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A model and case for supporting participatory public decision making in e-democracy

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Abstract In this paper, focusing on participatory public decision making processes, I propose a framework for group support systems and discuss related research issues. As a case illustrating the feasibility of participatory public decision making, I present the participatory budgeting experience in Porto Alegre, Brazil. The case is analyzed based on the proposed framework.

Keywords E-democracy · Group decision support systems · Negotiation support systems · Participatory budgeting · Porto Alegre

1 Introduction

Advances in information and communication technology (ICT) allow a much more substantive implementation of the democratic ideals described by Abraham Lincoln: the government of the people, by the people, and for the people. E-democracy articulates political and democratic procedures involving citizens in societal decision making in various ways through the use of ICT.

Although the debate on e-democracy became very active only recently, early arguments can be found in as early as the 1980s. For example, Toffler (1984) argued that ICT can remove time and space barriers and, as a result of this, direct democracy will become feasible. Similar arguments can be found in Nguyen and Alexander Jon (1996). The common ideal democracy suggested in this so called plebiscitary model was a political system where citizens actively participate in public decision making through electronic voting.

Another argument on e-democracy emphasized deliberation through ICT. For example, Elshitain (1987) believed that the critical element of democracy is the process of deliberation and claimed that, if electronic voting is overused, delibera-

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tion may be omitted and the democratic process will be replaced by mechanic button selection. Barber (2000) argued that e-democracy should focus on participation of citizens in discussion and deliberation on public matters rather than on electronic voting. This so called deliberative e-democracy model views cyberspace as a medium for implementing the public sphere described by Harbermas (1989) who defined it as a place where private entities may draw together as a public entity and engage in rational deliberation, ultimately reaching consensus on common affairs (Poster 1995).

Despite the difference in focus, both plebiscitary and deliberative models share the optimistic view on the role of ICT in democracy. Some views are even pessimistic on this. For example, Davis (1999) argued that the increase in the amount of information may cause overload and produce citizens with frustration and apathy.

This paper takes a pragmatic perspective noting that the major driving force of e-democracy has been experiments and practices. An e-democracy model does not have to focus only on either participatory decision making or deliberation, since they are complementary rather than conflicting. Modern decision theory and group support systems can facilitate participation in decision making, while enhancing collective deliberation. Focusing on the process of making decisions on public matters with citizen participation, this paper seeks answers to some of the critical questions in e-democracy. Can people participate? How can people participate? Do people want to participate? What are the ways to efficiently and effectively participate? What is the existing knowledge and what needs to be done?

The outline of this paper is as follows. First, I propose a framework for supporting participatory public decision making processes. This provides partial and preliminary answers to the last two questions. Then, as a case illustrating a feasible model of participatory public decision making, I present the participatory budgeting experience in Porto Alegre, Brazil. The case provides insights for answering the first three questions on citizen participation dynamics. Finally, I conclude this paper discussing several research issues.

2 A framework for supporting participatory public decision making

An important element of e-democracy is participatory public decision making. In this section, it is considered within the general class of policy making process. In order to encourage participation while integrating the plebiscitary and deliberative perspectives on e-democracy, we should support the participatory public decision making process in three aspects: communication, collective deliberation, and group decision. The following sub-sections explain these in detail.

2.1 Policy making process model

Dunn (1994) proposed the following five phase model of policy making:

1. *Agenda setting*: A social problem should be transformed into a policy problem.
2. *Policy formulation*: The alternatives that may solve the policy problem are identified after considering technical, societal, cultural, and legal aspects.
3. *Policy adoption*: The policy alternatives are transformed into a specific policy. This policy alternative is adopted as the law or order by the legislative or

administrative institutions. This phase may be de-composed into five sub-steps of *policy problem definition, policy objectives definition, collection of data and information, exploration of alternatives*, and *analysis and evaluation of alternatives*.

4. *Policy implementation*: Administrative resources are allocated to implement the policy conforming to the requirements determined in the policy adoption phase.
5. *Policy assessment*: The government, parliament, and/or court are monitored in order to check if they conform to the legal requirements of the adopted policy.

Typically all these phases are executed by bureaucrats and politicians with very limited citizen participation. Generally speaking, participation of the general public may increase in all of these phases in e-democracy. Especially, participation of the general public can be increased in the agenda setting and policy adoption phases. Support for deliberation will be useful for participatory agenda setting policy, whereas group decision support will be helpful for participatory policy adoption. Due to the technical nature of the task, participation in the policy formulation, implementation, and assessment phases may be limited to a group of experts.

