MODELLING BEHAVIOURAL CHANGE IN A SOCIAL DILEMMA OF COMMUTERS' MODE CHOICE

Yos Sunitiyoso
PhD Student
Centre for Transport and Society, University of the West of England

Shoji Matsumoto
Professor
Dept. of Civil and Environmental Engineering, Nagaoka University of Technology

Abstract

Our research attempts to apply an agent-based approach to modelling travel behavioural change in a transportation system. Utilizing the advantage of agent-based model of being validated at an individual level, a social dilemma situation of travel mode choice is modelled and viewed as a complex system. Behavioural process of individuals is examined in an agent-learning model considering psychological and sociological aspects.

A traveller is modelled to have expectations, which shows his beliefs about the influence of his action on other members of the group, as decision making rules. Two classes of beliefs are considered in the model: bandwagon and opportunistic expectations. Social interaction using a group-based interaction is hypothesized to be important to solve the social dilemma. We apply an imitation game based on social learning mechanisms to the traveller model in order to evolve the rules of each traveller. Two kinds of mechanism are used: payoff-biased transmission and conformist transmission.

The model revealed that some insightful results could be obtained, such as the conditions that make cooperation as a possible outcome. They are group-based interactions, limited information, and conformist transmission. Emergent phenomenon of the system may favour cooperation and resolve the dilemma of travel mode choice, if a strong conformist transmission presents. This gives an insight to the possibility of solving the social dilemma by incorporating an employer-based Travel Demand Management (TDM) measure.

Keywords: travel mode choice, social dilemma, agent-based approach, beliefs and expectations.

1. Introduction

In the field of artificial intelligence, agent-based approaches are familiar to researchers. But in transportation modeling, this approach is still not as widely used as equation-based approach. Most of models in transportation planning and analysis area rely on the equation-based modeling. In the equation-based modeling, the model is set of equations, and execution consists of evaluating them (Parunak et al, 1998). It assumes homogeneity among individuals, but individuals in real systems are often highly heterogeneous. The models, as well as agent-based models, can be validated at the system level, by comparing model output with the real system behaviour. But agent-based model can be validated at the individual level, since the behaviours encoded for each agent can be compared with local observations on the actual behaviour of the domain individuals. Understanding people's behaviour is important especially in studying effects of a policy in transportation. Agent-based approaches enable us to learn about individual way of thinking, making decision, and learning.

An agent-based model is defined as a computational model, which represents individual agents and their collective behaviour (Shalizi, 2003). An agent-based model steers us toward representing individuals, their behaviours and their interactions, rather than aggregates and their dynamics. It has also been stated the importance of agent-based modelling on building simulation model in social sciences (Axelrod, 1997).

Many of agent-based models in transportation have focused on travel route choice, focusing on day-to-day simulations. Several works on route choice behaviour by Nakayama et al. (1999, 2001) and Nakayama and Kitamura (2000) are the examples of agent-based approach in transportation modeling. Travellers are modeled to have bounded rationality, limited information and also capability to do cognitive learning. Klugl and Bazzan (2004) also studied route choice behaviour by using a simple heuristic model. They also simulated agents' learning to avoid a Braess Paradox by considering agents' past experiences and adaptation (Bazzan and Klugl, 2003).

A philosophical and cognitive science-based framework, which is named as belief-desire-intention (BDI), was used for modelling route choice behaviour Rosetti et al. (2002). Route choice and departure time choice behaviour of commuters' were modeled by endowing mental attitudes embedded in BDI framework. Dia (2002) simulated route choice behaviour of commuters under the influence of real-time information, also incorporating BDI framework. These researches demonstrated the feasibility of agent-based approaches to develop more complex driver behavioural dynamic.

In travel mode choice, there are not so many works done by researchers. One of the inspiring works by Kitamura et al (1999) is on travel mode choice by using a simple bi-modal transportation system and cellular automata. Agent-based approach made possible many things that could not be observed in conventional approach.

Travel mode choice

Commuters of different types will exhibit different decision-making behaviour not only on departure time choice but also on mode choice. The choice of transport mode has been considered as one of the most important classic models in transport planning (Ortuzar and Willumsen, 1990). The reason is the key role played by public transport in policy making. Public transport modes make use of road space more efficiently than private car. If some drivers could be persuaded to use public transport instead of cars, the rest of the car users would benefit from improved levels of service as the traffic is less congested. But car use provides the individual driver with a number of immediate advantages, it appears to be a cheap form of transportation, it creates feelings of freedom and independence, and it is efficient and convenient.

