alternatives in each criteria and weighting criteria [11]. In particular, Portfolio Decision Analysis (PDA) was found to be especially well-suited to select programmes that maximise benefits for limited available resources [6].

Given its features and its increasing relevance in resource allocation decisions in health [12], [13], [14], MCDA methodology was considered appropriate for aiding the allocation of health professionals in additional programmes in the FHU. The present study reports the development of a decision support tool to assist FHU LoureSaudável in the choice of an additional portfolio of services, using MCDA and PDA.

3 Methodological Framework

Since the methods available in the literature did not meet all the requirements to address the FHU′s problem, a methodology was developed in order to fill this gap. In the building process, it was used a multimethodology, which corresponds to a set of methodologies interconnected [15]. The steps involved in the construction of this methodology were a result of a sociotechnical approach and included: (1) model structuring; (2) measuring value (building value functions and weighting criteria); (3) determining the global value of each programme; (4) analysing efficient portfolios (Figure 1).

The social component included individual interviews with a representative group of the whole FHU, two decision conferences with the decision-making group and several meetings with the FHU′s Coordinator. The model structuring and the identification of alternative programmes were a result of the individual interviews and meetings with the FHU′s Coordinator. The construction of value functions, the determination of criteria weights and the determination of the global benefit of each programme were performed in the two decision conferences and, finally, the portfolio analysis was accomplished in a meeting with the FHU′s Coordinator. These social processes were guided by a neutral facilitator, who helped the DMs to share concerns and different points of view, enabling the development of a model that reflects the collective view of the group.

The multicriteria method MACBETH (**M**easuring **A**ttractiveness by a **C**ategorical **B**ased **E**valuation **Tech**nique) and its software M-MACBETH were used to build the multicriteria evaluation model. A strength of MACBETH is that it only requires qualitative judgements from the DM about differences in attractiveness between performance levels to score programmes on each criteria and to weight criteria [16]. The multicriteria model calculates an overall benefit value to each programme by a weighted sum procedure. The overall benefits and costs in number of working hours of each programme are used in a portfolio decision analysis in order to select the portfolio of programmes which maximizes the overall benefit for the limited number of working hours available. The portfolio analysis was supported by PROBE (**P**ortfolio **Rob**ustness **E**valuation) software, which allows to take into consideration different interdependencies between programmes, such as synergies and constraints, and to perform a robustness analysis of the portfolios considering uncertainty phenomena [17].

Considering m programmes j ($j = 1, ..., m$), the overall benefit v_j is obtained evaluating each programme on n evaluation criteria with an addictive model. The performance x_{ij} of each programme j on each criteria i is measured by one level of the descriptor X_i [12, 18]. The partial value of j in i is measured by converting x_{ij} into a value score $v_i(x_{ij})$, using a value function built with MACBETH, such that $v_i(neutral_i) = 0$ and $v_i(good_i) = 100$. The partial values v_{ij} are weighted with weighting coefficients w_i and the overall benefit v_j, as it is shown in Equation 1.

$$v_j(x_{1j}, ..., x_{nj}) = \sum_{i=1}^{n} w_i v_i(x_{ij}) \ with \ \sum_{i=1}^{n} w_i = 1, \ w_i > 0 \tag{1}$$

Assuming that each programme j has $v_j > 0$ and a cost c_j, in number of working hours, the best portfolio of programmes, the one offering the highest global benefit given the available resources, can be found by solving the knapsack problem (2):

$$Maximize: \sum_{i=1}^{n} v_j l_j \tag{2}$$

$$Subject\ to: \sum_{i=1}^{n} c_{kj} l_j \leqslant B_k$$

$$l_j \in 0, 1$$

Where B_k represents the total number of hours available for profession k, c_{kj} is the number of hours of profession k required for programme j and l_j is a

