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A REWARDING MECHANISM FOR E-DELIBERATION SYSTEMS: SIMULATION ANALYSIS AND FUTURE DIRECTIONS

Vassilis Tsakanikas and Vassilis Triantafyllou
Electrical & Computer Engineering Department, University of Peloponnese, Greece

ABSTRACT

This study introduces a novel e-deliberation model that integrates a rewarding mechanism designed to enhance citizen engagement and elevate the quality of deliberative processes. The model simulates interactions between citizens and proposals, examining how costs and rewards shape participation dynamics. Through detailed mathematical formulation and simulation, the results reveal that the rewarding mechanism significantly boosts engagement, particularly in the early stages of deliberation. Citizens with medium budgets demonstrated sustained participation, maintaining steady levels of comments, while low and high budgets resulted in declines during later stages. Additionally, the model highlights the impact of participant saturation, showing that rewards effectively increase engagement in smaller groups but may lead to diminishing returns as participation levels grow. These findings underscore the importance of a well-calibrated reward structure in sustaining meaningful participation and preventing disengagement. Future work will involve empirical validation of the model using real-world data collected through the Public Online Deliberation System (PODS), which will provide critical insights into optimizing incentives and refining the model for practical e-deliberation scenarios.

KEYWORDS

E-deliberation, Citizen Engagement, Rewarding Mechanism, Online Deliberation, Political Participation

1. INTRODUCTION

In the era of digital transformation, promoting civic engagement and public participation through online platforms has emerged as a central component of contemporary democratic systems. E-deliberation, defined as the utilization of electronic platforms for public deliberation and decision-making, represents a promising strategy for augmenting democratic participation. By harnessing digital technologies, e-deliberation facilitates citizen involvement in discussions, voting on proposals, and providing feedback, thereby fostering more inclusive and informed policy-making processes. This approach democratizes access to decision-making by eliminating geographical and temporal barriers, thereby enabling a diverse array of voices to be heard (Fishkin, 2018; Ercan *et al.,* 2022). Enhanced participation contributes to the legitimacy and quality of decisions by incorporating a broader range of perspectives and insights. Moreover, inclusive deliberation cultivates a sense of community and shared purpose, leading to sustainable and widely accepted outcomes (Curato, 2022). E-deliberation also ensures transparency and accountability, as the rationale behind decisions is subject to public scrutiny, thereby building trust in democratic processes (Mendonça, 2022).

Despite these advantages, significant challenges hinder the realization of e-deliberation's full potential. A primary concern is the low participation rates, which are often attributed to barriers such as limited digital literacy, apathy, and skepticism regarding the impact of individual contributions. Even when platforms are accessible, participation is frequently confined to a small, often unrepresentative subset of the population (Ercan *et al.,* 2022; Mendonça, 2022). The digital divide further exacerbates these challenges, as marginalized populations frequently lack access to digital tools, resulting in unequal representation and undermining the inclusivity of deliberative processes (Fishkin, 2018). Additionally, the dynamics inherent in online deliberation can perpetuate existing social inequalities. More vocal and technologically adept participants may dominate discussions, while others may feel marginalized or intimidated. The formation of echo chambers, where like-minded individuals reinforce their views without exposure to opposing perspectives, constitutes another significant concern (Ercan *et al.,* 2022). Addressing these issues to ensure meaningful and equitable participation remains a critical challenge for both researchers and practitioners. To address these challenges, this paper introduces a reward mechanism designed to enhance citizen engagement in e-deliberation platforms. By incentivizing participation through rewards for valuable contributions, such as insightful comments and active voting, the proposed model seeks to balance the costs and rewards to maximize participation and improve the quality of deliberation. The model integrates demographic factors, including age, gender, and profession, as well as the impacts of costs and rewards on individual behavior. Utilizing differential equations, the model captures the evolution of political opinions and the positions of proposals over time, with particular emphasis on how comments are received and integrated. Through simulations, the model offers insights into strategies that can increase engagement and foster meaningful contributions, thereby facilitating the development of more effective e-deliberation platforms.

The ongoing issue of low participation in digital deliberation platforms undermines their capacity to reflect a diverse spectrum of opinions (Davies & Chandler, 2012; Min, 2007). Many citizens either refrain from participating or engage intermittently, thereby limiting the platform’s inclusivity and legitimacy. Previous studies indicate that incentivizing participation through rewards is an effective approach to mitigating this issue (Lampe *et al.,* 2014; Harper *et al.,* 2007). This paper aims to bridge this gap by proposing a reward mechanism specifically designed to foster sustained participation, ultimately enhancing both the quantity and quality of engagement within e-deliberation systems.

2. STATE OF THE ART

Extensive research on e-deliberation systems has explored various strategies to enhance participant engagement and improve the quality of deliberative processes. Each approach offers unique advantages while facing distinct challenges, reflecting the complexity of fostering effective online deliberation.