There are many alternative modes that could be used for work trip. Such as: private car, bus, railway, tram, cycles and walking. In this study, we utilized the most simple bi-modal transportation system, which consists of private car and bus. Those modes are operated in a mixed lane, so that the interdependence of these two choices is high. Public transports, which operate on exclusive lanes such as rail-based transits and bus with exclusive lane, do not face the same situation as mixed-lane operated public transports. Mixed lane public transports operate on the same lanes with private car, so that they will experience same congestion as private cars when there are too many private cars on the road.

People have many different motives that encourage them to use car, such as minimizing the costs of travel time and travel time variability, as studied by Van Vugt et al (1996). Some people drive their cars even for short trips mainly because they were carrying heavy goods, giving lifts, in a shortage of time, and they needed the car for another trip (Mackett, 2003). Car use has a link to feelings of independence and convenience, so that little progress may be expected by requesting individual drivers to voluntarily reduce car use (Tertoolen et al, 1998). Decision to commute by car or public transportation not only bears an impact on the existence of individual commuter, but also on the existence of the others. As more individual commute by car, people may experience the negative consequences of the traffic congestion and environmental pollution. It is in the interest of all if more people decide to commute by public transportation, which would minimize the contributions to congestion and pollution. This particular type of interdependence with conflicting individual and collective interests can be framed as a social dilemma.

Social dilemma

A social dilemma is defined by two properties: First, the social payoff to each individual for defecting behaviour is higher than the payoff for cooperative behaviour, regardless of what the other society members do. Second, all individuals in the society receive a lower payoff if all defect than if all cooperate (Dawes, 1980). Social dilemmas cause inefficiencies, because an equilibrium state does not yield optimal performance.

A famous example of social dilemma is the "The Tragedy of the Commons" (Hardin, 1968). In general concept, the commons is any resource, which is shared by a group of people. In the paper, the commons refers to land to graze goats, cattle or sheep. The commons in our study refers to road or highway for travel. The logic of the commons is each user has the right to use the road to commute by using car or public transport.

There are several kinds of social dilemma categorization done by researchers. But, basically there are only three important types as described in a work of Komorita et al. (1991). They are prisoners' dilemma, chicken dilemma and trust dilemma. The commuting mode choice between by private car (defective choice) and by public transport (cooperative choice) is categorized as chicken dilemma game. When most of people using bus, some people will become free-riders by using car since the road is less congested and the cost of traveling by car is cheaper. On the other hand, when the road is full of private car users and became congested, bus users experience less cost of traveling even though they also experience same congestion as private car users, since a car user values travel time higher than a bus user does.

Solving the Dilemma

Solving social dilemma is important in order to keep the existence of public transit services. Roadway performance decreases with increasing volume: when there are more users on the road, the speed of travel decreases. However, transit performance can increase with increasing volume: greater fare revenues allow the transit operator to increase service density. The loss of transit customers will cause a loss of revenue for the transit operator, who, in the absence of increasing subsidies, will raise fares or cut service. The resulting deterioration of transit service causes even more people to switch modes, causing further congestion on the road facility. The positive feedback in the transit system is that transit becomes more viable and more attractive when more people use it. But, it needs to be strong enough to compete with car. The existence of selfish behaviour and dependence on car-based commuting usually reduce the attractiveness of public transport.

According to Dawes (1980) in his theory of social dilemma, two crucial factors may lead people to cooperate in a social dilemma situation. First, people must think to understand the nature of the dilemma, so that moral, normative and altruistic concerns as well as external payoffs can influence behaviour. Second, people must have some reason for believing that other people will not defect for, although differences in payoffs may always favour defection no matter what others do, absolute payoff is higher if others cooperate. Dawes also suggested several proposals to elicit cooperation in social dilemma situation. Changing the payoff structure could be an alternative, just as stated in Kitamura et al (1999). Giving reward for cooperative persons and punishment for defective ones might give solution. But this solution required central authority to reinforce the reward-punishment scheme. This solution changes the social dilemma situation into a more convenient situation for cooperative persons. In other word, there is no social dilemma anymore.

Altruism could also be a solution for social dilemmas. Linguistic meaning of altruism is “unselfish concerns for other people’s happiness and welfare”. An altruist person does not behave selfishly just on maximizing his individual payoff. He always cooperates in order to increase payoff for all people. All persons, without considering whether they are cooperative or defective, receive the same benefit gained by the moves of altruist persons. However, apparently not many people want to be an altruist as temptation to get better payoffs for not being an altruist.

It seems that the payoff utilities that lead the players to defect, while the other utilities (those connected with altruisms, norms, and consciences) lead the players to cooperate. It follows that manipulations that enhance the salience and understanding of these utilities should increase cooperation. Communication, public disclosure, and moralizing are precisely such manipulations. Creating new markets that, at least partially, restrict benefit to those that contribute, is also another proposed solution.

