Systems Research and Behavioral Science
Syst. Res. **25**, 663–673 (2008)
Published online in Wiley InterScience
(www.interscience.wiley.com) **DOI**: 10.1002/sres.948

■ *Research Paper*

Searching for Effective Policies to Prevent Bird Flu Pandemic in Bandung City Using Agent-Based Simulation

Utomo Sarjono Putro[1]*, Santi Novani[1], Manahan Siallagan[1], Hiroshi Deguchi[2], Yasuhiro Kantani[3], Toshiyuki Kaneda[4], Yusuke Koyoma[2], Manabu Ichikawa[2] and Hideki Tanuma[2]

[1]*School of Business and Management, Institut Teknologi Bandung, Jl. Ganesha No. 10, Bandung 40132, Indonesia*
[2]*Department of Computational Intelligence and Systems Science, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology, Suzukakedai Campus: 4259 Nagatsuta-cho, Midori-ku, Yokohama 226-8502, Japan*
[3]*Division of Environmental Medicine, National Defense Medical College Research Institute, Tokorozawa 359–851, Japan*
[4]*Omohi College, Graduate School of Engineering, Nagoya Institute of Technology, Gokiso, Showa-ku, Nagoya 466–8555, Japan*

This paper investigates the case of H5N1 bird flu in Southeast Asia, and develops a basic model of simulation using agent-based modelling to study the dynamic interaction between human activities in Bandung City, West Java province, Indonesia. It evaluates the effectiveness of several policies for Bandung City based on the infection process model for pandemic, depending on social and culture simulation using Spot Oriented Agent Role Simulator or SOARS. The results of these simulations suggest that the government should take action not only from a medical perspective, but also from the perspective of social interactions and their influences on the spread of H5N1 in Bandung City. Copyright © 2009 John Wiley & Sons, Ltd.

Keywords bird flu pandemic; agent-based simulation; infection models; social preventive policies; SOARS

INTRODUCTION

The objective of this research is to evaluate the effectiveness of incorporating social factors into a program to prevent a bird flu pandemic in Bandung City. First, we propose an infection model for bird flu using Spot Oriented Agent Role Simulator or SOARS (Deguchi, 2006; Deguchi *et al*., 2006). We then simulate the model using data from Bandung City (Bandung Dalam Angka, 2005). Bandung is 79 miles from Jakarta, the capital of Indonesia. Bandung has been

*Correspondence to: Utomo Sarjono Putro, School of Business and Management, Institut Teknologi Bandung, Jl. Ganesha No. 10, Bandung 40132, Indonesia.
E-mail: utomo@sbm.itb.ac.id

selected for this research because the spread of bird flu in this city has been very high and because many people in Bandung raise, care and sell fowl, the primary carriers of H5N1 bird flu.

In this research, an agent-based simulation was developed to look at the dynamic interaction among agents from the social perspective. Agents in this model are divided into groups: baby (0–5 years), schoolchild (6–12 years), student (13–18 years), young (19–34 years), middle (35–59 years) and old (>60 years). The simulation uses three modules: stage disease transition module, contamination and infection model for bird flu based on Deguchi's research (Deguchi, 2006; Deguchi *et al*., 2006) and previous work by Putro (2000, 2005), Bharwan (2000) and Axelrod (1997).

Finally, this paper evaluates several policies for preventing a bird flu pandemic: social protection program policies by government, such as a *social filter* (*virus excretion control*), attenuation contamination control with sterilization and humidity, *virtual space density control*, and *personal protection control*.

BIRD FLU IN BANDUNG CITY

Indonesia is the world's fourth most populous nation, an archipelago of 17 000–18 000 islands, 220 million people and 55 million households, 80% of which have backyard poultry flocks. Thirty of its 33 provinces have reported infections by a new virus, H5N1, from birds. If 80% of Indonesian households have poultry, and 27% of these poultry flocks are infected, then of the 55 million people in Indonesia, about 12 million are in constant daily contact with H5N1 (Bandung Dalam Angka, 2005).

Indonesia has seen a steady rise in its number of human infections and deaths since its first known of outbreak of H5N1 in poultry in late 2003. The cumulative number of confirmed human cases of avian influenza A/(H5N1) reported to WHO is shown in Table 1 (WHO, 2008).

As seen in Table 1, Indonesia has the highest number of cases (in bold) in bird flu. Indonesia has 33 provinces, and among them, West Java is the province with the highest number of cases (in bold) of bird flu. The traffic of chicken and poultry trading is difficult to control because the demand is so high and complicated. The numbers of victims of bird flu in Indonesia for each province is shown in Table 2 (Departemen Kesehatan Republik Indonesia, 2007).