2.2 Supporting communications: removing temporal and geographical barriers

In order to encourage participation of citizens who cannot attend a meeting at a specific place and time, system supported communication will be essential. Geographical barriers in communications can be reduced by computer-mediated communication (CMC) through the web or another network. The asynchronous communication mode provides means to overcome time barriers.

Various media are available for CMC including video, voice, sound, email, instant messaging, short message services, memos, bulletin boards, white boards, shared workspaces, virtual reality spaces, and so on. Research on media richness theory confirms that certain media work better for certain tasks than others. Thus, effective management should consider matching a particular communication medium to a specific task and to the degree of richness required by that task (Daft et al. 1987).

One of the relevant outcomes of previous research is that system supported face-to-face meetings result in good performance in idea generation tasks while computer-mediated meetings generally result in better performance in decision making tasks (Fjermestad and Hiltz 1998). A study by Ocker et al. (1998) found that the combination of face-to-face and asynchronous CMC yields better performance in idea generation tasks than any single mode. These results may suggest that the combination of face-to-face meetings and asynchronous communication mode be appropriate for the idea generation tasks in the agenda setting and policy adoption phases, while asynchronous communication support may be appropriate for decision making tasks in the policy adoption phase. However, because not all experimental studies found consistent results (Fjermestad and Hiltz 1998), these should be interpreted carefully, keeping the context in mind.

2.3 Supporting collective deliberation process: systematically directing interactions and/or content

Although group decision making may be beneficial, thanks to a wider range of expertise and more specific knowledge relevant to the problem at hand, it is not

always productive due to many reasons including coordination loss, communication overload, interpersonal conflict and disengagement (Raiffa 2002). In order to improve the productivity of group decision making processes, some form of facilitation is required. Facilitation may impact relationship development, participation, issue-based conflict, interpersonal conflict, negative socio-emotional participation as well as satisfaction and quality of the group decision (Miranda and Bostrom 1999). Various models of facilitation are presented in Table 1.

The role of a facilitator can be more complex in the asynchronous distributed setting than in the face-to-face synchronous one: a meeting in the asynchronous mode may last days, weeks, or even months; in addition, interactions of participants may happen whenever it is convenient for them and messages sent by a participant may be received by other participants in different order. Furthermore, because participants have greater freedom to work individually and interactions are less frequent and immediate, coordinating participants gets much harder (Tung and Turban 1998).

Besides facilitation, various tools to support group activities can be provided in policy making phases, including tools for divergence such as brainstorming, convergence such as idea selection, exploration such as in-depth analysis, consensus such as voting, team writing, and alternative evaluation (Briggs et al. 1997/1998). The effectiveness of these tools under various settings has been studied through experiments and field studies. One of the most relevant outcomes in these studies is that anonymity encourages generating ideas, whereas identification motivates more responsible actions (Fjermestad and Hiltz 1998). It may indicate that anonymity should be considered in tasks requiring idea generation such as bringing up agenda and alternatives.

2.4 Supporting group decisions: structuring the problem and analyzing decisions

Group multi-criteria decision analysis (MCDA) can be especially useful in the policy adoption phase. MCDA was originally developed to support a single decision-maker facing the problem of comparing discrete alternatives based on explicit multiple criteria. One of the most commonly used models uses a weighted additive model defining the decision making problem with the following elements:

- *Alternatives* $A = \{a_i, i = 1,..., m\}$: actions which can possibly solve the problem
- *Criteria* $C = \{c_i, i = 1,..., n\}$: aspects on which the alternatives are assessed
- *Weights* $W = \{w_i, i = 1,..., n\}$: assessment of the relative importance of the criteria
- *Criteria evaluation* v_i: $(a_i, c_i) \rightarrow R$: assessment of the alternative on a criterion
- *Alternative evaluation* v: $(a_i, C, W) \rightarrow R$: global assessment of the alternatives.

Table 1 Facilitation model

Role	Facilitator	Timing of facilitation
Structuration of the task	Internal leader	Before meeting
Guide content	A group member	During meeting
Guide interactions	External facilitator	After meeting
Handle socio-emotional issues	System	
Training		

In such a model, the evaluation of an alternative a_i is expressed, typically as

$$v(a_i) = \sum_{i=1}^{n} w_i v_i(a_i)$$

One of the problems in applying individual-oriented MCDA tools to group decision making is that the group may not agree on the definitions of the elements. Belton and Pictet (1997) suggested the following three methods to extend MCDA to group MCDA.