Komorita (1991) argued that individual favoritism on group interest could motivate individuals to cooperate. Social identity theory suggests that whether individuals act in the group interest rather than in their self-interest depends on whether they consider themselves as members of a group rather than as single individuals. Group members may express self-favoritism by serving their private interests instead of group interests. Group favoritism reflects a true motivation to serve the group interest than a means of serving one’s self-interest.

Travel demand management is one of solutions to solve the dilemma situation. The TDM measures could be the ways to discourage car use (push measures) or to encourage the use of alternative modes (pull measures). Current research direction as suggested by Garling et al. (2002) is to research about the effects of other users on the transportation system given the interdependencies present in the system. Users’ actions affect the actions of others, and the actions of others may affect a target user in ways other than intended by a particular TDM measure. Interdependencies between users will be the base of decision making process and interactions will be considered in the learning process of users in our model.

2. Focus of study

Our study focuses on commuters’ travel mode choice. Most modal-split models rest on the presence of equilibrium. Equilibrium analyses presuppose that the driver is rational and homogeneous and has complete information. Many studies assumed that a user predicts costs of transport modes and chooses mode with the smallest cost. Actually, they do not necessarily minimize cost but may adopt a strategy, such as continuing to take the same mode or change to other modes periodically. This study may also reach theoretical equilibrium point but the main focus is on the dynamic process of choosing travel mode and also on the behavioural changes of travellers during social learning process.

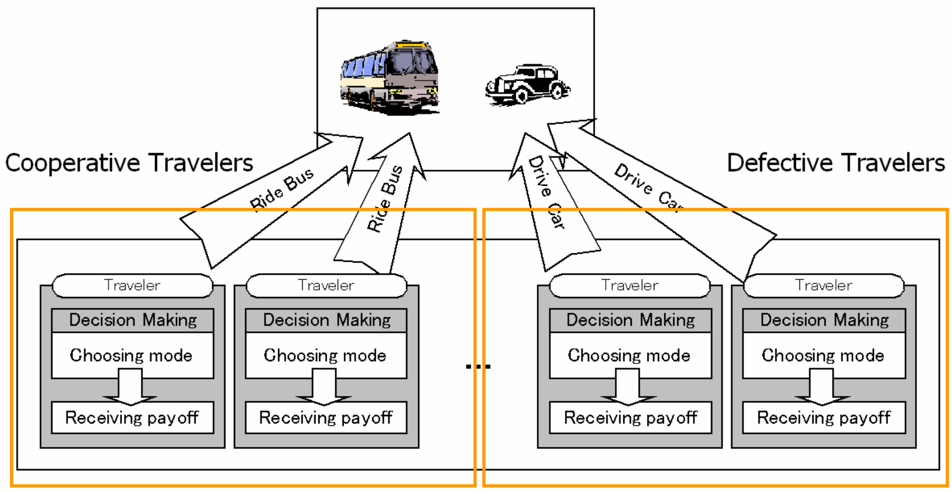

Figure 1: An illustration of travellers' mode choice

By using a simple bi-modal transportation system, the social dilemma situation of travel mode choice is modeled (see Figure 1). Travellers who use public transport, for example bus, are called as cooperative travellers, since they behave cooperatively for the sake of all people's benefit. Car users are defective travellers since they consider only their personal interest. Each traveller has a decision making rule which is used to decide mode of commuting and receives payoff of his decision on choosing travel mode.

This study aims to provide an agent-based simulation model of travel mode choice in order to understand behavioural process of commuters on choosing travel mode. Interaction among travellers is one of factors that are predicted to influence choice behaviour of travellers. A user equilibrium point may also be reached, but more important is the process to reach the point and the behavioural change of travellers during the process. By introducing evolutionary approaches into travellers' learning process, the model is expected to gain an insight into the way of solving social dilemmas.

