Towards Intelligent E-Participatory Budgeting

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Abstract: In this article we present a general framework for Intelligent E-Participatory Budgeting (E-PB). First, we review Participatory Budgeting (PB), identify past and current practices and highlight their successes and limitations. Later we describe a framework for E-PB, oriented toward the integration of smart community data and the use of intelligent technologies that can improve the participation process, help citizens in understanding complex socio-technical phenomena and help them make better decisions.

PB is a democratic instrument for deliberation and decision-making where regular citizens have the power to decide on how to allocate public budgets. PBs have become widely popular in municipalities around the globe since the Porto Alegre initiative in 1989, and have shown potential for improving the lives of the communities participating in this form of direct democracy. Despite the successes of PBs many issues remain open and new ones start emerging as a result of the changes in technology and urban dynamics. Conceptual issues have been long discussed in the literature such as, limited participation by citizens in decision-making, lack of long-term planning, underrepresentation of certain segments of the population, and lack of understanding by the participants about complex socio-technical processes. From the information and communication technologies (ICT) standpoint, we identify issues related to minimal use of ICT in general, and particularly decision support tools, GIS and lack of use of forecasting, simulation and intelligent technologies. We conclude that PBs need to be integrated in a new kind of participatory e-government that should incorporate Open Community Data, where organized citizens actively participate in the process of building a civic infrastructure of community-based software, sensors and ubiquitous ICT, challenging existing top-down structures and expanding civic networks.

The framework for E-PB incorporates: smart community data from distributed sources that can inform citizens about complex social and environmental phenomena; performance metrics of previous projects; group deliberation and decision support technologies, facilitating a collaborative environment for intelligent proposal creation and a guided and flexible decision support tool for citizens; simulation and forecasting technologies integrated with GIS, that will benefit participants to fully understand the future consequences of current decisions and map projects over locations; grassroots social technologies, that can aggregate civil society opinions and mobilize participants. The goal of this framework is to articulate and decentralize the decision processes involved in E-PB while at the same time empowering citizens in the construction of a participatory e-society.

Keywords: *E-Participatory Budgeting, Participatory E-Democracy, Open Community Data.*

1. Introduction

Participatory Budgeting (PB) is a process of deliberation and decision-making where “regular citizens” have the power to decide on how to allocate public budgets. Since its inception in Porto Alegre in 1989, PBs have shown to be very efficient instruments for social justice and government accountability, improving the lives of the communities participating in this form of direct democracy (Gret & Sintomer 2005; Gonçalves 2014). The initial experience of Porto Alegre was based on three objectives: democratize democracy through grassroots participation, prioritize the needs of the disadvantaged, and establish good governance practices. The participatory instrument developed to achieve these goals came about as a result of giving direct decision-making power to citizens at the grassroots and at the city levels.

After Porto Alegre, PBs rapidly spread through municipalities in Brazil, becoming popular later in Latin American cities and throughout the world (Cabannes 2004; Sintomer et al. 2010). Initially seen as instruments of leftist movements, PBs have adapted and evolved in different versions and in diverse contexts, having been promoted by

political parties from the Left, Right and Center, and by institutions as different as the Workers' Party in Brazil, the World Bank and United Nations. This capacity to adapt to different scenarios and countries is due to its flexibility and open form not limited to a single model. In (Sintomer et al. 2010) five criteria are given for PBs:

1) The budgetary dimension needs to be discussed.
2) The municipality, city or district unit needs to be part of the process.
3) PBs are iterative in nature. One single meeting/discussion does not account for PB.
4) Public deliberation is required.
5) Accountability on the output.

Amongst the thousands of experiences around the globe, scholars and practitioners have distinguished six types or models of PBs (Sintomer et al. 2010): adaptation of Porto Alegre, proximity participation, consultation on public finance, multi-stakeholder, community participation budgeting and participation of organized interests.

The Porto Alegre model has been adopted in several municipalities in Brazil, Latin America, and in Europe. In this model, citizens participate directly in the decision-making processes through open assemblies in the different districts. The role of the assemblies is to determine priorities and to elect delegates and representatives who develop the suggested proposals and projects. The delegates are strongly controlled by the citizens and can be replaced after a year. The PB council at the city level has the role of making sure that the priorities of the districts are being taken into account. In order to guarantee social justice, an allocation formula is used: the funds are distributed according to the needs, priorities and number of residents in a given district. In this way, districts lacking quality infrastructures or services will benefit from this formula. The main strength of the model is its deliberative nature; participants discuss in different forums issues and problems in depth, and can present and push forward their own solutions.

Proximity participation is a consultative instrument used by municipal governments to selectively listen to citizen demands and needs through assemblies. In contrast with the Porto Alegre type, in this model citizens engage in discussions, but the results are summarized and prioritize by the local government, which selects proposals that are in tune with their own objectives and interests.

Similarly to proximity participation, consultation on public finance is a consultative form of civic participation, where local governments organizes meetings and assemblies to present to the citizens financial projects and listen to their demands and needs. The main goal of this model is for the city to be transparent about finances, and to communicate budgetary decisions to citizens. The degree of participation and deliberation of civil society is normally very low.

