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A Simulation Analysis of Shop-around Behavior in a Commercial District as an Intelligent Agent Approach -A Case Study of Osu District of Nagoya City-

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Abstract. In our on-going 'shop-around' pedestrian agent project, the model is designed and implemented that performs planned actions as solutions of the scheduling problem under his/her own constraints, and has a reinforcement learning algorithm that updates the preference on the visited shops. In this paper, based on the data obtained from the questioning survey of Osu District in 2004, we examined the parameters and tried simulations under the conditions of this actual district. The validity was checked through the comparative analysis between the simulation and survey result. We also found further improvement works. In addition, by attempting an application to policy-case simulation, the research demonstrated the potentials of this simulation model.

Keywords: Agent-Based Social Simulation, Pedestrians' Shop-Around Behavior, Planned Action, Improvised Action, Osu District, Nagoya

1. Research Background and Objectives

In large modern cities, the behavior patterns of visitors to commercial districts have become increasingly diversified. For this reason, when the composition of a bustling commercial district is considered, it presents an excellent opportunity to analyze pedestrian micro behavior using a bottom-up approach. In such an analysis, pedestrians' shop-around behavior within the commercial district is the key factor to focus attention upon. Because, it is evident that each pedestrian's shop-around behavior consists of multiple units of activity; at first planned action in accordance with a preference pattern of the visitor, and later improvised action, such as the search for alternative facilities or information gathering. Furthermore, the pattern of behaviors built up is closely related to the effect of the positioning and accumulation of facilities in a commercial district. Accordingly, development of a simulation model of pedestrians' shop-around behavior in a commercial district can be a useful tool for analyzing the composition of a commercial district.

The following research on pedestrian behavior models are all worthy of mention: an absorbing Markov chain model by Sakamoto (1984), prediction of change employing a Markov chain by Saito and Ishibashi (1992), and a fusion of a Huff model and a Markov chain model by Yokoi, et al. (2000). However, these models do not give an explicit expression of planned action and improvised action, both of which are key characteristics of pedestrian behavior. In addition, with regard to diversification in the selection patterns of facilities by visitors, a modeling method that is suitable for a greater variety of expressions should be developed. To cover this point, it would seem a valuable model is Agent-Based Social Simulation (ABSS) involving an autonomous individual with intelligence; however, a model utilizing this method has not been established yet. Therefore, there is a need for a simulation model that addresses these issues.

Taking the above into account the authors designed and developed a simulator using a pedestrian behavior agent model incorporating planned behavior and immediate response behavior (Yoshida, Kaneda, 2007). In this paper, based on the data obtained from the pedestrian behavior survey of the Osu District, Nagoya City (Oiwa et al.), we established the parameters to enable this model to carry out a simulation. and we examined the validity of the simulation results through comparative analysis of the simulation and survey result, and considered points that needed improvement.

2. General Concepts of a Pedestrian Behavior Agent Model

2.1 Examination of the Characteristics of Pedestrian Behavior

First of all, planned action and improvised action, which are key characteristics of pedestrian behavior, were examined. In the research, pedestrian behavior is classified into 4 levels. Level 1 is Planned Action: before visiting a commercial district the visitor schedules their destination and the facilities to visit within a certain period of time. The remaining three levels are all categorized under the heading improvised action: Level 2 is Alternative Visit: when the visitor trips to facilities, if fails to achieve their errand then tries to visit alternative facilities. Level 3 is Erratic Visit: a visitor unexpectedly drops into other facility other than the planned or alternative ones. And Level 4 is Detour Action: the visitor deviates from the shortest route. Table.1 shows the hierarchical characteristics of the above-mentioned pedestrian behavior. The research addressed behavior model architecture for an agent that conducts Planned Action and Alternative Visit.

Table 1. Functional Levels of Pedestrians' Shop-Around Behavior

Level of action	Significance	Motivation
Detour Action(DA)	Walking out of the shortest route	Route preference, Information gathering
Erratic Visit(EV)	Visit a facility expect AV & PA	Facility preference, Information gathering
Alternative Visit(AV)	Visit an alternative facility expect PA	Try to visit another facility when the errand failed
Planned Action(PA)	Visit planned facilities	Efficient errand achievement under the constraints

2.2 Assumptions Introduced for Establishing a Model

To establish the model, the following assumptions were introduced:

(1) A city model has only one unipolar commercial district, and there is no other prominent commercial district in any other district.

