Participatory Budget Formation through the Web

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Abstract. We describe a web-based system to support groups in elaborating participatory budgets. Rather than using physical meetings with voting mechanisms, we promote virtual meetings with explicit preference elicitation, guided negotiations and, only if consensus is not reached, voting.

1 Basic Concepts in Participatory Budget Formation

Participatory budgets constitute an attempt to allow citizens to have a word and aid in deciding and approving how public budgets, mainly in municipalities, are spent, whether (and how much) in transportation, culture, education, urban development, health,... They constitute a budget allocation model based on dialogue and citizen participation, which diverges from the current predominant representative model in which citizens choose representatives for four years, with practically no other direct opportunity to influence council policies.

In a sense, participatory budgets are transforming the idea of a representative democracy, in which the preferences of the citizens are considered just at the moment of elections, through voting, to move closer to a participatory democracy, based on direct participation and discussion of issues. In words of Souza, see [10]:

> Participatory budgets constitute a universal, direct and volunteer kind of democracy which gives population the opportunity of discussing about budgets and public policy, making relevant decisions. Citizens not only vote, but also get involved.

Among many potential benefits of participatory budgets, we would include:

- Legitimation
- Approaching decisions to citizens
- Public decisions made publicly
- Mitigation of alienation and apathy
- Transparency

Participatory budgets stem from the initial experience at Porto Alegre in 1988, which was definitely consolidated in 1992. Since then, participatory budgets are becoming increasingly popular in many other municipalities, all around the world, with nearly 200 municipalities undertaking them in 2003. As an example, in Spain villages like Cabezas de San Juan or Rubi, and cities like Albacete or Valladolid have now established such experiences.

Although they are all grounded in a relatively simple general principle, a comparison of participatory budget municipal regulations shows us a variety of participatory municipal council budget forms, with differences in the percentage of budget directly allocated, the number of participants, the number of rounds,... However, far from amorphous and disoriented, participatory budgets are set up along structured lines, including the necessary bodies, functional rules and principles embodied in municipal regulations. These are set down in manuals, which address the population and are reasonably clearly formulated. They are meant to ensure that regulations fixing the number of delegates to each body, the role of the public authorities, the prerogatives and powers of a participatory budget council and the discussion fora are clear and transparent.

There are, however, several criticisms to be made stemming from the experiences undertaken in such processes. From the conceptual point of view, we should stress that participation is frequently limited to a small fraction of the population, in part against the own concept of participation. From an information technology point of view, we appreciate that, except at a few experiences which use discussion fora to collect suggestions for projects to be implemented, there is little use of new technologies, as processes are based on discussion and physical meetings, and preferences are usually established through voting, very frequently just by raising hands. Among other things, this entails that it has turned out difficult to involve the youngest and poorest population; moreover, they have induced problems in neighbourhoods unable to articulate a common coherent investment plan. This is related with our final critique, from the point of view of the little decision technology employed: no formal modelling or quantification of the intensity of preferences of citizens is undertaken and no use of formal negotiation or group decision support tools is used. To sum up, there is little methodology available.

In this paper, we shall sketch a model and a web based system to support participatory budget elaboration processes. We essentially view them as a negotiation problem with budget constraints and describe an implementation of the balanced increment method to support such negotiations.

Many authors have dwelt on how Internet is changing the way people interact with governments. However, so far most ideas relating Internet and politics, are directed towards facilitating traditional political methods through new technologies, like electronic voting or Internet voting, instead of voting with a piece of paper. Our proposal here aims at transforming, rather than facilitating, politics, through the use of IT: it is a tenet of ours that involving and communicating with the stakeholders at all stages of a decision making process leads to better quality, more consensual decisions.

2 A Method to Support Participatory Budget Elaboration

We outline a description and a model of the participatory budget problem. A full description together with mathematical details may be seen in [7].

Suppose a group of m persons has to decide how to spend a budget b. There is a set of q proposals, $a_1, \ldots, a_q$. Proposal i has cost c_i, and is evaluated by the j-th individual with n_j criteria, with values x_{ijk}, $k = 1, \ldots, n_j$, $j = 1, \ldots, m$, $i = 1, \ldots, q$. We assume that all evaluations are under certainty, i.e. we have a fairly accurate estimate of each project costs and features.