1. *Sharing*: Aims at obtaining a common definition of elements through *agreement*, by reducing differences by explicitly discussing their cause.
2. *Aggregation*: Aims at obtaining a common element by *acceptance*, through a vote or calculation of a representative value. Aggregation tries to reduce the differences without explicitly discussing their cause.
3. *Comparing*: Individual preferences obtained using a common approach form the basis for discussions or negotiations. Comparing aims at determining the elements individually first and use them as a basis of the final agreement. It acknowledges the differences without trying to reduce them.

Based on the additive MCDA model and these three methods, I suggest a group decision framework for participatory public decision making as in Fig. 1. It clearly shows the flow of activities for group MCDA. The group may not reach an agreement on the problem definition, objective, alternatives, and criteria. In this case, as pointed out by Belton and Pictet (1997), it is difficult to apply the MCDA model. Therefore, the definition of these elements needs to be agreed by the group members i.e., sharing.

The individuals are likely to have different opinions on weights (w_i's) and criteria evaluation (v_i's). Sharing, aggregating, or comparing may be used in this case. Different approaches may be taken for each weight (w_i) and criteria evaluation (v_i).

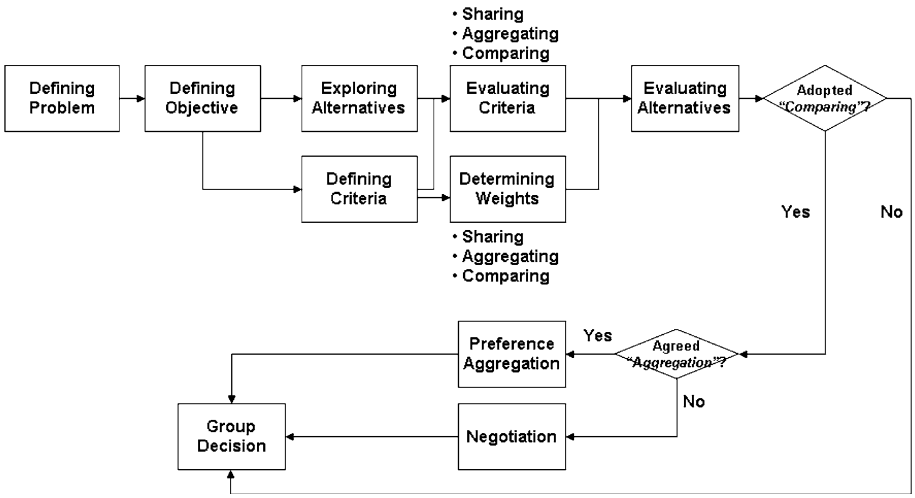

Fig. 1 Framework for group decision

For example, w_i may be determined by sharing, while w_j may be determined by aggregation.

Belton and Pictet (1997) did not consider the process after adopting the ''comparing'' method. When only sharing and aggregating approaches are used to obtain group definitions of these elements, group evaluation of alternatives can be easily constructed. However, if comparing is adopted for, at least, one w_i or v_i, group alternative evaluation cannot be obtained directly. In this case, when the rule of constructing group alternative evaluation from individual evaluation is agreed, group alternative evaluation can be constructed by applying it. When it is not agreed, group members should negotiate to obtain a compromised alternative evaluation. In the following subsections, preference aggregation and negotiation are explained in detail.

2.4.1 Preference aggregation

One approach to preference aggregation is to collect the individuals' rankings of the alternatives and build the group rankings on them. This can be formally defined as follows. Assume there is a set of n individuals I_i, $i = 1, 2,..., n$. Let P_i denote the i-th individual's complete preference order over the set of alternatives A. Let P denote the vector of individual preferences $\{P_1, P_2, ..., P_n\}$ and P_G denote the group's complete preference order over A. Preference aggregation is the function f such that

$$P_G = f(P)$$

An issue in preference aggregation is whether one can expect preferential coherence from group preference formed by aggregation as one may expect from an individual. It is well known that there is no f satisfying three properties known as Pareto efficiency (PE), non-dictatorship (ND), and independence of irrelevant alternatives (IIA) in non-trivial cases (i.e., $n \geq 2$ and $m \geq 3$) (Arrow 1951).