AGENT-BASED SIMULATION TO PREVENT BIRD FLU PANDEMIC

This paper proposes three modules of simulation based on Deguchi's research (Deguchi, 2006; Deguchi *et al*., 2006). First, it introduces a bird flu

Table 1. Cumulative number of confirmed human cases of avian influenza A/(H5N1) reported to WHO

Country	2003		2004		2005		2006		2007		Total	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
Azerbaijan	0	0	0	0	0	0	8	5	0	0	8	5
Cambodia	0	0	0	0	4	4	2	2	1	1	7	7
China	1	1	0	0	8	5	13	8	2	1	24	15
Djibouti	0	0	0	0	0	0	1	0	0	0	1	0
Egypt	0	0	0	0	0	0	18	10	16	4	34	14
Indonesia	**0**	**0**	**0**	**0**	**20**	**13**	**55**	**45**	**21**	**18**	**96**	**76**
Iraq	0	0	0	0	0	0	3	2	0	0	3	2
Lao People's	0	0	0	0	0	0	0	0	2	2	2	2
Nigeria	0	0	0	0	0	0	0	0	1	1	1	1
Thailand	0	0	17	12	5	2	3	3	0	0	25	17
Turkey	0	0	0	0	0	0	12	4	0	0	12	4
Viet Nam	3	3	29	20	61	19	0	0	0	0	93	42
Total	4	4	46	32	98	43	115	79	43	27	306	185

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

Table 2. *The victims of bird flu in Indonesia*

No.	Province	Bird flu positive		
		Number of cases	Death	Ratio (%)
1	West Java	**28**	**22**	**33.33**
2	DKI Jakarta	22	19	28.79
3	Banten	12	10	15.15
4	North Sumatra	7	6	9.09
5	East Java	6	4	6.06
6	Central Java	5	4	6.06
7	Lampung	3	0	0
8	South Sulawesi	1	1	1.51
9	West Sumatra	2	0	0
	Number of cases	86	66	

stage transition module, describing transition stages and possibilities after being infected by H5N1. A state transition module describes the stage transition structure of agents under the condition of age, vaccination and medical treatment. It further divides agents into several categories by age and vaccination. It uses five categories of age such as baby, child, young, middle and old. Stages for disease are expressed as 0, 1, 2, 2m, 3, 3m, 3s, 4c, 4m, 5, D and 0i. Level of virus excretion is expressed in the model not by the numbers of virus but by an excretion scale between 0 and 1. The stage model gives the excretion scale in each stage, as shown in Figure 1.