We shall also assume that each participant is a (multiattribute) value function maximiser, see e.g. [1]. This allows us to associate with each participatory budget problem a matrix of entries v_{ij}, the value that individual j gives to project i, which he aims at maximising. We tray here to, somehow, provide a feasible solution that jointly satisfies the group of m participants.

A feasible solution for such problem is a subset of proposals, $F \subseteq I = \{1, 2, \ldots, q\}$, which satisfies the budget constraint, that is, such that

$$\sum_{i \in F} c_i \leq b. \tag{1}$$

To simplify matters, we shall assume that the value given by the j-th individual to each feasible solution, F, is the sum of the values of the objects in F assessed by the individual:

$$v_j(F) = \sum_{i \in F} v_{ij} \ , \ j = 1, \ldots, m. \tag{2}$$

Then, if $\{F^1, F^2, \ldots, F^s\}$ designates the set of feasible solutions, conceptually we may view the participatory budget problem as a negotiation table, see [8]. Note

Table 1. This table shows the value given by each individual to each feasible solution

	1		j		m
F^1	$v_1(F^1)$	$\ldots$	$v_j(F^1)$	$\ldots$	$v_m(F^1)$
F^2	$v_1(F^2)$	$\ldots$	$v_j(F^2)$	$\ldots$	$v_m(F^2)$
$\vdots$	$\vdots$		$\vdots$		$\vdots$
F^s	$v_1(F^s)$	$\ldots$	$v_j(F^s)$	$\ldots$	$v_m(F^s)$
	$F_1^\star$		$F_j^\star$		$F_m^\star$

that just obtaining this table may be prohibitively costly from a computational point of view, because of the combinatorial nature of the problem. The last row includes the optimal solution $F_j^\star$ for each individual, which may be obtained solving a knapsack problem, see, e.g., [4]. Clearly, if $F_1^\star = F_2^\star = \cdots = F_m^\star$, this feasible solution is obviously the group decision. However, typically, various individuals involved will reach different optimal solutions, and, consequently, a round of negotiations should be undertaken to try to reach a consensus. As the group will rank the alternatives partially, through the Pareto order:

$$F \succeq F' \iff v_j(F) \geq v_j(F') \ , \ \forall j \in \{1, \ldots, m\}, \tag{3}$$

the agreement should be sought within the nondominated set.

We shall assume that participants enter in the multilateral negotiation within the full open and truthful intermediary disclosure (FOTID) framework. This will imply, for us, that negotiators may communicate privately their preferences to an entity (our web system) which will know the preferences of all negotiators and, based on them, and some concept of fairness, will offer solutions to the negotiators until one is accepted. Participants have access to the alternatives of the feasible set. As we mentioned, their preferences over these alternatives are modelled by a value function. We denote by $S \subseteq \mathbb{R}^m$, the set whose points represent the value levels that each participant can reach through an outcome associated with a feasible solution, if they choose it jointly. The disagreement point is a vector $d = (d_1, \ldots, d_n) \in \mathbb{R}^m$, in which the j-th coordinate represents the value level that the j-th participant would receive if the negotiation breaks down.

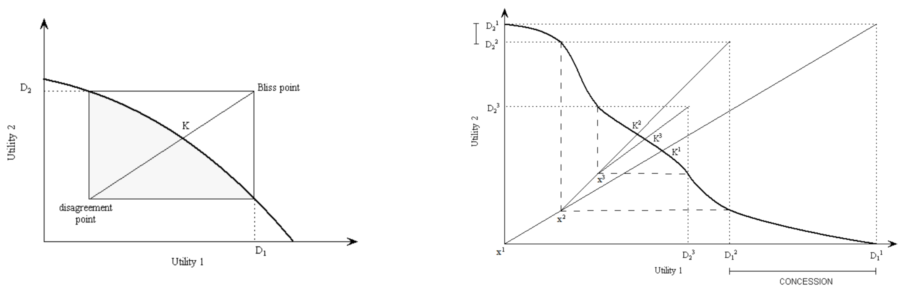
Mathematically, given (S, d), the problem of selecting a reasonable nondominated point in S is known as a bargaining problem and it has been studied under arbitration schemes. For us, the solution for this problem is meant to produce a recommendation as an impartial arbitrator would make. There are different solution proposals, formulated by a list of properties or axioms, which embody normative objectives of fairness, see [11] for a summary.

