Study of Decision Making Process Using Psychology-Oriented Artificial Society Model, Part 2: Analysis of Decision Making Process in Bangladesh Regarding the Acceptance of Nuclear Power Plants

Sarkar Barbaq Quarmal[1], M. Khaled Kamal[2], Shanjida Afroj[3], Nalin Warnajith[4], Md. Ruhul Amin[5], Masanori Itaba[6], Atsushi Minato[7], and Satoru Ozawa[8]

[1, 4, 6, 7, 8] Graduate School of Science & Engineering, Ibaraki University, Hitachi 316-8511, Japan
[2]University of Rajshahi, Rajshahi-6205, Bangladesh, [5]Robert Walters Japan K. K., Tokyo 150-0002, Japan

Abstract:

The decision making process in Bangladesh regarding the acceptance of nuclear power plants has been analyzed on the basis of authors' psychology-oriented artificial society model [1]. The first part of this paper includes the selection of agents for the modeling, and collection of various parameters of Bangladeshi society. In particular, a "keyword analysis method" is proposed to determine the knowledge function of agents. From the keyword analysis of various message data from the agents, it has been found that the knowledge functions of government, general people and mass media have a similar structure which reflects their positive attitude to the problem; only social network media is against the problem. In the latter part, computer simulations are carried out and the knowledge function of each agent is calculated as a function of time. It has been shown from the computational study that the Bangladeshi society, as a whole, will continue to have a positive attitude to the problem in the next six years, and that this trend will not change even in a suppositional case where the effect of social network media is 10 times stronger than that of the present.

Keywords: artificial society model, knowledge, social decision making, message transfer, cognitive psychology

1. Introduction

This is Part 2 of authors' work on "the study of decision making process using psychology-oriented artificial society model". In Part 1 of the work [1], an artificial society model (ASM hereafter) [2] has been proposed which describes knowledge-based decision making processes in society on a given problem. The model consists of a set of agents which represent groups of similar character people in society regarding the problem. The agents are characterized by the extent of knowledge that they have on the problem. The knowledge of an agent is expressed by a mathematical function. Thinking process of the agent is simulated by using a linkage model of cognitive psychology [3]. A message is formed by the agent based on the knowledge function and the decision of the agent on the given problem, which is also expressed mathematically, and is transferred to another agent and modifies the knowledge function of the agent that receives the message. As a result, the model enables to simulate dynamics of decision making processes in society. This paper concerns the application of the ASM to analyze the problem of decision making process in Bangladesh regarding the acceptance of nuclear power plants (NPP hereafter). The aim of this paper is to carry out computer simulations of message exchange processes between agents and to forecast a future trend of Bangladeshi society regarding the acceptance of NPP.

2. NPP Problem in Bangladesh

The Government of Bangladesh has a plan to establish NPP in order to solve the problem of electricity shortage. A bilateral agreement with Russia has already been signed for setting up a two-unit NPP with a capacity of 1,000 megawatts each [4, 5]. Before going into the details of the computational analysis of the social acceptance of NPP, let us have a look over the present situation of Bangladeshi society related to the NPP problem. Bangladesh is a developing third world country. The capacity of the electricity generation plants in operation is not enough to meet the demand even though more than half of the population still does not have electricity at their home. At the end of 2011, electricity generation capacity was about 5200 MW which was short to the demand by roughly 1600 MW, which is shown in Figure 1. Therefore, the people often suffer from the shortage of electricity, especially in hot summer days. The farmers suffer from the problem in irrigation season. The industrial development of Bangladesh is slow due to the electricity shortage problem. The people want to get rid of this problem and the government of Bangladesh is also looking forward to solve this problem to activate further development of the country.