Deliberative polling has been praised for improving participant knowledge and generating well-informed outcomes. By gathering a representative sample of citizens, providing detailed information, and facilitating structured discussions, it effectively reflects informed public opinion (Fishkin, 2018). However, the substantial resources required, including expert moderators and extensive preparatory materials, limit its scalability for broader applications (Fishkin, 2018). Gamification, which incorporates game-like elements such as points, badges, and leaderboards, has shown promise in attracting younger participants and increasing engagement (Ercan *et al.*, 2022). Despite its potential, gamification can result in superficial participation, where users focus on rewards rather than meaningful contributions, undermining the deliberative process's substantive quality (Ercan *et al*., 2022).

Machine learning algorithms present a cutting-edge solution for managing large-scale deliberations, facilitating discussions by identifying themes, summarizing content, and filtering irrelevant input (Mendonça, 2022). While effective in streamlining participation, these algorithms raise concerns about transparency and potential biases that may skew deliberative outcomes (Mendonça, 2022). Social media integration, another significant strategy, aims to expand e-deliberation's reach by leveraging existing networks to engage a larger, more diverse audience (Coleman & Gøtze, 2022). However, challenges such as misinformation, polarization, and echo chambers on social platforms can impede meaningful and balanced deliberation (Coleman & Gøtze, 2022).

Recent innovations have introduced deliberative systems designed as interconnected spaces to foster continuous engagement and adaptability in online deliberations. While promising in theory, implementing these systems requires substantial institutional support and infrastructure, posing barriers to widespread adoption (Dryzek, 2022). Similarly, the Public Online Deliberation System (PODS) exemplifies efforts to scale deliberative processes for large-scale public engagement. By emphasizing transparency and accountability, PODS enhances public trust and legitimacy (Triantafyllou *et al.*, 2019). However, ensuring equitable participation remains a challenge, as marginalized voices may still be underrepresented (Triantafyllou et al., 2019).

Building on these approaches, this study proposes a novel rewarding mechanism to enhance engagement and improve the quality of deliberation in e-deliberation platforms. The mechanism incentivizes participation by offering rewards for valuable contributions, such as insightful comments and active voting, fostering sustained and meaningful engagement. Through differential equations, the model simulates the dynamic evolution of political opinions and proposal positions, emphasizing how comments are received and integrated into deliberative discourse. Simulations highlight the model's ability to balance costs and rewards, optimizing both engagement levels and the quality of deliberative interactions. By addressing the persistent issue of low participation, this research contributes to the advancement of e-deliberation systems that are inclusive, effective, and capable of facilitating democratic decision-making (Davies & Chandler, 2012; Min, 2007; Lampe *et al.,* 2014; Harper *et al.,* 2007).

3. MODELING SCHEME

The proposed modeling framework for the e-deliberation system is meticulously crafted to simulate and examine the intricate interaction dynamics between citizens and policy proposals within a digital deliberative milieu. This framework emphasizes the comprehensive characterization of citizen behavior and the progressive evolution of proposal positions, thereby capturing the complex interplay inherent in online deliberative environments. Central to the model are several pivotal components that collectively facilitate a nuanced analysis of the deliberative process.

Firstly, the framework delineates the representation of citizens' political opinions and their temporal evolution. Each citizen's stance is dynamically influenced by their active participation in voting and commenting on various proposals. The model intricately incorporates demographic variables such as age, gender, and professional background, recognizing their substantial impact on shaping individual political perspectives and behaviors. By accounting for these demographic factors, the model ensures a more accurate and realistic simulation of citizen engagement patterns.

A second critical component involves the modeling of proposals and their corresponding political positions. This segment of the framework focuses on the perception and subsequent modification of proposals in response to citizen feedback. It meticulously tracks the rate at which comments are generated and assimilated into the proposals, thereby reflecting the dynamic and reciprocal nature of citizen-proposal interactions. This aspect of the model underscores the fluidity of policy positions as they adapt to incorporate diverse citizen inputs, highlighting the iterative process of deliberative refinement.

A distinctive feature of the proposed framework is the integration of a rewarding mechanism designed to incentivize active and meaningful participation. This mechanism offers rewards for valuable contributions, such as insightful comments and consistent voting, thereby encouraging sustained engagement. The reward system is strategically embedded within the model to equilibrate the costs incurred by citizens during their participation, ensuring that their involvement remains both motivated and sustainable over time. This balance is crucial for maintaining high levels of engagement without imposing undue burdens on participants.

The modeling framework provides a holistic and comprehensive structure to comprehend and enhance the efficacy of e-deliberation systems. By simulating diverse scenarios, the model aspires to identify optimal strategies that maximize citizen participation and elevate the quality of deliberative outcomes. This, in turn, contributes to the advancement of more inclusive and effective democratic processes, fostering a robust participatory environment.

