A Framework for Studying Voting in Group Support Systems

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Abstract

Group decision making is essential in organizations. Group Support Systems (GSS) can aide groups in making decisions by providing tools and process support. Voting tools have been considered valuable assets in groups' decision processes. However, there is an insufficiency of theory and experiments in research of voting in GSS. This paper presents a framework by identifying factors related to voting in GSS. These factors were scrutinized for their potential effects on processes and outcomes. Several ways of classifying voting methods are discussed. The framework can be used as a guiding basis for future research and usage of voting in GSS.

1. Introduction

Many organizations rely on groups for essential functions such as information gathering, decision making, and execution. Group Support Systems (GSS) that contain hardware, software, and procedural components, can augment a group's performance with various tasks, especially for geographically or temporally distributed groups. GSS may provide tools for these tasks to streamline the group processes. One simple model divides the decision making task roughly into intelligence-design-choice phases, which can be mapped to brainstorming-idea analysis-voting activities in GSS [17]. Researchers have developed many tools for these activities. Voting has been regarded as a valuable mechanism in aiding groups making decisions. GSS researchers also emphasize that proper use of voting is very critical in achieving better results. However, there is very little theory as guidelines for GSS researchers to conduct experiments. Data from GSS experiments is sparse. There is a need to develop theory for voting in GSS. The theory can guide GSS investigators in formulating experiments and guide GSS system builders in incorporating voting tools in GSS. Additionally, GSS facilitators and users can also benefit from the theory in how to utilize the voting tools.

2. Voting Tools in GSS

Voting is a formal method to collect members' preferences and combine the preferences into a group choice. The majority of GSS's, such as CM3 [15], EIES 2 [10], GroupSystems [35], PLEXSYS [8], SAMM [44], TERMS [42], WebIQ [45], and FacilitatePro [12] have voting tools. There are also web-based standalone voting tools, for example SZTAKI [40], that can be used in group decision making. Researchers have learned from field uses of GSS that voting tools in GSS can be and should be used differently from the traditional paper-based voting because voting tools in GSS can take advantage of the enhancement in communication capability and computing power provided by computers. Voting tools can be designed to record members' votes and compute an intermediate result, yet permit people to change their votes while the group is still deliberating the decision. Voting tools can also provide assistance to the users about the tools and help in the interpretation of result. Voting in GSS should not be used to signify the end of the decision process but to discover the lack of consensus and enable the group to explore the issue at a deeper level [26, 33, 34].

Even though the researchers have recognized its importance as well as made suggestions about its use for voting in GSS, there are very few controlled experiments in terms of developing and validating the theory behind voting in GSS. As shown in the review of GSS studies by Fjermestad and Hiltz [13], of the 184 studies reviewed, two studies [3, 10] have included voting into the experimental treatment and only one study [47] reports the group's voting behavior. This creates an opportunity for research to

better understand the interplay among attributes of voting tools, groups, tasks, and outcomes.

3. Two Aspects of Voting

3.1 Voting as Aggregation

Traditionally, studies on voting focus on how preferences are combined into a final decision. In this regard, voting can be viewed as a way to aggregate members' opinions. This view of voting is especially true if voting is used only once at the end of the decision process. Theories and findings from Social Choice Theory (SCT) [2, 6, 32, 36] can provide insight when aggregation aspect is the main focus of studying voting in GSS.

3.2 Voting as Communicating

Alternatively, voting can be seen as a concise form of communication about one's preference. This kind of communication is with predefined format and very lean. Nonetheless, group members will exchange information and have feelings about this communication process. The communication effect of voting will be more apparent when a group uses multiple rounds of voting to reach a decision. Media Synchronicity Theory [9] classifies media in five dimensions: immediacy of feedback, symbol variety, parallelism, rehearsability, and reprocessability (Table 1). Voting is low in symbol variety and parallelism because it only allows a formal way to express one's preference and one session for one issue at the same time. It is high in reprocessability since message size is small and message format is fixed. The immediacy of feedback and rehearsability of voting may range from low to high by system design and/or procedure. According to Media Synchronicity Theory, convergence communication processes are best matched with low symbol variety and parallelism as well as high immediacy of feedback and rehearsability. Communication characteristics of voting make it very appropriate for convergence communication processes. Voting in GSS might be able to gain greater benefit if the design and use also emphasizes feedback and rehearsability.