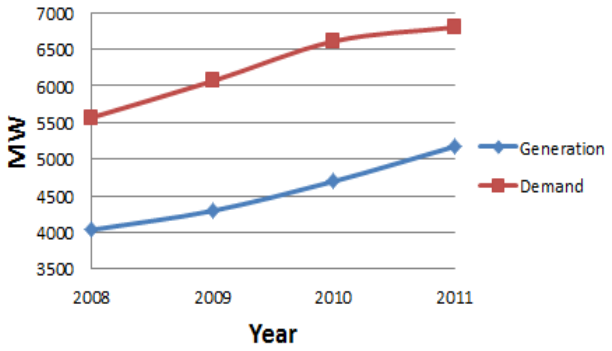

Figure 1: Electricity generation - demand curves in the last four years in Bangladesh (BPDB, Jan 2012).

Bangladesh is now depending on natural gas but the quantity of the possible reserves, which will sustain only for eight to ten years [6], is not enough to support the future energy demand. The government thinks that there is no other way but to depend on NPP. The government believes that NPP will help improving the electricity situation in a short period. When the government announced the NPP project in 2009, the major part of the general people welcomed it. The mass media of Bangladesh has not been negative to the NPP problem. But, when the Fukushima NPP accident happened in Japan on 11th March 2011, the general people in Bangladesh became panicked for fear that the radioactive contamination may reach to Bangladesh. Non-scientific rumors regarding radioactive contamination were spread by the people. The mass media in Bangladesh also played a role in driving the general people into the panic situation. A number of articles which stressed the negative aspects of using nuclear energy were published in most of the newspapers in Bangladesh. The television channels also did the same thing. On the other hand, social networking media, namely community blogs, were against the government's planning itself of producing NPP in Bangladesh. They discussed the negative aspects of using nuclear energy in a country like Bangladesh which is small, densely populated, and technologically non-matured. They urged the government to search for alternative energy sources such as solar energy, wind energy etc.

3. Modeling

In order to apply the psychology-oriented ASM of Part 1 to analyze decision making processes in Bangladesh regarding the acceptance of NPP, the following works are needed:

(1) Selection of agents,
(2) Definition and characterization of channels between agents,
(3) Preparation of knowledge functions of agents.

In the following subsections, these are described in detail.

3.1. Selection of agents

Bangladesh is a developing country in south Asia. By the constitution of Bangladesh, it is a democratic country where the prime minister is the head of the government. Bangladeshi economy is mainly agriculture-based and about two third of the total population are directly involved in agriculture. Table 1 shows some data regarding Bangladesh which portrays the society of Bangladesh.

Table 1: Bangladesh country profile [7-13]

Official name	People's Republic of Bangladesh		
Government	Unitary parliamentary democracy		
Gross national income per capita	$700		
	National	Urban	Rural
Population	150 million	38 million	112 million
Adult literacy	58%	68%	54%
Newspaper readers	40%	50%	36%
Mobile phone users	58%	80%	51%
Internet users	3.7%	10%	1.6%

To model the Bangladeshi society in the framework of ASM, we adopted four agents, i.e., general people (GP), government (GOV), mass media (MM), and social networking media (SNM). Hereafter, these agents are expressed in abbreviation. This model of four agents is very simple and basic. However, it can be the first approximation of the Bangladeshi society, from which we will deduce some valuable results on the problem. The first three agents, GOV, GP, and MM are "automatic choices" regarding this problem. We add here SNM as the fourth agent. The reasons why the first three are the automatic choices and why we need the fourth agent are described in the followings.

(1) The acceptance of NPP has become an issue of GOV for the electricity power supply. It is quite obvious that GOV plays the central role in decision making process regarding such a national problem in a country like Bangladesh.

(2) GP will be benefitted from the NPP by having enough electricity, and they support GOV's planning to produce NPP. On the other hand, GP will have to suffer if anything goes wrong in the NPP. So naturally, GP must take part in the decision making process regarding the establishment of an NPP. Although three-fourth of the population lives in the rural area, history of Bangladesh tells that the mass movements were mostly carried out in the urban centers, mainly at Dhaka, the capital of the country. Therefore, in the first approximation of Bangladesh society, GP is represented by the people in urban area. More detailed modeling which takes into account the negotiations between rural area and urban area will be given in author's next paper.