(2) Direct interaction between agents does not occur.

The model can express the following interactions: interactions inside the home of each agent, and group behavior with acquaintances and friends in a commercial district; such interactions, however, are not included in the model.

(3) All agents already know all facilities and routes.

Essentially, it is preferable that an agent increases and updates their knowledge of facilities and routes through learning by themselves; however, at the present stage, to simplify the model, this process was omitted.

(4) Erratic Visit and Detour Action are not examined.

For the establishment of the model, expression of planned action and improvised action were given priority and therefore, erratic and detour behavior, which occur spontaneously, were omitted. As our further research is to plan to include these two assumptions.

2.3 Agent Behavior Model

When a unipolar commercial district is assumed, the agent behavior model consists of the following three models: (1) Planning Model at home; (2) Shop-Around Model in the commercial district; and (3) Travel Model between their home and the commercial district. In Model (1), a variety of errands and time-budget are given to each agent; based on this given information and their own knowledge an agent generates the date and time to visit the commercial district, and a preliminary plan for their behavior in the commercial district. In Model (2), in accordance with the plan generated in (1), an agent who visits a commercial district walks to each of the facilities for the purpose of fulfilling their errands. If the agent fails to achieve their errand, improvised action, in which the plan is changed as required, then occurs. Moreover, based on the results of their behavior within the district, the agent updates their own knowledge base and makes use of it for a future visit to the commercial district. Model (3) connects the above (1) and (2), and expresses a round trip between the agent's home and the commercial district. Fig. 1 shows the concepts for an agent behavior model as mentioned above.

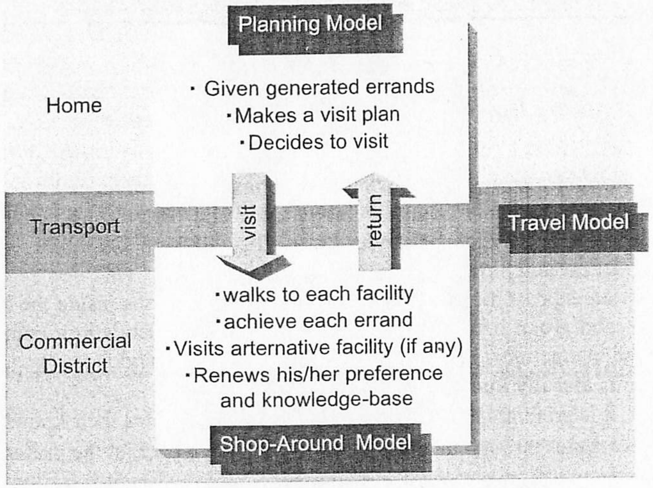

Fig. 1. Concept of Agent Behavior Model

2.4 Hierarchical Model of a Commercial District

A spatial model of a commercial district is expressed as three levels of hierarchical structure made up from the following five categories: (1) Whole District Model that expresses the whole commercial district; (2) an Area Model that expresses each area of the commercial district; (3) Routes across areas that connect with other areas; (4) facilities that exists in each area; and (5) routes that connect the facilities in each area. District Model (1) holds the highest ranking within the entire model and includes Models (2) and (3). In the same way, Area Model (2) includes Models (4) and (5). Fig. 2 shows the basic concepts for a spatial model of the commercial district mentioned above.

3 Verification of the Model with Simulation: Case Study of Osu District

3.1 Application to Osu District

Based on existing research data, in order to evaluate the validity of the simulation model, simulation was conducted using a case study of Osu District, Naka-ku, Nagoya City (Fig. 2).

When Osu District was modeled, the whole area of Osu District was applied as Whole District Model, and each shopping street was an Area Model. This resulted in 37 areas(includes 12 crossroads), 7 facility types, and a total of 685 facilities (Fig. 3). For a probability of an agent visiting the commercial district, $\alpha=2.13$ was assumed in Expression 2, and an errand type selection matrix was set in Table 2. The initial value of a preference variable for all facilities was set in accordance with a normal distribution, using $\mu=5$ and a standard deviation of $\rho=2$. With regard to the attribute that expresses an agent's place of residence, a short distance refers to places inside Nagoya City (it takes a half hour), a middle distance refers to places outside of Nagoya City and inside Aichi Prefecture (it takes one hour), and a long distance refers to places outside of Aichi Prefecture (it takes one and a half hours).

