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A Study on Organizational Decision-making from the Perspective of Uncertainty and Ambiguity – A Multi-Agent Simulation Model

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Abstract

This study examines the effects of ambiguity and uncertainty on organizational decision-making using an agent-based simulation framework. The model integrates hyperbolic discounting to capture shifts in decision-makers' preferences from long- to short-term orientations over time. Ambiguity is defined as unclear organizational goals and decision criteria, whereas uncertainty refers to unpredictable environmental changes. The simulation showed that uncertainty strongly reduces decision efficiency, whereas ambiguity degrades decision quality. The results highlight how excessive ambiguity and uncertainty can lead to organizational resource inefficiencies. Specifically, I found that situations with high ambiguity and low uncertainty produced the least resource-efficient outcomes than situations with both high ambiguity and uncertainty. This study emphasizes the need to design decision processes that consider environmental complexity and recommends further empirical validation.

Keywords: ambiguity, decision-making, hyperbolic discounting, simulation, uncertainty

1 Introduction

In recent years, the era of Volatility, Uncertainty, Complexity, Ambiguity (VUCA) and the modern business environment have undergone rapid changes, making it difficult to predict the future. In such an environment, it is becoming increasingly difficult for individuals and organizations such as companies to make decisions.

Organizations are established to address and overcome the limitations of human "bounded rationality" [1]. Simon [2] defined "bounded rationality" as the limit of human information processing and cognitive abilities. When a big problem that is difficult for an individual to solve occurs, it can be divided into smaller problems. By assigning the smaller problems to individuals, a hierarchical organization is formed. Thus, organizations can be seen as devices that avoid the bounded rationality of individuals. However, as is well known, there are countless examples of failed decision-making in companies.

Why do organizations seeking to avoid bounded rationality continue to fail when making decisions? One key to solving this problem is dealing with ambiguity and uncertainty. For example, there are cases where the set Θ of states is known, and it is known whether each element θ_k will occur, called "decision-making under certainty," and where only the probability of occurrence of the elements θ_k of the set Θ is defined, called "decision-making under risk" [3]. However, in

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situations of ambiguity and uncertainty, the set Θ is known, but the probability of the outcome of selecting an option is not known, or the set Θ is not even well understood. However, the definition remains unclear.

The garbage can model (GCM) is a decision-making model for organizations in ambiguous situations [4]. GCM is a study that analyzes universities and colleges, and explains that organizational decision-making in such situations is not done by participants actively solving problems and making decisions, but is extremely passive, with "Oversight" decisions being made before the problem becomes apparent, and "Flight" decisions being made after waiting for the problem to disappear without being noticed. In today's society, where ambiguity and uncertainty are high, the GCM can be a framework that appropriately explains organizational decision-making.

However, when it comes to organizational decision-making, it is necessary to focus not only on the functions of the organization as a macro-level decision-making system but also on the functions of individuals within micro-level organizations. In recent years, behavioral economics research has focused on anomalies in which individuals deviate from rationality. Among these, there is the concept of hyperbolic discounting, which explains how individual preferences change over time [5,6]. Hyperbolic discounting refers to the tendency of the time discount rate to be higher in the near future than in the distant future in intertemporal utility selection. Therefore, the evaluation of large long-term utilities and small short-term utilities differs depending on the time of choice. As a result, even if an option that brings high long-term utility is initially chosen, a short-term utility may appear relatively large over time, and the decision may change to the short-term option. Hyperbolic discounting explains this reversal of preferences (i.e., time inconsistency). Therefore, hyperbolic discounting is assumed to have a significant impact on organizational decision-making. This is because the preferences of the final decision-maker when making decisions in an organization have a significant impact on the decision. Hyperbolic discounting was derived from experiments using birds and is considered a fundamental property of living organisms, including humans [7]. Therefore, although there are individual differences, hyperbolic discounting is thought to affect decision-making.

