Construction of Artificial Life Model for Urban Transport Analysis

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Abstract – Urban transport phenomenon on introduction of transport policy is complex. Change process of traffic condition and interaction of trip makers are influenced to the effect of tranceportation policy. Interaction of mode choice of commuters and traffic flow esimation is descreibed with the artificial life approach in this study. The system has the bottom up process of element activities to produce the overall system behaviour. The model for decision of commuter and traffic flow estimation model are combined interactively. The artificial life approach might provide the knowledge to consider the advanced traffic management improving the traffic flow with self-organized traffic pattern.

I. INTRODUCTION

Urban transport phenomenon is complex. Dynamics of interaction arise within both system itself and the enviroment. Analizing the change of commuter mode choice in the transient period after introduction of urban transport policy is important. It infulences to efficiency of policy after convergence to constant traffic condition.

On the other hand, artificial life is a term originally intended to mean the simulation of macroscopic behavioral aspects of living beings using microscopically simple components. The emergence phenomenon with the self-organization of agents might be observed in the artificial life system of urban transport network. It corresponds to the microscopic transport phenomena derived from the summary of microscopic behaviours [1].

Artificial life model is constructed for observation of emergency process on urban transport in this study. The complex system has been introduced to analyze the social phenomena differently from the traditional reductionism approach. Change of commuter mode choice and traffic flow condition from day to day are described as the multi agent simulation. The effect of tranport policy can be observed with different intial conditions. The important factors can be distinguished to produce the effective market condition though the observation of emergence by local interaction.

II. CONSTITUTION OF ARTIFICIAL SOCIETY

Artificial society is composed with agent, enviroment and rules as the basic elements of multi agent simulation.

A. Condition of Urban Transport

Artificial society for urban transport analysis is constructed in this study. The solution for traffic congestion problem in the real world can not be given by urban transport analysis in the artificial society. However, the suggestion for congestion problem in the real world can be given through the analysis with reference to the real area.

Unexpected observation might be useful for urban transport analysis in the real world.

Commuting is only described as activity of agents in the artificial society. Alternative modes for commuting are illustrated in **Figure 1**.

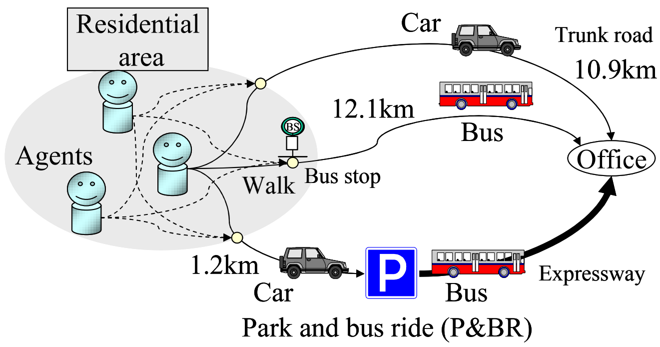

Figure 1. Alternative modes for commuting

Two modes (Car and Bus) can be available for agents from the initial condition. The park and bus ride (P&BR) system will be introduced as the implementation of urban transportation policy for transportation demand management (TDM), as the traffic congestion in the morning is a serious problem. Therefore, it is assumed that the agent who choose the P&BR make a trip with two sections such as from the residential area to parking place for P&BR as well as from express bus stop to the city centre. As the area of the city centre is small, the egress time to the office is negligible.

In term of land use, the residential area is divided into the 40,000 (=200^2) blocks. Origin of 730 agents are located in a block of the residencial area. The outline of residential area is illustrated in **Figure 2**.

