Enhancing Participation Process in Public Decision Making with MCDA and Trust Modeling

Vitri Tundjungsari[1], Jazi Eko Istiyanto, Edi Winarko, Retantyo Wardoyo
Department of Computer Science and Electronics
Gadjah Mada University
Jl. Sekip Utara
Yogyakarta, Indonesia

Abstract
Multi-criteria decision analysis provides an effective and valuable method of articulating and structuring deliberations within public participation. Public participation means that citizens are involved in the public decision making that has an effect on them. In order to encourage participation while integrating the deliberative perspectives from various participants in public sector, we should support the participatory public decision making process. Our effort is oriented towards integrating trust-based multi-agent modeling within multi-criteria group decision support systems. Decision makers are modeled as agents and each agent has a role in decision making processes which identified by trust level. In this paper, we propose a framework and model to enhance the success of participation process in participatory public decision making. A simple example is also presented in this paper to give a clarity how the framework and model can be implemented in the real situation.
Keywords: *Group Decision Making, Participation, MCDA, Trust, Supra Decision Maker.*

1. Introduction

Public decision making is usually tied with a high degree of complexity because of the scarce resources to be allocated and the conflicting interests, e.g. when beneficiaries and bearers of the costs are not equivalent. On the other hand, public concern of the state of the public sector has grown rapidly and this has also increased interest in participatory decision making [9]. Consequently, public approval has become an important decision objective, and the public participation has become a common element in decision making processes. However, the large number of stakeholders also induces a large number of conflicting views, therefore transparent and structured processes are needed to reach participants' shared understanding of the problem. Another problem in participatory decision making, public as decision makers consist of various background, knowledge, and interest (e.g. participants are not only experts but also citizen with lack of knowledge and or limited experience in making judgments and decisions) [12] [32].

The main objective of this paper is to overcome problems in participatory public decision making by providing structured and transparent mechanisms. This paper proposes framework and model which integrated structured mechanism using Multi-criteria Decision Analysis (MCDA) and transparent mechanism with trust algorithm. We argue that the framework and model provide ways to systematically structure and support learning process in group decision making (e.g. via interaction between regular/ novice decision maker and expert decision maker), thus it will increase the quality of participatory decision making processes under multi-criteria constraints.

The rest of this paper is organized as follows: section 2 describes the characteristics of group decision making in the public sector, some related works in public decision making, and several aspects constitute the success of participation process in public decision making. Section 3 discusses MCDA and trust concept as methodology approaches in our model. Section 4 presents our proposed participatory public decision making framework and model. We also extend the framework into participatory decision support systems model and trust model. The illustration of overall framework is provided in section 5. Section 6 presents conclusions and directions for our future work.

2. Participatory Public Decision Making

2.1 The Perspective of Public Decision Making

The public sector problems (e.g. public health, environmental, natural resource, public transportation, local budgeting allocation) are typically complex and disorganized [9]. There may be high risks involved and/or lack of scientific agreement on the cause of problems. The problems also may be ill defined, and the goals may not be clear [14]. In addition, numerous decision makers as stakeholders are often involved in the public sector planning having different and even conflicting views [12]. The stakeholders are defined to be "any group or individual who can affect, or is affected by, the achievement of a corporation's purpose" [14]. They could be persons like local population, or stakeholder groups such as organizations concerned with related public issues, rural communities, associations related to public issues. Each of them can have different objectives concerning the public issues, which further complicates the evaluation.

Most of the related works in public decision making employs decision analytic methodologies (e.g. MCDA, AHP) or decision support systems (e.g. Web HIPRE) to deal with those problems ([2][20][21] [23] [24] [25] [29]). Author in [20] propose a decision making framework in environmental problem using MCDA. MCDA also utilized in decision making process for the national teacher's payment scheme in Lithuania [24]; optimization of solar energy use in large building [2]; forestry management [29]. Author in [21] argue that AHP, one of MCDA's techniques, is suitable for participatory decision making. AHP is employed in forest planning and management decision making [21], budget determination procedure for public building construction process [17].

Author in [23] applies Integrated Methodological Approach, as a participatory multi-criteria decision support, to solve a problem in water allocation. Mustajoki et al. [25] utilized web-based multi-criteria decision support software, called Web-HIPRE, to deal with the evaluation of regulation policies in Finland. Other tools such as: CBA (cost-benefit analysis), CEA (cost-effectiveness analysis) also have been utilized in public matters ([9] [23]). All of them provide an entire decision-making framework from problem definition over valuation of decision alternatives to ranking/comparing alternatives even though the underlying methodology is different.

Grimmelijkhuisen [10] mentions two perspectives on public decision making: the rational perspective, and bounded rationality perspective. All of those works mentioned above, assume that a decision making process is a rational and calculative individual, which is called as the rational perspective. It is an assumption borrowed from rational choice theories (e.g. Homans, 1961; Blau, 1964; cited in [9]), which tries to simplify decision making process by listing all values, weighing them and calculate to find the solution of a problem. The rational perspective is a traditional view on public decision-making [10].