The underpinning mathematical model is grounded in established behavioral research related to digital platforms and gamification. Empirical studies have demonstrated that incentivizing participation through rewards can substantially augment user engagement, particularly in contexts where individuals are motivated by the anticipation of tangible benefits (Fishkin, 2018; Ercan *et al.*, 2022). This premise is integral to the model, positing that citizens are more inclined to engage actively when their contributions are duly rewarded. Furthermore, empirical evidence indicates that individuals are more predisposed to vote or comment on issues that resonate with their intrinsic beliefs, thereby emphasizing the necessity of aligning reward structures with user preferences (Boulianne, 2009; Margetts *et al.,* 2015). By integrating these empirical insights, the model endeavors to faithfully replicate real-world behaviors within a structured e-deliberation system.

Moreover, existing research has extensively explored the role of incentives in digital platforms and deliberative systems. For instance, gamification strategies, which incorporate elements such as points, badges, and leaderboards, have been proven to enhance engagement across various online environments (Hamari *et al.,* 2014; Seaborn & Fels, 2015). Studies in the domain of digital democracy further underscore the critical importance of sustained participation for the legitimacy and effectiveness of deliberative processes (Wright & Street, 2007). By synthesizing these diverse strands of research, the present work builds upon a robust foundation that elucidates the pivotal role of incentives in driving meaningful user engagement within e-deliberation systems.

In conclusion, the proposed modeling scheme offers a sophisticated and multifaceted framework for analyzing and improving e-deliberation systems. By meticulously incorporating demographic factors, dynamic interaction mechanisms, and incentivization strategies, the model provides valuable insights into optimizing citizen engagement and enhancing the quality of deliberative outcomes. This comprehensive approach not only advances the theoretical understanding of e-deliberation dynamics but also offers practical strategies for fostering more inclusive and effective democratic participation in the digital age.

3.1 Citizen Behavior

The citizen behavior component of the proposed modeling scheme is pivotal in understanding how individual political opinions evolve within an e-deliberation system. This section details the mathematical formulation used to capture the dynamics of citizen behavior, focusing on how their political opinions change over time based on their activities and demographic factors.

Political Opinion Dynamics: The political opinion of a citizen, denoted as $O_i(t)$, represents the stance of citizen i at time t. The change in political opinion over time, $\frac{dO_i(t)}{dt}$, is modeled as a function of the proposals they vote for, the comments they post, and their demographic characteristics. The fundamental equation governing this dynamic is:

$$\frac{dO_i(t)}{dt} = \alpha\, V_i(t) + \beta\, C_i(t)$$

where:

- $V_i(t)$ is the proposal that citizen i votes for at time t.
- $C_i(t)$ is the comment that citizen i posts at time t.
- α and β are parameters that describe the relative importance of voting and commenting in shaping a citizen's political opinion.

Incorporation of Demographic Factors: To provide a more nuanced model, additional terms are included to account for demographic factors such as age, sex, and profession. The extended model is represented as:

$$\frac{dO_i(t)}{dt} = \alpha\, V_i(t) + \beta\, C_i(t) + \gamma\, A_i(t) + \delta\, S_i(t) + \epsilon\, P_i(t)$$

where:

- $A_i(t)$ is the age of citizen i at time t.
- $S_i(t)$ is the sex of citizen i at time t.
- $P_i(t)$ is the profession of citizen i at time t.

- $\alpha, \beta, \gamma, \delta, \epsilon$ are parameters that describe the effect of age, sex, and profession on a citizen's political opinion.

Voting Behavior: The model assumes that the act of voting influences a citizen's political opinion. Voting behavior can be modeled as either a binary choice or a probabilistic decision. For the binary choice model, a citizen votes for a proposal if their opinion aligns with the proposal's position:

$$V_i(t) = 1 \; if \;\; O_i(t) \geq P_j(t) else \; 0$$

For a probabilistic model, the likelihood of voting for a proposal depends on the difference between the citizen's opinion and the proposal's position:

$$\mathrm{V_i(t)} = \frac{1}{1 + e^{-\mathrm{k_1}\left(\mathrm{O_i(t)} - \mathrm{P_j(t)}\right)}}$$

Commenting Behavior: The rate and content of comments posted by citizens also play a crucial role in shaping their political opinions. The commenting behavior can be influenced by various factors, including the perceived impact of the comment and the rewards associated with posting comments. The parameter β\betaβ captures the influence of commenting on opinion dynamics.

Demographic Influence: Incorporating demographic factors into the model allows for a more realistic simulation of political opinion dynamics. Age ($A_i(t)$), sex ($S_i(t)$), and profession (($P_i(t)$) influence how citizens perceive proposals and participate in the deliberative process. The parameters $\alpha, \beta, \gamma, \delta, \epsilon$ quantify these influences, ensuring that the model accounts for the diverse backgrounds and experiences of the participants.