3. Multiagent simulation model

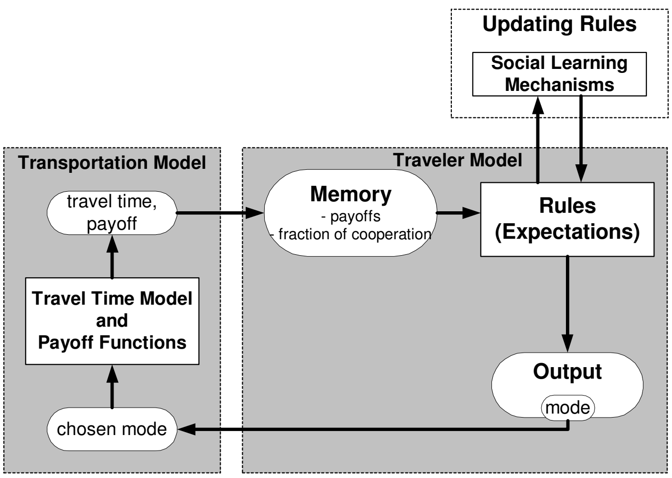

Figure 2: Multiagent simulation model

Travellers' commuting behaviour can be represented by behaviour of autonomous agents in a simulation model. Agents behave based on behavioural mechanisms updated by an evolutionary approach. The model is also used to represent interactions among travellers and complex decision-making processes by travellers.

Our model consists of two submodels (see Figure 2). In the traveller model, travellers decide mode based on the rules of expectations, which guide travellers on making decision. After all travellers decide the mode of commuting, then travel times are calculated in the transportation model. Generalized travel cost for each mode can be calculated and it returns to travellers as payoffs. Payoff value of each traveller depends on the mode he has chosen. These decision making processes are iterated 10 times for each generation. After that, there comes an evolutionary process to choose a type of expectations and to acquire adaptive behaviour of travellers by means of simulating social learning mechanisms.

Transportation model

A simple bi-modal transportation system, which comprises private car and bus as choices of commuting, is used as a transportation model. The two modes are assumed to be operated in the same lane so that there will be more interactions than if they are operated in exclusive lanes. This simple model is used in order to understand basic travel mode choice that represents social dilemma situation.

All travellers own cars so that they can easily change modes and they only know the cost of mode they choose. Private car users are assumed to be solo drivers. For public transport, bus operating frequencies and fare are adjusted so that bus passengers can pay the full cost of operating buses. Equations and their parameters of generalized travel costs for car and bus are derived from the work of Kitamura et al (1999).

Traveller model

Decision making rules: expectations' curve

Behaviour of a traveller is represented by an expectations curve, which shows traveller's belief about the influence of his action on others (Glance and Huberman 1993). There are two types of belief: bandwagon expectations and opportunistic expectations (Huberman and Glance 1994). For each type, there are three types of curve that represent agents' level of expectations: pessimistic, normal and optimistic. In this paper, we deal with only the bandwagon expectations (see Figure 3). A probability of cooperating represents a degree of an individual's beliefs about the influences of his action on others; and a criteria, which lies on 45 degree of straight line and the value is equal to the fraction of cooperation, represents a base of beliefs.

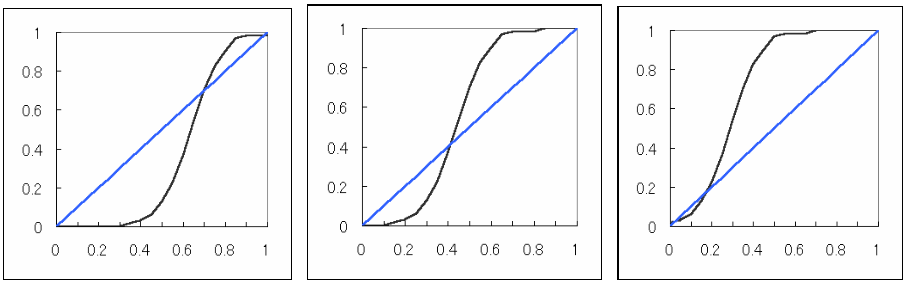

Figure 3: Types of bandwagon expectations curve (from left to right: pessimistic, normal and optimistic. x axis: fraction of cooperation, y axis: probability of cooperation)

Figure 4 shows decision making processes of a traveller. Initially, travellers are given a type of curve and a randomly chosen mode. Travellers make decision at an asynchronous time assuming only 10% of them observe current level of cooperation and make a choice at the same time. Another 90% continue to use their current mode of commuting. Based on travel mode they chose, travellers receive payoffs and accumulate them. After 10 iterations, the accumulation of payoffs is used as the fitness of agents' type of curve.