In spite of numerous use of rationality perspective, we agree with [10] and [36] that rational perspective ignores the political process of public decision-making and the bounded rationality of individuals. The bounded rationality is another perspective on public decision making that has different scientific approach which adopts an explicitly behavioral attitude rather than making assumptions about decision making and modeling the implications mathematically for aggregate behavior (as in markets or legislatures) [13]. Therefore it takes into account the cognitive limitations of decision makers in attempting to achieve those goals. Therefore, we believe that public decision making should consider individual's constraints in making judgments and decisions. Due to our literature surveys, there are limited works (e.g. [3] [15]) in public decision making which utilize other mechanisms than decision analytic methodologies to deal with bounded rationality view. Kim [15] proposes a framework for group support systems in e-democracy domain using Multi Criteria Decision Analysis (MCDA), considering negotiation process among decision makers. Bencina [3] applies trust value in linguistic variables and maps them into fuzzy number to assess the suitability of the project in public sector. Bencina [3] also states that successful implementation of decision support systems in the public sector, with engagement over the whole spectrum of decision making, is still unmet. This is due to public sector specific features compare to private sector. Therefore, we must take into consideration of the specific needs and demands of the public sector for the development of decision support systems for the public sector. Table 1 below presents the comparison of decision making processes in the public and private sector.

Table 1: Comparisons of decision making processes in the private and public sectors

Private sector	Public sector
Decisions are made by a single agent (individual manager or management team) whose authority is defined by a hierarchical organization structure.	Decisions come as result of a complex interaction among decision makers as stakeholders. They are varied from citizen, association member, member with expertise, etc.
Decisions are dominated by a single interest, typically the	Decisions involve many and often divergent interests of a

competitive position of the company (e.g. market competitiveness).	society; therefore conflict of interest has tendency to be occurred.
Decision alternatives are evaluated on the basis of a limited set of quantitative economic criteria such as market share, bottom line profit or shareholder value.	The set of evaluation criteria is large and has a wide variety of both quantitative and qualitative criteria, whose values are difficult to establish and/ or aggregate.
Decision makers typically consist of group of expertise with sufficient knowledge and experiences to evaluate on existing alternatives.	Public as decision makers consist of various level of knowledge, expertise, and experience. They are varied from experts to laymen.
Decisions typically have a planning horizon of months to at most several years (e.g. new products and markets).	Decisions may have a planning horizon of several decades (e.g. decisions on infrastructure).
Decision makers usually have adequate access to resources and information.	Decision makers typically do not have sufficient access to resources and information.
Decision makers commonly have same degree of motivation to make a decision.	Decision makers may have different degree of individual motivations to make a decision.

2.2 Participation and Group Decision Making

There are occasions where direct participation is claimed as necessary, first and foremost because it can effectively serve to represent people's preferences, which is the ultimate goal the democratic system is aiming at [9]. This grants the public more influence on the decisions, and improves the final decision makers with better understanding of the preferences of the governed people. As Renn 1993 in [9] emphasizes "the functioning of public involvement is therefore contingent on the approval of the technique or model of participation".

Participation inevitably means that we are discussing a group decision context; and the paradoxes and impossibilities that abound in group decision making and democratic systems are well known ([7] [27]). Group decision making in public sector is expected since it has impact and benefit to its stakeholder. Group decisions are quite more complex compared to single decision making, since a number of contradicting factors are involved such as individuals' personal opinions, goals and stakes resulting in a social procedure, where negotiation and strategy plays a critical role. Despite the inherent complexity within a group, members are able to express personal opinions and suggest solutions from a personal perspective increasing as well as decision quality.

French et al. [8] discuss several group decision making (GDM) models, i.e.:

- GDM 1. Obtain each group member's subjective probabilities and utilities, combine the individual probabilities and utilities into group probabilities and utilities, and choose according to their ranking.
- GDM 2. Work with each individual and develop a personal decision analysis to guide their choice. Each individual votes within the group and a group choice is made according to the vote.
- GDM 3. A supra decision maker (SDM) is imagined to exist. SDM observes the entire elicitation and decision analysis process for each individual and altruistically uses this knowledge to construct a single decision analysis for the group. The choice is made according to the SDM's analysis.
- GDM 4. Gather the group together in a facilitated discussion of the issues. Through discussion between the members, seek to agree on group probabilities and utilities without formally eliciting individual ones. Develop a group analysis and explore the areas of disagreement and seek to reach a decision by consensus without formal voting.
- GDM 5. Involves the theories of bargaining, negotiation and, perhaps, arbitration are deployed to define a process in which the group interacts and discusses a series of solutions, usually generated to converge to a point on the Pareto boundary which corresponds to a policy which they all can accept.

Most of the related works in public decision making implement GDM 1 with support of decision analytic methodologies (e.g. MCDA, AHP), as discussed in section 2.1 above. GDM 2 is utilized in e-Participatory Budgeting case in Brazil by allowing citizens to vote to their individual choice [26]. Kim [15] adopt combination of GDM 5 and GDM 1 approaches in his decision making model. Yet, GDM 3 and GDM 4 implementation in public sector are still rarely to be obtained in our literatures review.

We integrate GDM 1 and GDM 3 as our approach to develop framework and model in participatory public decision making. We utilize GDM 1 because it has been well-proven in providing participation model and facilitating each decision maker to express her individual preferences under multi-criteria constraints (e.g. MCDA). We also employ GDM 3 because in most cases of public decision making, the supra decision maker (SDM), as available in GDM 3, actually exists. SDM acts as an arbiter or leader, formally responsible for recommending a decision which balances all stakeholder perspectives [8]. The role of leader is required in participation decision style because she provides encouragement and resources to other members [1]. However, approach GDM 3 has some weaknesses related to SDM's role that tends to cause the irrationality and inconsistencies. To deal with this, we utilize trust model to construct agreement among the group in order to seek and manage SDM. We will expand the discussion about MCDA and trust in section 3.

2.3 Success of Public Participation Process

The success of public participation can be viewed from two different viewpoints: outcome and process [6]. Some people may evaluate the public participation only with respect to the outcome of the process. The criteria for the outcome include better accepted decisions, consensus, education, and improved quality of decisions (e.g. English et al. 1993 cited in [14]). The process also has an effect to the success. It has been noted that a fair procedure make people react less negatively to unfair outcome and that fair outcome could make people think more positively about the process [14].