Voting is one of the most commonly used tools for group decision making in social matters. It is a special class of preference aggregation that can be modeled by the following function g that selects an alternative based on the expressed individual preferences $\hat{P}_i$, which may not be a complete ordering of alternatives:

$$g(\hat{P}_1, \hat{P}_2, \ldots, \hat{P}_n) \in A$$

One of the most important issues in voting is to determine whether it is subject to strategic manipulation. Gibbard (1973) and Satterthwaite (1975) proved impossibility of satisfying PE, ND and another important axiom called strategy-proof (SP). An extensive review of various evaluation criteria, voting mechanisms, and evaluation of them can be found in Cranor (1996).

Keeney (1976) showed that when preferences are represented by cardinal utilities $\{u_i\ (a_j) \in R, j = 1, ..., m\}$, there exists a function f

$$u_G = f(u_1, u_2, \ldots, u_N)$$

satisfying PE, ND, and IIA. This indicates that eliciting cardinal utility from individuals, may be a better preference aggregation method than voting. However, this requires two critical assumptions which are frequently accepted in practice. First,

interpersonal utility comparison should be allowed. Second, people should be able to accurately represent their preferences in a cardinal form.

2.4.2 Negotiation

Typical negotiations in participatory public decision making processes are many-to-many negotiations involving multiple issues. For the n-party negotiation, $n \times (n–1)/2$ communication channels should be established and every individual should handle $(n–1)$ channels. When n becomes large, considering coordination loss, mediated negotiation is a reasonable choice since it can reduce the number of necessary channels to n and each individual may need to handle only one channel with the mediator. Mediation may be done by a human being or a system or a system-supported human being. Considering the potential for large participation, it is important to have an analytic support for mediation. Bargaining theory provides useful models for finding out solutions for recommendation that can be made in the mediation process.

Bargaining theory formally defines the bargaining problem and solution as follows. Assuming there are n individuals and m alternatives, let $S \subseteq R^n$ denote the set of utilities assigned to the set of possible alternatives as follows:

$$S = \{(u_1(a_j), u_2(a_j) \ldots, u_n(a_j)),\ j = 1, \ldots, m\}$$

The disagreement point (or status quo point) $d = (d_1, d_2, ..., d_n)$ is the vector of utilities that individuals will receive if there is no agreement. The bargaining problem is defined as (S, d) and a bargaining solution is a point $f(S, d) \in S$ such that $f(S, d) \geq d$, satisfying some desirable properties or axioms. Various bargaining solutions satisfying different axioms are extensively reviewed in Thomson (1994).

Since the bargaining solutions may be interpreted as the solutions which a neutral and fair third party would recommend, we can consider a mediation process based on these solutions. Let $R(f(S, d))$ denote the set of responses from all parties involved to the recommended solution $f(S, d)$. A mediation process based on bargaining theory can be generalized by the following algorithm:

Initialization: $S_0, d_0, f_0, t = 0$
Iterate until a stopping criterion is met
  Suggest $f_t(S_t, d_t)$
  Collect $R_t(f_t(S_t, d_t))$
  $t = t + 1$
  Update S_t, d_t, f_t

Various mediation methods can be considered depending on how to update S_t, d_t based on $R_t\,(f_t\,(S_t, d_t))$ and how to choose f_t. One may update only S_t and d_t and use the same bargaining solution f for every step. It is possible to adopt different types of bargaining solution at each step of iteration. For example, one may suggests a series of Nash's bargaining solution (Nash 1950) based on updated S and d, or one may suggest Nash's bargaining solution first and suggest Kalai-Smorodinsky's solution (Kalai and Smorodinski 1975) next, and so on. The stopping criterion does not have to be that every participant accepts the suggested solution because the mediation

scheme may be to suggest an improved solution at each step. In such case, there may be room to improve the solution even when every participant accepts it.

Figure 2 illustrates some of the possible mediation processes in the utility space. (A) shows the method based on updating d while S remains the same. This method can be interpreted as helping negotiators to reach an efficient agreement in a fair manner. The Balanced Increment Method (BIM) or Single Negotiating Text (SNT) presented in Raiffa et al. (2002) corresponds to this case. (B) is the case in which f_t used in each iteration always yields a Pareto efficient solution. This approach focuses on improving process efficiency, in the sense that the improvement step in (A) is omitted and obtained agreement is always non-dominated. The approach proposed by Rios Insua et al. (2005) corresponds to this type. In (C), both S and d change at each step. This can be interpreted as helping the negotiators to learn and realize opportunities. This can be achieved in different ways. When preferences are well-defined, it can be achieved by introducing another dimension that was not considered when modeling preferences. If preferences are not well-defined, it can be done by gradually identifying the preferences. The approach proposed by Ehtamo et al. (2001) corresponds to this case. In any case, in order to encourage and improve deliberation, it is important to ensure communication between parties, especially before and after collecting responses R_t for collective and continuous elaboration of solutions as close as possible to the interests of all the involved parties.