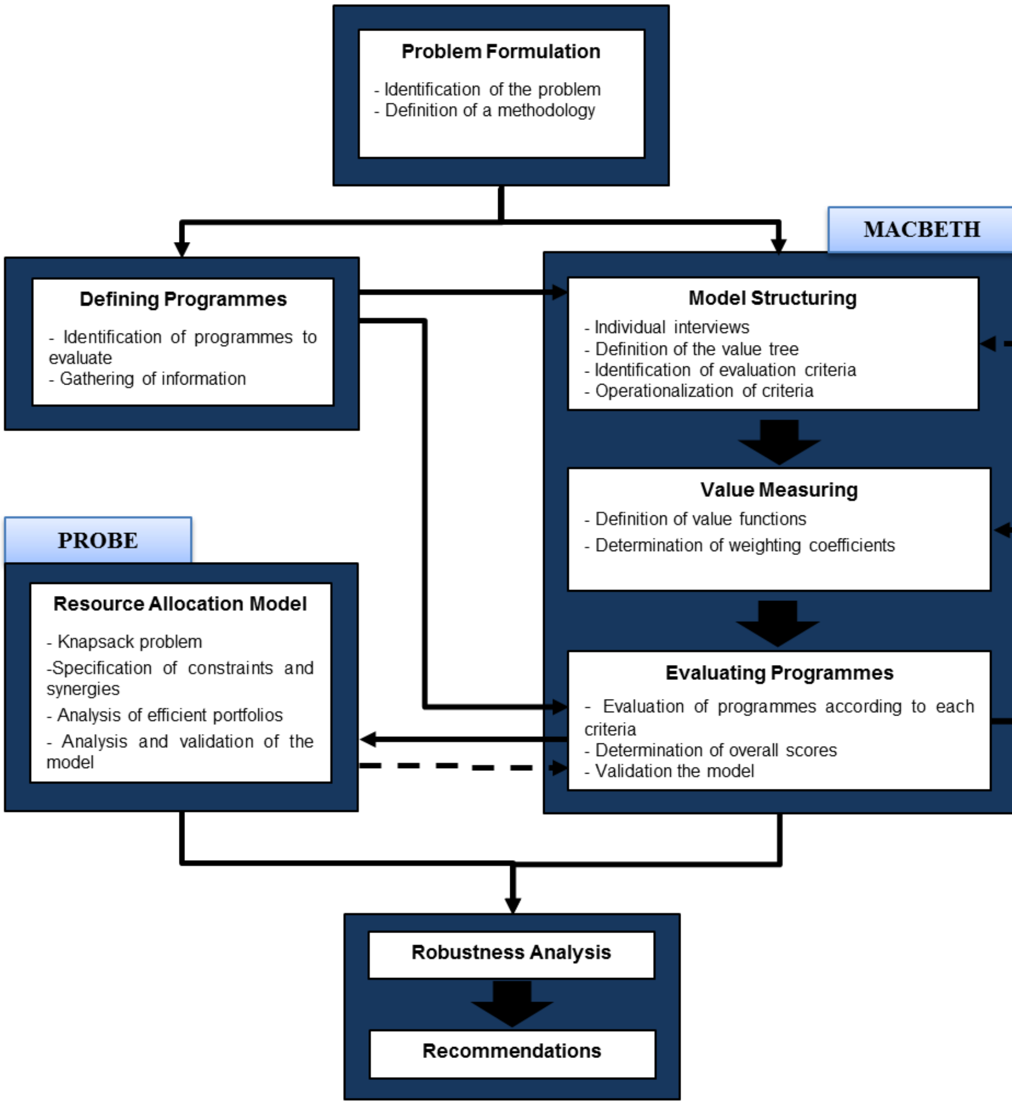

Figure 1: Conceptual framework of the proposed methodology. Solid arrows represent a sequential relation while dashed arrows correspond to iterative processes.

binary variable, such that $x_j = 1$ if programme j integrates the optimal portfolio and $x_j = 0$ otherwise.

Other linear constraints can be added to the model in order to capture interdependences between programmes. These constraints include: programme j must be chosen; programme j cannot be carried out; programme j can only be chosen if programme h is; programmes j and h need to be implemented simultaneously and programmes j and h cannot be chosen simultaneously (Equations 3 to 7, respectively) [17].

$$l_j = 1 \tag{3}$$

$$l_j = 0 \tag{4}$$

$$l_j - l_j \leq 0 \tag{5}$$

$$l_j - l_h = 0 \tag{6}$$

$$l_j + l_h \leq 1 \tag{7}$$

4 Application of the Framework

4.1 Model Structuring

During the interviews, strategic goals of FHU Loure-Saudável were clarified, since they should be the basis of any organisational decision. Resources should be allocated in services that contribute to fulfil the organisation mission [19]. Some of the strategic goals identified were interdependent and were clustered in three areas of concern: *Quality of Care*, *Efficiency and Sustainability* and *Operational Aspects* (Figure 2). The branch *Quality of Care* includes concerns such as health and equity improvement and covers two evaluation criteria. The second branch, *Efficiency and Sustainability*, considered the assistance the programme can offer to the services already provided in the FHU and its contribution to the achievement of contracted goals, to attend community needs and to reduce costs to the NHS and to the users. This area covers six evaluation criteria. Finally, in *Operational Aspects*, training and motivation, availability of space and materials and the need of external professionals were considered.