In this study, I developed an organizational decision-making model that incorporates individual preferences based on the GCM and analyzed the impact of ambiguity and uncertainty on decision-making through simulation. To build the model, I used a multi-agent simulation (Artisoc 4, KOZO KEIKAKU ENGINEERING Inc.). In related research, Ando and Nagata [8] conducted a simulation analysis that incorporated individual hyperbolic discounting into the GCM; however, the model was simple and required further refinement. Additionally, Ando and Tsurusaki [9] reconstructed the GCM using a multi-agent simulation but did not consider individual hyperbolic discounting. Based on previous studies, this study proposes a sophisticated organizational decision-making model that reflects individual preferences and quantitatively clarifies the impacts of ambiguity and uncertainty.

2 Review of Existing Research

2.1 Garbage Can Model

GCM is a model of organizational decision-making in ambiguous situations [4]. Ambiguous situations are defined as organized anarchies and are specifically defined as follows:

A) Problematic preferences: Organizations do not have set preferences, as in standard choice theory, but operate with poorly defined preferences and instead discover preferences through behavior.

B) Unclear technology: The existence of an organization and the processes involved in its production activities are not fully understood by its members, and they rely on knowledge acquired by chance from past experience and practical ingenuity developed as needed.

C) Fluid participation: The boundaries of an organization are uncertain and fluid, as the time and effort that organizational members spend on activities are not constant and depend on their level of involvement.

In such situations, organizational decision-making is carried out when problems, participants, and solutions are randomly thrown into the selection opportunity. This decision-making process, likened to tossing items into a trash can, takes place when the necessary conditions for making a decision are coincidentally met [4].

First, Problems are matters in which people inside and outside the organization are interested and are said to exist widely, ranging from work frustrations and workplace relationships to human crises and family problems. Next, Solutions are “deliverables” created by someone, and just as demand is created in the market, in decision-making, the solution may come first, and the corresponding problem may be recognized later. Understanding the answer clarifies this question. Participants are fluid and constantly enter and leave the organization. The characteristics of the new and previous options influence the involvement of participants in decision-making. The degree of participant involvement also depends on the time balance of other activities. Finally, Choice Opportunities are situations in which an organization is required to take some kind of decision-making action, and they occur regularly. These include signing contracts, hiring, promoting, and firing employees, and allocating budgets.

In the simulation, a preset number of choice opportunities, problems, and participants were presented. Specifically, the number of selection opportunities and problems gradually increased as the steps progressed, and eventually, a preset number appeared. The number of participants who appeared was initially set at the start of the simulation. In this manner, the step progresses as the problems/participants randomly enter and exit choice opportunities. Note that the solution is merely considered as a coefficient for participants to solve the problem and does not appear as an agent.

Decision-making is classified into three types: Oversight – deciding before the problem becomes apparent; Flight – deciding when the problem has not been solved and the problem has moved beyond chance opportunity; and Resolution – making an ideal decision like decision theory. The GCM indicates that decision-making in ambiguous situations tends to be passive, such as oversight and flight.

2.2 Garbage Can Model with Ambiguity and Uncertainty

The GCM regards organizational ambiguity as “organized anarchies.” Cohen et al. [4] define ambiguity as "situations in which goals are unclear or unknown" and base their discussion on this characterization. However, its meaning is open to interpretation and contains inherent uncertainty.