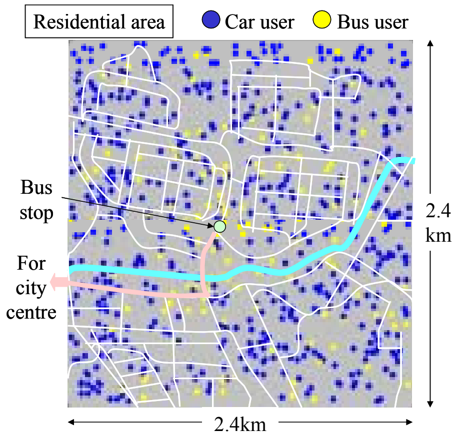

Figure 2. Agent location in residential area

Each dot is denoted as the agent location in the artificial society. White line representes the street network in figure.

B. Agents as the Commuter

An agent is defined as an actor which behaves in the artificial environment. It is assumed that agents repeat only commuting every day. An individual agent has the internal conditions and rules for the decision of commuting mode.

(1) The internal conditions of agent

The internal condition is determined with the constant elements and changeable elements related with the external circumstances and interaction of agents. Individual attributes for commuter is shown in **Table 1**.

Table 1. Individual attributes for agent

Indivisual Attributes	Setting
Adress [x, y]	0<x<2400, 0<y<2400
Value of time [yen/min]	μ=25,σ=5
Car cost [yen]	μ=760,σ=100
Car ownership	holder : 90%, non holder: 10%
Car lisence ownership	holder: 80%, non holder: 20%
Limit of bus access length [min]	μ=10,σ=5
Limit of bus waiting time [min]	μ=15,σ=5
Limit of bus congestion	μ=1.3,σ=0.3

It is assumed that the preference of agents in making the decision for commuting mode can be described according to characteristic of individual attributes. Individual attributes are determinded with normal random number at the initial priod. The proportion of individual attribute is defined based on observation result of the regional person trip survey.

(2) Rules for decision making

The mode choice behaviour for commuting is described with the two stages. The first stage is limitation of alternative choice set and the second stage is decision of commuting mode.

The available set of modes for each agent is different from others. The availability of car mode is determined based on the two individual attributes such as car licence ownership and car ownership. If the agent can not use car mode, the bus mode only can be available.

On the other hand, the availability of bus mode for the agent with car and licence is determined based on access length to the bus stop, waiting time at the bus stop and congestion level of passenger seat of bus.

C. Traffic Enviroment Situation

The travel time of car is determinded according to the number of car users. The travel time of link i is described with the performance function in formula (1).

$$t_i = t_{i0}\left\{1 + 0.15\left(\frac{x_i}{q_i}\right)^4\right\} \qquad (1)$$

t_{i0} :Travel time of link i with zero flow,

x_i :Flow of link i, q_i :Capacity of link i

Increace of travel time with traffic concentration can be described with the fomura (1).

On the contrary, bus travel cost is always set to 500 yen, where as car travel cost is set to normal random number considering fuel consumption, parking fee and upkeep of vehicle.

III. URBAN TRANSPORT ANALYSIS WITH ARTIFICIAL LIFE MODEL

Urban transport phenomenon in the artificial society is described in this section. The commuting behaviour of agents from day to day are estimated with multi agent simulation

A. Structure of Artificial Life Model

The essential points of multi agent simulation can be summarized that the social structure can be emerged as population behaviour through the interaction of agents in the environment according to the determined rules depending on the acquired information and ability of agents[2]. The mode choice behaviour of commuter is estimated in the agent mode choice model. On the other hand, traffic flow on urban network should be estimated summarizing the individual behaviours of commuter in traffic flow model. The outline of the multi agent simulation is shown in **Figure 3**. The simulator consists of two interactive procedures such as traffic flow model and agent mode choice model.