3.2 Modeling Proposal Behavior

The modeling of proposal behavior within the e-deliberation system focuses on how the political positions of proposals evolve over time. This evolution is influenced by the rate at which proposals receive and integrate comments from citizens. The following section provides a detailed description of the mathematical formulation used to capture these dynamics.

Political Position Dynamics: The political position of a proposal, denoted as $\mathrm{V_j(t)}$, represents the stance of proposal j at time t. The change in political position over time, $\frac{\mathrm{dP_j(t)}}{dt}$, is modeled as a function of the comments received and integrated. The fundamental equation governing this dynamic is:

$$\frac{\mathrm{dP_j(t)}}{dt} = \mu \, \mathrm{CR_j(t)} - \nu \, \mathrm{CI_j(t)}$$

where:

- $\mathrm{CR_j(t)}$ is the rate at which comments are received for proposal j at time t.
- $\mathrm{CI_j(t)}$ is the rate at which comments are integrated for proposal j at time t.
- μ and ν are parameters that describe the relative importance of comments received and integrated in shaping a proposal's political position.

Comments Received and Integrated: The rates at which comments are received and integrated into proposals are crucial for understanding the dynamics of proposal behavior. These rates can be influenced by several factors, including the number of participating citizens, their political opinions, and the relevance of the comments. The following equations describe these rates:

$$CR_j(t) \;=\; k_1 N_c(t)\, e^{-k_2\, |O_i(t)\, -\, P_j(t)|}$$
$$CI_j(t) \;=\; k_3 N_c(t)\, e^{-k_4\, |O_i(t)\, -\, P_j(t)|}$$

Influence of Citizen Participation: The number of participating citizens $N_c(t)$ significantly impacts the rates of comments received and integrated. A higher number of participants generally leads to an increase in both $CR_j(t)$ and $CI_j(t)$, as more citizens are engaging with the proposal.

Political Opinion Difference: The difference between a citizen's political opinion $O_i(t)$ and the proposal's position $\mathrm{P_j(t)}$ affects how likely a citizen is to comment on and influence a proposal. The exponential terms $e^{-k_2\, |O_i(t)\, -\, P_j(t)|}$ and $e^{-k_4\, |O_i(t)\, -\, P_j(t)|}$ indicate that as the difference between $O_i(t)$ and $P_j(t)$ increases, the rates of comments received and integrated decrease. This reflects the idea that citizens are more likely to engage with proposals that are closer to their own opinions.

Parameter Sensitivity: The parameters $\mathrm{k_1, k_2, k_3}$ and $\mathrm{k_4}$ play critical roles in modulating the behavior of the model:

- $\mathrm{k_1, k_3}$ adjust the overall magnitude of the comment rates.
- $\mathrm{k_2, k_4}$ determine how sharply the comment rates decline as the opinion-proposal difference increases.

By tuning these parameters, the model can simulate various scenarios and explore the effects of different engagement levels and opinion distributions on the deliberative process.

Rewarding mechanism

The rewarding mechanism is a crucial component of the proposed e-deliberation model, designed to enhance citizen engagement by providing incentives for meaningful participation. This mechanism incorporates both costs and rewards associated with citizen activities, such as posting comments and voting on proposals. By doing so, it aims to motivate citizens to contribute constructively, thereby improving the quality and quantity of deliberative interactions.

Costs and Rewards: The model includes a system where citizens incur costs for posting comments and receive rewards when their comments are integrated into proposals. This dual approach ensures that participation is not only encouraged but also regulated to maintain the quality of contributions.

Comments Received Rate with Costs: The rate at which comments are received can be adjusted to include the costs incurred by citizens. This is represented by:

$$CR_j(t) \;=\; k_1\, N_c(t)\, e^{-k_2\, |O_i(t) - P_j(t)|) - k_3\, \sum(b\ if\ B_i(t) \geq b\ else\ 0)}$$

where:

- b is the cost for posting a comment.
- $B_i(t)$ is the budget of citizen i at time t.
- k_3 is a parameter that adjusts the impact of costs on the comment rate.

Comments Received Rate with Rewards: Similarly, the rate at which comments are received can include the rewards received by citizens:

$$CR_j(t) = k_1 N_c(t) e^{-k_2 |O_i(t)-P_j(t)|)+k_4 \sum(g \ if \ C_j(t)\geq 1 \ else \ 0)}$$

where:

- g is the reward for having a comment integrated.
- $C_j(t)$ is the number of comments integrated for proposal j at time t.
- k_4 is a parameter that adjusts the impact of rewards on the comment rate.