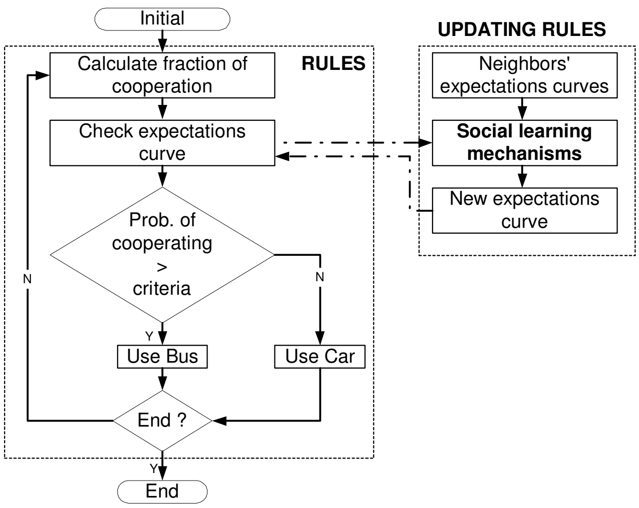

Figure 4: Decision making of a traveller

Interaction among agents: group-based interaction

A possibility of incorporating employer-based TDM measures to solve a social dilemma of travel mode choice is studied by introducing a group-based interaction, where a group represents employees of a company. We also need this grouping to make travellers interact each other in order to acquire adaptive behaviour by local interactions. A traveller interacts with other travellers of the same company he works in a torus plane so that eight neighbours around him influence his choice of behaviour. Each group is independent from others so that there is no interaction among members of different companies. Assuming limited information, a traveller knows only his own payoff information and types of expectations curve of eight surrounding neighbours.

Evolution of expectations using imitation game

We apply an imitation game based on social learning mechanism in order to evolve expectations' curve of each traveller. Two kinds of mechanism are used: payoff-biased transmission and conformist transmission (Henrich 2004). The relative strength of each transmission depends on the strength of conformist (α) in a traveller's psychology (Henrich and Boyd 2001). For each traveller, there are α probability to use conformist transmission and ($1 - \alpha$) probability to use payoff-biased transmission.

The transmission process of social learning can be illustrated in the Figure 5. For example, a person named as Person X has two kinds of propensity on doing social learning, by payoff-biased transmission and conformist transmission. The relative strength of each transmission depends on the strength of conformist (α) in a traveller's psychology. For each traveller, there are α probability to use conformist transmission and ($1-\alpha$) probability to use payoff-biased transmission.

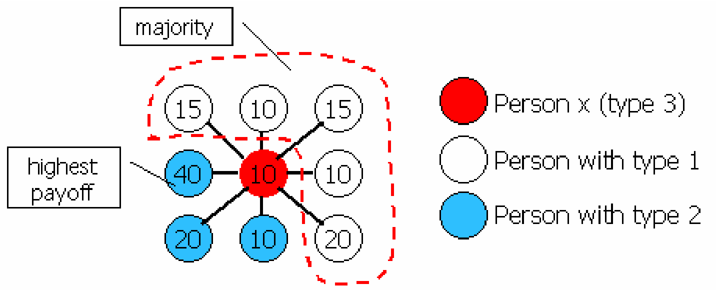

Figure 5: An illustration of social learning mechanisms

Assuming that Person X has a type of curve, for instance, Type 3. When he uses conformist transmission, he imitates the behaviour of majority of people in his group. If person X knows that majority of his neighbours have Type 1, then he will change his curve's type to become Type 1. Person X will change his type into Type 2, when he uses payoff-biased transmission, since a neighbour with highest payoff has Type 2.

4. Simulation results and discussions

A number of agents, exactly 4096, are assigned into 16 homogeneous groups with size 256. Each agent has a type of bandwagon expectations (pessimistic, normal or optimistic), which is assigned randomly giving the same proportion of agents for every type of expectations curve We run a simulation with various initial levels of cooperation, ranging from 0.2 to 0.8 with increment 0.1. The strength of conformist transmission (α) ranges from 0.0 to 0.4. Simulations are run up to 100 generations with 10 iterations per generation. The economic rationality of travellers is simulated by payoff-biased transmission, where travellers always try to adopt behaviours with high payoffs. With α=0, travellers use only payoff-biased transmission to evolve their type of expectations' curves. Combination of payoff-biased and conformist transmission is demonstrated by using various value of α ranged from 0.1 to 0.4.

Social learning by payoff-biased transmission (α=0)

The simulation resulted in an equilibrium point for initial level of cooperation from 0.2 to 0.7 (see Figure 6). According to the cost functions defined before, the number of bus users at the equilibrium point should be around 1200 or equal to 30% of travellers. High initial level of cooperation (0.8) resulted in full level of cooperation (all travellers chose bus) because for all types of curve, the probability of cooperating at a fraction of 0.8 was higher than the criteria (please refer to Figure 3), so that all travellers suddenly cooperated.

Figure 7 shows the level of cooperation within groups at initial level of cooperation equals to 0.5. In some groups all members cooperate, and in some others all members defect. There are three groups consisting both of car users' proportion and bus users' proportion.