In the community participation and multi-stakeholder models a fund of investments is dedicated to projects in the social, environmental and cultural sectors. The investments usually come from outside the municipal budget (companies, NGOs, international programs...) and the legislative doesn't have the final decision. In the multi-stakeholder case, companies and private organizations provide part of the funds and can influence the result of the process. In community participation, companies are excluded and only international programs and NGOs can participate, and its objective is to favor the most disadvantaged segments of the community. In both models the degree of deliberation is high, with several meetings taking place in which citizen's delegates, association representatives and community leaders discuss on priorities and projects.

In the participation of "organized interests" model, policy and strategic planning issues are discussed, concrete projects are not developed as a result of the deliberation process. It has a consultative orientation and together with citizens, companies, NGOs, and other civil organizations can participate.

PBs have spread around the globe and developed under different modalities, where the degree of participation and deliberation varies between experiences. Besides its successes, several limitations have been discussed in the literature (Souza 2001; Cabannes 2004; Gret & Sintomer 2005; Shah 2007), such as limited participation by citizens in decision-making, lack of long-term planning, underrepresentation of certain segments of the population, and lack of understanding by the participants about complex socio-technical processes. While PBs have brought higher degree of accountancy and transparency to government, and strengthen democratic practices by engaging local communities in policy making, the connection of civil society with the decision-making spheres is minimal in most experiences. In (Baiocchi & Ganuza 2014) they differentiate between two dimensions in PBs: the communicative and the empowerment. The first dimension regulates the conditions of communication by opening meetings and discussion forums to citizens. The second connects those meetings and deliberation activities to the centers of decision-making. Besides the Porto Alegre experiment, most PBs do not explore the empowerment dimension,

leading to a reduction of the participatory process in which the demands of civil society do not necessarily transform in budgetary decisions. The real power and emancipatory qualities of PBs as democratic instruments rely precisely in their capacity to connect citizens and government in collaborative decision-making processes.

This paper presents a review of the use of Information and Communication Technology (ICT) in PBs, presents new scenarios under which new participatory civic technologies and practices can emerge, and outlines a general framework for E-PB.

2. Reviewing technology use in participatory budgets

In this section a review of the literature on technology use in PBs is made on past practices, and electronic review of media (websites and apps) is carried for understanding current ones. Technology is analyzed and classified according to their functionality in PBs. This review is by no means exhaustive, but has the intention of providing a general understanding of how ICT has been incorporated in PB experiments.

The use of ICT in governmental practices has been considered by officials as an opportunity to enhance the access and delivery of government information and services to citizens, business partners, employees, other agencies, and government entities (McClure 2000). This "opportunity" has left aside in many cases, the main ideal of e-democracy: citizen involvement and direct participation in government through the use of ICT.

In the last decade, some PBs have incorporated the use of ICT as a medium to strengthen citizen interaction and participation. In Brazil, two of the oldest PBs, Porto Alegre and Belo Horizonte, nowadays include online tools for articulating some of the stages. (Sampaio, Maia & Marques 2011) have shown in the case of Belo Horizonte, that even if there is no empowerment of the digital tools and low levels of deliberation, E-PBs can improve social learning among participants. Ipatinga (Minas Gerais, Brasil) started in 2001 the use of the internet in their PB experiments. In order to eliminate the digital divide, the municipal government made available in different locations computers, and technical staff to support citizens in the use of the tools. In the United States, digital technologies have been used extensively in the New York and Vallejo PBs (PBP n.d.). In Europe, Lisbon was the first European capital to extend PB to the whole municipality, and considered the use of ICT as the only viable way for incorporating not only residents, but also the floating population of the capital.

In the following subsections, the use of ICT in several PB experiences will be classified in two different categories in relation to their functionality:

1. Informative: technological tools oriented at informing citizens not only about the process and the conditions of participation, but more importantly, about municipal and community issues.
2. Participative: tools that can mediate or enhance the process of deliberation towards the creation of proposals and projects and inform decision-making.

2.1 Informative

A website with general information about the process and the conditions of participation is usually found at municipal sites. More sophisticated information, such as instructional videos and district maps with previously funded projects are found in the New York PB site (PB NYC n.d.). Geo-referenced information is also found in websites like the Observa POA project of the Brazilian city of Porto Alegre (Cidade de Porto Alegre n.d.), where citizens can access geographic information about completion of projects by planning region, and was used in conjunction with PB as a source of supporting information. In Modena, Italy, web broadcasts of face-to-face meetings were offered to citizens, who can also solicit to receive SMS about the proceedings, enlarging the participation of PBs. In Getafe, Spain, live streaming of the meetings of one district was broadcasted to citizens, amplifying the reach among the community. The City of Vallejo in California uses Google apps to deliver information to citizens and to organize public meetings. In Solo, Indonesia, the combination of GIS with the help of human mapping resulted in a geo-referenced application for citizen planning (Yayasan Kota Kita Surakarta 2010). Once the data is collected and presented in the system, citizens can access the information for later use in face-to-face deliberations. In 2012, in two local municipalities of Yaundé, Cameroon, supported by the World Bank Institute and the World Bank Open Development Technology Alliance, SMS services were introduced in a strategy to extend

participation, information sharing and inclusion in PB. The result of this strategy was a total participation of 45.000 citizens, compared with 25.000 in the previous year 2011 (The World Bank 2013).