For a bargaining problem (S, d), the highest value that the i-th participant can get from the disagreement point d without worsening the value of the other participants is known as the dictatorial solution for this participant, $D_i(d)$, and represents his preferred solution or his most optimistic expectation. This is

$$D_i(d) = \max_{d \prec x} x_i. \tag{4}$$

Given d, the bliss point will be $B(d) = (D_1, \ldots, D_n)$ and represents an ideal point, because participants can rarely get these values jointly through a feasible solution. The Kalai-Smorodinsky solution $K(d)$ lies where the diagonal linking the disagreement point and the bliss point crosses the set of nondominated solutions, as shown in Fig. 1a). See [3] for an axiomatic description of this solution. The direction of this diagonal represents a compromise direction in which joint value improvements are proportional to the participant's most optimistic expectation. Raiffa, in [6], proposed to compute a reasonable solution by beginning at the status quo and effects step by step improvements of the participants' utilities in the same direction of the line joining the point at the current solution with its bliss point, until a nondominated solution is reached. This limiting solution is known as *balanced increment solution*.

We propose such approach with the modification that, at each iteration, we offer parties the nondominated solution closes to the diagonal to see whether they



a) Kalai-Smorodinski solution

b) First steps of BIM

Fig. 1. Balanced increment method with two participants

accept it. Figure 1b) shows the first steps of our modified balanced increment method (BIM), see [9], for details. In the i-th iteration, the system offers K^i, the Kalai-Smorodinsky solution from d^i. For participant 1, the value of K^i will be in the interval $[d_1^i, D_1^i]$, where d_1^i may be interpreted as the value of the dictatorial solution of participant 2, D_2^i, from the point of view of the participant 1. If participants do not accept unanimously the offered solution, the system offers another solution involving a concession in the participants' most optimistic expectation.

Initially, we propose helping the individuals to reach an agreement in the participatory budget problem using the balanced increment method (BIM), whose status quo shall be the solution which includes no proposals. With this initialisation of BIM, the set of nondominated solutions will not be constrained and all nondominated solutions can be considered potentially. In [8], we prove that such method leads to a nondominated solution with several nice properties from a group decision point of view. However, its implementation is extremely costly from a computational point of view, as it essentially implies precomputing the whole nondominated set in a combinatorial problem. Computation times will be unacceptable, when the number of projects is moderately big.

As an alternative, we propose using a greedy heuristic which we have found fairly powerful and proceeds in two stages. To wit, in a first stage we identify the set of nondominated projects; if this set does not exhaust the budget, we incorporate it to the solution and eliminate them from the set of project which participant will negotiate. We repeat until one layer of nondominated projects exhausts the remaining budget. At that point, we start the second stage, in which participants negotiate among the remaining projects with the BIM method. Specifically, we have

- Stage 1:
  - Compute set of nondominated projects

  - If budget is not exceeded, add to solution, else go to stage 2
  - Repeat with rest of projects after updating the budget
- Stage 2:
  - Negotiate over the remaining set of projects and available budget using the BIM method

As pointed out in [8], this heuristic does not guarantee a nondominated agreement.

It may happen, as well, that negotiators do not reach an agreement through negotiations. In such case, we would allow them, as usual in participatory budgets, to proceed through voting.

3 Supporting Participatory Budget Formation through the Web

We implement through the web the previous model, integrating it in a complete system to support group decision making in the area of participatory budget formation. To some extent, the whole integrated process provides an asynchronous implementation of the philosophy and methodology of decision conferencing, see [5].

Among, many technological possibilities, we have adopted the LAMP (Linux, Apache, MySQL, PHP) environment. We distinguish three basic profiles:

- the *problem owner*, the entity which aims at solving a participatory budget problem, structures and publicizes it, which would be the mayor, in this case,
- the *stakeholders* or participants, which provide input to the decision making process, in our case, the citizens,
- the administrator, who takes technical care of the process development, from supporting the problem owner to structuring the problem, to providing access rights to stakeholders, to defining time windows for voting.