With regard to routes, connect the centers of each area, and each area connect each facility. In this simulation, the distance of the route in an area was assumed as all 0; therefore, there is no difference in distances between facilities in the same area.

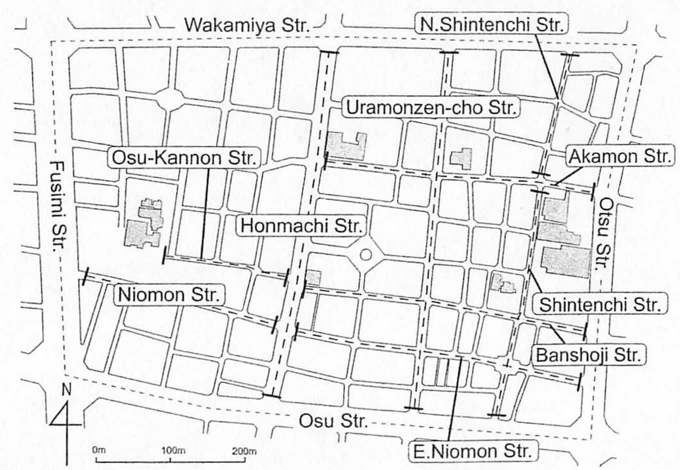

Fig. 2. The map of Osu District, Naka-ku, Nagoya City

Table 2. Distribution of errand type each attribute of agent

Attribute of Agent		(%) Deli & Grocer's	General Goods & Furniture	Appli-ances	Clothing	Park & Temples	Second-Hand Store	Others
Sex	Male	21.7	10.0	38.6	7.2	5.6	10.8	6.1
	Female	25.8	13.5	8.7	21.2	8.9	14.4	7.5
Age	Less Than 30	21.5	12.8	22.8	23.4	5.8	8.5	5.2
	30 To 49	25.3	11.6	26.9	11.4	6.3	13.8	4.8
	50 or More	24.6	11.8	18.7	11.0	11.0	15.4	7.4
Trans port	Railway	23.4	11.4	22.9	15.7	5.7	13.5	7.4
	Car	25.0	10.4	27.7	14.6	5.1	11.5	5.8

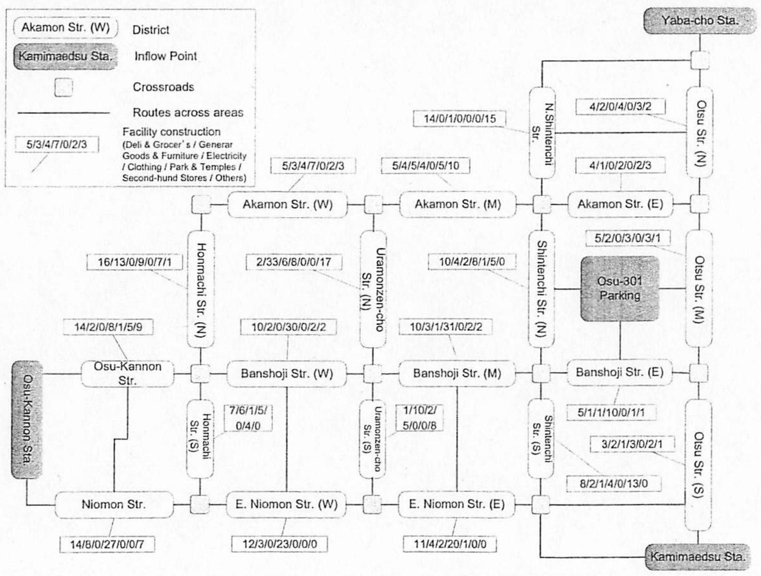

Fig. 3. Spatial model of Osu District

3.2 Illustration of Simulation from Viewpoint of Agent Behavior

This section shows the results of the simulations, and illustrates the validity of the model by observing each agent's behavior that was obtained as the results of

the execution of the simulation of the previously described model using the case study of Osu District.