(3) MM is a very important agent in almost any social issue. It works as the main source of information to GP and ensures constant flow of public information or news about events occurring within the country and in the world. By providing information, MM works as the "agent of social change" and play important role in changing of attitudes, beliefs, and social norms [14-16]. On the other hand, thoughts and opinions from different part of the society on a particular problem are also reflected in MM. In this way MM works as a bridge between different parts of the society. As for the present problem, MM in Bangladesh has apparently positive attitude. Because, GOV and GP are showing positive attitude to the problem and their attitude reflects in MM.

(4) The emergence of SNM is not so old, but, it has already become a notable source of information as well as a popular media to exchange message around the globe. It is said that the SNM played a crucial role in the recent revolutions (the so called "Arab Spring") in Arabic world [17]. Few years ago, such phenomenon was observed in Bangladesh also. Local community blogs played a good role in building mass opinion to initiate the trial procedure of war criminals in the country's liberation war. The popularity and reliability that SNM has gained so quickly is due to its openness. Bangladesh is a democratic country and the MM is enjoying quite a freedom, while in some countries, voice of MM can be suppressed in many ways. However, SNM is free from this problem because it is the Internet-based and no one can completely control the flow of information through the Internet.

3.2. Definition and characterization of channels between agents

In the present study, there are four agents. Therefore, there are ${}_4P_2 = 4 \times 3 = 12$ channels among the agents, i.e., message flows through twelve channels from MM to GP, from GP to MM, from MM to GOV, from GOV to MM etc. But, no evidence has been found regarding direct message exchange between GOV and GP, and that between GOV and SNM in Bangladesh. GOV sends its message through MM. Also, GP send their messages to GOV through MM. Hence, message transfers from GOV to GP, from GP to GOV, from GOV to SNM and from SNM to GOV are excluded in the present model (See Figure 2). Table 2 shows the number of messages regarding NPP problem which are sent from one agent to the other agents per one year in Bangladesh.

Table 2: Number of messages sent by agents per year

To / From	GP	GOV	MM	SNM
GP	-	-	1	2.5
GOV	-	-	1.5	-
MM	3	3	-	3
SNM	3.5	-	3.5	-

In the ASM described in Part 1 [1], each agent has different character in receiving message. Some of them accept it as it is and the others do not. But, in the present study, the agents are assumed to be "simple-minded". Namely, they receive the messages from other agents without filtering. So, no modification has been implemented in the message receiving process of the agents. The parameter, $C_{i,j}(x)$ in Section II D of Part 1 is assumed to unit. Note that the definitions of $C_{i,j}(x)$ in Sections II C and II D are different although the same notation $C_{i,j}(x)$ is used there. In Section II C, it is used to modify conclusion function to produce message function, while in Section II D, it is a factor that represents effectiveness of acceptance of message. The message modification factor $C_{i,j}(x)$ in Section II C is also neglected in this study. Namely agents are assumed to express their idea honestly

as they are. Table 2 shows the channel capacity measured by the number of messages sent by an agent per one year. The messages from one agent do not reach all the members of the other agents. It depends on the "audience rating". For example, in Bangladesh, only about 50% of urban people read newspaper [12]. Therefore, the audience rating coefficient of the channel from MM to GP is 0.5 and the effective channel capacity, i.e., the number of messages from MM to GP is $3 \times 0.5 = 1.5$ per one year. Although the rate of the Internet users in Bangladesh [13] is about 3.7%, it rises to 10% in the urban areas. Therefore, the audience rating coefficient of the channel from SNM and GP is 0.1 and the effective capacity of the channel is $3.5 \times 0.1 = 0.35$. Note the character of GP regarding the social decision making process is estimated by that of GP in urban area (See (2) of Section 3.1). The audience rating coefficients of channels are summarized in Table 3, and the effective capacities of the channels are in Table 4. Thus, we obtain the distribution of channels between agents and their effective channel capacities, which is summarized in Figure 2.