Comments Integrated Rate with Costs: The rate at which comments are integrated also considers the costs:

$$CI_j(t) = k_3 N_c(t) e^{-k_4 |O_i(t)-P_j(t)|)-k_5 \sum(b \ if \ B_i(t)\geq b \ else \ 0)}$$

Comments Integrated Rate with Rewards: And includes the rewards:

$$CI_j(t) = k_3 N_c(t) e^{-k_4 |O_i(t)-P_j(t)|)-k_6 \sum(g \ if \ C_j(t)\geq 1 \ else \ 0)}$$

Budget Dynamics: The budget of each citizen changes over time based on the costs incurred and rewards received:

$$\frac{dB_i(t)}{dt} = -b \cdot CR_j(t) + g \cdot CI_j(t)$$

This equation ensures that a citizen's budget reflects their level of activity in the system, promoting sustained and balanced participation.

Constraints: To ensure fairness, the budget equation is subject to constraints such as non-negativity:

$$B_i(t) \geq 0$$

This constraint prevents citizens from overspending their budget, which could discourage future participation.

Discrete Modeling: In a discrete-time setting, the budget update equation is:

$$B_i(t+1) = B_i(t) - \sum(b \cdot CR_j(t)) + \sum(g \cdot CI_j(t))$$

Impact on Citizen Behavior: By incorporating costs and rewards, the model aims to balance the motivation to participate with the need to maintain quality contributions. Citizens are encouraged to post comments and vote thoughtfully, knowing that their budget will be positively or negatively affected by their actions.

Discrete Modeling

The discrete modeling approach is used to simulate the e-deliberation system over distinct time steps, allowing for the analysis of how citizen behavior and proposal dynamics evolve in a step-by-step manner. This method is particularly useful for capturing the iterative nature of deliberative processes and understanding the impact of specific actions and events on the overall system.

Citizen Behavior in Discrete Time: In a discrete-time model, the political opinion of a citizen iii at time step t+1t+1t+1 is updated based on their voting and commenting activities, as well as their demographic factors. The discrete-time equation for updating political opinions is:

$$O_i(t+1) = O_i(t) + \alpha V_i(t) + \beta C_i(t) + \gamma A_i(t) + \delta S_i(t) + \epsilon P_i(t)$$

where:

- $V_i(t)$ and $C_i(t)$ are the voting and commenting activities of citizen i at time step t.

- $A_i(t)$, $S_i(t)$, and $P_i(t)$ are the age, sex, and profession of citizen i at time step t.
- $\alpha, \beta, \gamma, \delta, \epsilon$ are parameters that describe the influence of these factors on political opinion.

Proposal Behavior in Discrete Time: The political position of a proposal j at time step $t + 1$ is updated based on the rates of comments received and integrated. The discrete-time equation for updating proposal positions is:

$$P_j(t+1) = P_j(t) + \mu\, CR_j(t) - \nu\, CI_j(t)$$

where:

- $CR_j(t)$ is the rate of comments received for proposal j at time step t.
- $CI_j(t)$ is the rate of comments integrated for proposal j at time step t.
- μ and ν are parameters that describe the impact of these rates on the proposal's position.

Impact on Citizen and Proposal Dynamics: The discrete modeling approach allows for the step-by-step analysis of how citizen opinions and proposal positions evolve over time. By updating the state of the system at each time step, this approach provides a detailed view of the iterative interactions between citizens and proposals. It helps identify key patterns and trends in participation, opinion formation, and proposal adjustments.

Simulation and Scenario Analysis: Using discrete modeling, researchers can simulate various scenarios by adjusting the parameters and initial conditions. This allows for the exploration of different strategies to enhance engagement and improve deliberative outcomes. The model can be used to test the effectiveness of different rewarding mechanisms, identify potential issues, and optimize the design of e-deliberation systems.

4. RESULTS

The simulation was designed to evaluate the effectiveness of the rewarding mechanism in enhancing citizen engagement and improving the quality of deliberative processes. It aimed to examine how costs and rewards influence citizen behavior, proposal dynamics, and the overall quality of participation in an e-deliberation framework. The simulation initialized citizens with attributes such as political opinions, demographic characteristics, and budgets, while proposals were assigned initial political positions. The system evolved over discrete time steps, updating its state based on equations governing citizen and proposal behavior, as well as the dynamics of the rewarding mechanism.

To validate the rewarding mechanism's impact, the simulation was conducted under varying scenarios, both with and without its implementation. The analysis focused on key outcomes, including the level of citizen engagement, the diversity of opinions expressed, and the responsiveness of proposals to citizen feedback. By comparing these scenarios, the simulation provided valuable insights into the design of incentives that promote active and meaningful participation. The results demonstrated the significant advantages of the rewarding mechanism and offered practical recommendations for its implementation in real-world deliberative platforms.