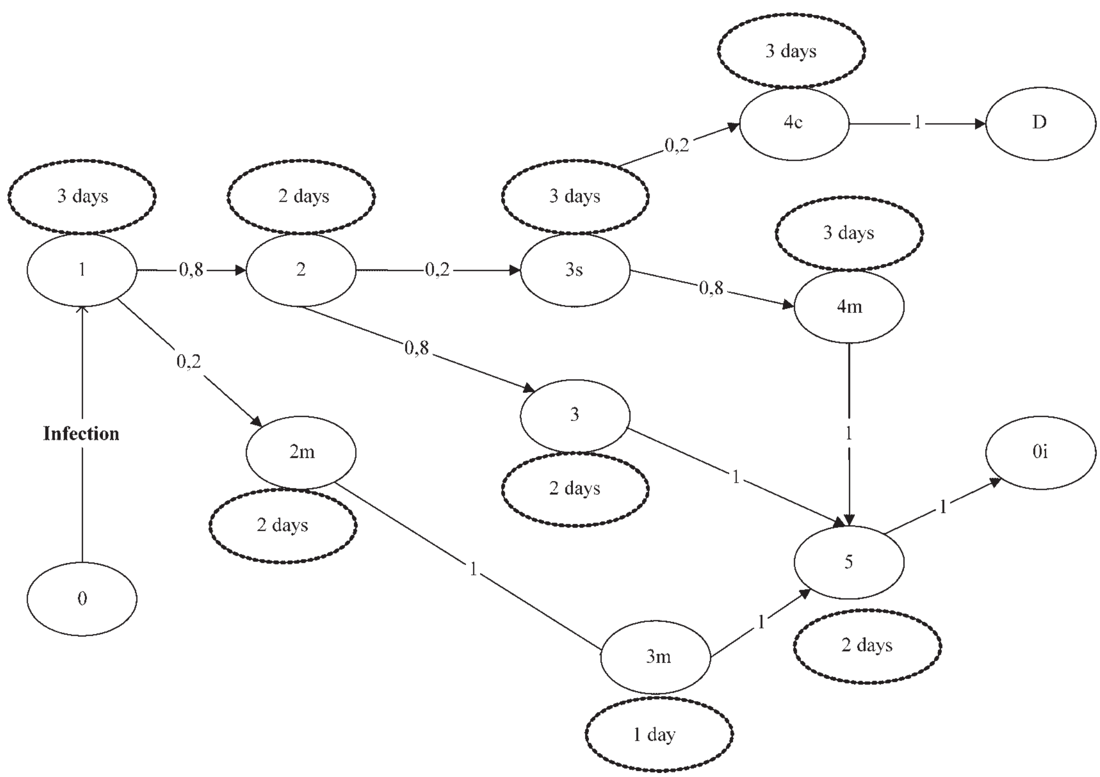

Figure 1. Disease state transition model

DOI: 10.1002/sres

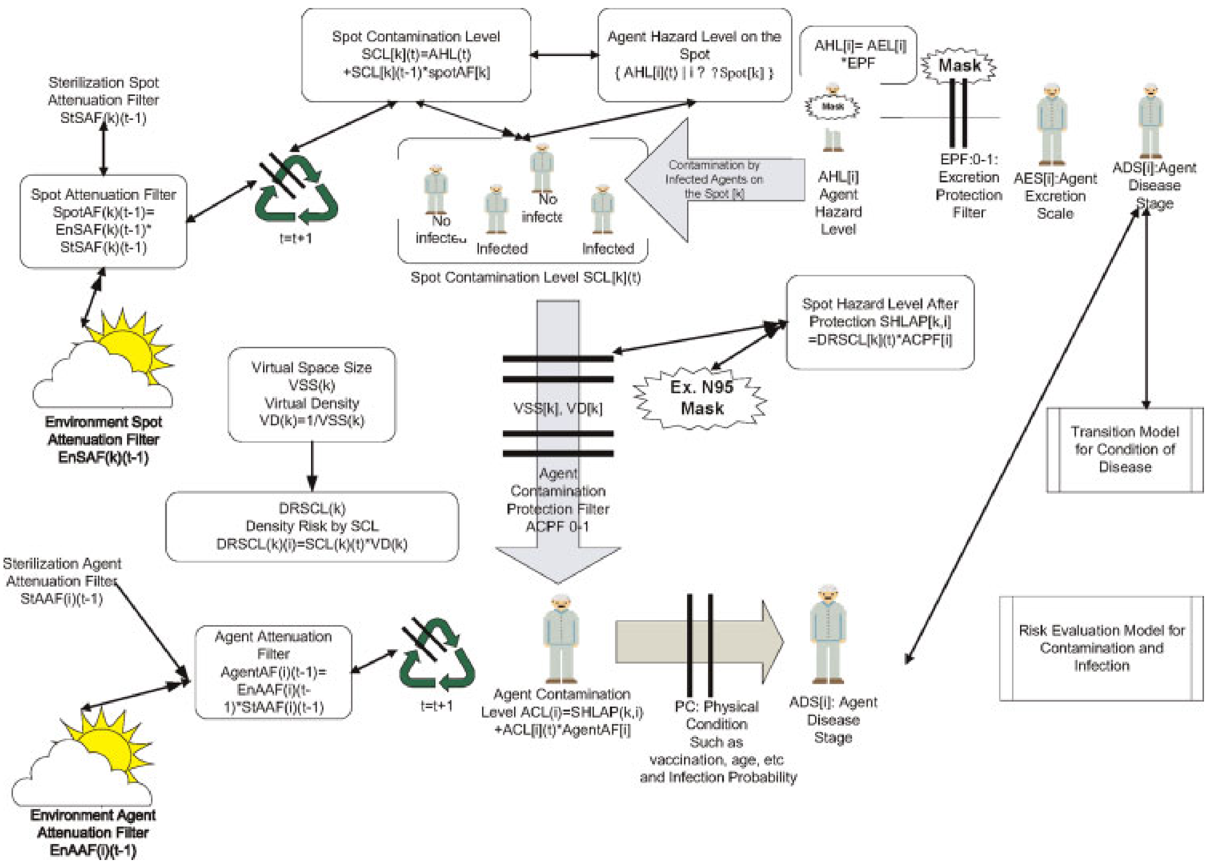

Figure 2. Virus contamination and infection model

Then, this paper introduces the several alternatives of virus protection policies based on the contamination and infection model in a small city. The full model structure of contamination and infection process is shown in Figure 2.

Based on Deguchi's research (Deguchi, 2006; Deguchi *et al.*, 2006), an infected agent has an excretion scale level depending on his disease stage as described by Figure 1. The agent visits a certain spot. Then the agent might use an excretion protection filter such as a mask. The agent hazard level for the spot is defined by the excretion scale and whether the agent is using an excretion filter or not. AHL[i] means Agent Hazard Level of an agent [i], AES[i] denotes Agent Excretion Scale of an agent [i] and EPF[i] indicates the level of Excretion Protection Filter. EPF[i] means the effectiveness of the mask if an agent [i] is using a mask. AHL[k] denotes total agent hazard level of agents in a spot [k].

Spot Contamination Level of a spot [k] is denoted by SCL[k](t); AHL[k](t) is the agent hazard level of a spot [k] at the present step, SCL[k]($t-1$) is the Spot Contamination Level at the previous step, and SpotAF[k]($t-1$) is Spot Attenuation Filter at the previous step. SpotAF[k] denotes the attenuation scale for the previous spot contamination. EnSAF[k] means Environmental Spot Attenuation Filter that is affected by the seasonal changes of climate or controlled humidity in the spot. StSAF[k] indicates Sterilization Spot Attenuation Filter that is controlled by sterilization of the spot. Spot contamination may eventually contaminate each agent in the spot (Figure 2). The infection of an agent depends on his/her physical condition. In this paper, inter-agent infection may be a sequential process from the spot contamination by the infected agents, the agent contamination by the contaminated spot and the agent infection.

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

This paper introduces two types of protection policies that can be used while a spot contamination effects an agent contamination. The one is called the 'virtual space density control', or simply the 'density control'. The density means contact density among agents in a spot. The density is affected by both the activity pattern and the size of the physical among agents. The density can be evaluated by a social experiment. The virtual space density of the home depends on the cultural life style and family structure. The virtual space density is an easier factor to control. The other protection policy is called the 'personal contamination protection by an agent', such as wearing an N95 mask that is effective for protection against the virus. Then, there is density risk. The agent Contamination Protection Filter (ACPF[i]) denotes the effectiveness of the above way of contamination protection by an agent [i]. The possibility of an agent being infected by H5N1 is defined as follows:

$$P(\text{infection of agent }[i]\text{ per Step}) = 1 - \exp(-\mathrm{FP} \times \mathrm{TP} \times \mathrm{ACL}[i]).$$

where TP is called the tick parameter that adjusts the selection of time scale in the simulation and FP (fitting parameter) denotes a parameter for the total calibration.