Therefore, I reconsidered the meaning of uncertainty and ambiguity. According to Galbraith [10], who developed the contingency theory, uncertainty is defined as the gap between the information an organization needs to perform its duties and the information it actually has. Kobashi [11], based on the idea of the unpredictable speed of change behind Galbraith [10], and referring to Thompson [12], Duncan [13], and others, defines uncertainty as “the speed of unpredictable changes in the environment.” In other words, uncertainty refers to the difficulty in predicting future environmental changes and can be considered a situation in which organizations do not have enough information to respond appropriately to the future. On the other hand, ambiguity is an ambiguous situation caused by the unclear goals and decision-making criteria of an organization and is considered to have a different nature from a simple lack of information. Thus, uncertainty is mainly related to the speed and complexity of environmental changes, while ambiguity is related to the framework of goal-setting and decision-making within the organization. For instance, during periods of rapid market change and heightened uncertainty, when it is unclear which technology will emerge as the next mainstream choice, gathering information can help mitigate this uncertainty. When there is a high level of ambiguity because there is no agreement within the organization on how to utilize new technology, improvements to the organization's decision-making structure may be necessary. However, Kobashi [14] noted that fluctuations exist in how uncertainty, ambiguity, and vagueness are perceived, and it must be noted that perceptions differ depending on the research field and perspective.

From the discussion thus far, I conclude that problematic preferences, unclear technology, and fluid participation in organized anarchies contain ambiguity and uncertainty. For example, problematic preferences contain ambiguity in their definition and uncertainty in their interpretation of things that vary over time. Unclear technology also contains ambiguity in the interpretation of technological processes by members and uncertainty about next-generation technologies. In contrast, fluid participation also contains ambiguity in organizational boundaries and uncertainty in member involvement over time. It is naturally difficult to completely separate ambiguity and uncertainty. However, in organizational decision-making, it is necessary to distinguish uncertainty from ambiguity and consider their effects. Keeping this in mind, I will be able to better understand the actual decision-making processes of organizations.

2.3 Criticism of Garbage Can Model

Although the GCM has spread as a theory, the simulation model, which is key to the theory, has not been verified for several decades since its publication. Consequently, Bendor et al. [15] severely criticized the simulation model for not being based on the randomness of participants, problems, solutions, and choice opportunities, forcing a review of the model. Although Inamizu et al. [16] conducted follow-up tests that faithfully reproduced the original model, it was confirmed that the simulation model could not express the GCM concept. Specifically, the rule known as the "allocation assumption" suggests that when participants and problems are assigned to a choice opportunity, they are allocated to the option that is most closely aligned with the decision at hand. Simply put, in the GCM, the energy (ability) of the participants in the choice opportunity is compared with the energy (difficulty) of the problem, and a decision is made when the ability is equal to or greater than the difficulty. Therefore, the choice opportunity closest to the decision is the choice opportunity with zero net energy; participants and problems are flooded into the choice opportunity that has just appeared in the simulation, and agents are not randomly put into multiple-choice opportunities.

In response to this criticism, Fioretti and Lomi [17] transformed the GCM into a multi-agent simulation and fundamentally revised the model. Specifically, participants, problems, solutions, and choice opportunities were randomly placed as agents in a virtual space divided into cells. Each agent randomly moves one cell to the east, west, north, or south at each step, regardless of the allocation assumption, and a decision is made when a cell gathers agents capable of making a decision. The concept of the GCM is chance decision-making brought about by the randomness of each agent; however, it is more concrete than the original model. As a result, like Cohen et al.

[4], Fioretti and Lomi [17] concluded that the majority of decision-making will predominantly revolve around oversight.

3 Modeling

3.1 Active Garbage Can Model

The model I am developing is an extension of the Active Garbage Can Model (AGCM) [9]. While referring to the basic ideas of GCM, AGCM uses multi-agent simulations, as in Fioretti and Lomi [17], to model the GCM in more detail. However, to further increase randomness, the agents move freely within a virtual space, not in units of cells, and in addition to the conventional oversight, flight, and resolution decision types, a “deadline exceeded” decision type has been added, in which a decision cannot be made within a limited period. As shown in Table 1, the definition of an agent has changed based on the idea that an agent is a “human agent that acts autonomously and changes its behavior by exchanging information and interacting with other agents to solve problems.” Based on this concept, the model is one in which the reviewer and reviewee create an output, and the decision-maker makes a decision based on that output, improving the concreteness of the agent [9]. However, these problems cannot occur without human intervention. As in Cohen et al. [4], the solution is treated as the solution coefficient (SC) multiplied by the reviewee’s ability. Similarly, a load coefficient (LC) was established and applied as a multiplier to the reviewer’s level of difficulty.