Safety mechanisms are available, with participants using appropriately secure validation mechanisms. The following system modules are included.

3.1 Proposal Elaboration

The system includes a module that allows the problem owner to structure the problem, if necessary with the aid of the administrator. The stakeholders will use the same structure to explore issues of interest concerning the problem. The module allows for:

- Defining the number of alternatives.
- Specify the alternatives and associated costs.
- Specify the budget.

We assume that the problem owner publishes a first draft of possible projects and invites citizens for comments and suggestions, and then consolidates, together with his technical staff, the final list of projects under consideration.

3.2 Value Function Assessment

The system includes a module that allows users to build their preference model. We assume that any user (problem owner, stakeholder) may build his own value function, as we have placed a lot of emphasis on usability. Each user will assess his value function privately and may communicate it to the system. Without much loss of generality, we assume that the users' preferences may be modelled through a weighted additive value function, see [2] for details. The system allows for:

– Specification of basic properties of (multiple) objectives by the problem owner: number of objectives, their scale and range, whether the objective is to be minimised or maximised. It is assumed that all participants will share these objectives. Some participants may disregard some of these objectives, e.g., by giving them zero weight.
– Assessment of each component value function. For each objective, and each user, the value of some attribute values is assessed with the probability equivalent method. Then, a concave-convex or convex-concave (exponential) value function is fitted through least squares.
– Assessment of the weights of the additive value function.
– Saving the value function for later purposes.

Users are expected to provide their preferences within a given time frame. Several facilities are included to provide convenient summaries of the value functions.

3.3 Individual Optimal Solutions

Once with the preferences of a participant, we may proceed to compute his optimal alternative. For that purpose, the system includes a module that allows users to evaluate the feasible alternatives, based on his value function, to obtain his preferred projects through the corresponding knapsack problem. The problem owner may find out his optimal alternative privately, as the stakeholders may do. If so, they may make public their solutions.

3.4 Negotiating

Typically, various parties involved (problem owner, stakeholders) will reach different optimal solutions. Consequently, a round of negotiations may be undertaken to try to reach a consensus. The negotiation is driven by our two stage heuristic, modification of the balanced increment method, as briefly explained above.

At each iteration, the system offers a solution to participants and, if accepted, it stops, that being a consensus. Alternatively, the procedure stops when two of the subsequent solutions offered are close enough. If the last one is accepted, a consensus is reached. Users are expected to communicate whether they accept or not an offered solution within a given time window.

3.5 Voting

Our (automatic) negotiating scheme converges to a solution, but it is conceivable that participants may not accept such solution, neither the sequence of solutions offered. This deadlock should be solved through voting.

For that reason, our system includes a voting module, which permits the design of a voting session, and its execution. Specifically, the rule implemented for voting is that of approval voting, with which participants provide at most one vote to as many alternatives as they feel like, the winner being that receiving the biggest number of votes. Users are expected to vote within a specific a time window.

3.6 Post-settlement Module

If the system detects that the voted solution is dominated, we have the option of renegotiating an agreement starting again the negotiations taking the last solution as disagreement point, that is, as initial solution of the BIM.

4 An Experiment

An experiment has been conducted with a group of executives of a firm to decide in which projects invest the available budget for next year, with two criteria: the expected Net Present Value (NPV), the expected time of Pay-Back (TPB), that is the time to return on investment, labour costs and country risk. Twelve projects were considered. Participants were pleased with the session run.

5 Discussion

We have proposed a group decision support system implemented in the web to solve the participatory budget elaboration problem. To prepare the negotiation, the participants have to assess their preferences models privately. The negotiation is driven by the BIM. If the negotiation does not provide an agreement, the joint decision may be made by voting.

Rather than using new technologies to facilitate standard political decision making mechanisms, our scheme radically modifies them by allowing more participation from stakeholders, a more informed and transparent decision by the problem owner, and, even, a more consensual approach. The experiments performed have been successful.

The underlying model assumes equal importance to all participants. We should study negotiation methods in which participants can have different weights.

Acknowledgments

Research supported by MEC grant TSI2004-06801-C04-01, by the Decision Engineering Lab, URJC - DMR Consulting Foundation and the ESF programme on Electronic Democracy.

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