As the sample, Fig.4 shows the behavior locus when on the 70th day an agent No.65 visited the commercial district. This agent is a housewife in their 30s or 40s and resident in the long distance zone; the agent planned to visit Facilities (1): Appliances, (2), (3): Deli & Grocer's, (4): Second-Hand Store and (6): Deli & Grocer's and traveled to the commercial district by car. When checking the behavior results, after the agent parked her car in "Osu-301 Parking Lot", she visited (1) and in this facility failed to achieve her errand; improvised action then chose (5), as an alternative facility. This alternative reorganized of the plan resulted in (5) being inserted between (4) and (6). The agent then visited (2), (3) and (4), and in Facility (4) she again failed to achieve her errand and as an alternative facility, (7) was chosen. After this, she visited (5) and achieved the errand originally planned for (1); moreover, the agent visited (6) and (7) and left for home from the "Osu-301 Parking Lot", her original appearance point. From the results, it was found that the model expresses the following situation: according to the success or failure of an errand, the agent generates improvised action and while rearranging the behavior plan as needed, the agent walks around the district. From those behavior results, it was confirmed that planned action and improvised action, which are key features of random behavior, are expressed in the model and it can be said that the objective mentioned at the beginning was achieved.

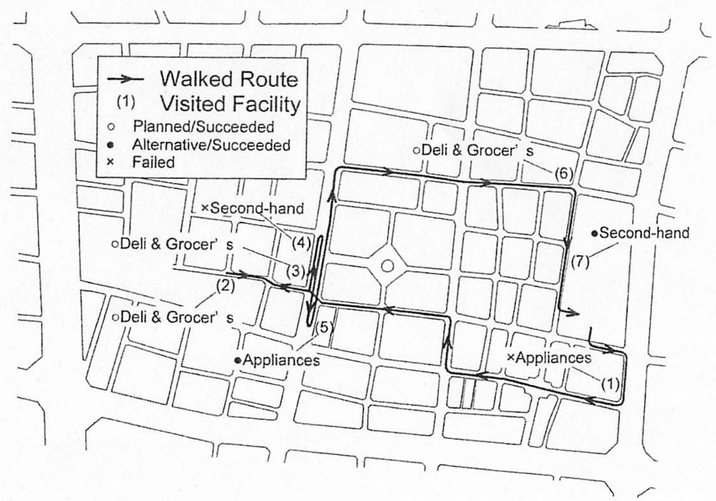

Fig. 4. Walked route of agent No.65 (a housewife in their 30s or 40s and resident in the long distance zone)

4 Comparative Analysis of the Simulation Results and the Survey Result

4.1 Outline of Simulation Setting

This section presents the analysis of the results of the agents' behavior we obtained from the simulation and by comparing them with the survey results of the actual district, checks the operation, and verifies the validity of the model.

When the simulation was conducted, we established a condition of 1,500 agents living in the city and conducted a 10-day trial run; we then ran the simulation for 30 days, and calculated the average daily values of pedestrian behavior in the district as shown in the figure.

4.2 Comparative Analysis of Behavior in the District

Table 3 shows the comparison of the simulation results with the survey results. The table shows that the simulation results for the duration of a visit were shorter and the number of facilities visited was less than the survey results. It could be thought that the results were affected by the omission of erratic behavior and detour behavior; the inclusion of such behaviors would have given a high level of immediate response to the model. With regard to the walking distance distribution, the simulation adopted time distance and the result is shown as a reference. Generally a pedestrian's unrestricted walking speed is taken to be about 1.2 to 1.5m/s, giving a simulation distance of about 1.02 to 1.28km. The difference between the actual and simulation walking distance is small, but the difference in the number of facilities visited is large; from these results, it could be inferred that in this district, the impact of erratic behavior is greater than that of detour behavior.

The percentages for the walking flow lines and for the facilities visited are shown in Fig. 5-left for the survey results, and Fig. 5-right gives the simulation results. The survey and simulation definitions of these percentages are different; therefore in this section, the spatial distribution is compared. Firstly, spatial distribution of the walking flow line percentages is focused on, and in Osu-Kannon Street, Hommachi Street and Niomon Street the values of the simulation results are lower than those of the survey results. In the spatial distribution of facilities visited in the whole district a great difference between the simulation and survey results can be seen. It could be considered that the reason for the difference is that in the simulation, any difference in each facility, such as gross floor area or a difference in the targeted group, is not expressed.