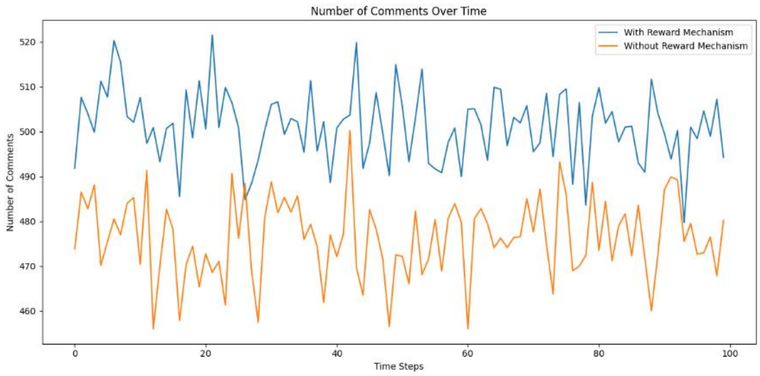

Figure 1. Number of comments over time with and without the rewarding mechanism

The first simulation examined the number of comments over time under scenarios with and without the rewarding mechanism (Figure 1). The results revealed that, with the rewarding mechanism, citizens posted more comments early in the deliberative process, particularly when participation levels were low. However, as the deliberation progressed and the number of participants increased, the comments began to stabilize or decline due to saturation effects. In contrast, without the rewarding mechanism, the number of comments increased more steadily over time, but engagement levels were lower at the beginning of the deliberation process. These findings highlight the trade-offs of the rewarding mechanism, which boosts engagement initially but experiences diminishing returns as participation grows.

The second simulation explored the effect of initial budgets on comments per participant over time (Figure 2). Budget levels (ranging from 0.1 to 5) were found to strongly influence participation dynamics. Citizens with lower initial budgets posted fewer comments, particularly in the later stages of deliberation, as their resources were depleted. Conversely, citizens with higher budgets initially posted more comments but experienced a noticeable decline over time due to diminishing returns and disengagement. Citizens with medium budgets, however, maintained steady participation throughout the simulation, resulting in a consistent number of comments per participant across all time steps. These results suggest that medium budgets strike an optimal balance between encouraging initial engagement and sustaining meaningful participation. This insight underscores the importance of calibrating initial budgets to maximize engagement and ensure long-term effectiveness in deliberative processes.

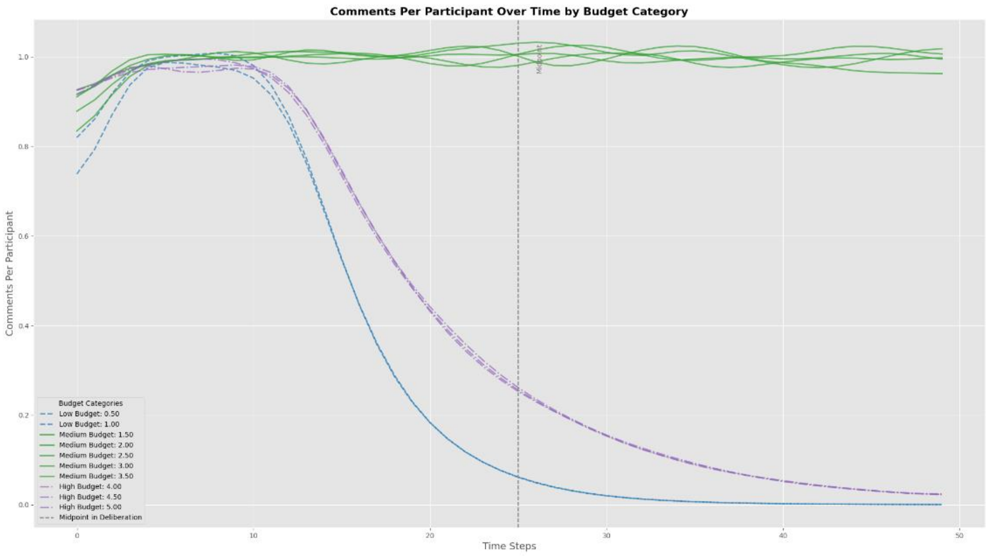

Figure 2. Comments per participant over time by budget category

The third simulation focused on the impact of participant saturation on the total number of comments (Figure 3). The results demonstrated contrasting trends under scenarios with and without the rewarding mechanism. Without the rewarding mechanism, comments followed a non-linear trend, increasing steadily as the number of participants grew, with no significant saturation effects. However, at low participation levels, the absence of incentives resulted in fewer comments, reflecting limited engagement. With the rewarding mechanism, the number of comments was significantly higher at low participation levels, highlighting its ability to boost early engagement. As the number of participants increased, however, saturation effects became evident, causing the number of comments to stabilize or decline. This behavior reflects the diminishing returns of the rewarding mechanism at higher participation levels, where the system's capacity to integrate feedback becomes a limiting factor.

Together, these simulations illustrate the rewarding mechanism's strengths and limitations. While it effectively motivates engagement in smaller groups and enhances participation during the initial stages of deliberation, its performance diminishes as saturation effects set in with higher participant numbers. By balancing rewards and system capacity, it is possible to optimize engagement and maintain the quality of deliberation, contributing to the development of more inclusive and effective democratic processes.