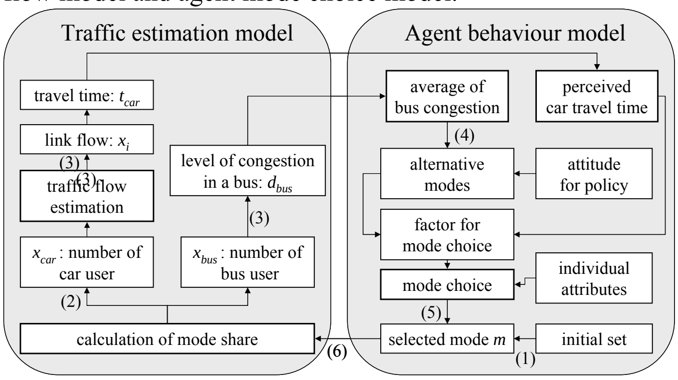

Figure 3. The structure of Artificial Life System

The left structure represents the global system and the right structure for many agents. It is derived as a result of interactive behaviour between the agents and the global environment [3],[4].

The procedure for daily traffic in the simulation is summerised as follows;

(1) Initial commuting mode is determinded in individual agent.

(2) From the result of decisions for all commuting agents, the OD traffic and path flow on the network could be estimated by assembling individual behaviour.

(3) Travel time of car and level of congestion in a bus should be memorized as a result of commuting by selected mode.

(4) If the decision period of individual agent has come, alternative modes are reconsidered with attitude for policy.

(5) Commuting mode is determined for individual agent during the priod of mode choice.

(6) The traffic flow on the next day is considered (go to (2)).

The constitution of the artificial society and individual attributes of agent are defined as above.

Commuting mode is determined based on available modes. The generalized travel cost is adpoted as the index for dertermination of commuting mode. The generaized travel costs can be calculated fromt the formula (2) and (3).

$$gc_i^{bus} = c^{bus} + \mu_i \times t_i^{bus} \quad (2)$$

$$gc_i^{car} = c^{car} + \mu_i \times t_i^{car} \quad (3)$$

c^{bus} :bus travel cost, t_i^{bus} :bus travel time, μ_i : value of time, c^{car} :car travel cost, t_i^{car} :car travel time

Travel cost is common for all agents. On the contrary, travel time is updated with experience of commuting behaviour.

B. Learning Process of Agent

The commuting mode in real world can not be decided from day to day. The commuting mode is selected from the evaluation result for a certain period. Timing of decision making for each commuter is differnet from others.

The commuting mode of agent in the artificial society is determined for every month (25 days). The first day of decision making is set up at random within 25 day.

The update of knowledge by travelling experience of an agent is described in **Figure 4**.

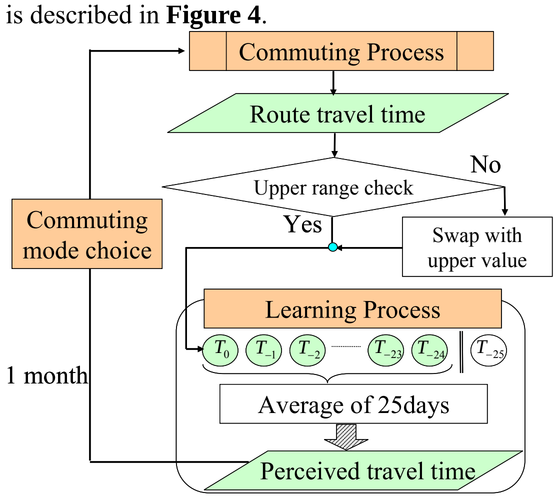

Figure 4. Update perceived travel time with experience

Perceived travel time of agent is updated with travelling experience. Therefore, the driver can accumulate the experience corresponding to actually used route [5][6]. The agent can memorize the experience travel times of 25 days. Average of these travel times can be calculated as perceived travel time of agent.

It settles with a traffic condition as the result of the mode choice of the autonomy based on the empirical knowledge of an individual agent. It feedback into the learning with recognition of an individual agent.

C. Simulated Traffic Condition

The simulation of traffic flow in artificial society has been performed with several different initial conditions. The cases are determined as different share rates of car at the initial stage of simulation. **Figure 5** summarize the time series change of number of car users corresponding to the initial conditions. The results in seven cases can be shown in the figure.