2.2 Participative

Online proposal submission was one of the first uses of digital technologies in PBs. In 2001, Porto Alegre introduced this tool in their PB as an innovative use of technology. With the use of this application participants were able to submit their proposals for later deliberation in face-to-face meetings. Ipatinga developed different participatory web tools for citizens during their PBs experiences, geared towards the inclusion of participant's demands and submission of proposals. The case of Ipatinga showed to be one of the most successful at incorporating participants in PBs for the indication of priorities via online tools. In 2003, 96% of the submissions of priorities were sent via the internet (Martinez De Oliveira, Vaz & Carty 2003). In Lisbon, electronic proposal submission was made available to participants since 2008; after the evaluation and approval of the ideas by municipal officials, proposals considered viable are put forward for public voting (P2P Foundation n.d.). Many other PBs use online voting for the selection of proposals or for selecting the priorities of the investment, such as San Francisco, Rochester or Belo Horizonte. In the online only experience of Belo Horizonte (2006 and 2008), electronic voting was used to select the projects to be executed, with 8% of the citizens participating, up to 5 times more than the face-to-face PB (Peixoto 2009).

Participation tools combined with GIS are found in the PB of the City of New York District 39 (PBNYC District 39 n.d.), where citizens can propose projects based on specific locations and others can engage in the conversation by supporting the idea or incorporating new ones. Even though this application is not meant for deliberation, it can motivate users to start discussions about ideas and projects or spread the word over social networks.

In the City of Vallejo, they strengthen community participation and online deliberation through the use of a community oriented app (Nextdoor n.d.). Nextdoor is a private social network for neighborhoods, where members of the community can discuss on their issues and engage with municipal departments and officials.

Since 2008, the City of Freiburg im Breisgau has developed online deliberation tools such as forums and discussion boards, and a budget simulator to increase citizen understanding of budgetary issues (Beteiligungshaushalt Freiburg n.d.).

The city of Pune in India, has built an e-platform for citizens to send their priorities for the allocation of budgets (Pune Municipal Corporation n.d.).

2.3 Conclusions

The use of technology in PBs concentrates mainly in its informative and communicative dimensions. Most of the tools that we have previously reviewed are situated on the first category. These are basic one-directional information tools such as websites, blogs and SMS, oriented at informing citizens on procedures, participatory processes and results. More advanced information technologies such as GIS and budget simulators are no so often found in E-PBs, and have the potential of providing planning information that can be later use for deliberation and decision-making.

Online deliberation web tools such as wikis, forums and discussion-boards allow users to discuss on ideas, alternatives, preferences and actual projects. Deliberation is one of the fundamental components of PBs, and while online tools have been widely used, the quality and degree of deliberation is normally low in online settings, but they can enhance social learning and help disseminate ideas among the community (Sampaio, Maia & Marques 2011; Cunha, Allegretti & Matias 2011).

E-voting is the only technology used in E-PBs for the selection of projects and proposals, where a simple aggregation of preferences by the participants is evaluated. Even though frameworks for PB decision support exist in the literature (Rios Insua et al. 2008; Alfaro et al. 2010), they have not been put into practice by municipalities and practitioners.

The main reason for including ICT in PBs was to promote new forms of citizen participation and democracy. As seen in the previous review, most online tools in PBs are used to reinforce informational flows between municipal officials and civil society in a top-down fashion. The information is collected and summarized by municipal bodies, and presented to citizens using municipal knowledge infrastructures. This one-way approach raises a major question: how can citizens (or organized citizens) trust, verify and dispute official data? "Packaged" data may raise concerns of validity and manipulation on one side, but raw data without preprocessing is meaningless to citizens on the other end. Incorporating participatory data collection mechanisms and its associated technologies and actors could become an instrument to control governmental practices and to increase the type of data available to the public. This participatory community data would necessarily need its appropriate knowledge infrastructures to manage, present and preserve it.

A deliberative process, as a two-way interaction between citizens to critically analyze an issue and to arrive at possible agreements that will inform decision-makers, is situated at the center of PBs in its empowerment dimension. Limitations of online vs face-to-face deliberation have been recently highlighted in the literature (Hartz-Karp & Sullivan 2014). Online deliberative tools that were previously reviewed showed limited capacity at generating discussions between participants. Moreover, these applications, in most cases, were not connected to decision-making structures. Finding virtual spaces for citizen deliberation, rather than applying technological fixes, should be the main objective for improving online deliberation. Internet social networks have shown to be a free space for the emergence of social movements and a medium for citizen participation and mobilization (Castells 2013). Their political deliberation capacities have been studied in the literature (Gonzalez-Bailon, Kaltenbrunner & Banchs 2010) with results showing deeper and more nested levels of discussion. Connecting online social networks to participatory budgets should be articulated around topics and projects, where deliberation can be channeled towards a more inclusive and elaborated submission of proposals, and at informing decision-making.