Tuler and Webler [31] studied the opinions of participants concerning a good process. They found seven normative principles, i.e.:

1. Access to the process.
2. Power to influence process and outcomes.
3. Structural characteristics to promote constructive interactions.
4. Facilitation of constructive personal behaviors.
5. Access to information.
6. Adequate analysis.
7. Enabling of social conditions necessary for future processes.

In order to achieve success of public participation, we only focus on process aspect. We argue that the success of public participation processes will in turn determine the success of its outcome as well. We make use the principles which mentioned above as a foundation to build our framework and model.

3. Methodology Overview

3.1 MCDA

Commonly used decision-support tool that has been applied in public issues is MCDA (multi-criteria analysis), as discussed in previous section 2.1. MCDA facilitates the use of both, qualitative as well as quantitative measurement scales, which makes it possible to address multidisciplinary problems (e.g. involving consequences on the environment and/or public health issues) [28]. MCDA also structures and facilitates stakeholders's involvement in the decision processes, which has been shown to increase the quality of decisions ([4] [23] [24] [25] [28]). For further surveys of MCDA applications, see Hamalainen [11].

Although MCDA methods differ in their details, they are often deployed by adopting rather similar decision support processes. Salo and Hamalainen [28] mention MCDA methods, i.e.:

1. Clarification of the decision context and the identification of group members. In this phase, it is necessary to clarify what the decision is really about, how the group members are identified and engaged, and in what role they will participate in the process.
2. Explication of decision objectives. The relevant decision objectives are elaborated and transformed into corresponding evaluation: (1) *criteria* $C = \{ci, i = 1,..., n\}$: aspects on which the alternatives are assessed; and (2) associated measurement scales with the help of which the attainment of these objectives can be assessed.
3. Generation of decision criteria and alternatives. A sufficiently representative and manageable set of *alternatives*, $A = \{ai, i = 1,..., m\}$: actions which can possibly solve the problem, is generated considering how the decision objectives could be achieved through alternative courses of action.
4. Elicitation of preferences. Here, the group members are engaged, where subjective preference statements are requested. The preferences include: (1) how important the different evaluation criteria are relative to each other, and (2) how much value the group members associate with the alternatives' performance levels on criterion-specific measurement scales. The measurement scale is represented by *weights* $W = \{wi, i = 1,..., n\}$: assessment of the relative importance of the criteria.
5. Evaluation of decision alternatives. All criteria and alternatives are measured with regard to every decision criterion using a related measurement scale, i.e.: (1) *Criteria evaluation* $vi: (ai, ci) \rightarrow$ R: assessment of the alternative on a criterion; and (2) *Alternative evaluation* $v: (ai, C, W) \rightarrow$ R: global assessment of the alternatives.
6. Synthesis and communication of decision recommendations. Here, a careful examination of the resulting recommendations is assessed. This phase is in conjunction with the learning process of MCDA analysis and may suggest a re-specification of alternatives or even objectives. It also may be appropriate to repeat some of the above phases.

MCDA is employed to represent the participatory approach under multi-criteria and multi-decision maker constraints, as it facilitates GDM 1 characteristics. We agree with [28] that MCDA provides a sound methodology for promoting a good decision-making process. Despite its benefit, we argue that MCDA should be attached with other mechanisms to cope with individual's limitations in making decisions. As a consequence, we construct trust mechanism and integrate it within MCDA method.

3.2 Trust in Decision Making

Trust is a complex concept from sociological and psychological studies which has recently been attracting research from many fields, such as: computer science, cognitive sciences, sociology, economics, and psychology ([19] [33] [35]). Related to computer science, trust has been used in various fields, e.g. information filtering and collecting strategy ([18] [19] [33]), security mechanism ([5] [30]), and recommender system ([34] [35] [37]).

McKnight et al. [22] define trust toward an e-commerce system as an individual's belief in an agent's competence, benevolence, and integrity. According to [22] definition, a competence-belief refers to an individual believing that the trustee has the ability, skills, and expertise to perform effectively in specific domains; a benevolence-belief refers to an individual believing that the trustee cares about her and acts in her interests; and integrity-belief means that individual believes that the trustee adheres to a set of principles (e.g., honesty and promise-keeping) that she finds acceptable.

Komiak and Benbasat [16] decompose the concept of trust into cognitive and emotional trust, hence when an intelligent agent (e.g. recommender systems) becomes personalized, adoption by customers is not only based solely on cognitive factors but also on emotional. Therefore, they conceptualize trust as a combination of cognitive and emotional trust, based on the assumption that trust decision tend to involve both reasoning and feeling.

Whitworth [36] discusses how social interaction in daily life can be implemented in computing and called this as socio-technical systems. The socio-technical systems based on community normative exchanges emerge from Human Computer Interaction (HCI) systems to face problems in a community (e.g. mistrust, unfairness, and injustice). Figure 1 below shows that society bears the physical consequences of its social acts, as productivity outcomes, which then reflect to its individual members [36]. We apply trust model because trust exists in human society interaction, hence we argue that trust among intelligent agent can deploy better participation process in decision making.