Observing which kinds of type exist at the end of simulation, all three types of curve still exist as seen in Figure 8. Pessimistic type was chosen by the highest number of members, around 2500 travellers. Followed by normal type with around 1000 members and the rest is optimistic type.

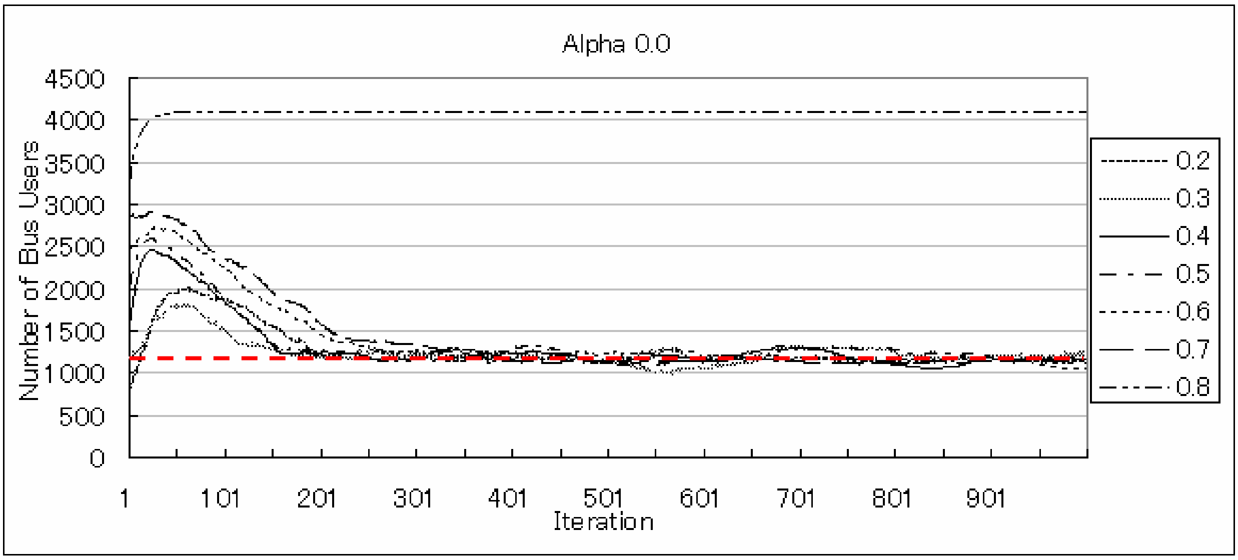

Figure 6: Dynamics of cooperation level (α=0.0)

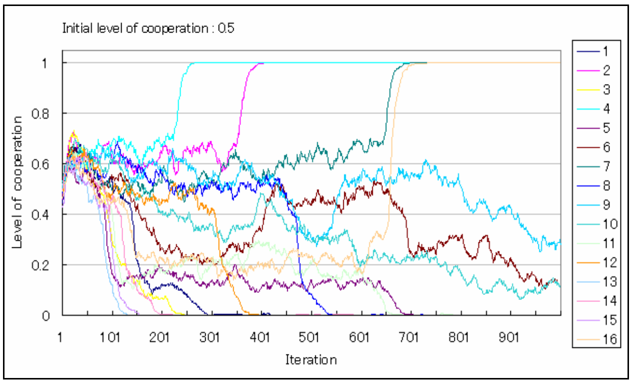

Figure 7: Level of cooperation within groups (α=0.0)

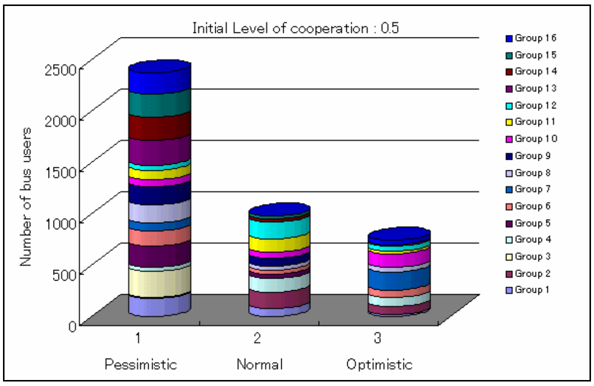

Figure 8: Type of curves at end of simulation (α=0.0)

Dynamics within a group at α=0.0

Dynamics of behavioural change within a group can be seen in Figure 9, which is taken from a simulation run with initial level of cooperation 0.5. The number of bus users is taken from the average value of 10 iterations in one generation.