While PBs have been incorporating ICT in their design together with face-to-face interactions, they have not fully accomplished their initial objectives: broaden citizen participation and be a catalyst for civic empowerment. In a time of big data and complex socio-technical interactions between citizens and urban systems, the concept of an "informed citizenry" goes beyond the model of city administrative units delivering information as a service to its citizens. With the advent of participatory methods and technologies to "sense" the city, accessible open source hardware, and civic hacker groups, urban information infrastructures will move to a more open, distributed, intelligent, and sustainable model, which places the citizen at the center of its activity and not at its periphery. This change will help open sourcing governmental black boxes and develop new civic knowledge networks and infrastructures that have the potential to facilitate a more direct dialogue between citizens and governments, enhancing participatory democratic practices. In this context, PBs will need to place higher importance at including intelligent technologies as a catalyst for participation.

3. Building intelligent communities: a bottom-up approach

Urban centers will face in the next decades severe challenges associated with population growth, social, economic and environmental sustainability (UN Secretary-General (UNSG) 2009). Under these circumstances, there is a common consensus that cities need to become smarter in order to overcome these challenges, but what the term 'smart city' means, has different interpretations in the literature in relation to its focus (Meijer & Bolívar 2013). From a technical point of view, authors emphasize the use of ICT to build the critical infrastructures of the city more intelligent and efficient (Washburn et al. 2009; Caragliu, Del Bo & Nijkamp 2011; Walravens 2012; Lee, Phaal & Lee 2013). These authors set ICT as the key component in the operation of the intelligent city. Other authors (Shapiro 2006; Winters 2011), without leaving technological considerations aside, focus on smart citizens as the fundamental element in the functioning of the city, where the degree of education and knowledge of the population are the main drivers for urban transformation and growth. Socio-technical synergies between human and technological networks are considered by fewer authors in the literature as key in the development of the smart city (Meijer & Bolívar 2013). The role of government in smart city development has also been discussed in the literature, and while most authors concentrate in transformations in governmental structures and administration to improve citizen services (Winters 2011; Alkandar, Alnasheet & Alshekhly 2012), other authors focus on the smart collaborations between communities and municipal governments to make the construction of the city citizen-centered with the use of advanced ICT (Bătăgan 2011; Kourtit, Nijkamp & Arribas 2012).

Putting definitions of what 'smart' means aside, smart city projects have been characterized by large ICT deployments, where technological infrastructures have been 'implanted' in urban spaces with the goal of optimizing resources and achieve sustainability. These deployments are based on a top-down model, where city officials define their operational objectives and core services, and technological partners implement these goals by means of ICT (Falconer & Mitchell 2012). This model has raised several questions regarding the construction and management of the smart city in relation to its citizens, in terms of participation, accessibility, lack of standardization, data privacy and security, and the need for future alternatives to this vision (Conti et al. 2012; Cáceres & Friday 2012; Townsend 2013). While this top-down approach has developed the critical hardware infrastructure, little attention in the literature has been given to new emergent forms of civic pervasive computing and its associated practices as an alternative for intelligent community development.

3.1 Emergence of intelligent civic infrastructures

In the last decade, the growth of social media sites, smart phones, Global Positioning System (GPS) enabled devices, distributed sensor networks for environmental monitoring, and robots, has created unprecedented amounts of digital footprints of users and their cyber-physical interactions. This "Big Data" explosion has created new possibilities for the understanding of urban phenomena, but also has raised new concerns related to the use and ownership of this information, and how it can be utilized for surveillance and public control (Lyon 2014).

Social networks like Facebook and Twitter, have become channels, amongst others, for civic participation, political deliberation, social movement activism, distributed collaboration, and disaster management response (Bertot, Jaeger & Grimes 2010; Keim & Noji 2010; Castells 2013). Participatory sensing and geographical mapping applications have been instrumental in the last years for creating social shared narratives of complex phenomena, where groups of people, with the use of their mobile devices, act as sensors to generate a body of knowledge in a given domain (Burke et al. 2006; Sieber 2006; Haklay & Weber 2008). With the advent of open source hardware and new and affordable electronics platforms such as Arduino (Arduino n.d.) and Raspberry Pi (Raspberry Pi n.d.), and environmental monitoring projects such as Air Quality Egg (airqualityegg n.d.), and Safecast (Safecast n.d.), community-based ubiquitous computing devices and their associated networks, have played an important role in developing transformational practices in social contexts, and at empowering individual citizens. Robots and autonomous computing devices have also been used for augmented environmental sensing and for strengthening grassroots participation (Angus, Lane & Roussos 2014). These emergent and pervasive infrastructures of distributed human interactions and devices, articulate new social narratives in geographical contexts, specifically around urban centers, linking the physical with the virtual. In this article we argue that while community technologies have emerged that have the potential to mobilize grassroots and to be the catalyst for social transformations, all practices and artifacts developed by these independent efforts and communities could have a much larger impact in the construction of urban spaces if they can be articulated in a cohesive manner, as civic hubs for building intelligent community infrastructures and open knowledge repositories. In order for this change to take place, first, a collaborative organizational structure needs to emerge that will link isolated practices and conduct communities towards a global goal, which is building future intelligent urban spaces and societies. Second, the data generated by the interaction of artifacts and citizens has been, in its majority, stored in privately owned and governmental repositories, making data not exchangeable and linkable between systems, limiting knowledge creation. In order for this emergent infrastructure to have 'meaning', data needs to be stored, managed, shared and reused in publicly open systems, where it can be linked with other data repositories. This implies the existence of two parallel infrastructures: a pervasive one (U-Infrastructure), created by networked devices and citizens, and an open knowledge infrastructure (K-Infrastructure) composed by data storage and management systems (see Figure 1). The community data generated and stored in these systems would be open to citizens for sharing and reuse. This integration will facilitate the development of intelligent urban communities, creating new scenarios for public participation and deliberation, and making cities more resilient, sustainable and less vulnerable.