4. A Framework for Studying Voting in GSS

It is clear that a framework is needed to study the effects of voting tools and voting procedures. Here we adopt the input-process-output system view similar to

Table 1. Dimensions in Media Synchronicity Theory [9]

Immediacy of feedback	The extent to which a medium enables users to give rapid feedback on the communications they receive.
Symbol variety	The number of ways in which information can be communicated.
Parallelism	The number of simultaneous conversations that can exist effectively.
Rehearsability	The extent to which the media enables the sender to rehearse or fine tune the message before sending.
Reprocessability	The extent to which a message can be reexamined or processed again within the context of the communication event.

the frameworks proposed by Pinsonneault and Kraemer [37] and Dennis et al. [8], as shown in Figure 1. In addition to those input, process and output factors that have been studied in GSS research, factors specific to voting, (i.e., voting procedure and voting methods) should be considered. The possibility of interactions among these input factors should also be examined. The voting method factor is especially highlighted because it is a conspicuous feature of voting, yet receives very little attention in GSS studies of voting. There are many ways to vote on an issue. Table 2 is a list of some commonly used voting methods and their descriptions. People can use plurality method, approval voting, Borda count, or other voting methods to aggregate their opinions.

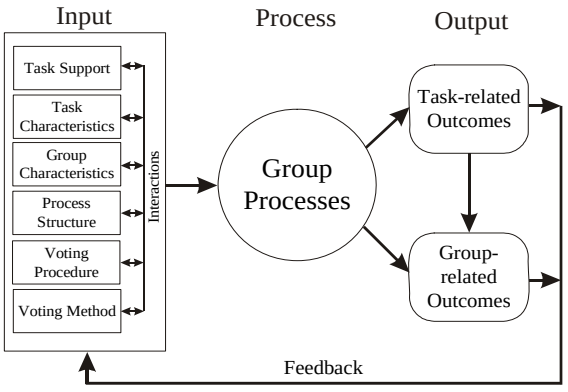

Figure 1. Research Framework for studying Voting in GSS

Table 2. Description of Commonly Used Voting Methods

Voting Methods	Description
Plurality Method	Also called Simple Majority Voting. Everybody has one vote. Each one will endorse the most preferred alternative. The alternative that has the most votes wins.
Majority Rule	Similar to the plurality method except that the winning alternative must have more than a preset threshold, usually 50% of the total votes. If there is no alternative passed the winning threshold, voters have to vote again until one alternative wins.
Approval Voting	Every voter can cast one vote for any number of alternative(s) he/she approves. The alternative with the most votes is declared as the winner.
Multiple Vote	When electing *k* winners, a member can cast up to *k* votes. Each alternative can receive one vote for one member at most.
Borda Count	Each alternative is given a count based on its ranking on each individual's preference. For *n* alternatives, the most often used way to assign count to an alternative is *n*-1 points for each ballot it is ranked first, *n*-2 for second, etc., down to 1 point for second to last, and 0 for last place. The alternative with the highest total count wins.
Average Rating	Voter has a fixed amount of scores that can be assigned to alternatives. Each alternative is given a total score by adding the scores by all voters. The alternatives with the highest total score wins.

Research in SCT has shown that the different voting methods can make different alternatives being selected. It is plausible to hypothesize that different voting methods will produce different group interactions and group outcomes.