Table 3: "Audience rating" coefficients of channels between agents

To / From	GP	GOV	MM	SNM
GP	-	-	0.08	0.02
GOV	-	-	1	-
MM	0.5	0.2	-	0.07
SNM	0.1	-	0.1	-

Table 4: Effective capacity of channels

To / From	GP	GOV	MM	SNM
GP	-	-	0.08	0.05
GOV	-	-	1.5	-
MM	1.5	0.6	-	0.21
SNM	0.35	-	0.35	-

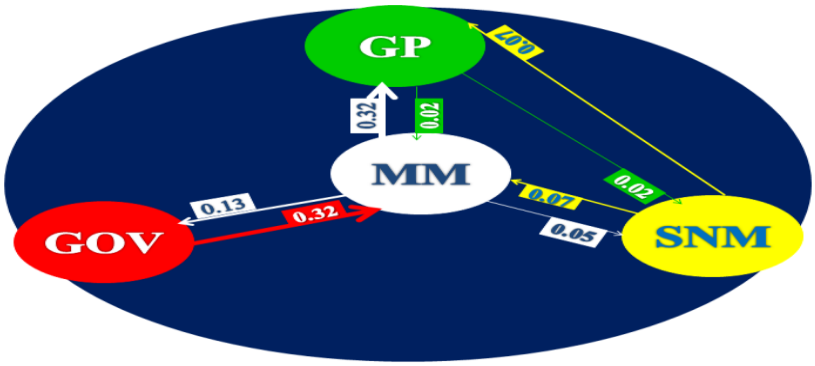

Figure 2: Assignment of channels and their effective channel capacity parameters.

3.3. Preparation of knowledge functions of agents

In the process of the application of the psychology-oriented ASM, preparation of knowledge functions is the most important part of the work. In order to explain how to do it, let us go back to the definition of knowledge function which was described in Section II of Part 1 of this study [1]. Look at Figure 3 of Part 1, where the ensemble of knowledge of an agent is shown. Each of the elements of the knowledge is labeled by an influential parameter, x ($x = 0$ is labeled to the knowledge completely negative to the question; $x = 1$is labeled to the completely positive knowledge; and $0 < x < 1$ correspond to the intermediate). As shown in Figure 4 of Part 1, we can produce the knowledge function of the agent if we arrange a lot of elements of the knowledge against the parameter x. Therefore, the method of obtaining the knowledge function of an agent is composed of the following two steps.

Step 1: Collection of elements of knowledge of an agent regarding a given problem.

Step 2: Labeling a value of influential parameter x to each of the elements of the knowledge.

One problem in Step 1 is that knowledge stored in human brain is not observable directly. But there is a method to guess the knowledge structure of an agent. It is to analyze messages from the agent. Note that message of an agent is formed from the knowledge of the agent (See Figure 2 of Part 1). The messages from an agent are samples of knowledge of the agent. There

would be various methods to analyze messages from agents. The authors propose here "keyword analysis method" to analyze messages from agents.
The keyword analysis method is composed of the following processes.

(1) The problem studied in the ASM is expressed in the form of a question: "Do you support or accept (something: action of the problem) in order to (do something)?" In our case, it becomes "Do you accept construction of NPP in order to solve the problem of shortage in electricity supply in Bangladesh?"
(2) Two kinds of questionnaire surveys are carried out, which correspond to Step 1 and Step2. In the questionnaire of Step 1, the question of (1) is asked to the members of an agent. This question triggers thinking and some ideas related to the question are coming into their mind (See Figure 5 of Part 1). They are requested to write their answers freely in sentences.
(3) These sentences are analyzed by computer and "keywords" are extracted by the software prepared by the authors for this purpose.
(4) These keywords and key phrases (combination of keywords) are tested by inserting them into a format: "Do you think the idea of (keyword/key phrase) leads positive answer to the question?" If the inserted sentence makes sense, it is adopted as a question of the questionnaire in Step 2. The sentence is rewritten without changing its meaning in case the sentence is not fluent even if it makes sense. In such a way, questionnaire format of Step 2 is prepared. The examinees of the questionnaire of Step 2 are requested to answer by "yes" or "no". The frequency of "yes" gives the value of the influence parameter, x.
(5) The number of one keyword counted in Step 1 versus the corresponding influence parameter, x curve gives the knowledge function of the agent.