This paper also assumes a human activity scenario of how agents move among spots in the society or are isolated in the hospital. In this paper, there are 3667 families of 10 000 agents in Bandung City. Figure 3 shows the human activity model in Bandung City.

There are several types of spots in the city such as transportation (bus, train, or mini bus), office, school, yard, hospital, stall (small and big), market and homes. This paper assumes a simple activity of agents. Young and middle age agents

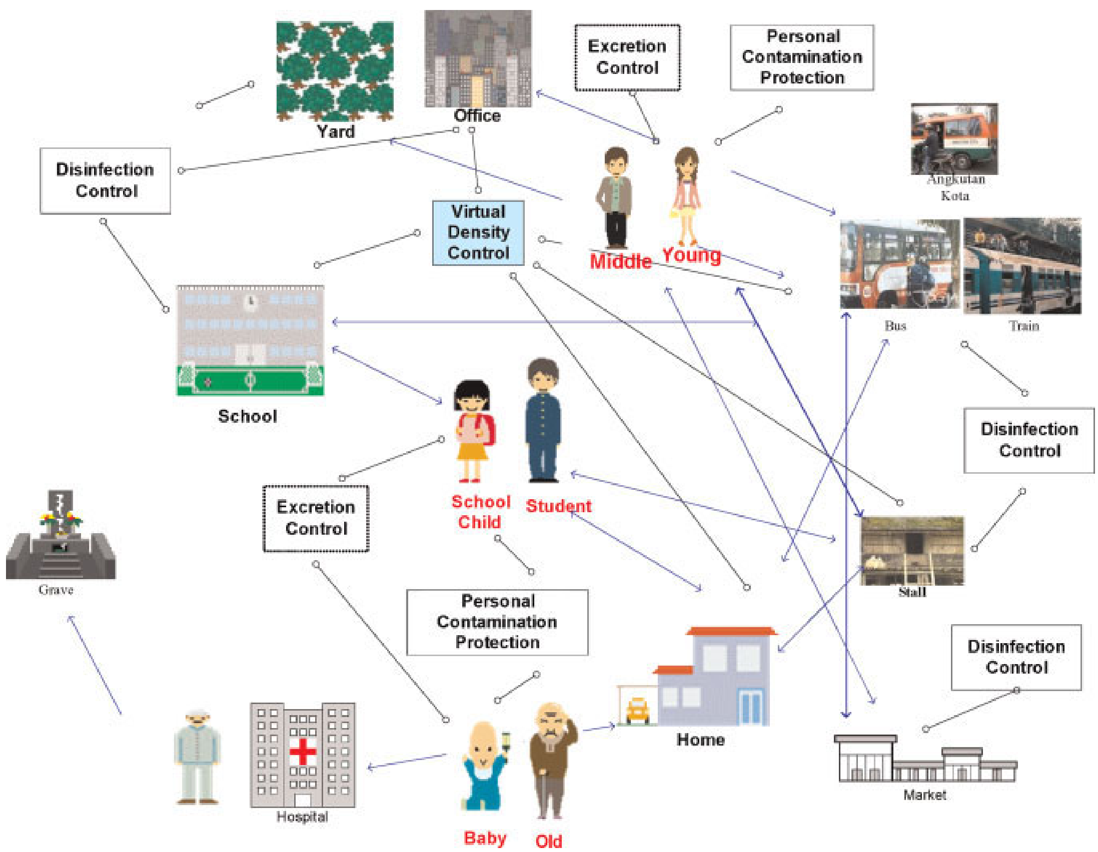

Figure 3. Virtual human activities model in Bandung City

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

go to the office every morning from their own home by transportation and come back to their homes in the afternoon. But, not all of young and middle age agents in Bandung go to the office, some of them go to a yard (they are not employers, but work as entrepreneurs, labourers, etc.), and come back to the home at uncertain times, and they also go to a stall to take care of their animals (birds, chickens, etc.).

Also, if a young and middle age woman is married, usually they do not work, but they will go the market to buy food such as meat, chicken or vegetables. Schoolchildren go to school every morning and come back to their homes early in the afternoon. But not all children in Bandung go to school, some of them go to yards to work as labourers. Old agents stay in their homes in this model, because the elderly in Bandung no longer work, but they still take care of their own animals. If they are infected by H5N1 and their disease stage goes to stage 2, then they go to the hospital. But, if their disease stage becomes 2m then they do not go to the hospital for isolation.

The agents in the hospital go back to the homes and return to their daily lives once they recover, represented by stage 0i. This paper evaluates the effect of social protection filters, that is the humidity control policy (environmental spot attenuation filter), the virtual space density control policy, the excretion protection filter policy, and the agent contamination protection filter policy. The effectivity of the social protection filters is defined as the product of each protection filter.

SIMULATION USING SOARS

In order to simulate this model, this paper combines three modules as shown earlier using SOARS. SOARS is an agent-based simulation language and its application development environment. SOARS was developed at the Deguchi Laboratory under the COE program of the Tokyo Institute of Technology www.absss.titech.ac.jp/en/, www.cs.dis.titech.ac.jp/en/. The objective of this research using the SOARS methodology (Deguchi, 2006; Deguchi *et al*., 2006) is to look at what policy must be implemented by the government to prevent a bird flu pandemic in Bandung City (Figure 4).

Parameter Simulation

Scenarios in this simulation are only focused on *social protection filter policies*. The parameters of this simulation are shown in Table 3.