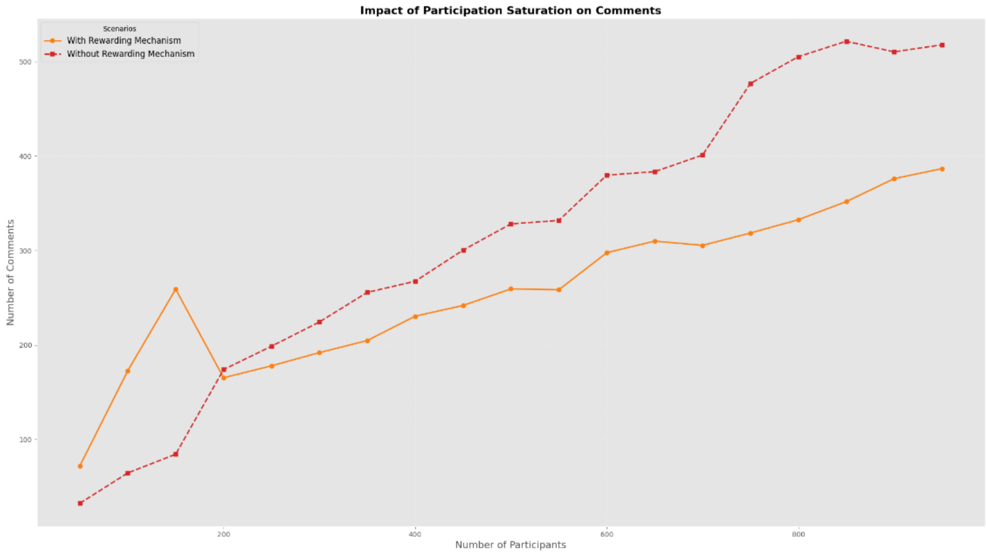

Figure 3. Impact on participation saturation on comments

5. CONCLUSION AND FUTURE WORK

This study presents an e-deliberation model incorporating a rewarding mechanism to enhance citizen engagement and improve the quality of deliberative processes. Through mathematical formulation and detailed simulations, the study examines the interplay of costs and rewards in shaping citizen behavior, with a particular focus on the dynamics of comments over time. The simulation results reveal that the rewarding mechanism significantly influences participation patterns, with notable differences in engagement levels across varying scenarios.

The results demonstrate that the rewarding mechanism effectively boosts engagement in the early phases of deliberation, especially when the number of participants is low. Citizens with access to medium initial budgets maintained a steady level of participation throughout the deliberation process, generating consistent comments over time. This finding highlights the critical role of balanced resource allocation in sustaining engagement. Conversely, both low and high budgets resulted in reduced participation during later phases, emphasizing the need for careful calibration of incentives to achieve long-term effectiveness.

Further analysis of participant saturation underscores the trade-offs inherent in the rewarding mechanism. For smaller groups, the mechanism generated higher engagement compared to scenarios without rewards, showcasing its potential to motivate meaningful contributions. However, as the number of participants increased, the system exhibited saturation effects, with the total number of comments stabilizing or even declining due to the limited capacity of proposals to process feedback effectively. These findings highlight the importance of tailoring reward structures to participation levels, ensuring that the system remains scalable and capable of handling large-scale deliberations.

While these results underscore the potential of the proposed model, empirical validation is critical to establish its practical applicability. To this end, future work will leverage the Public Online Deliberation System (PODS) developed by Triantafyllou *et al.* (2019) to collect real-world data. This platform will enable the observation of actual user behavior in controlled e-deliberation settings, providing an opportunity to refine the model based on empirical evidence. By comparing real-world participation patterns with simulation outcomes, the study aims to validate the model's ability to mirror human behavior and assess the rewarding mechanism’s efficacy in promoting sustained engagement.

Additionally, future research will explore advanced mechanisms to address saturation effects in high-participation scenarios, such as dynamic reward adjustments or prioritization of valuable contributions. These refinements will help optimize the balance between engagement and deliberation quality, paving the way for the development of more inclusive and effective e-deliberation platforms. This work contributes to the ongoing discourse on digital democracy by offering actionable insights into incentive-based systems, with the potential to transform citizen participation in decision-making processes.

6. DISCUSSION

The results of this study carry significant implications for the design and implementation of e-deliberation systems. The introduction of a rewarding mechanism is demonstrated as an effective strategy for incentivizing substantive participation. By providing tangible incentives, such as budget increments for well-integrated comments, the mechanism motivates citizens to contribute constructively to the deliberative process. This aligns with prior research emphasizing the benefits of incentivizing engagement on online platforms (Ercan *et al.*, 2022; Fishkin, 2018). Moreover, the results from the simulations highlight the importance of calibrating initial budgets and tailoring reward structures to achieve sustained engagement. Medium budgets were shown to optimize participation, maintaining steady levels of comments over time, while low and high budgets led to declines in participation in later stages of deliberation. These findings underscore the necessity of balancing resource allocation to foster both initial and long-term engagement.