5. Input Factors and Voting

5.1 Task Support

Task support in GSS can interact with the use of voting. For example, anonymity, which reduces the personal influence of dominant individuals, may also reduce the possibility that people can form alliances in voting. Anonymity makes it harder for members to identify others with compatible preferences so they may swap votes. It also makes it harder for people to verify if an ally has kept his/her promises. Voting can be conducted with the voter's identity revealed (open vote) or concealed (secret ballots). Open vote is used when it is important to record individual positions on an issue. However, there are issues with open ballots. Powerful people can influence other voters by casting their votes with their identities revealed. A voter may not express his/her true preference if the supported alternative is considered radical or is against the dominant member. Furthermore, people are reluctant to change position in an open vote situation because of cognitive dissonance [14, 25]. Because of these reasons, members may hesitate to express themselves or disclose information supporting their true positions during discussions. Secret ballots, or anonymity in voting, can reduce these problems associated with open vote. As there are different levels of anonymity in discussion [43], there can be different levels of anonymity in voting. The membership of the group can be known or unknown to members. Members can have no identity associated with them or can be identified with pen names or aliases. The least approach can trace the position change of a member but not reveal the true identity of the individual.

The effect of anonymity in group discussion has been studied in GSS research for a long time. Researchers have found that anonymity can lead to positive effects such as more objective evaluation, more equal participation, and better decision quality [24, 33, 34]. Anonymity also has negative impacts like increasing free riding. Nevertheless, while most of the analysis and findings about anonymity in group discussion may also be pertinent to voting, there are little experiment data validating the effect of anonymity in GSS voting. In addition, because people are used to thinking that identities should be kept secret in voting since this is the norm in most free elections, a more interesting question might be to ask what is the effect of open balloting. Would people spend more time before casting their votes to ponder the alternatives? Or, would people wait and then follow the majority fearing that they might become ostracized if they cast an unpopular vote? Clearly,

these questions make relevant and interesting research topics.

Moreover, the level of anonymity in discussion and voting can be different. Members can have a discussion session using their true identities or aliases to avoid free riding, yet vote anonymously to eliminate influence of powerful members. Or, the group can have their discussions anonymously to enable the expression of unpopular options, but have members' formal positions recorded in an open vote. There are many possible combinations of anonymity in discussion and voting. The interplay between anonymity in discussion and voting warrants future research.

5.2 Task Characteristics

The optimal use of voting tools in GSS will depend on the type of task. For example, for a type 3 intellective task in McGrath's task circumplex [31], it may be more suitable to use voting tools to determine the decision criteria rather than to decide the final choice because the task has a correct answer based on the criteria. On the other hand, it may be more appropriate to use voting tools to discover the viewpoints of participants in a type 5 cognitive-conflict task, which is to resolve conflicting viewpoints.

Task complexity also affects voting. Voting with few alternatives requires less effort. The difference among voting methods is less prominent when there are few alternatives. The number of alternatives can also affect the possibility for members to estimate the group preference profile and manipulate the voting outcome by voting insincerely. When choosing an appropriate voting method for a task on hand, the group should also take the task complexity into account. A large number of alternatives coupled with a voting method that requires a lot of efforts can easily cause information overload and render the voting process unproductive.

The output of the task also dictates what kind of voting method is more appropriate. A voting method that allows members to vote for more than one alternative would be more suitable for a task requiring members to choose several alternatives instead of only one [16].

5.3 Group Characteristics

Winniford [47] has shown that group size affects the use of voting in GSS. Large groups need more rounds of votes to reach decision than small groups do. However, there is no significant difference in decision time for large and small groups. In addition, the decision quality is higher for large groups. Since large groups usually suffer more group process losses [35], the use of voting tools seems to reduce group process losses more effectively in large groups. Nevertheless, studies are needed to verify this hypothesis and to explore the effects of other group characteristics on voting in GSS.

5.4 Process Structure

The use of voting and the features of voting tools should be designed to match the process structure. For example, a decision session based on Delphi process [28] could be matched with dynamic voting tools to enable members to explore their differences and speed up consensus building without the need to wait until all opinions are collected and tallied as in the traditional Delphi process. Voting tools can also change the process structure. It was found in a field study that voting before discussing may result in higher agreement among members and higher satisfaction with the interaction. The voting before discussion approach may be useful when group agreement is important. It can also be employed when interpersonal conflict might cause problems in meetings [46].