Table 1: Changing the definition of agents (by Ando & Tsurusaki [9])

As-Is		To-Be	
Problems	→	Reviewer	A reviewer who has Difficulty, which is the ability to point out reviews and review the output of reviewers.
Participants	→	Reviewee	A task person who has Ability, which is the ability to execute a task, and who creates output.
Choice Opportunities	→	Decision-Maker	A decision-maker responsible for evaluating the reviewers' output and deciding appropriate response policies.

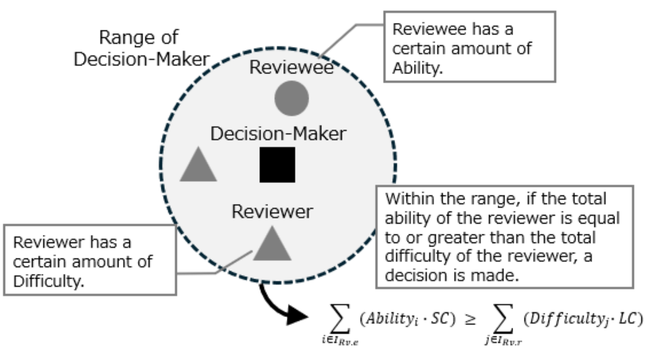

Figure 1: Image of decision-making.

The specific simulation process is explained below. First, the main initial settings of the simulation are the number of agents (reviewee/reviewer/decision-maker), range of the decision-maker, decision-making deadline (set all at once/randomly), SC, and LC. When the simulation started, the initially set agents were placed at random positions in the virtual space and moved at a speed and direction that were set randomly when the agents were generated. If the agents reached the boundary of the virtual space, they bounced randomly. Additionally, the reviewee is randomly given Ability, which is the ability to perform the task. Similarly, the reviewer is given Difficulty, which is the ability to point out problems in the review. While the agent moves randomly, as shown in Figure 1, the Reviewer and Reviewee come within the range of the decision-maker, and a decision is reached when the total ability is greater than the total difficulty. After a decision is made, the Ability, Difficulty, and speed of the agents involved in the decision are reset, and they are relocated to a random position in the next step.

As shown in Table 2, four types of decision-making are assumed. First, oversight. Overall, a decision is made only when the reviewees are in the range of the decision-makers. In these cases, a decision was made before the reviewers provided proper feedback. Next is flight. During the flight, reviewees and reviewers are in the range of decision-makers. Still, the total difficulty of the reviewers is large, and the problem cannot be resolved with the total ability of the reviewees. However, as time passes, the reviewers leave the range, and the total difficulty decreases, leading to a decision. In this case, a decision can be made because the reviewer who is strict with his work is no longer a member of the team. Next is resolution. In resolution, a decision is made when the total ability of the reviewees in the range of decision-makers, other than oversight and flight, exceeds the total difficulty of the reviewers. In other words, this is rational decision-making. Additionally, this model considers the deadline to be exceeded when a decision cannot be made within the deadline. When a reviewee or reviewer enters the range, the decision-maker counts the time steps as long as either agent remains within that range. If the step count exceeds the decision deadline randomly assigned to the decision-maker, the deadline exceeded is counted. This situation should be avoided if the deadline is exceeded.