Application of bargaining theory requires individuals to fully reveal their preferences to a neutral third party. This has been considered as a rather unrealistic assumption and the limit of the theory when it comes to application in practice. However, recent advances in ICT allow implementing systems that protect privacy of preference information. Beside technical development, wide social acceptance of cryptography and other security technologies can encourage full open to the intermediary disclosure (FOTID). Under the FOTID assumption, a system founded on bargaining theory can play a significant role as an impartial arbitrator or mediator (Rios Insua et al. 2003).

3 A case of participatory public decision making: participatory budgeting (PB)

An interesting example of a participatory public decision making procedure is participatory budgeting (PB), a process of allocating the budget to various public projects based on the priorities determined through citizen participation. The first

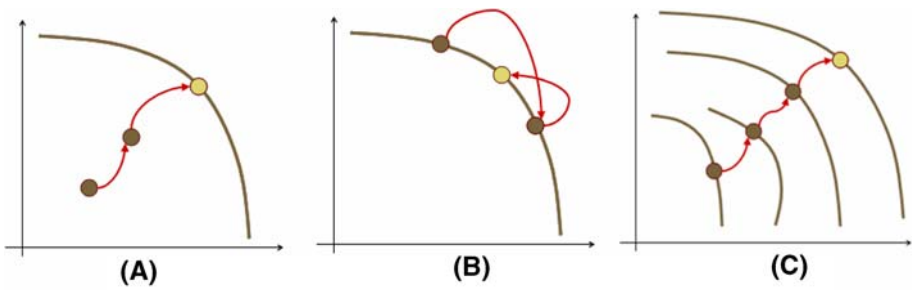

Fig. 2 Three types of mediated negotiation processes represented in the utility space (2-party case)

report on a successful PB implementation was from Porto Alegre, a southern Brazilian city with 1.3 million population. United Nations and the World Bank recommended PB as one of the best policy practices that improves transparency, reflects minority interests, and educates the public. Nowadays, more than 240 municipalities in Brazil and other countries including Ireland, Canada, India, South Africa, and many south American countries are practicing PB (World Bank; UN-HABITAT 2004).

The implemented PB processes differ due to various social, political, and cultural contexts. According to the survey of 103 Brazilian municipalities in 1997–2003, the proportion of capital budget debated through the PB ranges from less than 10% to 100% (15% of them with less than 10% of the budget and 21% of them with 100% of the budget). In some cases, all citizens are entitled to freely participate; in other cases, participation is allowed only through organized communities such as unions, political parties, churches, or housing associations (UN-HABITAT 2004).

The PB process implemented in Porto Alegre is a good representative case because, first, it has been a reference for many PB implementations, and second, it has the longest history (15 years). In these sections, the details of the PB process in Porto Alegre will be explained.

3.1 PB process in Porto Alegre, Brazil

The PB process in Porto Alegre is based on three basic principles. First, all citizens are entitled to participate. Second, direct and representative democracy rules are combined. Third, resource allocation is decided by an objective method, the so called budget matrix. It has been modified many times during the 15 years of practice. Hence, the PB process in Porto Alegre described in the literature is slightly different. The PB cycle can be roughly described as follows.

In the first step, the community is mobilized through various media. Next, the first round of regional (i.e., neighborhoods) and thematic (i.e., issue specific) forums are held in March or April. In 1997, there were 16 regions and 13 themes (housing, sewage, pavement, education, social assistance, health, transportation and circulation, city organization, leisure areas, sports and leisure, economic development, and culture). In the forum, the municipal government presents the current year's budgeting criteria. After then, the regional and thematic groups have intermediate meetings. Demands and priorities are determined by voting of the participants in those meetings. In June and July, there is a second round of regional and thematic forums. In the forums, the government gives account of and the expected income and the regional groups hand in demands and priorities. In this round, two participatory budgeting councilors are elected in each region. The PB council consists of the representatives from the government and organized communities as well as the elected councilors. Courses and seminars on public budgeting are offered to the elected PB councilors. In August, the government drafts the budget proposal considering demands and priorities identified in earlier stages. In September, the PB council discusses the criteria for resource allocation on the details and votes on the proposed budget. Then, the PB council and government submit the budget proposal together to the legislative body and the budget proposal is approved by voting by the end of November.