A descriptor of performance was associated to each evaluation criteria. Some criteria, such as *Effective health gains*, were measured by quantitative descriptors. *Effective health gains* were given by the product of predicted health gains, effective population and percentage of accomplishment of the objectives of the programme, following a similar procedure as [12]. Predictive health gains were measured in QALYs (Quality Adjustred Life Years) and *good* and *neutral* levels were defined to this criterion as 50 $QALY$ and 0 $QALY$, respectively. Qualitative descriptors were also defined to several criteria, one of which *Equity*. This criterion was associated to a six-level scale shown in Table 1.

4.2 Definition of Alternative Programmes

The individual interviews were also a way to identify the set of programmes to be evaluated in the model: (a) Smoking cessation programme (P1); (b) Nutritional programme (P2); (c) Benzodiazepine withdrawal programme (P3); (d) Anticoagulation programme (P4); (e) Group meetings for diabetic individuals (P5); (f) Group meetings for hypertensive individuals (P6); (g) Prenatal classes (P7);

At this point, it was necessary to determine the performance of the programmes in each evaluation criteria. Some information was provided by the FHU′s professionals, but, for some criteria, it was required to conduct a literature research based on ISI Web of Knowledge, PubMed and Google. Predicted health gains were quantified in QALYs, which is the most common measure to determine health gains when comparing health interventions [20]. Several studies were consulted in order to obtain these measures, but only the studies with similar objectives and target population were considered. The costs associated to target diseases were obtained in national and international studies. Since they had been estimated in different years, a conversion of these values to 2012 prices was performed using inflation rates of each year [21]. Finally, the savings for the users associated with the programmes were estimated based on knowledge and expertise of FHU′s health professionals, since no related information was found in the literature.

It is important to mention that the performance for effective health gains and savings for the user were estimated in a long time horizon, in order to capture all present and future benefits of the programmes. A discount rate of 3% was considered to discount future gains and savings.

4.3 Building Value Functions

In order to determine value functions for each criteria, the DMs were asked to compare differences of attractiveness between performance levels of each descriptor, filling the MACBETH matrix. An example of a consistent matrix of MACBETH judgements can be seen in Figure 3. M-MACBETH assigned a score to each performance level, creating a scale discussed and adjusted with the DMs in order to represent the relative magnitudes of the judgements. Figure 4 displays the validated value scale for *Equity* criterion.

	N1	N2	N3	N4	N5	N6
N1	no	moderate	strg-vstr	strg-vstr	vstrg-extr	extreme
N2		no	weak	mod-strg	strong	v. strong
N3			no	weak-mod	mod-strg	strong
N4				no	vweak-weak	moderate
N5					no	moderate
N6						no

Figure 3: M-MACBETH judgements for *Equity* criterion.

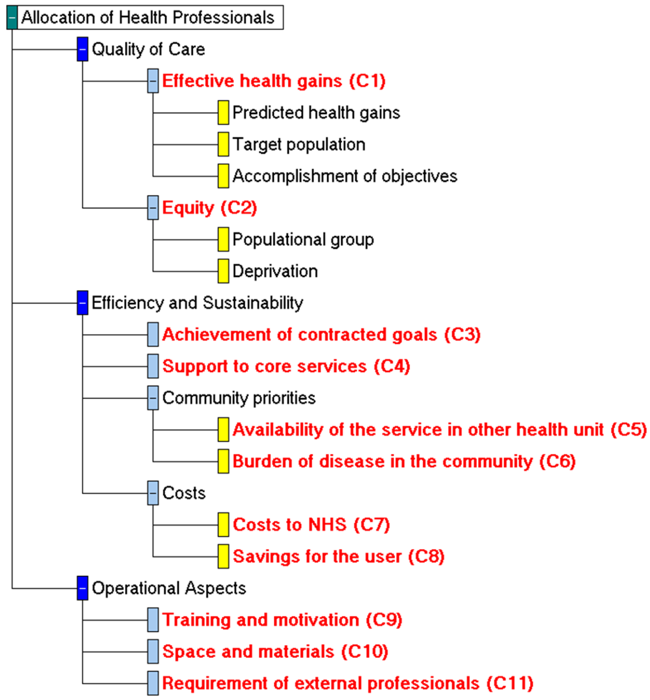

Figure 2: Value tree (evaluation criteria in bold and red).