Table 2: Conditions of decision-making type

Decision Type	Current Condition	Other Condition
By oversight	Sum of Ability ≧ Sum of Difficulty	Current Difficulty = 0, Previous Ability = 0
By flight		Previous Difficulty > Current Difficulty, Previous Ability ≠ 0
By Resolution		Other than the above
Deadline exceeded	Step Count > Deadline	-

3.2 Treatment of Hyperbolic Discounting in Models

The AGC-based model that I am developing incorporates hyperbolic discounting into the decision-maker, who has decision-making authority. Hyperbolic discounting explains changes in human preferences that do not occur in traditional economics. In other words, because the human time discount rate is a hyperbolic function rather than an exponential function, people initially aim for long-term profits with an eye to the future, but as time passes, they begin to aim for immediate short-term profits. Here, future-oriented decision-making is called long-term orientation, whereas present-oriented decision-making is called short-term orientation. Based on this, in the simulation, the decision-maker is programmed to act in such a way that "initially, they are long-term oriented and aim for a solution by resolution, but after the preference change, in the short-term orientation, they aim for decision-making including oversight and flight that are not particular about the decision type" (Figure 2). In both cases, deadline expiration was considered.

Specifically, the step at which preferences reverse is determined by multiplying the hyperbolic parameter H (0.0-1.0) randomly given to the Decision-Maker by the decision deadline. For example, if the hyperbolic parameter is 0.5 and the decision deadline is 10 steps, the preference will be long-term oriented up to step 5 and short-term oriented from step 6 onwards. Although simple, I simulate hyperbolic discounting.

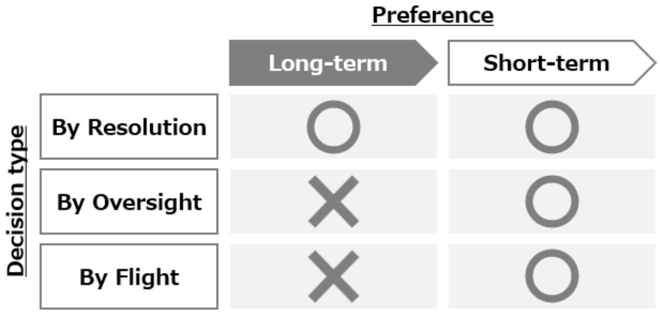

Figure 2: Preference and Decision type

Here, it is said that there are two types of people who have hyperbolic discounting. Some sophisticated people foresee falling into a short-term orientation in the future and restrain themselves by trying to commit to a long-term orientation, and naïve people simply follow hyperbolic discounting [18]. Normally, these two types should be considered; however, in this model, preference changes occur simply as the steps progress. It is important to note that this logic is not incorporated into the model.

3.3 Dealing with Ambiguity and Uncertainty in Models

This simulation analysis focused on the perspectives of Ambiguity and Uncertainty. As discussed in Section 2.2, ambiguity refers to ambiguous situations caused by unclear organizational goals and decision-making criteria, and uncertainty refers to the difficulty in predicting future environmental changes and can be considered a situation in which an organization does not have enough information to respond appropriately. Therefore, in the simulation, ambiguity and uncertainty were controlled for by addressing the following:

A) Ambiguity: The reviewee's ability and the reviewer's difficulty are controlled by the SC and LC. In other words, if SC>LC, the ability is sufficiently higher than the difficulty, and it can be considered that the organization's goals and decision-making criteria are clear. However, if LC>SC, the ability is significantly lower than the difficulty, the goals and criteria are ambiguous, and the task difficulty is very high.

B) Uncertainty: Controls the range of decision-makers. In other words, if the range is large, it is easier to predict the future because it can accommodate more agents. However, if the range is narrow, it is more difficult to predict the future because reviewees and reviewers come and go more frequently.

3.4 Simulation Conditions

The simulation was performed for four cases with different Ambiguity and Uncertainty conditions, as listed in Table 3. The number of agents was 20 in each case, making the total number 60, and all conditions were identical except for "SC and LC that control Ambiguity" and "range of

Decision-Maker that controls Uncertainty." The simulation was performed for 100 trials, with 1000 steps per trial. The decision deadline was a maximum of 50 steps and was randomly assigned to the Decision-Maker.