In 2001, all of the capital investment in Porto Alegre, which is 14.22% of the total budget or US$ 179,000,000, was determined through PB (Center for Urban and Development Studies 2004). The budget is allocated to themes and regions by three criteria and pre-determined weights on these criteria. The criteria used in Porto Alegre were the total population in the region (weight 2), lack of public services and/or infrastructure in the region (weight 4), and a thematic priority elected in the region (weight 5). Table 2 shows the method of evaluating criteria used in Porto Alegre.

Table 3 shows an example of the budget allocation. Table (A) shows that theme 1 will be allocated 8.1% of the total budget because the total score of all themes is 5,400 and theme 1 received 440 (440/5,400 = 8.1%). Table (B) shows how this 8.1% budget is allocated to 16 regions. Region 1 has population less than 25,000 (grade 1), lacks 60% of infrastructure or 40% of infrastructure is implemented (grade 3), and voted theme 1 as the theme with third priority (grade 2). Based on Table 2, region 1's score is $2 \times 1 + 4 \times 3 + 5 \times 2 = 24$. As stated earlier, the summation of scores for theme 1 from all regions was 440. Therefore, region 1 will be allocated 24/440 = 5.5% of the budget allocated to theme 1, which is 0.44% (0.081×0.055) of the total budget. This becomes a budget envelope for theme 1. Each theme is composed of sub-themes. For example, the housing theme includes sub-themes such as relocation, urbanization, and housing construction. The final budget allocation considering the details on the sub-themes is drafted by the PB council.

In Porto Alegre, thematic priorities have changed reflecting changes in demands with priorities. Table 4 shows three themes selected as highest priority through the votes aggregated from all regions. The table indicates that paving, housing, and basic sanitation were recognized as the highest priorities during the 11-year period (1992–2002). Significant improvement in those themes has been reported during the 15 years of the PB practice (1989–2003). The deficit of paved roadways was reduced from 690 km in 1998 to 390 km in 2003. The average number of housing units produced locally doubled from 494/year to 1,000/year. The percentage of dwellings with access to treated water rose from 94.7% in 1989 to 99.5% in 2002. The percentage of treated liquid waste went from 2% in 1989 to 27.5% (UN-HABITAT 2004). This outcome can be interpreted as an indication of effective decision making when the budget decisions are made by participation of the citizens: money for public works is likely to be spent where citizens feel it is most needed.

Table 2 Evaluation of criteria in Porto Alegre (Center for Urban and Development Studies 2004)

Total population in the region (weight 2)		Infrastructure implemented in the region (weight 4)		Thematic priority elected in the region (weight 5)	
~25,000	Grade 1	76%~	Grade 1	Fifth or more	Grade 0
25,000–45,000	Grade 2	51–75.99%	Grade 2	Fourth priority	Grade 1
45,000–90,000	Grade 3	15–50.99%	Grade 3	Third priority	Grade 2
90,001~	Grade 4	0.01–14.99%	Grade 4	Second priority	Grade 3
				First priority	Grade 4

Table 3 Determination of the budget allocated to themes and regions

(A) Determination of thematic priority			(B) Determination of regional priority for theme 1					
Theme	Total score from 16 regions	Proportion (%)	Region	Criterion 1 (Weight 2)	Criterion 2 (Weight 4)	Criterion 3 (Weight 5)	Score	Proportion (%)
1	440	8.1	1	Grade 1	Grade 3	Grade 2	24	5.5
2	360	6.7	2	Grade 2	Grade 4	Grade 3	35	7.9
...	...	...	...	...	...	...	...	...
13	380	7.0	16	Grade 4	Grade 2	Grade 1	21	4.8
Total	5400	100	Total				440	100

3.2 Analysis of PB in Porto Alegre

Among the five phases of the policy making model, the PB process in Porto Alegre focused citizen participation in the agenda setting and policy adoption phases. The agenda setting phase is performed allowing for citizen participation through a forum where community needs are discussed and priorities are determined. In the policy adoption phase, the budget matrix is determined through voting of participants. The details of the budget investment plan are determined through representative participation—collaboration between the elected PB councilors and the government officials. The policy formulation, execution, and assessment phases are executed with limited citizen participation. The government decides many elements including the regions, thematic areas, and the rules of aggregating priorities. There was little room for citizen participation in executing the policy and the execution is just reported to the citizens and reviewed by the PB council.