The questionnaire experiments of Step 1 and Step 2 were carried out between June, 2011 and August, 2011 for GP of Bangladesh. One hundred people of different ages and of different professions were randomly selected and were interviewed with the aid of the questionnaire document of Step 1. Then, "keywords" were extracted by using the software, "Keyword Extractor" developed by authors [18]. They were tested by the method described in the process (4), and the questionnaire document for Step 2 was prepared. The questionnaire experiment of Step 2 was carried out also to one hundred examinees. Table 5 shows the result of the questionnaire experiments. The value of influence parameter, x for each keyword is obtained by dividing the number of "yes" by the number of examinees. By plotting the 2nd column data against the 4th column data, the knowledge function of GP can be obtained.

Table 5: Result of key word analysis for GP

Keyword or key phrase	Number Counted in Step 1	Number of "yes" in Step 2	Value of x
Nuclear waste management	12	8	0.08
Many countries going to stop using nuclear energy	14	16	0.16
Past accidents	23	20	0.20
lack of financial & tech. abilities	20	22	0.22
Radioactivity/health hazard	21	31	0.31
corruption	40	35	0.35
plant safety	45	39	0.39
Safe & clean source of energy	48	49	0.49
Efficient	48	51	0.51
Low cost	46	55	0.55
New employment opportunity	54	65	0.65
National development	63	74	0.74
Solve electricity crisis	68	80	0.80

These keywords were also examined in newspaper articles (the daily "Prothom Alo" [19] published in Bengali and the Daily Star [20] published in English), websites of the governmental organization [21], documents presented by Bangladesh government at International Atomic energy Agency (IAEA) [22] and articles published in social networking blogs ("Somewhereinblog" [23]). And the numbers of appearance of the keywords in these documents were counted. Namely, the 2nd column data were prepared also for GOV, MM and SNM. In such a way, we finally obtained the knowledge functions of the four agents, which has been

shown in Figure 3. Note that the knowledge functions are presented after the normalization. (See Section IIA of Part 1). It is seen from Figure 3 that the knowledge functions of GOV, GP and MM are similar and have a positive attitude to the problem; only SNM is against the problem. This is quite consistent with the description about the present status of Bangladeshi society (See Section 3.1 for the details.) As GP suffer a lot due to the shortage of electricity, GP as well as GOV wants a solution to this problem as soon as possible by any means. Such idea of GOV and GP reflects to MM. Therefore, the knowledge functions of GOV, GP and MM have a positive structure to the problem.

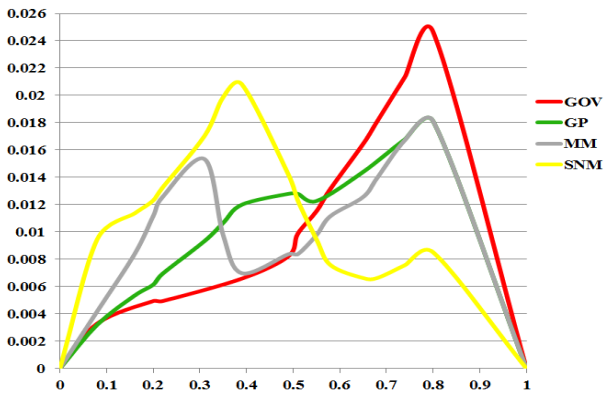

Figure 3: Knowledge Functions of four agents regarding acceptance of NPP in Bangladesh.