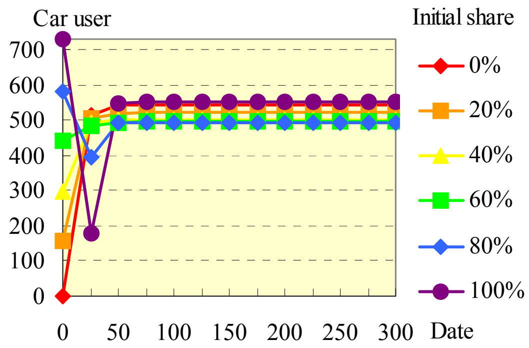

Figure 5. Time Series Change of Car Share

Even though the initial conditions are defined differently with extremely large range, the share rate of car tends to terminate similar value after 100 days iteration. The number of car users among the cases comes to be around 500 in the stable situation of traffic. The car users seem to be automatically produced as a result of learning of agents in the artificial society. In other words, the share rate of mode might not be influenced by the initial condition of modes in the society. The observation can be regarded as an example of user equilibrium even in the artificial society.

In general, the different definition of attributes for agents may provide the different structure of the society. At the same time, the urban transport condition as an environment of society affects the attitude of agent through the feed back influence. Therefore, the emergence of the society might be observed through the day to day simulation.

In the previous simulation, it is assumed that all agents hold a car as well as driver's license. The share rate of car is estimated as 82 percent in the stable stage. The spatial distribution of modes for commuter is shown in **Figure 6**.

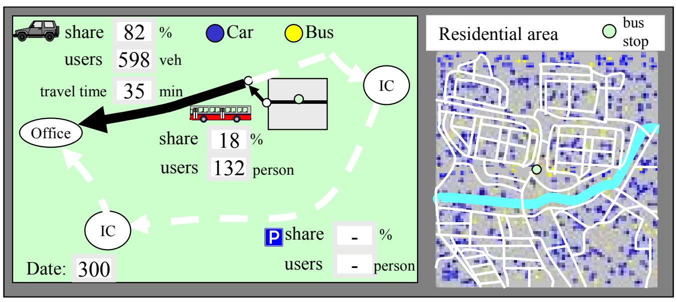

Figure 6. Spatial Distribution of Commuter with Mode

Blue and yellow dots indicate car user and bus users respectively.

It is observed that bus users distribute the roadside of streets connecting to the bus stop as indicated in white lines.

IV. Evaluation of Urban Transport Policy

The phenomenon of emergence from the self-organization of agents might be observed at the implementation of P&BR system in the artificial society .

A. Introduction of Urban Transport Policy

The government in the society considers the introduction of P&BR as a transport policy. A car park with high capacity is assumed to be constructed near the bus station. Therefore, the mixed mode trip for commuters is provided with changing from car to bus at bus station.

The charge of parking and the express bus for P&BR system are defined as 600 yen. The travel time by express bus from bus stop near the parking to the city centre is 27 minutes. The generalized travel cost of P&BR system is smaller than other modes at the initial condition.

Even if the government promote for commuters to use P&BR system, the commuters may not always accept the proposal. Therefore, the reactions of commuter to the introduction of transport policy would be classified. Three types of agents are defined in the artificial society.

The policy taker is the agent who takes P&BR system into account as an alternative of commuting mode. The second type agent is anti policy commuter who insists not to accept the government proposal. Therefore, the agent never introduces P&BR into the set of alternative modes. The third type agents belong to the floating class of commuter. The agent determines to accept P&BR after the observation of surroundings. According to the classification of the agent reaction, the distribution of specific agents in the society can be indicated as (25%, 50%, 25%) corresponding to the proportion of (type 1, type 2, type 3).

Change of mode share in case of introduction of P&BR can be observed in the artficial society. In this section, it is assumed that the commuting mode of agent is determind by learning without interaction of agents. The mode of P&BR system can not be choosen by type 2 and type 3 of agents. Time serises of share of P&BR is illustrated in **Figure 7**.