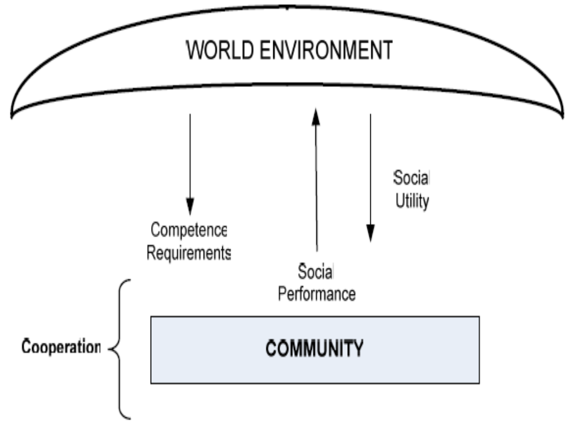

Fig. 1 A community cooperating in a world environment [36]

The model we propose here reflects on how individuals in a community cooperating with each other, as illustrates in figure 1. We implement trust as a means to serve and cooperate among individuals in a community. Competence requirements are represented by trust value among individuals (agents) thus the community rewards them with reputation. Reputation represents as social performance of individual in the community. As a return, the system (world environment) compensates different task and role in the community which related to individual's trust level, such as: supra decision maker, advisors, and other participants.

4. Proposed Framework and Model

4.1 Participatory DM Framework and Model

The close involvement of group members within group decision making will be particularly crucial in our framework. It employs MCDA methods using trust as a foundation of cooperation and participation among agents in providing synthesis and communication of decision processes. Hence it promotes constructive interactions and positive personal behavior, as principles of good process mentioned in section 2.3 above. Figure 2 below presents the proposed framework of participatory public decision making.

The framework consists of three main processes, i.e.:

1. Agenda setting process. This process mainly contains of clarification of the decision context, i.e.: problem and objective definition, criteria and alternatives exploration, and identification of participants. The participants can take part in different roles, for instance, as decision makers, sources of expertise, or representatives of their respective stakeholder groups. Each role is identified by each individual trust level. Member who has the highest trust level and trust value

respectively chosen as the supra decision maker. Trust value and level are identified by our proposed trust model, which will be discusses later in section 4.2.

2. Knowledge sharing and education process. This process involves iterative learning process by providing advice taking service. A decision maker can find and ask advisors using trust and reputation mechanisms, in order to improve her decision's quality. This process also aim to inform participants about the why and how decision is made from other participants' (e.g. experts) perspectives.
3. Group decision making process. This process includes evaluation of decision criteria and alternatives. All alternatives are measured with regard to every decision criterion using a related measurement scale. These evaluations based on subjective judgments by participants themselves. This process also supports participants' decisions iteration and refinement in order to reach consensus, facilitating by supra decision maker role.

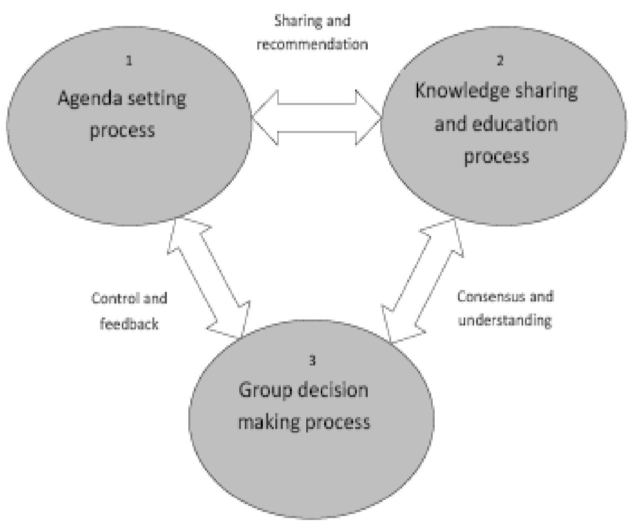

Fig. 2 Participatory decision making framework

As the process moves from one to another, there is a synthesis and communication flow. In some cases, it may be appropriate to repeat some of the above processes using the flows. The flows are described as follows:

1. Sharing and recommendation. This flow supports both agenda setting process and knowledge sharing and education process. It may suggest a re-specification of alternatives or even objectives.
2. Consensus and understanding. This flow delivers common understanding among participants based on some agreement rules.
3. Control and feedback. This flow is very important to identify whether the current decisions have fulfilled the specification requirements or not.

The framework can be extended to more detailed decision making model, as presented in figure 3.

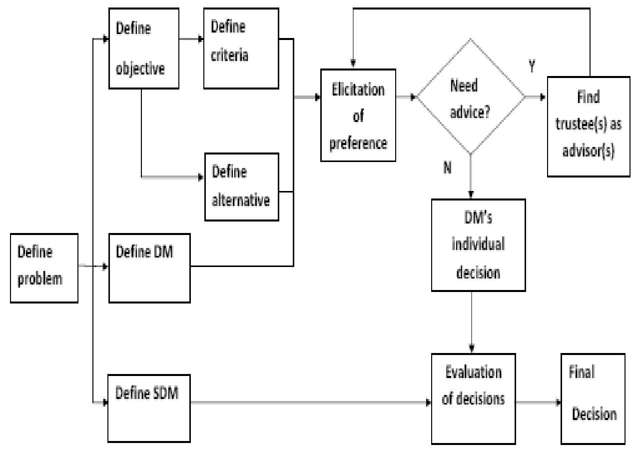

Fig. 3 Schematic illustration of participatory decision making model

The decision making model in figure 3 is compatible with the previous framework, which accommodates the framework's processes, as follows:

1. The agenda setting process covers some activities, i.e.: problem clarification, objective definition, participants identification (e.g. decision makers and supra decision maker).
2. The knowledge sharing and education process involves opinion sharing, information exchange, and advice taking among participants. This process includes some decisions on, i.e.: criteria and weight measurement, alternatives exploration, individual preferences. Participants as decision makers are able to ask advisor(s) provided by our proposed trust model, so then they can decide and possibly do some refinement on their decisions.
3. The group decision making process consists of evaluation and aggregation of individual's decision. This process is supervised by supra decision maker role. During this process, consensus achievement should be feasible in order to gather the final decision.