5.5 Voting Procedures

The time to invoke voting, length of the poll, stop conditions, and rules to interpret the results are all parts of the voting procedure. Variations in procedures may lead the group to emphasize certain aspects of the decision processes. The procedures may be designed to speed up consensus building, to achieve higher decision quality, or to prompt information exchange. Clearly, a contingency theory is needed to match the procedures with task support and task characteristics.

5.6 Voting Methods

Researchers in SCT have proposed many conditions for an ideal voting method. When a voting method fails to meet a desired condition, it may make members feel the method is unfair or it might choose a less appropriate alternative under certain situations. For example, the universal criterion [1] states that a method should produce a result (with the possibility of ties) no matter how members voted. If a voting method can not produce a winner then voters will question the usefulness of the voting method. Considering the independence of clones criterion [41], i.e., the voting outcome is unaffected by the addition or removal of

alternatives that are the same or very similar. If a method failed independence of clones criterion, it might select a less preferred alternative rather than stronger preferred alternatives when supports for stronger preferred alternatives are divided among similar alternatives. These deficiencies may limit the application of a voting method in GSS. Knowing which voting method exhibits what properties can help a group choose a more appropriate voting method if the group recognizes a voting method may failed under that situration.

Voting method can also affect how information are used in the decision making process. In a study of rank-order effects [23], groups in which members had to rank order alternatives exchanged more information than groups in which members only needed to choose the best alternative. Voting methods, such as the plurality method, approval voting, or Borda count, require a person to choose only one alternative, select several acceptable alternatives, or rank order all alternatives, put different information processing loads onto individuals and yield different amounts of information exchanged among members. The difference may make the group contemplate more information or process the information more deeply before making the final decision.

On the other hand, how the alternatives are compared and selected may also have an effect on individuals. For example, certain voting methods, such as approval voting and Borda count, allow an individual to advocate for not only the most preferable alternative but also acceptable alternatives at the same time. This may reduce post-decision regrets if an individual's most preferable alternative is not chosen. However, very little has been done to examine the effect of voting methods on processes and outcomes in GSS.

5.6.1 Individual Efforts in Voting

To come up with a vote, an individual has to make comparisons among alternatives. In a more complex voting method the voter will need to process more information in making comparisons. Gavish and Gerdes [16] have suggested a five-level classification of ballot complexity that can be seen as a combination of mental and physical efforts at an individual level. The first level is simply marking the highest valued alternative. The second level is to partition the alternatives into two sets and mark all alternatives in the acceptable set. The third level is to rank alternatives in the acceptable set and allocate limited votes. The fourth level requires the voter to rank the entire alternative set. The voter has to quantify the whole preference profile in the fifth level. Table 3 is a summary of the ballot complexity.

Deeper processing of information by individuals can lead to better decision quality because an individual can integrate more information into his/her decision framework [21]. The individual has to put in more effort and there is more information to be discussed in a complex voting method. Each round of voting may take longer to complete. This may make the group spend more time before it reaches a final decision.

5.6.2 Exchange of Task-related Information

Coombs [5] proposed a "Searchingness structure," which arranges data collection procedures on two general dimensions: the number of items presented at a time (from 1 to n) and whether the respondent has the task of choosing some items (pick k), or rank ordering two or more of the items (order k). According to Coombs, the data collection procedures in the searchingness structure vary in "channel capacity" and "redundancy." Channel capacity reflects how much information a procedure yields and provides a measure of the relative power of the method. Redundancy indicates how much of the capacity is used in measuring and controlling inconsistency in the procedure. Voting methods, like data collection

Table 3. Ballot Complexity [16]

Ballot Complexity Level	Description of Efforts	Example
1	Mark highest valued alternative	Plurality Method
2	Separate alternatives into two sets, mark all alternatives in acceptable set	Approval Voting
3	Rank alternatives in acceptable set to allocate limited votes	Multiple Vote
4	Rank whole preference profile	Borda Count
5	Quantify whole preference profile	Average Score Method