The parameter for physical condition was taken based on age classification, that is PC_baby = 0.8; PC_schoolchild = 0.8; PC_student = 0.8; PC_young = 0.8, PC_middle = 0 or 0.3; PC_old = 0 or 0.3. The school attendant rate for a schoolchild is 0.5722 and for a student is 0.4112. The job rate for a young agent is 0.3134, middle age agent is 0.2237 and old agent is 0.107.

Data Simulation

Data for this paper was collected from Bandung Dalam Angka (2005). This document lists numbers of people based on age classification, number of members of family, number of public transportations, numbers of offices (big and small office), the school attendant rate, job rate, number of stalls, (small = <2000, big = >10 000), number of hospitals, number of markets, etc. The real data will be scaled (1/10 000) for the data simulation as described by Figure 5.

EXPERIMENTS

This paper focuses only on the social protection filter policy and runs the simulation model four times with different parameters of agent and spot.

Experiment 1

The first experiment is the worst scenario. It uses parameters of agent as: environmental attenuation filter of agent of value 0.9 (the strength of attenuation filter is not the strongest), sterilization attenuation filter of agent, which is not strong or has value 1 (the agent did not use a mask to protect from excretion), agent contamination protection filter, which has value 1 (the protection from contamination by the virus was not the strongest) and excretion protection filter

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

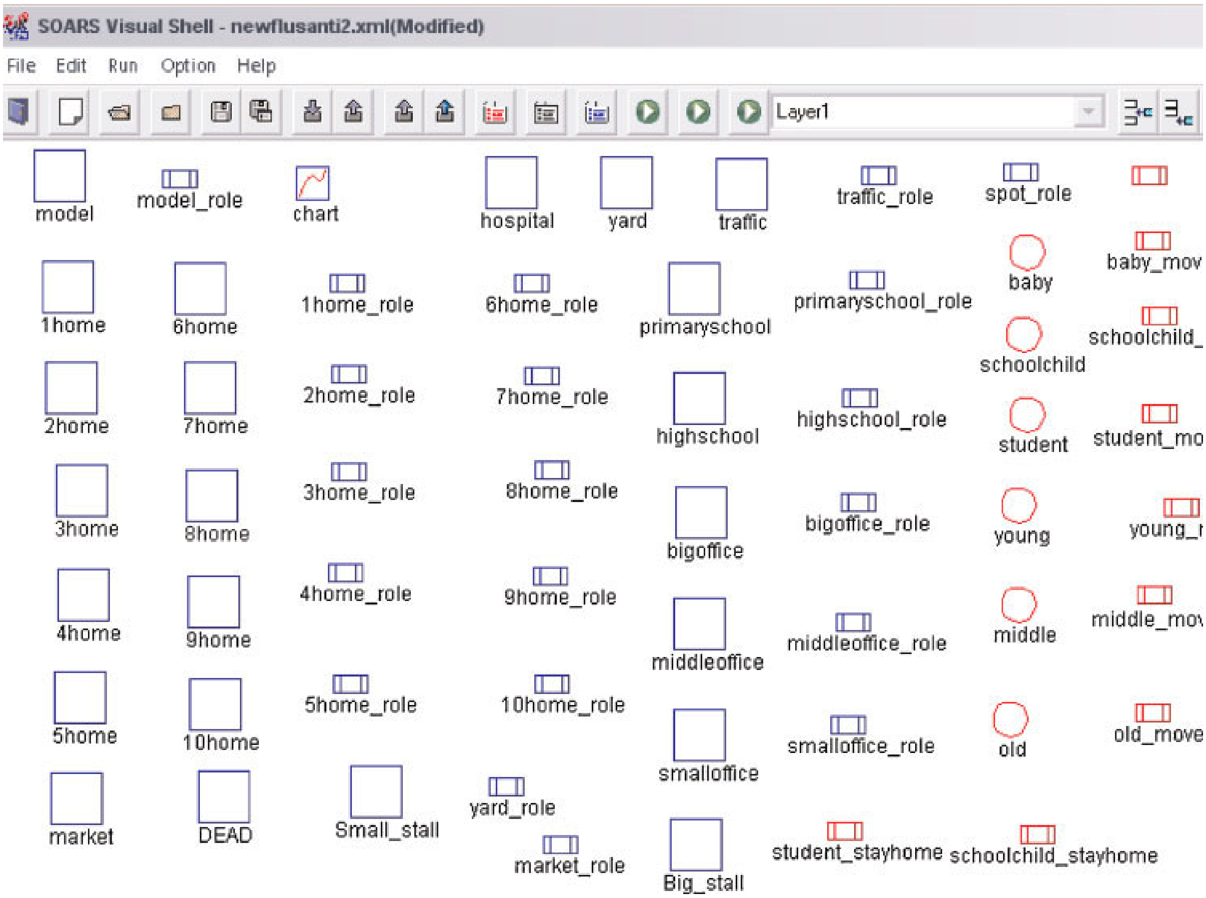

Figure 4. SOARS visual shell modelling for bird flu pandemic

that is not the strongest or has value 1 (the agent did not use a mask to protect from excretion).

The parameters of spot in the simulation are environmental attenuation filter for the big stalls spot, its value is 0.9 (the filter is not the strongest, since there is no filter to protect at the spot of big stalls, such as vaccination), and environmental attenuation filter for the spot of small stalls, which is 0.9 (the filter is not the strongest, since there is also no filter to protect small stalls, such as vaccination). The value of the environmental attenuation filter for spots home, school, transportation (traffic), hospital, market, office and yard has the same value, that is 0.9. It means that the filter was not the strongest at each of these spots, so the virus can be spread readily.