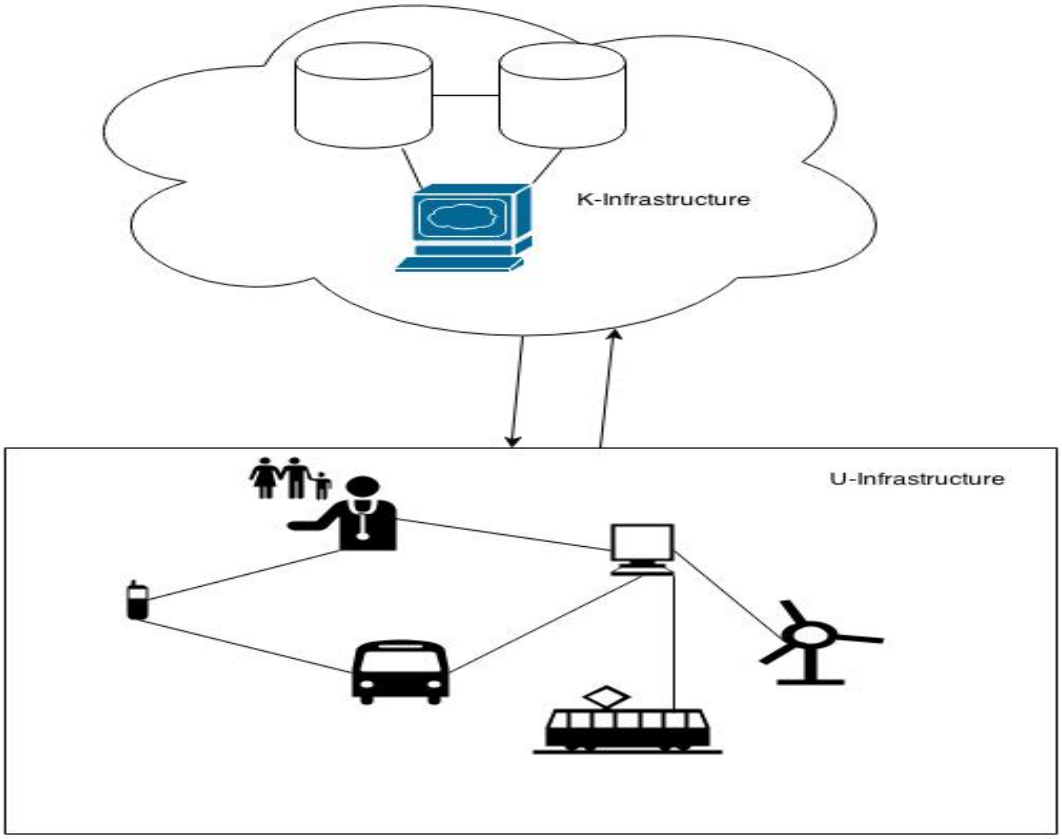

Figure 1: U and K infrastructures

Following this approach, we posit the key role of open community data, as a result of the social cyber-physical interactions of the actors involved in the urban processes, to democratize civic infrastructures and networks that integrate the city. At the same time, we do not ignore the need for top-down ICT infrastructures to exist, but highlight the importance to integrate these emergent technologies and practices, and the need for both (top-down and bottom-up) to coexist, creating new synergies and democratizing urban spaces.

3.2 Intelligent citizenry and participatory governance

In the context presented in the previous subsection, citizens will become the main driver for intelligent community development. Intelligent governance of future cities will have to surpass the one-directional model of municipalities delivering services to "responsive citizens", and concentrate on how to integrate community based technologies and data for collaborative decision-making.

In this framework, collaborative decision-making implies opening up new communication channels between municipal governments and civil society, integrating citizen knowledge practices in the decision processes, and developing new technologies for massive and distributed decision support.

With ubiquitous technological infrastructures blurring the distance between the physical and the virtual, and with societies becoming more knowledge driven, one might think of new forms of socio-technical divide that can limit its potential powers for social transformation. Contrary to this argument, if socio-technical infrastructures are built bottom-up following an open source model, and data generated by citizens can be managed by grassroots organizations and incorporated for collaborative decision-making, the risk of a divide is much less than with current e-government practices, where products and data are closed systems. Nevertheless this risk should be assessed, and civic organizations together with municipalities should guarantee open source and open collaboration practices, where products (systems and data) and its designs are open to anyone for subsequent modifications and improvements, creating open networks of innovation.