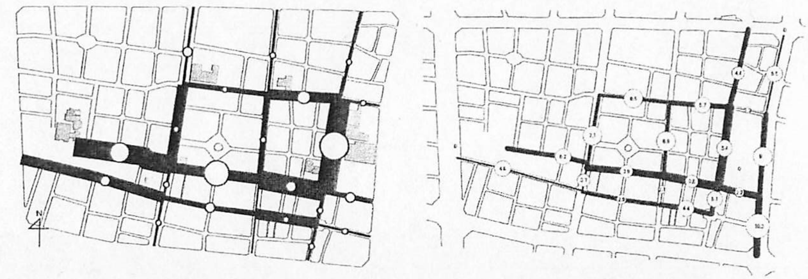

Fig. 5. Walking flow lines and facilities visit (left: by the questioning survey in 2003 (Oiwa et al. 2005), right: by the simulation results).

Table 3. Comparison between simulation result and survey result

	Simulation Results	Survey Results
Stay Time in Osu District	122min	148min
Walk Time / Walk Length	14.2min	1.15km
Number of visited Facilities	2.6 places	5.0 places
Number of visited Facilities (scheduled)	1.4 places	(Uninvestigation)

5. An Attempt to Use the Simulation for Policy-making

As an example of applying the above-mentioned simulation model, we estimated how changes in the district affected agent behavior and verified the possibility of the simulator as a means of contributing to the revitalization of a shopping district. In the policy-making simulation the following two scenarios were examined.

· **Scenario A: Increase of Parking Lots**

As shown in Fig. 3, in the base case, a single parking lot is located at "Osu-301 Parking Lot", which fronts on Otsu Street, Banshoji Street and Shintenchi Street. We then provided a second parking lot on Niomon Street, verified how agent behavior changed due to this increase in parking spaces, and estimated the effect of the establishment of a new parking lot on the district as a whole.

· **Scenario B: Decrease in the Number of Facilities**

By radically decreasing the number of facilities on a certain street from the level of the base case, a so-called "shutter town" situation was created. We verified the behavior of agents in response to such a situation and examined the impact of such conditions.

5.1 Scenario A: Simulation Results

In scenario A, a new parking lot was established on Niomon Street. Fig. 6 shows the result. The location for the new lot is within the oval in the figure. According to the result, it can be seen that the walking density distribution increased along Niomon Street and Higashi-Niomon Street; however, along Banshoji Street and Shintenchi Street, the walking volume decreased. The reason why the walking volume in the directions of east and west decreased is that the car user agents with business on the west side of the district stopped using "Osu-301" and started using the newly established parking lot. With regard to the number of facilities visited, on the whole it can be seen that the number increased within the Osu District; it could be inferred that the establishment of a new parking lot encouraged revitalization of the district.

From the above, although average walking distance tended to decrease, the number of facilities visited increased; therefore, it could be thought that establishment of a new parking lot will contribute to the revitalization of a shopping district. However, as can be seen in the present Osu District, the walking volume in the east and west directions is the distinctive behavior of visitors, wandering from one shopping street to another shopping street, but in the simulation the decline in walking volume is an indicator of the atrophy of this typical behavior; therefore, on a long-term basis it is possible that the establishment of a new parking lot may damage the integrity of the district and have an overall negative effect.

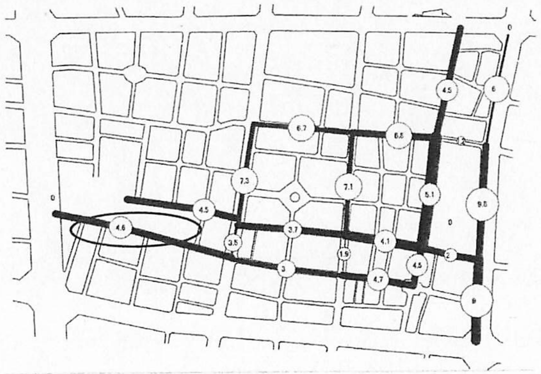

Fig. 6. Simulation results of scenario A -increase of parking lots-

5.2 Scenario B: Simulation Results

In Scenario B, the number of facilities in the northern part of the Uramonzencho Shopping Street was decreased by 77% from 66 stores to 15 stores. Fig. 7