Table 4. Channel Capacity of Voting Methods

Voting Method	Possible Number Of Combinations	Channel Capacity	Capacity for a 10-alternative Case
Plurality Method	n	$\log_2 n$	3.32
Approval Voting	2^n	n	10
Borda Count	$n!$	$\log_2 n!$	21.79
Average Score Method with m points	$H_n^m = C_{n-1}^{m+n-1}$	$\log_2 C_{n-1}^{m+n-1}$	With 50 points: 33.55 With 100 points: 41.96

procedures, expects the voters to either pick or rank order some alternatives. Thus it is possible to apply techniques in the searchingness structure to analyze these voting methods. The channel capacity will indicate information contributed by the voter.

The channel capacity is based on information theory [38]. The information value of a vote can be estimated from all possible presentations of votes. We start with the formula for entropy (in bits) $H = -\sum_i p_i \log_2 p_i$, where p_i is the probability for the i^{th} presentation. To calculate the maximum theoretical channel capacity for a voting method, we assume that all combinations have equal probability of occurring, and then probability for a presentation becomes 1/k, where k is the number of all possible combinations. The channel capacity C for a voting method is $C = -\sum_{i=1}^{k} \frac{1}{k} \log_2 \frac{1}{k}$, or, after simplification, $\log_2 k$.

Based on an n-alternatives voting scenario, we can compute the channel capacity for some voting methods. For the Plurality Method, because the voter can only pick one from all the alternatives, the possible number of combinations is $P_1^n = n$ (Pick 1 from n). There are 2^n possible combinations for Approval Voting as a voter can either vote for or not vote for each alternative. In Borda Count, the voter has n! ways of ordering all the alternatives. A voter has $H_n^m = C_{n-1}^{m+n-1}$ different ways to allocate m points to n alternatives in the Average Score Method. Table 4 is a summary and sample calculation of the channel capacity for several voting methods.

Difference in channel capacity does not only mean a member can express more or less in one's vote; it can also lead the group to exchange different amount of information in discussion. A high bandwidth voting method allows more precise expression of members' preferences. The group may be able to discover uncommon information because some members make very different votes. A group is likely to find similarities and disparities in members' preference profiles in a high bandwidth voting method and then it can explore the underlying reasons more deeply. The exploration will lead the group to exchange even more information.

Interaction among members will make members feel more confident about their decision [20]. Since a high bandwidth voting method prompts interaction among members, it will lead to higher confidence about the decision. The expressive power of a high bandwidth voting method should enable a group to use less rounds of voting to reach a decision. Thus using a high bandwidth voting method might reduce the time for a group to reach a decision. However, high bandwidth voting methods tend to be complex voting methods, which may require more time for each round of voting. The net effect of complexity and bandwidth of voting method on time to reach a decision is not clear.

5.6.3 Exchange of Social Information

Although voting is a very lean and formal communication, it is still possible for the group to exchange some social information, that is, members' preferences. A member can learn about other members' preferences over a series of voting sessions. More complex voting methods give out more information about a member's preference. In spite of this, this kind of social information exchange is very weak compared to other media that allows more freedom in expressing one's feelings. This social information exchange may also be nullified by anonymous voting. Thus, the effect of social information exchange with voting might not be noticeable.

5.7 Access to Voting Results

A group can have access to the voting result earlier or later. There are different degrees of accessibility similar to anonymity. The most unrestricted access is

that a member can see the result at any time even before casting his/her vote. The most restricted access would be that the group cannot see the results even after the voting session, although it is difficult to find a real-world example for this kind of restricted access. Between the extremes, a member might have some restrictions in viewing the results. The most common restriction is the results will only be made available after the voting session. A less restrictive access to the results might be that one can see those after a voter has cast his/her vote. Other variations may include showing the result after a certain percentage of members have voted or promulgating the result after a certain time period.