Another parameter of spot is the sterilization attenuation filter. At the spots for big stall and small stall its value is 1 (e.g. where small stall and big stall were not sterile). The values of sterilization for the spots of home, school, traffic, hospital, market, office and yard are 1. This means that the filter was not the strongest at each of these spots, so the virus is spread readily.

The last parameter of spot is virtual space size. This parameter can affect the spread of bird flu virus for each spot. Virtual space size for each spot is 400, which was not too big. The virus can be spread faster in the small spot.

The result of simulation for experiment 1 is described in Figure 6.

From Figure 6, it can be seen that the number of infected people (red line) is 9306 and number of deaths (black line) is 335. The ratio of death for this experiment is 0.03599. This number was very high, because the social filter for agent and spot for experiment 1 was not strong, so the virus spread quickly.

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

Table 3. Parameters for social protection policies simulation

Name of variables	Type 1	Related place in the model	Range and meaning of value
$EnSAF_home	Environmental Attenuation Filter of *Spot*	*Spot* (Home)	0–1 Strength of filter(0:strongest)
$EnSAF_office	Environmental Attenuation Filter of *Spot*	Spot (Office)	0–1 Strength of filter(0:strongest)
$EnSAF_school	Environmental Attenuation Filter of Spot	Spot (School)	0–1 Strength of filter(0:strongest)
$EnSAF_traffic	Environmental Attenuation Filter of Spot	Spot (Traffic)	0–1 Strength of filter(0:strongest)
$StSAF_home	Sterilizing Attenuation Filter of Spot	Spot (Home)	0–1 Strength of filter(0:strongest)
$StSAF_office	Sterilizing Attenuation Filter of Spot	Spot (Office)	0–1 Strength of filter(0:strongest)
$StSAF_school	Sterilizing Attenuation Filter of Spot	Spot (School)	0–1 Strength of filter(0:strongest)
$StSAF_traffic	Sterilizing Attenuation Filter of Spot	Spot (Traffic)	0–1 Strength of filter(0:strongest)
$StSAF_small stall	Sterilizing Attenuation Filter of Spot	Spot (small stall)	0–1 Strength of filter(0:strongest)
$StSAF_big stall	Sterilizing Attenuation Filter of Spot	Spot (big stall)	0–1 Strength of filter(0:strongest)
$StSAF_yard	Sterilizing Attenuation Filter of Spot	Spot (yard)	0–1 Strength of filter(0:strongest)
$StSAF_market	Sterilizing Attenuation Filter of Spot	Spot (market)	0–1 Strength of filter(0:strongest)
$VSS_home	Virtual Space Size of Spot	Spot (Home)	50–1000 (depend on cases)
$VSS_office	Virtual Space Size of Spot	Spot (Office)	50–1000 (depend on cases)
$VSS_school	Virtual Space Size of Spot	Spot (School)	50–1000 (depend on cases)
$VSS_traffic	Virtual Space Size of Spot	Spot (Traffic)	50–1000 (depend on cases)
$VSS_small stall	Virtual Space Size of Spot	Spot (small stall)	50–1000 (depend on cases)
$VSS_big stall	Virtual Space Size of Spot	Spot (big stall)	50–1000 (depend on cases)
$VSS_yard	Virtual Space Size of Spot	Spot (yard)	50–1000 (depend on cases)
$VSS_market	Virtual Space Size of Spot	Spot (market)	50–1000 (depend on cases)
$a	Fitting Parameters	Model Structure	0.5 fixed
$agent_ACPF	Contamination Protection Filter of Agent	Agent (all)	0–1 Strength of filter(0:strongest)
$agent_EPF	Excretion Protection Filter of Agent	Agent (all)	0–1 Strength of filter(0:strongest)
$agent_EnAAF	Environmental Attenuation Filter of Agent	Agent (all)	0–1 Strength of filter(0:strongest)
$agent_StAAF	Sterilizing Attenuation Filter of Agent	Agent (all)	0–1 Strength of filter(0:strongest)

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

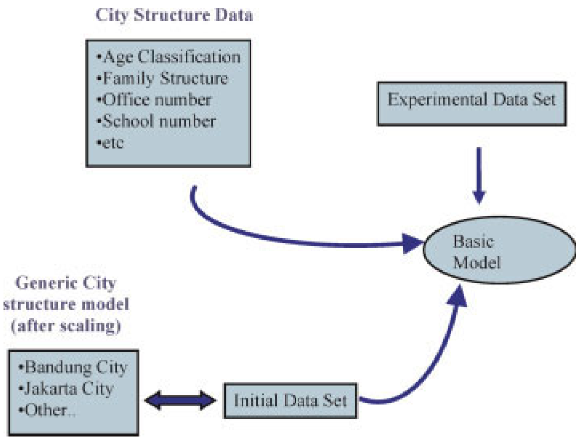

Figure 5. Process of scaling data into simulation

Experiment 2

In the second experiment, parameters of agent were used such as environmental attenuation filter of agent, with a value of 0.5 (the strength of attenuation filter is middle), sterilization attenuation filter of agent that is not strong or has value 1 (the agent was not using a mask to protect from excretion), and agent contamination protection filter of value 1 (protection to contaminate by virus was not the strongest) and excretion protection filter that is not the strongest or has value 1 (agent did not use a mask to protect from excretion).