4. A general framework for intelligent e-participatory budgeting

In this section we outline a general framework for E-PB taking into consideration the scenarios presented in 3. Intelligent, in this framework, means the ability to understand, manage and decide about complex socio-technical problems that arise in urban environments in a collaborative manner. Intelligent E-PB is therefore, an instrument for the optimal allocation of budgets in municipalities, taking into account the aggregated knowledge of citizens, municipal governments and their systems, and integrating them in the decision-making processes.

As reviewed in section 1, PB models are flexible participatory instruments and adapt to individual experiments across countries and municipalities. Among the phases that have been used in PB processes, and following the general decision theoretic methodology for participatory democracy presented in (Rios Insua et al. 2008), we identify the following as being fundamental for citizen empowerment to take place:

1. Defining and structuring the problem
2. Discussions
3. Individual preference modeling
4. Conflict resolution: negotiation
5. Conflict resolution: voting
6. Improving budgets

Defining and structuring the problem before a final list of proposals is identified, is fundamental in order to avoid myopic approaches. In this phase, an initial set of proposals should be determined. After phase 1, participants can start discussions on the existing list of proposals, propose new ones, or modify existing proposals. In phase 3, participants explore projects individually and express their preferences in order to determine their general feasibility. In phase 4, participants make offers on how to allocate budgets and discuss their offers. Participants can accept or reject offers submitted by others. If negotiations fail, voting should determine the budget allocation. If the resulting budget can be jointly improved, participants should engage in a negotiation process that should determine such an improvement. In most forms of PBs, only phases 2 and 5 are implemented.

4.1 Actors participating in the process and system outline

For compactness, we will group actors participating in the PB in the following:

- Citizens: includes regular citizens, citizen representatives, interest groups and civic organizations.
- Municipal officials: includes municipal representatives and technical staff.
- Negotiation agents: can be human and/or machine.

The roles of each of the actors involved in the process are summarized in Table 1.

Actor	Role
Citizens	Present proposals, deliberate about proposals, make offers based on their preferences and negotiate and vote (if needed) to find a globally acceptable budget.
Municipal officials	Structure the initial budget allocation, and coordinate (together with citizens) the participation process.
Negotiation agents	Coordinate, and mediate the negotiation process, and present alternatives.

Table 1: Actors and roles in PBs.

The different PB phases will be described now in the workflow of Figure 2 showing how they can be combined and sequenced.