The analysis of participant saturation provides further insights into the dynamics of engagement. While the rewarding mechanism increases the number of comments at low participation levels, its performance diminishes as the number of participants grows and saturation effects emerge. This highlights the need for adaptable reward structures that can mitigate diminishing returns in high-participation scenarios. By aligning incentives with participation levels and proposal capacity, e-deliberation systems can maintain quality deliberation while accommodating larger groups.

Despite these promising results, the study acknowledges several limitations and identifies opportunities for future research. The model simplifies the dynamics of citizen behavior and proposal interactions, which may not fully capture the complexity of real-world deliberative processes. Future iterations of the model should incorporate more sophisticated behavioral frameworks, including the impact of diverse reward types such as social recognition or enhanced decision-making influence. Addressing potential issues, such as superficial engagement driven by gamification, is also critical. Prioritizing the quality of contributions over quantity can help mitigate this risk, ensuring deeper and more meaningful deliberations (Mendonça, 2022).

Empirical validation of the model represents a vital next step. Leveraging the Public Online Deliberation System (PODS) developed by Triantafyllou *et al.* (2019) offers a practical avenue for testing the model in real-world settings. PODS provides a robust platform for collecting real-time data on citizen participation, commenting behavior, and voting patterns. Integrating the model with PODS will enable researchers to observe the effects of the rewarding mechanism in live environments, offering an opportunity to refine parameters such as costs and rewards based on actual user behavior. This empirical validation will also help identify potential adjustments needed to accommodate the diverse needs of participants and optimize the balance between engagement and deliberation quality.

In conclusion, this study demonstrates the potential of rewarding mechanisms to enhance citizen engagement in e-deliberation systems. By embedding economic principles into model design and carefully calibrating incentives, it is possible to create more inclusive and effective deliberative environments. These findings provide a strong foundation for further research and practical applications aimed at advancing democratic participation through digital platforms. Future efforts should prioritize real-world testing, iterative refinement based on user feedback, and the development of scalable strategies to address the challenges of high-participation scenarios.

REFERENCES

Boulianne, S., 2009. Does Internet use affect engagement? A meta-analysis of research. *Political Communication*, Vol. 26, No. 2, pp. 193-211.

Coleman, S. and Gøtze, J., 2022. *Deliberative Systems*. Cambridge University Press.

Curato, N., 2022. *Research Methods in Deliberative Democracy*. Oxford Academic.

Davies, T. and Chandler, R., 2012. Online deliberation design: Choices, criteria, and evidence. In T. Nabatchi et al. (eds) *Democracy in Motion: Evaluating the Practice and Impact of Deliberative Civic Engagement*. Oxford Academic, pp. 103-122.

Dryzek, J. S., 2022. *Deliberative Democracy at the Large Scale*. Cambridge University Press.

Ercan, S. A., Asenbaum, H., Curato, N. and Mendonça, R. F., 2022. *Researching Deliberative Democracy: Methods and Approaches*. Oxford Academic.

Fishkin, J. S., 2018. *Why deliberation and voting belong together*. Res Publica.

Hamari, J., Koivisto, J. and Sarsa, H., 2014. Does gamification work? – A literature review of empirical studies on gamification. *Proceedings of the 47th Hawaii International Conference on System Sciences*. IEEE, Waikoloa, HI, USA, pp. 3025-3034.

Harper, F. M., Li, S. X., Chen, Y. and Konstan, J. A., 2007. Social comparisons to motivate contributions to an online community. *Proceedings of the 2nd International Conference on Persuasive Technology*. Palo Alto, CA, USA, pp. 148-159.

Lampe, C. et al., 2014. Psychological motivations for participation in an online collective action. *Journal of Communication*, Vol. 64, No. 6, pp. 1062-1080.

Margetts, H., John, P., Hale, S. and Yasseri, T., 2015. *Political Turbulence: How Social Media Shape Collective Action*. Princeton University Press.

Mendonça, R. F., 2022. *Research Methods in Deliberative Democracy*. Oxford Academic.

Min, S.-J., 2007. Online vs. face-to-face deliberation: Effects on civic engagement. Journal of Computer-Mediated Communication, Vol. 12, No. 4, pp. 1369-1387.

Seaborn, K. and Fels, D. I., 2015. Gamification in theory and action: A survey. *International Journal of Human-Computer Studies*, Vol. 74, pp. 14-31.

Triantafyllou, V., Tsakanikas, V., Asimakopoulos, G. and Christodoulopoulos, J., 2019. Public online deliberation system (PODS). In *17th International Conference on e-Society 2019*. pp. 159-166.

Wright, S. and Street, J., 2007. Democracy, deliberation and design: The case of online discussion forums. *New Media & Society*, Vol. 9, No. 5, pp. 849-869.