4.2 Trust Model

There is no universal agreement on the definition of trust and reputation since it depends on its research context and objectives. In this paper, we use the following working definitions [32]:

Trust – believe in another entity's capabilities, honesty and reliability to make judgment and decision *based on its own direct interaction between truster and trustee*. Truster is an entity who believe another and trustee is an entity who has been put into a trust for a truster. This belief is interpreted in trust value.

Reputation – believe in another entity's capabilities, honesty and reliability *based on recommendations and direct trust value* received from others. The reputation is interpreted in trust level.

Trust in this model is integrated with MCDA methods and used as participation means, whereas participants build sharing and understanding through trust and reputation mechanisms. We modify the properties of a trust relationship from our previous trust model proposed in [32] and apply in our decision making model, i.e.:

1. It is always between exactly two agents: truster and trustee.
2. It is always non-symmetrical: if agent A trusts agent B, it does not mean that B also trusts A.
3. It is conditionally transitive: if agent A trusts agent B and agent B trusts agent C, then A also trusts C with condition that B as recommender to C based on C's reputation.
4. It is contextual: each trust value only valid for each category.
5. It is reflexive: each agent must have confidence upon its own system before it starts to calculate another agent's trust value.
6. It is dynamic: trust and reputation relationship increase or decrease with further experience (direct interaction). It also decays with time.

We present the proposed trust model as in figure 4. Mechanism in trust model (figure 4) is divided into (1) trust mechanism and, (2) reputation mechanism, which works as follow [32]:

1. User as a truster finds a few expert decision makers recommended by the system (based on their trust level and expertise category) (step 1). A trustee is chosen based on trust level saved in User Identity Database (UIDB). Information provided in UIDB is: user ID, trust value, trust level, and expertise category.
2. User as a truster decides whether a trustee is trustworthy or not (step 2). If the truster decide not to believe the trustee, then she can select another trustee candidate (step 3 a). If the truster decide to believe trustee's capability in providing guidance and judgment then the truster and trustee can have direct interaction (step 5 a). However if the truster has a doubt regarding candidate trustee's capability then the truster can search other trustees (step 3 b), and reputation mechanism can be used (step 4a). If for example the truster has confidence in trustee's reputation, the truster and trustee can have direct interaction (step 5 b), otherwise the truster can find out other trustees (step 4b).
3. Based on direct interaction result, the truster can evaluate the interaction process and give trust value toward her trustee (step 6 and 7). Trust value then can be computed and updated in *Trust References Database* (TRDB) (step 8 and 9). Trust value gained is checked upon trust level threshold ε (step 10). If trust value > ε for a specific trust level then trust level in UIDB should be renewed as an addition to trust value update itself (step 11).
4. Trust value as a result of recommendation (recommender trust value) also can be updated in TRDB (step 12).

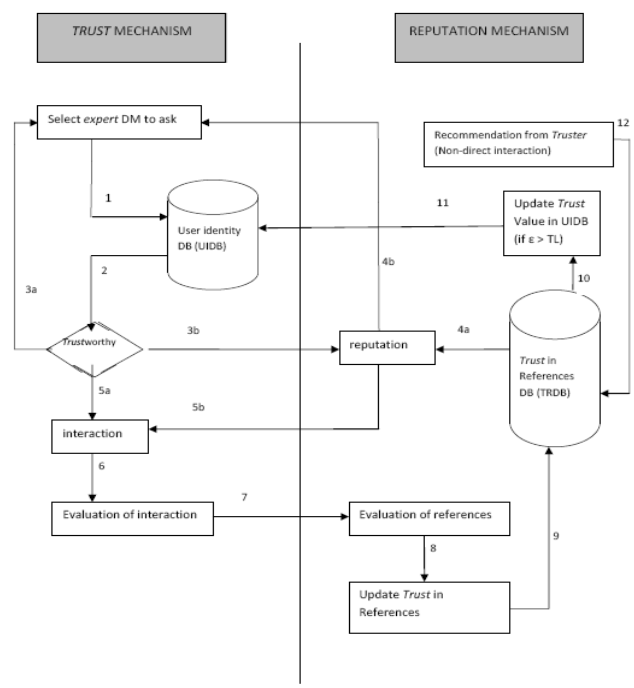

Fig. 4 Proposed Trust Model

In order to provide knowledge sharing and learning process to our previous framework, we establish three main strategies in our trust model, i.e.:

1. Trustworthiness path building. The path between truster and trustee is built by interaction between truster and trustee, with or without recommenders' supports. The pseudocodes of algorithm are described below.

```
Truster ti transmits query (ti, cj) for category (cj)
  to (one or some) trustee (s)
Truster ti assign trust value to trustee tk (direct
  trust value or recommender trust value).
  For each trustee tk receives query (ti, cj)
    If tk does not know the answer (aj) for the
    particular category (cj) then
      Passes query (ti, cj) to other trustee (tn)
      Truster tk assign trust value to tn (direct
      trust value or recommender trust value).
    Else (tk knows the answer aj for a
    particular category (cj).
      Returns a response (aj) to previous
      neighbor (tk-1) until reach truster ti.
```

2. Trustee searching. A truster finds trustee(s) by implementing algorithm below.

```
Truster set minimum trustee's trust level
  threshold (tl_th)
Truster set trustee's category of expertise
  (cat_exp)
Truster set maximum hop to get trustee
  (max_hop)
  For each path found from truster (first node)
  to trustee (last node)
     do count hop
        for each trustee where current hop ≤
        max_hop and tl_th ≥ min tl_th and
        cat_exp = required cat_exp
            calculate trustee's trust value
Get trustee with the highest trust value
```