Table 3: Simulation Case

No.	Case		Range of D.M.	SC	LC
	Ambiguity	Uncertainty			
1	Low	Low	40	8	1
2	High	Low	40	1	8
3	Low	High	5	8	1
4	High	High	5	1	8

4 Results and Discussion

4.1 Simulation Results

Table 4 shows the simulation results. The results show the average number of decisions per trial by the decision type. Below, I examine the results of each case.

Table 4: Average number of decision/trial (%)

No.	Total	Oversight	Flight	Resolution	Deadline exceeded
1	3875.0 (100)	5.4 (0.1)	728.7 (18.8)	2794.4 (72.1)	346.5 (8.9)
2	955.8 (100)	1.4 (0.1)	280.3 (29.3)	7.1 (0.7)	667.0 (69.8)
3	186.2 (100)	100.3 (53.9)	1.6 (0.9)	41.5 (22.3)	42.8 (23.0)
4	149.4 (100)	96.8 (64.8)	10.9 (7.3)	1.8 (1.2)	40.0 (26.8)

4.1.1 No.1: Low Ambiguity and Low Uncertainty

In this case, the total number of decisions is high, and even when broken down by decision type, the resolution rate is over 70%, while the deadline exceeded rate is also the lowest at under 10%. Therefore, it can be said that the decision-making system is functioning optimally. Because there is almost no oversight, no decisions are made without the reviewer pointing out any problems and the problems not becoming apparent.

4.1.2 No.2: High Ambiguity and Low Uncertainty

Compared to No.1, the total number of decisions decreased significantly, the resolution is less than 1%, and the deadline exceeded accounted for 70%. Flight accounted for 30%, and the reviewer is unable to address the reviewer's comments. The Decision-Maker is unable to make decisions with a long-term orientation. Although he/she reaches decisions with a short-term orientation, there is no option but to passively let things go, so the possibility of resolution is almost zero, and the risk of the deadline being exceeded is very high.

4.1.3 No.3: Low Ambiguity and High Uncertainty

Compared with No.2, the total number of decisions decreased even further. Here, oversight accounts for more than 50% of the total number of decisions, and there are many situations in which decisions are made before problems become apparent. The narrow range of decision-makers makes it difficult to predict the future. If a decision cannot be made when oriented toward the long term, it is likely that when the focus shifts to the short term, decisions will be made with oversight, or the deadline will be exceeded.

4.1.4 No.4: High Ambiguity and High Uncertainty

This situation has the highest level of ambiguity and uncertainty. The total number of decisions is approximately the same as in No. 3, but oversight dominates at approximately 65%, and the deadline exceeds approximately 25%. Similar to No. 2, Decision-Makers find it difficult to make decisions when they are long-term-oriented but are more likely to make decisions when they are short-term-oriented. In such cases, they are caught in a situation where they must either make a decision with oversight without waiting for the reviewer's comments or wait until the deadline is exceeded.

4.2 Discussion

The simulation results show that uncertainty has a significant impact on overall decision-making. At the same time, ambiguity has a significant impact on resolution among decision types. If you organize your decision-making styles on two axes, Ambiguity and Uncertainty, then you can organize them as shown in Figure 3.