Within Group 1, all members finally chose car. Pessimistic behaviour dominates the group with around 200 agents. Small numbers of normal and optimistic agents could not increase the level of cooperation and furthermore they chose defection. The situation within group 2 is quite different. Within this group, there is no type of behaviour dominates the group until generation 40's. A medium level of cooperation, with around 150 bus users could be maintained. The increase of normal and optimistic behaviour, as a result of agents who changed from pessimistic curve into normal and optimistic curves, could push the level of cooperation into maximum level. The spread of those behaviours could maintain the cooperation and decreased the number of pessimistic agents.

The situations between Group 7 and 9 are quite different. Group 7 shows the role of optimistic agents to elicit cooperation, since they acted alone as altruist agents following the fall of normal agents. They could maintain the level of cooperation and increased to the maximum level, after some pessimistic agents changed type to optimistic one. Group 9 has a different pattern. Almost the same numbers of pessimistic and optimistic agents dominate early 30 generations and maintain level of cooperation as high as the initial point. After generation 40's, the number of pessimistic agents increased and followed by decreasing level of cooperation. Although the cooperation level increased again during generation 60-80's, it was not stable and decreased gradually since there were not many optimistic or normal agents who could stabilize it.

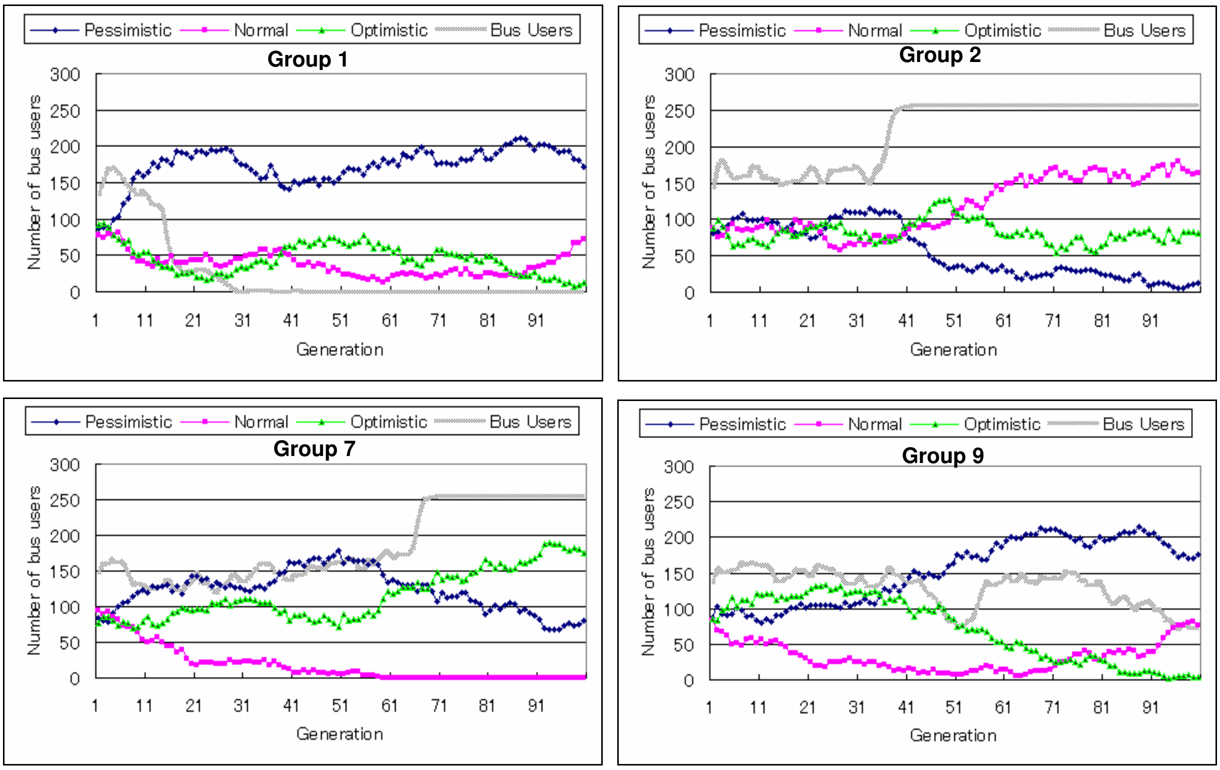

Figure 9: Dynamics of behaviours within a group (α=0.0)

Combining payoff-biased transmission and conformist transmission (α=0.1 – 0.4)

The strength of conformist is represented by a value of α. High value means high probability of using conformist transmission for an agent. Dynamics of cooperation level for α equals to 0.1 to 0.4 can be seen in Figure 10. The dashed line is the user-equilibrium line. Small values of α (0.1-0.2) gave only small differences compared to the case of payoff-biased transmission only (α=0.0), but it could not move the system out of equilibrium point. At α=0.3, conformist transmission could push the system to converge to a higher level of cooperation than the general equilibrium point for several cases only. But at α=0.4, higher level of cooperation could be reached for all initial levels of cooperation.