3. Trust value and trust level computation. Trust value is produced by: (1) direct interaction between trustee and truster (direct trust value), and (2) non-direct interaction between recommender and trustee (recommender trust value). Trust level is updated when trust value (tv) > trust level threshold (ε). The value is called as reputation trust value (rtv) or simply as trust value (tv) which summed from direct trust value and recommender trust value. Trust value of the trustee candidate could be computed with the collected information using equation (1):

$$tvp(T) = tv(R1)/4 \times tl(R1)/4 \times .. \times \square tl(Rn)/4 \times \square rtv(T) \quad (1)$$

where:

tv p (T) = *Trust value* of *Trustee* T
tv (Ri) = *Recommender Trust Value* in a *return path* (includes *first recommender* and *last recommender*)
tl (Ri) = *Trust level* of *Trustee* T
rtv (T) = *Recommended Trust Value*

If a trustee has more than one route of return path, then trust value is calculated based on its average as in equation (2):

$$tv\,(T) = Average\,(tv\,1\,(T), \ldots, tv\,p\,(T)) \quad (2)$$

Trust level can be increased or decreased by trust value after reaching a defined trust threshold (ε). For example, a trustee can increase her trust level from 2 to 3, by having many direct interactions with others and result in increasing trust value, so then her trust value ≥ ε for trust level 3. Trust level for each participant represents several applicable roles within decision support systems, as presented in table 2.

Table 2: Participants classification based on trust level

Level	Description	Transaction type
1	Participants with no trust level or no confidence in the affirmed identity's validity	Registration to access the system; read common news regarding public decision event
2	Participants with little trust where the affirmed identity is valid and accurate	Information exchange and opinion sharing as learning and education activities; read specific news regarding public decision event
3	Participants with medium trust who has sufficient capability and knowledge to judge and decide	Knowledge sharing; judgment and decision activities
4	Participants with very high trust who has sufficient capability and knowledge	Compare decision makers' preferences; facilitate, lead and develop final group decision

5. The Example

In this section, we present an illustration of how a participatory public decision support system works within our proposed framework and model. We take a participatory budgeting (PB) case in a municipality. Participatory budgeting is a public decision making process which directly involves local people in making decisions on the spending and priorities for a defined public budget. Figure 5 illustrates several participants involved in a decision support systems related to PB case which is implemented within our proposed framework and model.

We identify eight participants in the system, for instance: A, B, C, D, E, F, G, and H. Participant E acts as a new member in the system with trust level = 1, hence she has to be verified further regarding her identity to be involved in participation process. However, E still can access the information by reading some common news regarding the public decision making event. Participants D, A, B, C, F, G, H having minimum trust level (tl) = 2 can contribute in participation process (i.e. agenda setting and education processes). Participants A, B, C, F, G, H having minimum trust level (tl) = 3 can engage in every process of our framework and mainly participate in group decision making process.

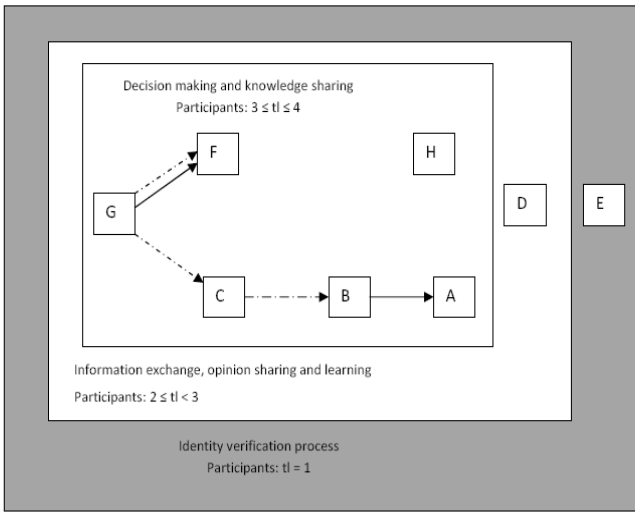

Fig. 5 Participants identification in the proposed model

Suppose that the system selects only five decision makers, i.e., N = {A, B, C, F, G}. A supra decision maker (SDM) role is chosen among participants A, B, C, F, G, H who has minimum trust level (tl) = 4 and highest trust value compare to others, in a specific category (e.g. in public health category). The system then, for instance, chooses participant H as SDM. Each decision maker, i.e., *N = {A, B, C, F, G}* will evaluate each alternative in *A = {A1, A2, A3}* with respect to three criteria *C = {C1, C2, C3}*. Suppose that one of the decision makers (e.g. participant G) has limited knowledge in prior to make any judgment regarding his preferences *A1*, where *v: (A1, C, W)*. Let say that alternative A1 is related to budget allocation for public health improvement. Trust model is then utilized to assist participant G for deciding his individual preferences in related category. Hence, the model should provide a successful advice-taking mechanism as well as learning process between participants.

In order to assure that G will get any advice from other participants, we have to set up maximum hop in each path, as mentioned in our previous trust algorithm. This set up is very important so then we can avoid any endless hop and enforce any participant to learn and serve others, not only as a recommender but also as a trustee (also called as an advisor). If any trustee still doubts her own preferences, she can ask for supra decision maker's assistance and advice. Here, the learning process is extended and provided by supra decision maker role.