4. Computer Simulation

Since the knowledge functions of agents have been obtained in the previous section, the next step is to study how they will change in time. This work is equivalent to forecasting the future Bangladeshi society regarding the acceptance of NPP. The mechanism of the dynamics of the development of knowledge function is given in Part 1 of this work [1]. The decision making process (1) - (3), the message producing process (4), (5), and the knowledge modification process (6) - (8) are included in the present study. (See Section II of Part 1). However, the aging of received knowledge (9) - (11) is neglected here because the dynamics of knowledge function is to be studied for a short period less than six years (Compare the curve (2) to the others in Figure 12 of Part 1). The Figure 4 shows the flow chart of the program for the computer simulation of decision making processes in society. Note that after the calculations of the decision function, the message function and the modified knowledge function, they are always normalized numerically. All the procedures between the channel selection and the knowledge modification are repeated until a maximum number of iterations which corresponds to six years. Programming language C together with a graphics tool, SGL (Simple Graphics Library) [24] has been used in the program code.

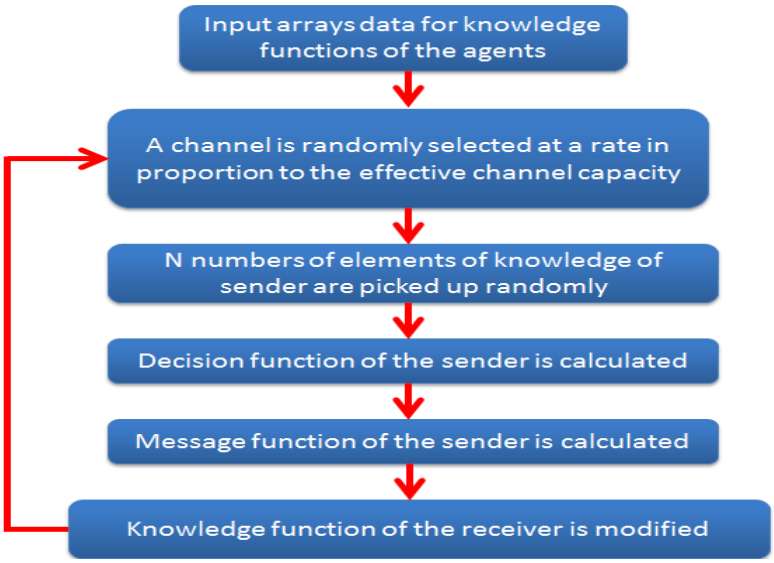

Figure 4: Flowchart of the computer simulation to realize time development of knowledge functions.

4.1. Computer Simulation by Using Real Channel Parameters

Computer simulations have been carried out using the channel parameters shown in Figure 2. Figure 5 shows the time-variation of the shape of the knowledge function of each agent.

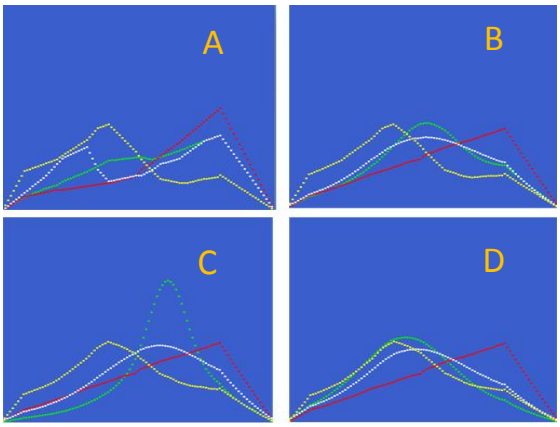

Figure 5: Time variation of the knowledge functions of the agents. (A) at present, (B) after 2 years, (C) after 4 years, and (D) after 6 years. The red, green, white and yellow curves represent knowledge functions of GOV, GP, MM and SNM, respectively.

It is seen from Figure 5 that the shape of knowledge functions of GP and MM changes dynamically in six years, while that of GOV and SNM does not change so much. The reason why the shape of knowledge functions of GP and MM fluctuate so much is that they have a wide structure of knowledge ranging from very positive to very negative to the problem and their conclusions sometimes fluctuate (see Section IIIA of Part 1). The reason why the shape of knowledge functions of GOV and SNM do not fluctuate is understood from the fact that their knowledge structure is sharp and they do not have strong message flows from the other agents. This is related to the strict attitude of the government concerning NPP problem as described in Section III A. The change in attitude of the agents regarding the problem can more clearly be observed if we calculate the center x_c of knowledge which is defined as

$$x_c = \frac{\int_0^1 x\, f(x)\, dx}{\int_0^1 f(x)\, dx} = \int_0^1 x\, f(x) dx.$$

Here, $f(x)$ is knowledge function of an agent. Note the knowledge function is always normalized, i.e., $\int_0^1 f(x)\, dx = 1$.