shows the result (the decreased area is within the oval in the figure). It can be seen that in addition to Uramonzencho Street, where a decrease in walking density distribution was expected, both Banshoji Street and Higashi-Niomon Street located in the southern part of the Uramonzencho Shopping Street, suffered a relatively large decrease in walking volume too. In addition, on most of the shopping streets a slight decrease in walking volume can be seen; the exception to this trend was on Otsu Street where the walking volume increased slightly. From these results, it appears that a significant decrease in the number of facilities in Uramonzencho lowered the pedestrian circulation throughout the whole Osu District and would affect the crowded and busy feeling of the district apart from the station and the area around the parking lot. However, the result did show that the number of facilities visited in the whole Osu District hardly decreased.

In the model, a unipolar city was assumed; if in an actual city the same situation occurs, we must consider that the visitors would flow out to other commercial districts and commercial complex facilities. It can be said this point is beyond the scope of the model and is an issue that should be improved in the future.

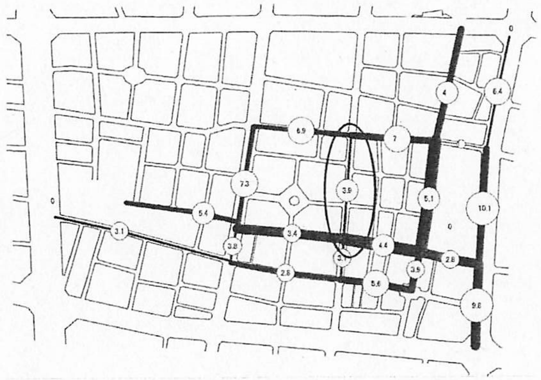

Fig. 7. Simulation results of scenario B - decrease in the number of facilities -

6 Conclusion

In this simulation when a pedestrian agent model that expressed planned behavior and one category of immediate response behavior – alternative behavior – was applied to the Osu District, Nagoya City, the research demonstrated the specific behavior of pedestrian agents, and compared the behavior of agents with actual survey results, and thus verified the validity of the simulation model. In addition, by attempting an application to policy-making simulation, the research demonstrated the usefulness of the simulation model. The following points were shown to be issues to be focused upon in the future: it is particularly necessary for an agent to have functions of erratic behavior and detour behavior – essentially a higher degree of responsiveness – and for the city model to be improved by the expansion of a unipolar model and the expression of facilities within the model. Moreover, it is necessary to make more suitable and established analysis technique for the verification of the function of the model and the simulator.

In the future, through the adjustment of parameters, the expansion of functions based on the above points, and by analyzing the evaluation of a commercial district we will continue to develop simulators, so as to be able make further contributions to the design and maintenance of commercial districts.

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Interacting Advertising and Production Strategies - A Model Approach on Customers' Communication Networks

Jürgen Wöckl

Abstract In this paper we describe a simulation approach to explore different advertising and production strategies in a heterogeneous consumer market. The main focus is to model the dynamics of interacting marketing and production strategies. Such models are needed to find the right tradeoff between two general main targets: adopting the product to customer needs and/or communicate the products' features to the market. One essential key factor for a successful product launch is to set up the right product profile, which fulfills the market needs or respectively the needs of the targeted segment. The development process of new innovative products is quite complex and cost-intensive and due a potentially strong competition in most high-tech markets, the companies are forced to launch new products regularly to fulfill the steadily increasing needs of the customers. The model approach presented in this study can be used to determine the optimal product release cycles and to define suitable advertising claims to succeed in highly competitive markets. One considered advertising channel effects all consumers at the same time representing traditional large-area advertising instruments like broadcasting or print media, and a second represents the dispersion of post-purchase information in the customers' social circle - so-called word-of-mouth advertising. Here a model of an artificial consumer market has been used to provide an experimental environment for the simulation and optimization task - modelling typical stylized facts of software business. So the stylized facts are modeled using a hybrid approach of combining a continuous process described by an ordinary differential equation with discrete update processes of cellular automata and further network structures like 'random' and 'scale-free'-networks. The stability of the model is shown by comparing different market scenarios with different communication structures. Additionally the gap between the products features and the advertising claim has been varied

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