It can be observed that the traffic condition is converged within 50 days after the implementation of the P&BR system.

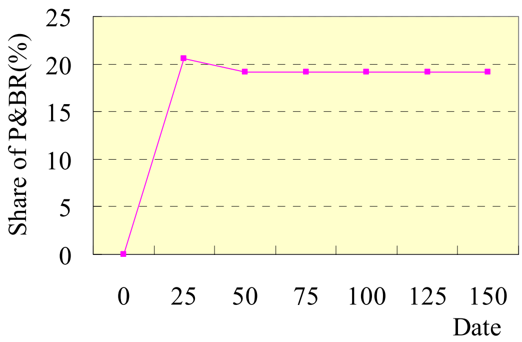

Figure 7. Time Series of P&BR Share

The share of P&BR system is smaller than other modes, though the generalized travel cost of P&BR system is smaller than other modes.

B. Interaction of Agent

The number of user with the introduction of urban traffic policy can be observed smaller than expected number in several cases. Traffic demand with the introduction of urban traffic policy is expected in the prediction method of a traditional reductionism approach without interaction of constitution elements. The additional mode with urban transport policy may not be acceptable by any commuter in the policy with addition of the alternative choice such as P&BR in particular.

It is assumed that the attitude of agent can be affected by the surrounding commuter condition. It means that the agent tends to change the attitude from the observation of behaviour distribution of neighbours. The mechanism of attitude change for the agent is summarized in **Figure 8**.

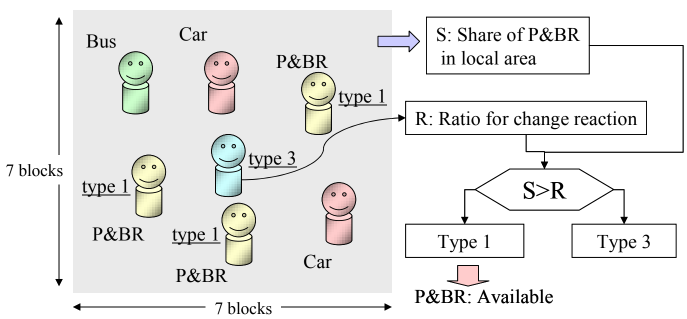

Figure 8. Change Attitude of Agent with Interaction

The intensity of interaction between agents is determined in proportion to the distance. The neighbour commuters are defined as the agents located within three cells distance to the target agent. Therefore, it corresponds that the agent may observe the area consisting of forty eight cells.

C. Consideration with Initial Share of Policy taker

The expected share of P&BR is analyzed considering the distribution of agent types in the society. As mentioned previously, local interaction between agents should be essential to determine the behaviour of the society. If local interaction cannot be formulated, the evolution of the society is only observed through the feedback between the agents and the environment. On the contrary, if local interaction is formulated in the simulation, the emergence in the society might be observed as unexpected result.

Therefore, the share of policy takers is determined as initial condition in the simulation assuming interactive agents as well as independent agents. The initial share rate is altered from 5 % to 25 % for three cases. Therefore, the proportion of agents is assumed as (5%, 50%, 45%), (10%, 50%, 40%) and (25%, 50%, 25%).

Figure 9 shows the share of P&PR in the stable condition of 150 days for each case.

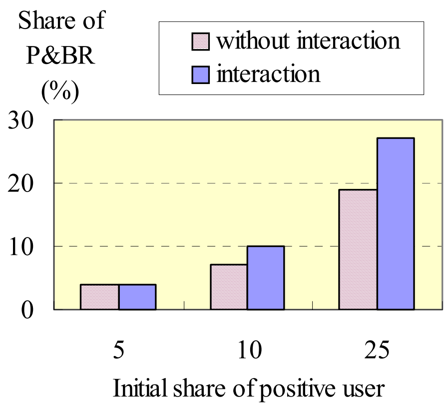

Figure 9. P&BR Share with Interaction

The share of P&BR terminates with higher rate corresponding to the initial proportion of policy takers. The local interaction obviously produces high share rate of P&BR in any initial condition. It is a sort of emergence that number of P&BR agents increases more rapidly though the spread effect in local interaction. The experiment suggests that the government should have a scheme to provide many policy takers at initial stage of the implementation of P&BR.