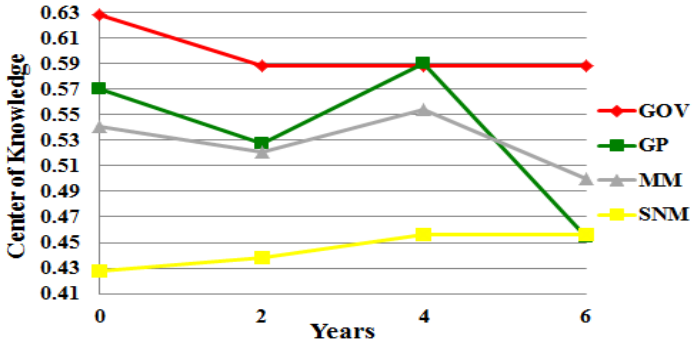

Figure 6: Time variation of center of knowledge of four agents.

The value of center of knowledge can be a measure of "mean attitude" of the agent to the problem. When the value of center of knowledge is higher than 0.5, it represents a positive attitude to the problem. And the values lower than 0.5 represent a negative attitude to the problem. It is seen from Figure 6 that all the agents except SNM usually have a positive attitude to the problem, and GOV is the most positive. It should be noted again that the attitude of GP fluctuates so much. The fluctuations are also seen for MM. The knowledge function of MM has two peaks which correspond to negative and positive groups of knowledge. The wide range of the knowledge distribution produces greater fluctuations in the decision making processes, which, in turn, produce

fluctuations in time variation of their attitude. The fluctuations occur in the real society as well. But we like to discuss here "mean time variation of attitude". So we repeated the same computer simulations only by changing the series of random number and produced thirty samples of time variation of knowledge functions, and then calculated the mean of x_c over the thirty samples. Figure 7 shows the ensemble-averaged time variation of x_c. Small fluctuations of x_c are still observed for GP and MM in Figure 7. The fluctuation becomes smaller if we take ensemble average over much more samples. It is seen from Figure 7 that GOV moves by a small extent to negative direction but its attitude is still most positive to the problem; GP and MM do not change notably; SNM moves to positive direction but its attitude is still the most negative. As a whole, the Bangladeshi society keeps the positive attitude to the problem of the acceptance of NPP. The change in the attitude in six years is negligibly small as far as we discuss the problem on the basis of "ensemble-averaged time variation of attitude". In real society as well as in computer simulations, fluctuations of the attitude always happen. For example, if NPP accident occurs, then the knowledge functions tend to shift to the negative direction. Since we cannot forecast such happenings, we cannot discuss when and how the knowledge function fluctuates. We should note that the thing we can discuss here by this model is only "ensemble-averaged" quantity. This is because the model is based on stochastic processes where the causality is not taken into account. In this sense, the formulation of the present study is similar to that of quantum mechanics, which is stressed in Section III B in Part 1 of this study [1].

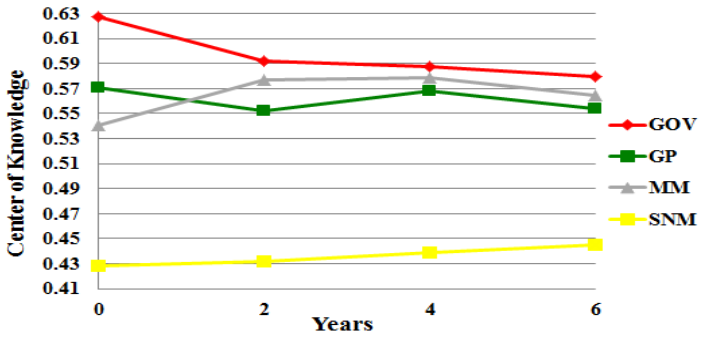

Figure 7: Ensemble-averaged time-variation of center of knowledge of four agents.