The parameters of spot in this simulation are environmental attenuation filter for spot big stalls, its value is 0.5 (the filter strength is middle, there is a filter to protect spot big stall, such as vaccination, but it had not been done seriously), environmental attenuation filter for spot small stalls that has value 0.5 (the filter strength is middle, there is a filter to protect spot small stall, such as vaccination, but it had not been done seriously). Values of environmental attenuation filter for spots home, school, traffic, hospital, market, office and yard are 0.5. This means that the filter strength was middle at each spot, so the virus can still be spread.

Another parameter of spot is sterilization attenuation filter for spot big stall and small stall that has a value 1 (i.e. small stall and big stall were not sterile, because there is no filter to protect, especially if there are dead chickens in the stall). The values of sterilization for spots home, school, traffic, hospital, market, office and yard are 1. This means that the filter was not the strongest at each spot, so the virus can be spread, because the spots were not clean from the virus.

The last parameter of spot is virtual space size. This parameter can affect the spread of bird flu virus for each spot. Value of virtual space size for each spot is 150, which denotes a small size. The virus can be spread faster in the small spot. The result of simulation for experiment 2 is described in Figure 7.

From Figure 7, it can be seen that the number of infected people (red line) is 8403 and number of deaths (black line) is 292. The ratio of death for this experiment is 0.03475. This number is high, but it is not higher than experiment 1. The

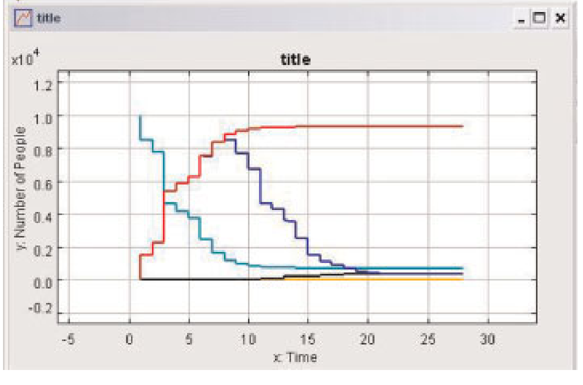

Figure 6. Number of infected and dead people in Experiment 1

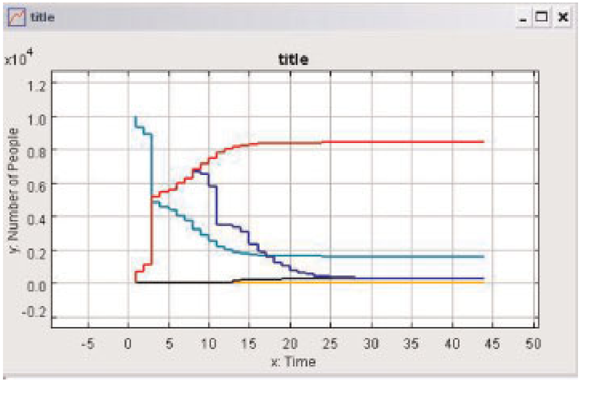

Figure 7. Number of infected and dead people in Experiment 2

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

strength of social filter for agent and spot for experiment 2 was only middle (not too strong), so the virus can still be spread through the air.

Experiment 3

In the third experiment, this paper uses parameters of agent of environmental attenuation filter, value 0.1 (the strength of attenuation filter is almost strong), sterilization attenuation filter of agent that is not strong or has a value of 1 (agent was not using a mask to protect from excretion), agent contamination protection filter of value 1 (protection from contamination was not the strongest), and excretion protection filter that is not the strongest or has value 1 (agent did not use a mask to protect from excretion).

The parameters of spot in this simulation are environmental attenuation filter for spot big stalls, its value is 0.1 (it means that the filter is almost strongest, there is a filter to protect spot big stall, such as vaccination, etc.), and environmental attenuation filter for spot small stalls, its value is 0.1 (it means that the filter is almost strongest, there is a filter to protect spot small stall, such as vaccination). Values of environmental attenuation filter for the spots of home, school, traffic, hospital, market, office and yard are 0.1. This means that the filter was almost strongest at each spot, so the virus could not be spread easily.

Another parameter of spot is sterilization attenuation filter for spot big stall and small stall, its value is 1 (small stall and big stall were not sterile, because there is no filter to protect, especially if there are dead chickens in the stall). The values of sterilization for the spots of home, school, traffic, hospital, market, office and yard are 1. This means that the filter was not the strongest at each spot, so the virus can spread over a wide area, because the spots were not clean from the virus.

The last parameter of spot is virtual space size. These parameters can affect the spread of bird flu virus for each spot. Virtual space size for each spot is 200, which was not too big. The virus still can be spread in this size of spot. The result of simulation for experiment 3 is described in Figure 8.