PB in Porto Alegre did not use ICT to support communications and collective deliberation processes. Most of the communications were through face-to-face large town hall meetings. The number of participants steadily rose from 628 in 1990 to 14,408 in 2000 (de Sousa Santos 1998) as the impact of PB becomes real and the importance of participation is recognized. However, considering the total population in the city was 1,360,033 in 2000, the proportion of participation is still very low (less

Table 4 Thematic priorities determined by PB in Porto Alegre between 1992 and 2002 (Center for Urban and Development Studies 2004)

Year	1st Priority	2nd Priority	3rd Priority
1992	Basic sanitation	Education	Paving
1993	Basic sanitation	Paving	Land use regulation
1994	Land use regulation	Paving	Basic sanitation
1995	Paving	Land use regulation	Basic sanitation
1996	Paving	Basic sanitation	Land use regulation
1997	Housing	Paving	Basic sanitation
1998	Paving	Housing	Basic sanitation
1999	Basic sanitation	Paving	Housing
2000	Housing	Paving	Health
2001	Paving	Housing	Basic sanitation
2002	Housing	Education	Paving

then 1%). Supporting communications through ICT may increase participation rates overcoming time and geographic barriers.

Lack of communication support may have also led to skewed representation in Porto Alegre. More participation was from typically under-represented people in the established political system such as people with low education level and low income (de Sousa Santos 1998). ICT based communication support may lead to a more balanced representation while still ensuring that the voice of minorities is reflected.

The town-hall meetings or forums were held with a facilitator typically assigned by the government. The facilitator is reported to have provided all the roles listed in Table 1. As stated earlier, if communication support is provided, the facilitation task may become more complex and difficult. Appropriate facilitation models for the large-scale face-to-face & asynchronous combination need to be studied.

As for group decision making, sharing, aggregating, and comparing were all used. Sharing was used for defining the problem (i.e. budget allocation) and defining the objective (i.e., fair budget allocation proportional to the needs). The three criteria (population, lack of infrastructure/service, and priority) and the weights assigned to them were also shared by all participants. Evaluation of two criteria (population and lack of infrastructure/service) adopted the sharing method. The priority of the theme for each region was selected by voting of the residents (i.e., aggregation). Then, regions try to reach a consensus acknowledging that each region has different priorities in the themes (i.e., comparing). The proportions of the total budget allocated to the themes and the proportions of the thematic budget allocated to the regions were calculated by the rule of budget matrix calculation (i.e., preference aggregation). Figure 3 describes the analysis of the PB process in Porto Alegre.

The rules for budget allocation used in Porto Alegre is preference aggregation discussed in section 2.4.1. The key element of PB is the budget matrix specifying the proportion of the budget allocated to a specific region for a specific theme. The budget matrix determination based on the additive valuation model can be generalized as an allocation method as follows.

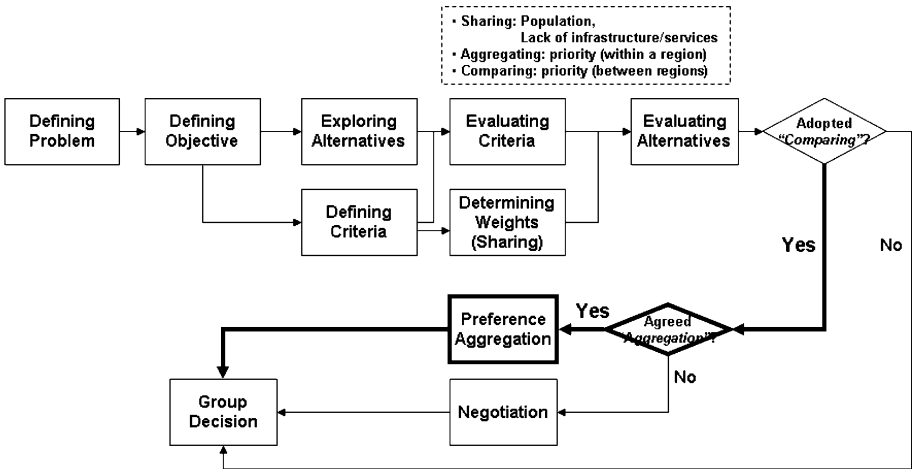

Fig. 3 Group decision model used in Porto Alegre

Consider the allocation of a resource B to a project k (B_k) and the allocation of the project budget B_k to a group j (B_{kj}). Assume there are n groups and m projects. Let a denote the number of criteria, w_i denote the weight assigned to the i-th criterion, w^j denote the weight assigned to group j, and v_{ij}^k denote j's evaluation of criterion i for project k.