Table 1: Qualitative descriptor for *Equity* criterion (adapted from [12]).

N1	**[Good]** The programme targets the youth, children and pregnant women, most of them living under deprived conditions and/or suffering from family problems and negligence.
N2	The programme targets the elderly, functionally dependent individuals or individuals with chronic diseases, most of them living under deprived conditions.
N3	The programme targets individuals with high risk behaviours and other individuals living in the Health Centre (HC) area, most of them living under deprived conditions.
N4	The programme targets the elderly, functionally dependent individuals and individuals with chronic diseases.
N5	The programme targets the youth, children and pregnant women.
N6	**[Neutral]** The programme targets individuals living in the HC area.

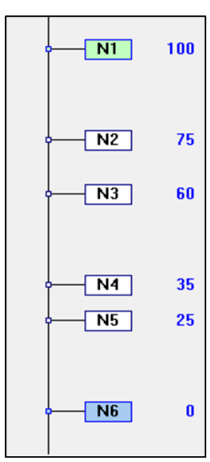

Figure 4: Validated value scale for *Equity* criterion.

4.4 Weighting Criteria

The weighting coefficients represent the scaling constants that allow the aggregation of the partial scores of the alternatives in the additive model. The MACBETH methodology for determining criteria weights involves filling a judgment matrix regarding differences of attractiveness of fictitious alternatives, each one neutral in all criteria except one, in which the alternative has a good performance. The DMs were asked, in decreasing order of overall attractiveness, the swings from *neutral* to *good* in all criteria. Then, the DMs qualitatively judged the attractiveness of each swing, filling the last column of MACBETH matrix of weighting judgements. Finally, the DM compared each two swings, completing the matrix presented in Figure 5. During the filling process, some questions were asked in order to validate the weights proposed by M-MACBETH software and sensitivity analysis was performed until an agreement was reached and final weights established (Figure 6).

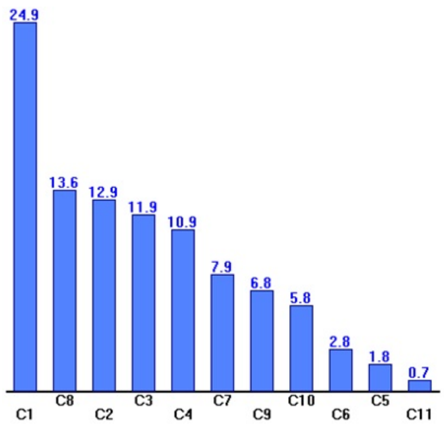

Figure 6: Histogram of criteria weights.

4.5 Portfolio Analysis

The second stage of the methodology consisted in the development of the resource allocation model to analyse several efficient portfolios through PDA. PDA allows the analysis of combinations of alternatives for determining efficient portfolios, which should be subject of critical analysis with the DMs. The knapsack problem presented in (2) was solved taking into account different future scenarios, modulated by different constraints. This methodology made use of PROBE software for the computation of efficient frontiers and portfolio analysis. Portfolios are considered efficient when there is no other portfolio with a greater global benefit with an equal or lower cost. Efficient portfolios were compared using the cost-benefit triangle of Figure 7 as a reference. This Figure illustrates that the shift from portfolio A to portfolio B has an additional cost, given by the base of the triangle and an additional benefit, given by the height of the triangle. The comparison of the base and height of the triangle facilitated the DM′s choice of whether or not to shift from portfolio A to B. The slope of the triangle represents the value for money associated with each portfolio. This cost-benefit triangle is very intuitive and helpful to explain to the DMs the concepts of PDA. However, it is crucial to note that it is not valid when there are constraints and synergies in the portfolio analysis.