In this case, G set up maximum hop = 3, counted from the first node (truster) and the last node (trustee). G also define minimum trustee's trust level = 3 in a specific category (e.g. public health). Suppose that G finds his trusted source, namely: C and F, which then forms two trustworthiness paths. Let say that F can provide the answer to G, therefore F does not have to pass the query from G to another trusted source. It then develops the first path (G→F). On the other path, C does not know the answer (recent hop = 1) so then C passes the query to another trusted source, i.e. B (recent hop = 2). Unfortunately, B does not know either thus he passes the query to A (recent hop = 3). Having maximum hop = 3, A has no choice but to answer G's query. In this path, C and B act as recommender while A acts as a trustee; thus it develops the second path as G→C→B→A. If for some cases, a trustee (e.g. participant A) needs further assistance to provide advices, she can ask for supra decision maker's (e.g. participant H) guidance.

Since the system gets more than one trustee candidates (i.e. participant F and A), it has to find the highest trust value among trustee candidates. Our trust computation algorithm, using equation (1), then calculates the total value for each path (path 1: G→F) and (path 2: G→C→B→A). For example, in path 1, G trusts F with trust value (tv=2) whereas F has trust level (tl=3). Hence, trust value computation for path 1 is: $tv(F) = ¾ \times 2 = 1.5$. In path 2, let say that G trust C with trust value (tv) = 4 and C has tl = 3. C give a recommender trust value to B (tv) = 3 and B has trust level (tl) = 4; and finally B recommends A with trust value (tv) = 4 and A has trust level (tl) = 3. Therefore trust value A for this path (path 2: G→C→B→A) is: $tv(A) = 4/4 \times ¾ \times ¾ \times 4/4 \times 4 = 1.68$. Here, $tv(A) > tv(F)$; consequently the system will choose A as G's trustee. As a result of this, tv(A) and tv(F) will get updated, e.g.: new tv(A) = old tv (A) + 1.68 and new tv(F) = old tv (F) + 1.5. Participant F also gets some trust value rises even though she does not selected as a trustee. As trustee's trust value increase and achieve minimum trust level threshold (ε), it will improve her trust level in a specific category as well.

In the above example, A and F gain more trust value from others by serving advice to others. Other participants also can improve their trust value as well as their trust level, by actively participating in the system. For example, participant D who does not involve in the decision making process also can increase their trust values, by engaged in opinion sharing or learning process (e.g. training and education); thus she can increase her trust value and trust level providing by recommender trust value from others.

6. Conclusions

In this paper, we presented the framework and model of participatory public decision making, by integrating multi-criteria methods and trust model. We believe that a participatory public decision making should support three processes (i.e. agenda setting, knowledge sharing and education, and group decision making). Moreover, each process should be supported with synthesis and communication flow in order to achieve the objective related to the problem.

The example shows that the proposed framework and model supports extensive access to information and process, thus it supports adequate resources and analysis to decisions, and in turn is likely to contribute to enhanced decision quality. The attainment of such quality is facilitated by structural and transparent mechanisms which encourage participants to share their opinion and knowledge by learning from others. In addition to this, involvement of all stakeholders with help of supra decision maker's role will ensure that the results of the decision model are fully understood in relation to the inputs.

Our next step will be focused on web-based decision support systems building, using our proposed framework guidelines, as our prototype. Also in the future, we will attempt to apply our prototype in the real community to demonstrate that decision's quality in public sector can be improved by implementing our framework and model. As an addition to our effort, we plan to extend our model by adding consensus achievement mechanism within participatory public decision making.

References

[1] H. Armesh, "Decision Making", in The 12th International Business Research Conference, Dubai, UAE, April 8-9, 2010.

[2] J. D. Balcomb, A. Curtner, "Multi-Criteria Decision-Making Process for Buildings", in The American Institute of Aeronautics and Astronautics Conference, Las Vegas, Nevada, July 24-28, 2000.

[3] J. Bencina, "Web-based Decision Support System for the Public Sector Comprising Linguistic Variables", Informatica, Vol. 31, 2007, pp. 311–323.

[4] T. C. Beierle, "The Quality of Stakeholder-based Decisions, Risk Analysis, Vol. 22, No. 4, 2002, pp. 739–751.

[5] S. Bhanwar, S. Bawa. "Establishing and Evaluating Trust in a Grid Environment", in The 10th International Symposium on Pervasive Systems, Algorithms, and Networks, Kaohsiung, Taiwan, December 14-16, 2009.

[6] C. Chess, K. Purcell, "Public Participation and the Environment: do we know what works?", Environmental Science and Technology, Vol. 33, 1999, pp. 2685–2692.

[7] S. French, D. Rios Insua, Statistical Decision Theory, London: Arnold, 2000.

[8] French, S., Rios Insua, D., Ruggeri, F., "e-Participation and Decision Analysis", Decision Analysis, Vol. 4, No. 4, 2007, pp. 211-226.

[9] C.D. Gamper, C. Turcanu, "Methods on the Governmental Use of Multi-criteria analysis", Ecological Economics, Vol. 62, 2007, pp. 298-307.

[10] S. Grimmelikhuijsen, "Transparency of Local Public Decision-making: towards trust or demystification of government?", in The 2009 Annual Conference of EGPA, Malta, September 2009.

[11] R. P. Hamalainen, "Reversing the Perspective on the Applications of Decision Analysis", Decision Analysis, Vol. 1, No. 1, 2004.

[12] N. C. Hjortsø, "Enhancing Public Participation in Natural Resource Management using Soft OR – an Application of Strategic Option Development and Analysis in Tactical Forest Planning", European Journal of Operational Research, Vol. 152, 2004, pp. 667–683.