Researchers have long confirmed the "bandwagon effect" in election [30, 39, 48]. A candidate who wins early primaries can influence the people who were previously committed to other candidates. When those people get a chance to vote later, a lot of people change their position to support the early winner. Although the scale of voting in group decision is smaller compared to the scale of elections, it is also possible that people will change their position simply because they have viewed the partial voting result before casting their votes. Early access to partial result may also dissuade people who see their preferred alternative lose by a wide margin from expressing their true opinions. Some people might also free ride on other people's effort so they wait until there is a winning alternative then vote in order to be on the winning side if they have access to partial voting result.

Early access to voting results is not without its merits. People may feel more satisfied with the process because they can go on with their discussion without the need for waiting until all other members have voted. It may also prompt a quicker consensus building process. However, the consensus building process should only start after all parties' views have been considered. This may require a carefully designed procedure that balances discussion and voting sessions.

5.8 Frequency of Voting

Researchers in GSS have suggested that voting should not be used as a one-time mechanism to signal the end of discussion. Instead, they suggest that there should be multiple rounds of voting to foster discussion [26, 33, 34]. Nonetheless, there are no guidelines for how often a group should vote. Will long discussions with fewer rounds of votes do better, or will short discussions with more rounds of votes do better? The issue might be even more complex than matter of rounds of votes because the best approach might be contingent on other factors such as task type and member ability. Action Regulation Theory [18, 19] which is about modes and sequences of task may offer hints in designing the voting process. In any case, there is very little empirical data to predict which approach would be better.

Alternatively, if we treat the frequency of votes as a dependent variable, then what factors affect it? Winniford [47] has identified two factors, communication mode (Face-to-Face vs. GSS) and group size, that impact on the number of voting rounds needed. The complexity of voting method might also have an effect on how many rounds of voting a group needs in order to reach a decision. A complex voting method requires more effort from individual members. Group members may feel exhausted and vote less often. On the other hand, people can exchange more information with a complex voting method, thus they might be able to reach a decision in less rounds of votes.

5.9 Dynamic Listing of Alternatives

As voting selects one alternative from a set of alternatives, a voting procedure cannot divine a good decision among a list of poorly formulated alternatives. If a voting procedure allows dynamic addition and deletion of alternatives, it might be able to improve the quality of decision, especially if the new alternative is an improvement on old alternatives and/or synergy of old alternatives generated during discussion. People will be able to eliminate those alternatives that are obsolete so the group does not have to spend time and energy to discuss them.

In order for dynamic listing of alternatives to function, the system needs to provide additional support. The system should notify members that the alternatives have changed. Either people will have a chance to change their votes or the system will invalidate the pervious vote and start a new round of vote with new alternatives. In either case, the frequency of re-vote should be carefully controlled, otherwise people will get frustrated and become dissatisfied with the voting process.

5.10 Representation of Voting Result

The representation format of data can influence the decision making process [4, 7, 22, 29]. The design of voting system in GSS has to consider the output format because it will affect the final outcome. It is possible for the system to show the voting results in different format such as text or graphic formats. The system should allow the flexibility for its users to choose

among output formats. Some voting methods can be used to produce additional information. For example, a complete rank order or a binary comparison matrix of all alternatives can be used to compute a group scale [11, 27]. The group can see the strength of the agreement or disagreement. The extra information can be very useful for the group to make further analysis if members want to spend extra effort to understand the extra information.

6. Conclusion

Because of the scarcity of theory and empirical data, new research investigating the relationship between voting methods, group processes, and decision outcomes under a GSS is strongly needed. This paper presents a framework to study voting by expanding existing frameworks of GSS. Factors about voting have been reviewed and examined. In addition, we reviewed and proposed ways to classify voting methods. This framework can provide the theoretical background for building and using voting tools in GSS. Experiments to validate the framework are the next critical steps in studying voting in GSS. Organizations and groups can benefit from better understanding of voting in GSS by using voting more effectively and efficiently.

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