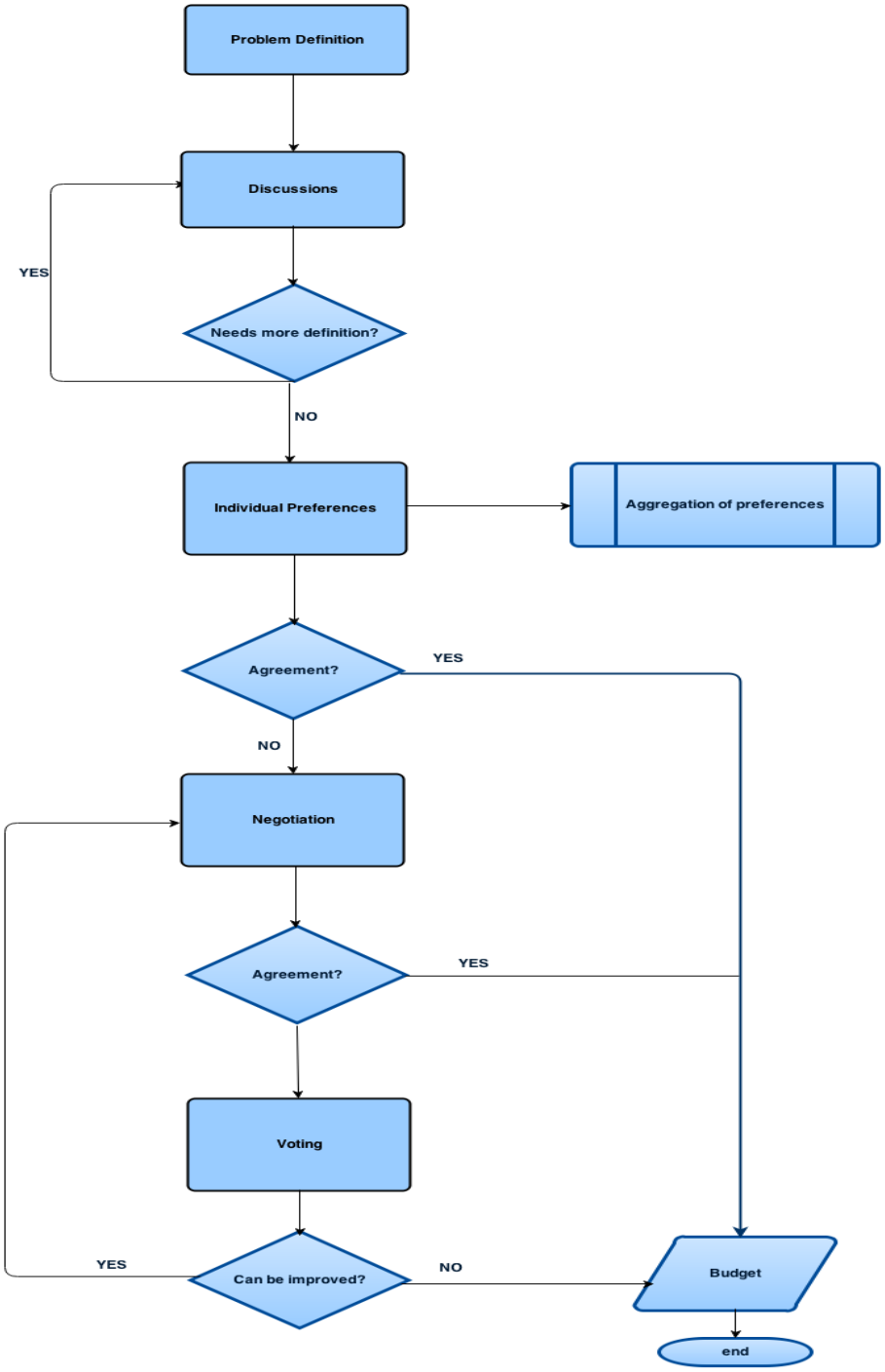

Figure 2: PB workflow

Each process has their actors participating on it, and their own function assignment. In Table 2 we describe these relations.

Process	Actors	Functions
Problem Definition	Municipal officials	Set the total amount for the budget, establish a calendar and advice on projects and their associated costs.
	Citizens	Frame issues and determine possible projects.
Discussion	Citizens	Deliberate on the initial set of projects, and propose new ones, criteria, or improvements and modifications.
Individual Preferences	Citizens	Define their preferences.
Negotiation	Citizens	Propose offers
	Negotiation agents	Coordinate the proposed offers amongst participants, and give feedback of possible agreements.
Voting	Citizens	Vote on projects (if negotiation fails)
Improvements	Municipal officials	Offer alternatives to citizens for improvement.
	Citizens	Propose alternatives for improvement.

Table 2: function assignment in PB

4.2 A general architecture for intelligent E-PB

Based on the two infrastructures and participatory ecosystem defined in 3.1, we can elucidate a general architecture for intelligent E-PB. The main components of this architecture can be grouped in the following modules or sub-systems:

- City web dashboards
- Budget simulation environment
- Participatory project development
- Deliberation and argumentation support system
- Decision and negotiation support system

We briefly now describe the functionality of the different modules, and show in Figure 3 the complete architecture.

4.2.1 City web dashboards

A knowledge base of linked data coming from different sources and activities such as participatory sensing, citizen science projects, sensor and autonomous agents data, citizen opinions extracted and aggregated from social media, and government data. This geo-referenced knowledge platform is the basis for our architecture, since it provides the participants and other sub-systems with structured information for deliberation and decision-making, and it is a live repository of information coming from different sources, combining real time with historical data.

4.2.2 Budget simulation environment

In order for participants to understand policy implications of complex budgetary decisions, and as a learning platform on how to allocate budgets, a simulation environment open to PB participants will allow them to test their decisions. Data for the simulation can be obtained from sub-system 4.2.1.

4.2.3 Participatory project development

The main functionality of this sub-system is to allow participants to develop proposals and projects collaboratively. A user can create or contribute, by suggesting improvements or modifications, to projects and proposals using geographically enabled forums.

4.2.4 Deliberation and argumentation support system

This module provides the core functionality to support the deliberative phase of E-PB. The deliberations are linked to specific projects and to sub-system 4.2.3. Amplifying the impact of the deliberations and extending the reach of the participation, this module will be connected to existing social media sites. Since argumentation is a fundamental skill for deliberation, and taking into account that regular citizens are not experts, an argumentation support tool will facilitate the construction and organization of arguments, providing possible alternative solutions to an issue.

4.2.5 Negotiation and decision support system

A massively distributed decision support system will be the module dedicated for handling the elicitation of individual preferences and the negotiation phases. Participants will be able to make offers, evaluate tradeoffs, and investigate alternatives. The negotiation will be guided by autonomous negotiation agents, that will interact with the participants and help them at exploring solutions.