The resources allocated for project k, B_k, can be determined by

$$B_k = B \times \frac{\sum_{j=1}^{n} w^j \left[\sum_{i=1}^{a} w_i v_{ij}^k \right]}{\sum_{k=1}^{m} \sum_{j=1}^{n} w^j \left[\sum_{i=1}^{a} w_i v_{ij}^k \right]}$$

The resource for project k allocated to group j, B_{kj} can be determined through

$$B_{kj} = B_k \times \frac{w^j \left[\sum_{i=1}^{a} w_i v_{ij}^k \right]}{\sum_{j=1}^{n} w^j \left[\sum_{i=1}^{a} w_i v_{ij}^k \right]}$$

The matrix $[B_{kj}]$ is a resource allocation matrix. The participatory budgeting process covered in section ''A case of participatory public decision making: participatory budgeting (PB)'' is a special case of this resource allocation method. Instead of n individuals, there are n regions, and instead of m projects, there are m themes. Although the evaluation of the region was not weighted (i.e., $w^j = 1$), regions are weighted implicitly by having two criteria reflecting the weight on the region (i.e., lack of resources in the region and population) in the valuation formula.

4 Conclusion

In this paper, focusing on the participatory public decision making, I tried to integrate the plebiscitary and deliberative perspectives on e-democracy. The system implementing such a perspective should support three aspects (communications, collective deliberation processes, and group decision making) in all phases of the policy making process.

As a reference case showing the feasibility of participatory public decision making, the participatory budgeting experience in Porto Alegre is presented. The experience in Porto Alegre shows that one of the factors that determines the level of citizen participation is the perceived impact of their participation. It hints that system support, especially communication tools and process support for the provided communication tools, is important to increase participation and encourage balanced representation.

The case also illustrates how the group MCDA approach can be used in large scale public decision making. The success in Porto Alegre was partly due to the fact that the participants did not have to fully understand the underlying group MCDA model and express complete preferences. The outcome of PB during the last decade shows that that participatory public decision making based on group MCDA is not only possible but may lead to effective decisions.

PB in Porto Alegre was implemented without any system support. System support may improve the process but may also cause problems. The body of knowledge accumulated in group decision and negotiation support systems can provide guidelines for developing systems for participatory public decision making and reduce the social cost of trials and errors.

I conclude this paper identifying six major challenges in developing systems supporting participatory public decision making processes:

1. *Non-expert users with diverse profiles*: While the users of decision support systems are usually assumed to be specialists, many citizens are not familiar with decision analytic model and decision support systems. In addition, citizens have different cognitive capabilities, interests, communication and computer skills, etc. Therefore, the system should minimize technical difficulties and guarantee access to all citizens, including impaired people, while utilizing decision sciences to improve the quality of decisions.
2. *System flexibility*: As the system will be used in different contexts (i.e., different portions of budget, numbers of citizens, degrees of participation, methods of participation and making decisions, etc.), it should be flexible enough to be deployed in many different contexts and should support functionalities such as defining the problem, designing the procedure, developing algorithms for mediation and conflict resolution, choosing communication mechanisms for information and opinion exchanges, etc.
3. *Algorithms*: Supporting communication is essential but not sufficient for the system. In order to utilize decision sciences, various algorithms should be considered for constructing and modifying individual/group preferences and risk attitudes, suggesting a series of intermediate solutions for mediation, generating a solution for arbitration, processing various voting mechanisms, etc. Considering the potential size of the problem instance, scalability of the algorithm is very important. But scalability is not sufficient. Algorithms should be also investigated if they are not susceptible to strategic manipulation by groups of users, protect privacy, and preserve anonymity while providing accountability.
4. *System scalability and stability*: The user base of the system could be thousands or easily even more. Because the user base is large and simultaneous access to the system is expected, the system should be stable even when a large number of requests arrive within a very short time period.
5. *Security*: The system should support proper and legal authentication and non-repudiation mechanisms while protecting privacy of users. The system should be widely accessible, but should be also protected against malicious user groups.
6. *Social issues*: The digital divide has been a critical argument against promoting democracy through using ICT. In addition, societies have different degrees of technology diffusion, cultures, legal, and political systems. Often, they are barriers against applying modern decision sciences and ICT to make public decision with increased citizen participation.

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