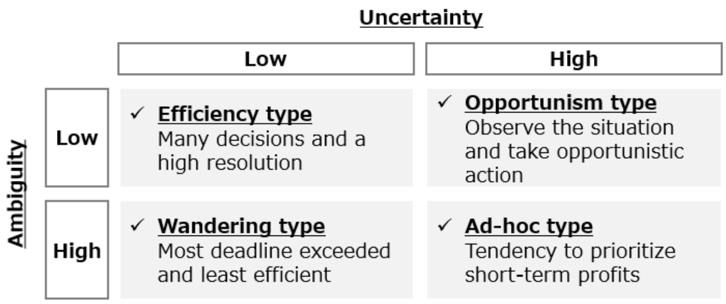

Figure 3: Ambiguity and Uncertainty matrix

The first is the efficiency type. This is an environment in which both Ambiguity and Uncertainty are low, and ideal decision-making is easy. This can be said to be the most desirable state for organizational decision-making. The next is the opportunity type. Ambiguity was low, but uncertainty was high. The various objectives and standards of the organization are clear, and it is an environment where tasks are easy to carry out, but it is difficult to predict the future. Therefore, decision-makers seek to assess the situation, pinpoint opportunities, and take action when a chance for resolution arises. However, as the deadline nears, their focus shifts to supervising the process. This can be considered a flexible response. The next type was wandering. Ambiguity was high, but uncertainty was low. At first glance, it appears that the situation that should be avoided the most is one with high Ambiguity and Uncertainty; however, this situation has the highest deadline exceedance rate and should be avoided the most. It is good to expand the scope of the decision-maker to predict the future; however, ambiguity is high, and information overflows, resulting in a situation where nothing can be decided. Finally, an ad-hoc type was discribed. Ambiguity and uncertainty are both high; however, because of this, oversight is chosen to prioritize immediate profits over long-term profits. Of course, this is not a favorable situation. Still, because it is a crisis, the minimum necessary decisions can be made, so it is thought that exceeding the deadline is suppressed to some extent.

In summary, fluctuation and equivocality of information, such as ambiguity and uncertainty, are likely to waste organizational resources. For example, the paradox of choice in Schwartz [19] and Iyengar and Lepper [20], which focus on individual decision-making, shows that in individual-level decision-making, an excess of options leads to reduced satisfaction. The results of this simulation extend this to the organizational level and suggest that excessive ambiguity and uncertainty can waste organizational resources and reduce decision-making quality. Furthermore, these findings can also contribute to discussions in organizational theory, particularly in the context of the new institutional perspective. The ambiguity and uncertainty explored here are closely related to the concept of institutional logics multiplicity [21], and the resulting institutional fluctuation merits further consideration in the study of organizational behavior and decision-making.

However, are the targets of Ambiguity and Uncertainty to be eliminated? For example, as pointed out by March [22] and O'Reilly and Tushman [23], "exploitation," which utilizes existing knowledge to generate short-term profits, and "exploration," which creates new knowledge based on long-term strategies should be emphasized, and how to manage the balance is a challenge in business strategy. Using this concept as a reference, Ambiguity and Uncertainty must be controlled depending on the functions required of the organization, that is, which department should prioritize "exploitation" or "exploration." It is also important to focus on business processes rather than departments. For example, consider the system development. In the requirements definition phase, it is necessary to increase the number of departments and their numbers and make decisions with an eye on long-term profits. In this case, both Ambiguity and Uncertainty can naturally be high; However, during the design and coding phases after development has started, the key is to minimize ambiguity and uncertainty and make decisions as efficiently as possible using resources.

5 Conclusion

In this study, I developed an organizational decision-making model that incorporates individual preferences and analyzed the impact of ambiguity and uncertainty on decision-making through simulation. As a result, I obtained results suggesting that ambiguity and uncertainty can have a significant impact on organizational decision-making.

However, since the analysis relies solely on simulation, the model's real-world applicability remains unverified at this stage. Additionally, while the study provides conceptual insights into how ambiguity and uncertainty affect decision-making, the practical implications for management require further elaboration based on empirical evidence.

In constructing the model, I considered hyperbolic discounting in the decision-maker and assumed ambiguity and uncertainty from individual preferences that change over time. I did not conduct a comparative analysis with or without hyperbolic discounting. Still, exploring how this influences decision-making could serve as a compelling avenue for future research. This point needs to be taken into consideration, but as I have discussed, this property has a significant impact on the decision type, and it is inferred that macro organizational decision-making and micro individual influence are closely related. In the current model, hyperbolic discounting is simply implemented so that preferences change when the preference reversal step is reached, but in future I plan to explore more detailed models that take into account individual differences.

Future studies could collect empirical data using experiments and questionnaire surveys, in addition to simulations, and examine the impact of ambiguity and uncertainty on organizational decision-making in more detail.

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