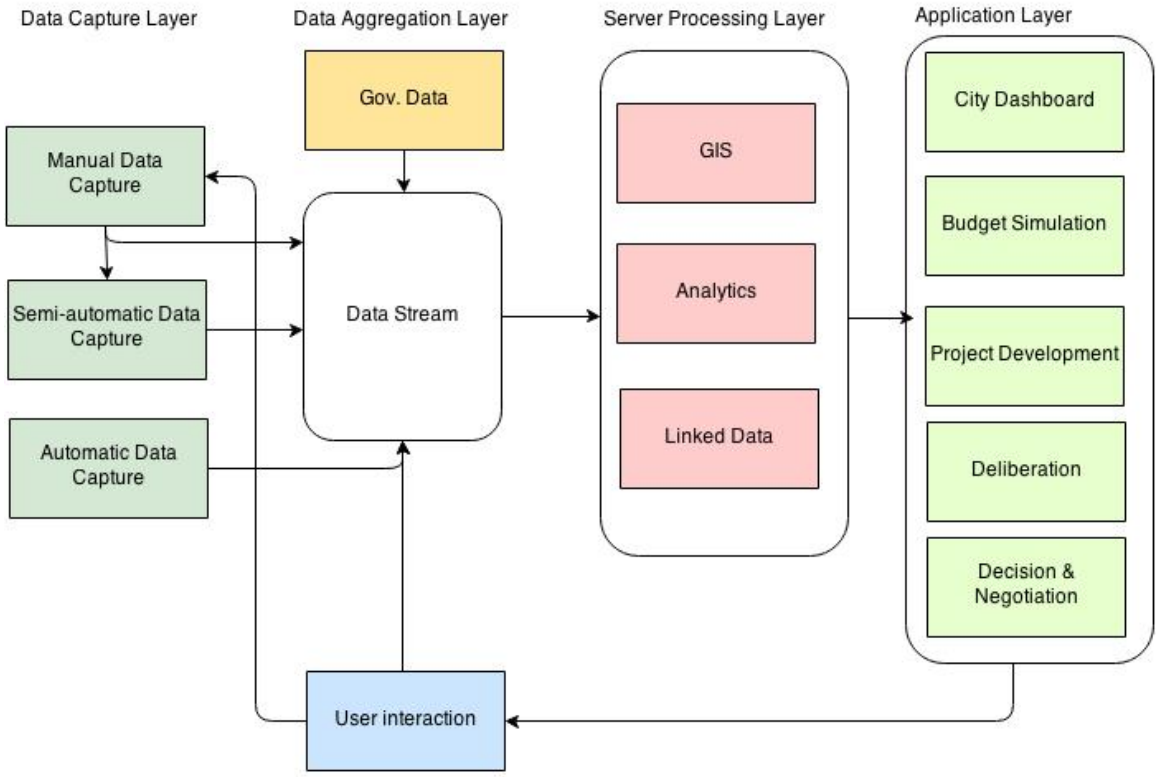

Figure 3: General system architecture

4.3 Socio-technical considerations

While technologies described in this architecture currently exist, they haven't been yet orchestrated in such a way. The main challenge in the development of a participatory system with the architecture previously described, will be the integration of the different layers of the emerging organizational, social and technological forces with existing ones (government, current information infrastructures, and organized interest groups).

Integration of grassroots technologies and their data with existing privately owned technologies, will bring new challenges in the management and security of the data. Community leadership in coordination with existing power structures will need to guarantee citizen data rights and the continuous openness of the U and K infrastructures.

Decision and negotiation support systems will need to surpass their current status of group decision support and transform into crowd decision support systems, where hundreds of thousands, or even millions, of participants will engage in complex negotiation processes.

5. Conclusions

Participatory budgeting experiments have spread around the globe since the initial Porto Alegre experience of 1989. While ICT has been incorporated in PBs in the last decade with the goal of opening up new channels for civic participation and engagement, their role has been limited to a communication facilitator and little have they contributed to the development of the empowerment dimension of PBs. This limitation is due not to technology itself, but to the lack of a socio-technical design capable of incorporating new emerging participatory technologies and practices into PBs in particular, and to open, participatory government in general.

In this article we layout future scenarios for civic participation and empowerment based on the raise and emergence of intelligent community infrastructures. We differentiate between a ubiquitous infrastructure (U-Infrastructure) of civic software, hardware and human components, that generate data of their interactions with the urban environment, and a knowledge infrastructure (K-Infrastructure) composed by data storage and management systems that articulate urban knowledge practices. The raise of pervasive computing and the human activities based on these ubiquitous devices are shaping our daily life. Civic hackers, open source software and hardware activist, and open innovators together with citizens, are designing artifacts in neighborhoods across the world that have the potential to transform society. In this article we argue that, in order for these isolated activities to have "meaning" in the shape of a participatory computing infrastructure, first an organizational community structure needs to emerge that links these isolated efforts; and second, community data needs to be incorporated together with existing governmental and private data in open repositories.

This participatory open infrastructure will bring new opportunities, challenges and risks that need to be assessed and further research. The democratization of data will bring questions regarding the use of personal and community data for purposes outside of the public domain, and how communities should manage and control their own data. Also the role of local versus non-local data should be explored, and how communities worldwide could benefit from this exchange. The emergence of pervasive computing practices need to be consolidated in open standards, making the development of this type of computing infrastructure replicable in other communities. In comparison to top-down smart city projects and due to the low cost associated with it, a participatory open infrastructure could be used as a model for building intelligent communities in developing countries. Further research needs to be done on how robots and other autonomous devices should be integrated in urban spaces and citizen practices, and how they can be utilized for the disadvantaged.

The future of intelligent participatory instruments for governance, and E-PBs in particular, strongly relies in a socio-technical design that reinforces the role of citizens as the main driver for the development of intelligent, sustainable and resilient communities, based on open innovation practices and standards. The architecture proposed in this article could be used as a template not only for the implementation of E-PBs, but also for e-participatory processes in general.

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