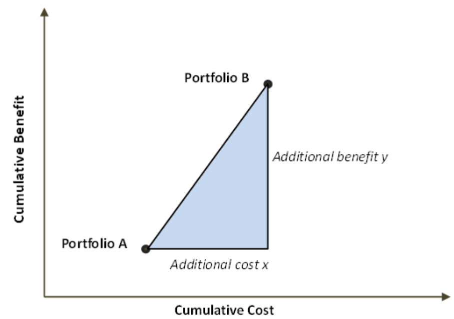

Figure 7: Cost-benefit triangle.

5 Model Results

The model was applied to a set of possible programmes to include in an additional portfolio of programmes in FHU LoureSaudável. Regarding the criteria *Effective health gains* and *Savings for the user*, the DMs found appropriate to use a time horizon sufficiently long to capture all the future outcomes of the programmes and two versions of each programmes were considered: programmes defined to include a small percentage of the potential beneficiaries (category A) and programmes defined to include all potential beneficiaries (category B). Both health gains and savings were discounted using a discount rate of 3%. The results obtained from the multicriteria model are presented in Figure 8.

The benefits and costs of the programmes were, then, analysed in a portfolio analysis with the support of PROBE software for three different future scenarios, modulated by different constraints:

- **Scenario 1:** Annual availability of 288 hours of doctors and nurses and no availability of professionals external to the FHU (psychologists and nutritionists).
- **Scenario 2:** Annual availability of 1008 hours of doctors and nurses, 48 hours of psychologists and 96 hours of nutritionists. Constraints were imposed on the number of medical and nursing programmes (at most

[C1]	[C8]	[C2]	[C3]	[C4]	[C7]	[C9]	[C10]	[C6]	[C5]	[C11]	Neutro
no	vstrg-extr	positive	positive	positive	positive	positive	positive	positive	positive	positive	extreme
	no	weak	positive	positive	positive	positive	positive	positive	positive	positive	extreme
		no	moderate	positive	positive	positive	positive	positive	positive	positive	v. strong
			no	moderate	positive	positive	positive	positive	positive	positive	v. strong
				no	strong	positive	positive	positive	positive	positive	strong
					no	moderate	positive	positive	positive	positive	strong
						no	mod-strg	positive	positive	positive	mod-strg
							no	strg-vstr	positive	positive	mod-strg
								no	mod-strg	positive	moderate
									no	mod-strg	weak-mod
										no	weak
											no

Figure 5: MACBETH matrix of weighting judgements.

two medical programmes and two nursing programmes).

- **Scenario 3:** Annual availability of 672 hours of doctors and nurses, zero hours of psychologists and zero hours of nutritionists. Constraints were imposed on the number of medical and nursing programmes (at most two medical programmes and one nursing programme).

Figure 9 shows all the efficient portfolios for scenario 2. DMs focused their attention in blue and green portfolios, since they provide a higher benefit for the available resources. Comparing the two, DMs noted that the green portfolio has significantly higher costs for a small incremental benefit. At the end, the choice of blue portfolio was consensual, which means DMs were not willing to pay more 48 hours for an additional benefit of 5 units. The selected portfolio has a cost of 960 hours and a benefit of 533.93 units, including a smoking cessation programme without psychologists, a nutritional programme with a nutritionist, group meetings for diabetic individuals and group meetings for hypertensive individuals (all category A programmes).

A robustness analysis confirmed that the portfolios chosen were stable, concerning uncertainty in criteria weights and imprecisions in performance values. The DMs maintained the chosen portfolios for all three scenarios.

6 Discussion

The described methodology intended to support FHU LoureSaudável decision by following a multicriteria approach, in a rational and transparent way, throughout an interactive consulting path. The DMs felt related to the results obtained by this decision support tool and intend to use them in the selection of the set of programmes to include in the additional portfolio of services. The analysis of the results made the DMs realise that the programmes could add a considerable benefit to the community, therefore justifying the extra effort from the health professionals. Furthermore, the DMs realised that these additional programmes could support significantly the services already available in the FHU, improving the efficiency and performance of the organisation.

The structure of multicriteria model reflects organisational goals and targets, highly important in prioritizing programmes at the local level. FHU are currently pressured to fulfil demanding contracted goals, many of them unrelated to health gains, equity and community needs. This model incorporates these fundamental criteria in the decision of the activities to perform in these primary care units. However, there were some challenges that had to be overcomed during the development of this methodology. Available literature lacked information about health gains in QALYs of certain interventions. Data of similar studies had to be used to determine the effective health gains of the considered programmes. Similarly, very little information was found about savings that interventions can bring to the users. Approximated values were estimated based on FHU′s professional knowledge and expertise.