D. The emergence in spatial distribution

It is quite interesting in artificial life approach to observe the emergence in the self-organization of the system. It corresponds to the observation of transport deformation in the artificial society. In particular, spatial distribution of transport mode is helpful to find out the emergence in the society. **Figure 10** shows the spatial distribution of agents with commuting mode as coloured dots for three alternatives. The illustration corresponds to the third case with policy taker with 25 percent as previously mentioned. The distribution of the initial stage is illustrated in top diagram. The distribution in the stable stage as 150 iterations is illustrated in bottom diagram as well.

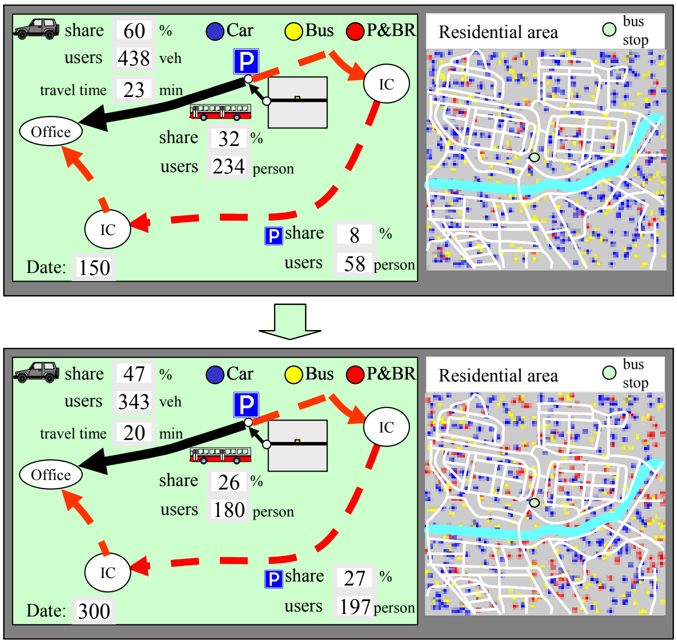

Figure 10. Change of P&BR User Distribution

The distribution of dots for P&BR in stable stage tends to distribute on the area with high density of policy takers in initial stage. Furthermore, several clusters of red dots can be found in the bottom diagram. The specific spatial distribution would be regarded as a result of emergence of the system through self-organizing mechanism.

V. Concluding Remarks

The primitive artificial life model for urban transport is constructed in this study. The decision of commuting mode is also described. Time series observation of commuting mode becomes available in the artificial society. The major results of the study are summarized as follows;

(1) The basic structure of artificial society simulation is discussed for analysing the urban transport policy. In particular, the behaviour of agents can be formulated with learning process as well as local interaction with considering the problems in real transport system.

(2) The reaction of agent to the government transport policy is specified to analyze the requirement for the government to promote the P&BR system. The share of P&BR is strongly affected by the initial distribution of types of agent even through local interaction among the agents.

(3) The emergence of the system can be observed in the spatial distribution of agents. The initial distribution tends to determine the overall patterns in the stable stage of the society. It is concluded that the self-organizing should be analyzed for practical implementation of P&BR even from a few examples.

Some further studies are recommended as follows;

(1) Collective decision making in the block of residential area for transport policy should be described by considering the cooperation of action of agent. The judgment process might be descrived with fuzzy logic

(2) According to type of transport policy, the travel behaviour model should be expanded. Travel behaviour model for commuting should be described not only with mode choice but also route and deperture time choice.

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