3.2. Computer Simulation by Using Suppositional Channel Parameters

As is shown in the previous section, GOV, GP and MM have positive attitude to the acceptance of NPP in Bangladesh. Only SNM has negative attitude to the problem. It has been found from the computer simulation that this situation will not change in next six years. It is because SNM is very weak in Bangladeshi society at present. Now, let us consider a suppositional case where SNM is much stronger than as it is today. For example, we assume that the effective channel capacity is five times larger than it is now, namely, we modify the corresponding values in Table 4 from 0.35 to 1.75. The reason why we consider such suppositional case is that the number of the Internet users is rapidly increasing in Bangladesh [13]. Figure 8 show the result of the computer simulation in which the suppositional parameters are adopted. It is seen from this figure that GOV, GP and MM move much more to the negative direction as compared with the computer simulation with the real parameters (Figure 7). However, as a whole, the Bangladeshi society still remains at positive attitude to the problem even if SNM is five time stronger than the present situation of SNM in Bangladesh. From a similar computer simulation where the effect of SNM is ten times stronger than that of the present, it has been found that the Bangladeshi society will be, as a whole, positive to the problem in the next six years.

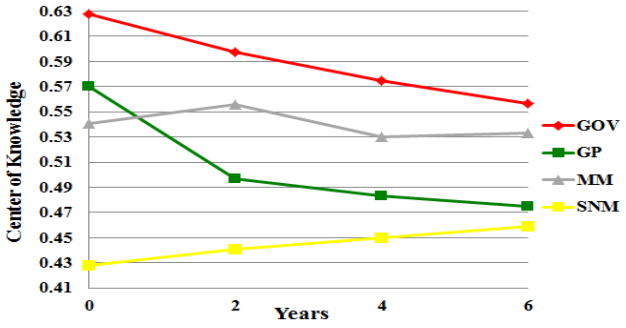

Figure 8: Ensemble-averaged time-variation of center of knowledge in the suppositional case where SNM is five times stronger than present.

5. Conclusion

The psychology-oriented ASM of Part 1 of this study [1] was used to analyze decision making processes in Bangladesh regarding the acceptance of NPP. The four agents, GOV, GP, MM and SNM were selected to model the Bangladeshi society in the framework of the psychology-oriented ASM. Between the agents, the channels were defined and the effective channel capacities were determined from the data in references. The keyword analysis method was proposed to determine the knowledge functions of the agents. This method was applied for the analysis of publications of GOV, questionnaire data of GP, newspaper articles of MM, and blog articles of SNM. It has been found from the analysis that the knowledge functions of GOV, GP and MM have a similar structure which reflects their positive attitude to the problem; only SNM is against the problem. Computer simulations were carried out to forecast the future trend of the acceptance of NPP in Bangladesh. It has been found from the simulations that the structure of knowledge of GP and MM changes dynamically in six years, while that of GOV and SNM does not change so much. The reason for the behavior of GP and MM is that they have a wide structure of knowledge ranging from very positive to very negative to the problem and their conclusions sometimes fluctuate. The reason why GOV and SNM do not fluctuate is that their knowledge structure is sharp and they do not have strong message flows from the other agents. Such fluctuations actually happen in real society. However, we liked to exclude the fluctuations from our discussion because the fluctuation has a stochastic character and it is nonsense to forecast. So, the same computer simulations were repeated only by changing series of random number, and the obtained data were ensemble-averaged over many samples. From the analysis of the ensemble-averaged time-variation of center of knowledge, it has been found that the Bangladeshi society, as a whole, keeps their positive attitude to the problem in the next six years. The computer simulation showed that this trend does not change even in a suppositional case where the effect of SNM is ten times stronger than that of the present.

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