[13] B. D. Jones, "Bounded Rationality", Annual Reviews Political Science Vol. 2, 1999, pp. 297-321.

[14] A. Kangas, J. Kangas, M. Kurttila, Decision Support for Forest Management: Managing Forest Ecosystem, Finland: Springer, 2008.

[15] J. Kim, "A Model and Case for Supporting Participatory Public Decision Making in e-Democracy", Journal of Group Decision Negotiation, Vol. 17, 2008, pp. 179–193.

[16] S. Y. X.. Komiak, I. Benbasat, "The Effects of Personalization and Familiarity on Trust and Adoption of Recommendation Agents", MIS Quarterly, Vol. 30, No. 4, 2006, pp. 941-960.

[17] Y-T. Lai, W-C. Wang, H-H. Wang, "AHP and Simulation-based Budget Determination Procedure for Public Building Construction Projects", Automation in Construction, Vol. 17, 2008, pp. 623–632.

[18] Z. Liang and W. Shi. "PET: A PErsonalized Trust Model with Reputation and Risk Evaluation for P2P Resource Sharing", in The 38th Annual Hawaii International Conference on System Sciences, January 03-06, 2005.

[19] Z. Lin, X. Feng, W. Yuan, L. Jian, "A Semantic and Time Related Recommendation-Feedback Trust Model", in The 2nd International Conference on Availaibility, Reliability, and Security, Vienna, Austria, April 10-13, 2007.

[20] I. Linkov, A. Varghese, S. Jamil, T. P. Seager, G. Kiker, T. Bridges, "Multi-criteria Decision Analysis: a Framework for Structuring Remedial Decisions at Contaminated sites", in Comparative Risk Assessment and Environmental Decision Making, Netherland: Kluwer, 2004, p. 15-54.

[21] T. Mau-Crimmins, J. E. de Steiguera, D. Dennis, "AHP as a means for Improving Public Participation: a Pre–post Experiment with University Students", Forest Policy and Economics, Vol. 7, 2005, pp. 501– 514.

[22] McKnight, D.H. & V. Choudhury and C. Kacmar, "Developing and Validating Trust Measures for E-commerce, An integrative Typology", Information Systems Research, Vol. 13, No. 3, 2002, pp. 334-359.

[23] F. Messner, O. Zwirner, M. Karkuschke, " Participation in Multi-criteria Decision Support for the Resolution of a Water Allocation Problem in the Spree River Basin, Land Use Policy, Vol. 23, 2006, pp. 63–75.

[24] B. Mikulskiene, A. Kriksciunaite, "Multicriteria Decision Analysis for Social Oriented Decision Making, the Compromise for Teacher's Salaries", Economics & Management, Vol. 14, 2009.

[25] J. Mustajoki, R. P. Hämäläinen and M. Marttunen, "Participatory Multicriteria Decision Analysis with Web-HIPRE: a Case of Lake Regulation Policy", Environmental Modelling & Software, Vol. 19, 2004, pp. 537-547.

[26] T. Peixoto, "e-Participatory Budgeting: e-Democracy from Theory to Success?", e-Working Papers, E-Democracy Centre, Universität Zürich, Switzerland, 2008.

[27] H. Raiffa, J. Richardson, D. Metcalfe, Negotiation Analysis: the Science and Art of Collaborative Decision Making, Cambridge: Mass, Harvard University Press, 2002.

[28] A. Salo, R. P. Hamalainen, "Multicriteria Decision Analysis in Group Decision Processes", Advances in Group Decision and Negotiation, Vol. 4, Part. 3, pp. 269-283, 2010.

[29] S. R. J. Sheppard, M. Meitner, "Using Multi-criteria Analysis and Visualisation for Sustainable Forest Management Planning with Stakeholder Groups", Forest Ecology and Management, Vol. 207, 2005, pp. 171–187.

[30] C. Tian, S. Zhou, W. Wang, S. Cheng. "An Efficient Attack-Resistant Trust Model for P2P Networks", International Journal of Computer Science and Network Security (IJCSNS), Vol. 6, No.11, November 2006.

[31] S. Tuler, T. Weber, "Voices from the Forest: What Participants Expect of a Public Participation Process", Society & Natural Resources, Vol. 12, 1999, pp. 437–453.

[32] V. Tundjungsari, J. E. Istiyanto, E. Winarko, R. Wardoyo, "A Trust based Reputation Model to Seek Judgment and Advice in Participatory Decision Making", in The 2nd Distributed Framework and Application International Conference Yogyakarta, Indonesia, August 2-3, 2010.

[33] D. Umuhoza, J. I. Agbinya, D. Moodley, A. Vahed, "A Reputation based Trust Model for Geospatial Web Services", inThe 1st WSEAS International Conference on Environmental and Geological Science and Engineering (EG'08), Malta, September 11-13, 2008.

[34] Y. Wang and J. Vassileva. "Trust and Reputation in Peer-to Peer Networks", in The 3rd International Conference on Peer-to-Peer Computing, 2003.

[35] F. E. Walter, S. Battiston, F. Schweitzer, F.," A Model of a Trust-based Recommendation System on a Social Network", Journal of Autonomous Agents and Multi-Agent Systems, vol.16(1), 2007, pp. 57-74.

[36] B. Whitworth, C. Sylla, "A Social Environment Model of Socio-technical Performance", in The International Academy of Business and Economics, Bangkok Summer Conference, June 4-6, 2010.

[37] W. Yuan, D. Guan, S. Lee, Y. Lee, A. Gavrilov, "Finding Reliable Recommendations for Trust Model", Lecture Notes in Computer Science, Vol. 4255, Berlin: Springer-Verlag publisher, 2006, pp. 375-386.