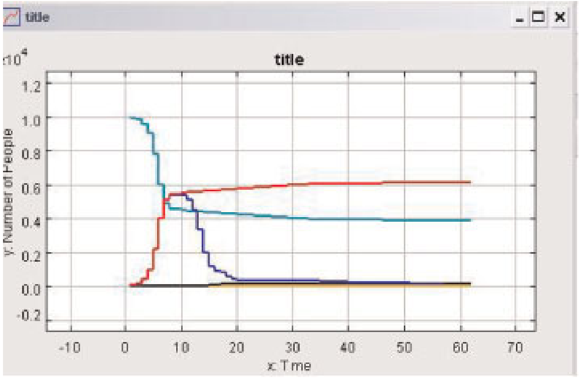

Figure 8. Number of infected and dead people in Experiment 3

From Figure 8, it can be seen that the number of infected people (red line) is 6090 and number of deaths (black line) is 173. The ratio of death for this experiment is 0.02841. This number is lower than the previous experiment. The strength of social filter of agent and spot for experiment 3 was almost the strongest, so the virus could not spread easily.

Experiment 4

In the last experiment, this paper uses parameters of agent such as environmental attenuation filter of agent, its value is 0.2 (the strength of attenuation filter is almost strong), sterilization attenuation filter of agent, which is not strong or has value 1 (agent was not using a mask to protect from excretion), and agent contamination protection filter, which has value 1 (contamination protection of virus was not the strongest), and excretion protection filter that is not the strongest or has value 1 (agent did not use a mask to protect from excretion).

The parameters of spot in our simulation are environmental attenuation filter for big stalls spot, its value is 0.0 (the filter is the strongest, there is a filter to protect spot big stall, such as vaccination), and environmental attenuation filter for spot small stalls that has value 0.0 (the filter is the strongest, there is a filter to protect spot small stall, such as vaccination). Values of

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres

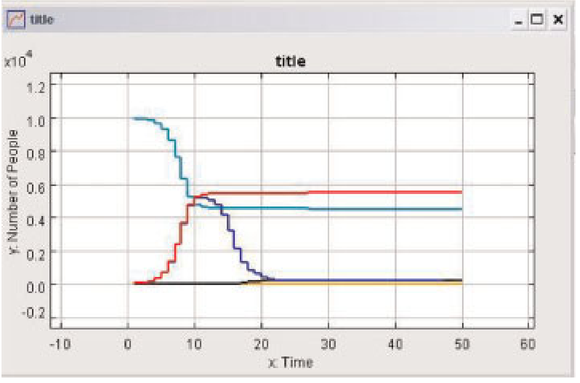

Figure 9. Number of infected and dead people in Experiment 4

environmental attenuation filter for the spots of home, school, traffic, hospital, market, office and yard are 0.0. It means that the filter was the strongest at each spot, so the virus could not spread easily.

Another parameter of spot is sterilization attenuation filter for big and small stalls, its value is 1 (small stall and big stall were not sterile, because there is no filter to protect, especially if there are dead chickens in the stalls). The values of sterilization for the spots of home, school, traffic, hospital, market, office and yard are 1. It means that the filter was not strongest at each spot, so the virus can spread widely, because the spots were not clean from the virus.

The last parameter of spot is virtual space size. This parameter can affect the spread of bird flu virus for each spot. Virtual space size for big stall spot is 400 and small stall is 50, which was not large. For each spot like home, traffic, office, yard, market and hospital, its size is 400. So the virus still can spread in the spot since its size was not large. The result of simulation for experiment 4 is described in Figure 9.

From Figure 9, it can be seen that the number of infected people (red line) is 5499 and number of deaths (black line) is 191. The ratio of death for this experiment is 0.03473. This number is lower than the previous experiments. The social filter for agent and spot for experiment 4 was the strongest, so the virus could not spread easily.

CONCLUSION

Based on the results of simulation of social protection policies using the methodology of SOARS, it can be seen that the number of people who are infected and die averages 3%. With current government policy (without the social protection policies) the average is about 33%. Hence this research concludes that social protection policies such as the usage of masks (virus of excretion control), control of attenuation of contamination protection filter with dampness and sterilization, controlling the density of the room (control density space virtual) in school, market, yard, home and transportation such as bus and mini bus, and controlling personal protection like sanitation, are very important in preventing a bird flu pandemic in Bandung City.

REFERENCES

Axelrod R. 1997. *The Complexity of Cooperation. Agent-Based Models of Competition and Collaboration*. Princeton University Press: Princeton, New Jersey.

Bandung Dalam Angka. 2005. *Badan pusat statistik propinsi*, Jawa Barat.

Bharwan N. 2000. *Model State Influenza Pandemic Preparedness and Response Plan*. Ministry of Health and Family Welfare: New Delhi, India.

Deguchi H. 2006. *Program and Project Design for Pandemic Protection via Social Simulation*. Tokyo Institute and Technology: Japan.

Deguchi H, Kanatani Y, Kaneda T, Koyama Y, Ichikawa M, Tanuma H. 2006. *Anti Pandemic Simulation* by SOARS, *SICE-ICASE International Joint Conference*, October 18–21, Bexco, Busan, Korea.

Departemen Kesehatan Republik Indonesia. 2007. *Kasus Flu Burang Terkonfirmasi* 2O Maret 2007. Website http://www.depkes.go.id/index.php?option=news&task=viewarticle&sid=itemid=2

Putro US. 2000. Adaptive learning of hypergame situations using a genetic algorithm. *IEEE Transactions on Systems, Man, and Cybernetics* **30**(5): 562–572.

Putro US, *et al*. 2005. Agent Based Modeling and Simulation of Knowledge Management, *Proceedings of the IFSR Conference, Kobe, Japan*.

WHO (World Health Organization). 2008. website http://www.who.int/csr/disease/avian_influenza/avian_faqs/en/

Syst. Res. **25**, 663–673 (2008)
DOI: 10.1002/sres