The MACBETH process of determination of value functions, weighting criteria and analysis of portfolios was a clear framework for programmes comparison, where M-MACBETH and PROBE support systems played a vital role. This process helped the FHU

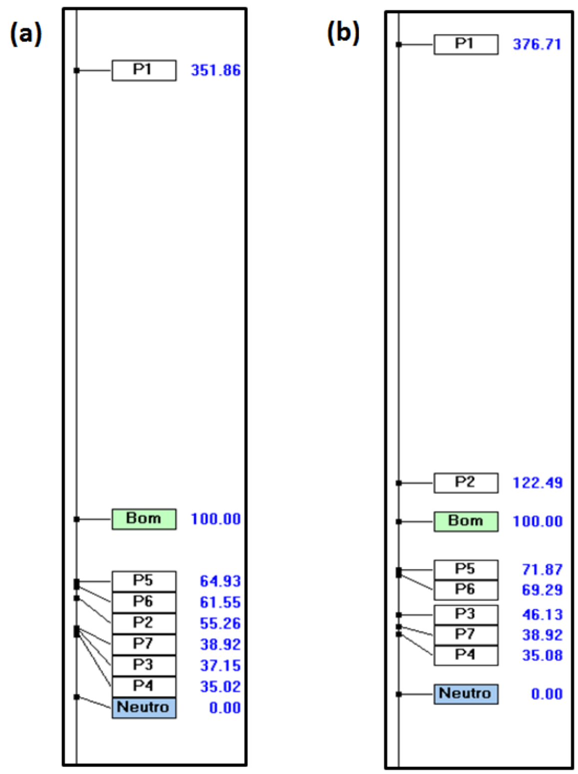

Figure 8: (a) Final thermometer for category A programmes. (b) Final thermometer for category B programmes.

to mature its strategic planning, to clarify the requirements and different possibilities to build an additional portfolio of services and to realise that these extra services can provide an important support to core services and can help to achieve contracted goals.

7 Conclusion

The developed methodology intended to support the decision of FHU LoureSaudável, by adopting a multicriteria methodology, in a rational and transparent way. It was regarded as very useful to inform the allocation of human resources to additional primary care programmes in the FHU. DMs showed great confidence in the model results, since the model reflected their concerns and points of view and it was built with their involvement.

This methodology contributes to the literature on the prioritization of health care interventions by proposing rational and transparent methods based on MCDA and on PDA. This methodology enables an allocation of resources strategically aligned with the organisation mission and values. It can be applied in other contexts and different scenarios, but becomes especially appropriate in resource allocation problems with multiple and possibly contradictory objectives and with constraints and synergies between alternative programmes. Even though it is still rare to find MCDA studies in resource allocation problems in the health sector, these approaches present a great potential to improve health care management.

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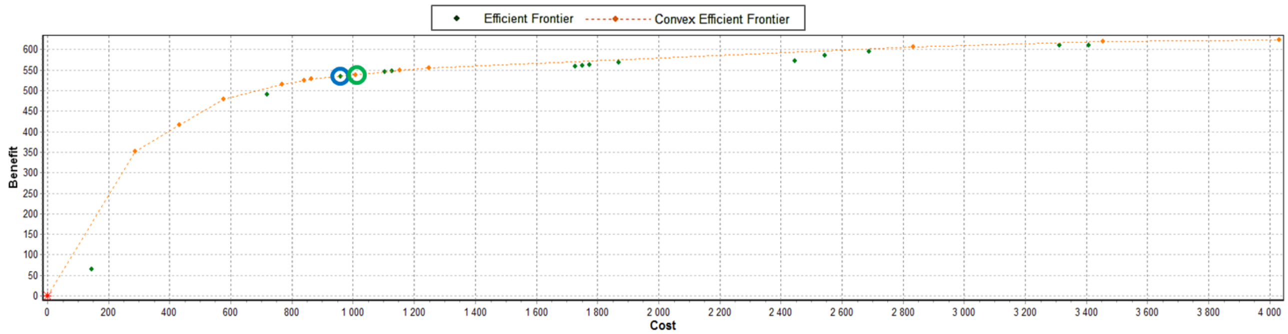

Figure 9: Efficient portfolios for scenario 2. The selected portfolio is highlighted in the blue circle.

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