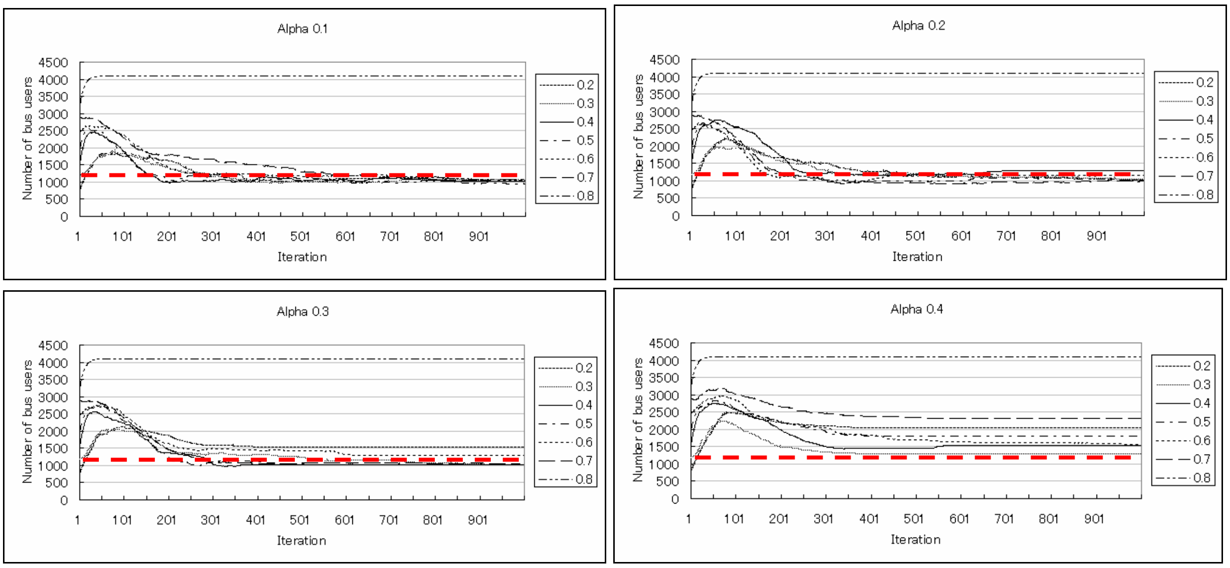

Figure 10: Dynamics of cooperation level (α=0.1-0.4)

Let us focus on α=0.3 and α=0.4. Low initial level of cooperation (0.2) gave a quite different behaviour, because in the beginning the cost of bus was lower than car, so that most of users preferred bus to car. The level of cooperation suddenly increased and the conformist transmission spread cooperative behaviour to other travellers. If the strength of conformist were strong enough then cooperative behaviours could spread fast to make all group members cooperate and stabilize cooperation within the group, without giving payoff-biased transmission a chance to push the global cooperation to the equilibrium point. It can be seen that low initial level of cooperation 0.2 gave higher convergence value than initial level 0.3, 0.4, 0.5, and 0.6.

Middle to high initial value of cooperation (0.4-0.7) had different processes. In that range, the higher the initial level, the higher is the convergence point. Let us focus on the case of α=0.4. In the beginning, cooperation increased suddenly because of the existence of optimistic agents who chose cooperation, since the initial fraction of cooperation was higher than the criteria of cooperation. They were followed by some normal agents who later also cooperated, after observing a certain level of cooperation which was higher than their criteria. Finally, payoff-biased transmission that has probability 0.6 (1-α), had pushed the cooperation level to lower state before the system converged. High initial level of cooperation (0.8) favoured cooperation for all types of expectations so that full level of bus users was achieved.

Dynamics within a group at α=0.4

Early dynamical processes within a group are complex and important to determine the succeeding processes and ending results of simulation (see Figure 11). Conformist transmission helped the spread of a type of expectations' curve and later the group would become homogeneous with an only type of curve. In some groups, optimistic expectations may dominate. But in some other groups, pessimistic or normal expectations may also dominate.

Group 1 shows a group that was dominated by optimistic agents and total cooperation of all group members. At the end of simulation, only optimistic curve existed and the group was a homogeneous group. For Group 2, total cooperation was also reached, but this time normal curve dominated, not the optimistic one.

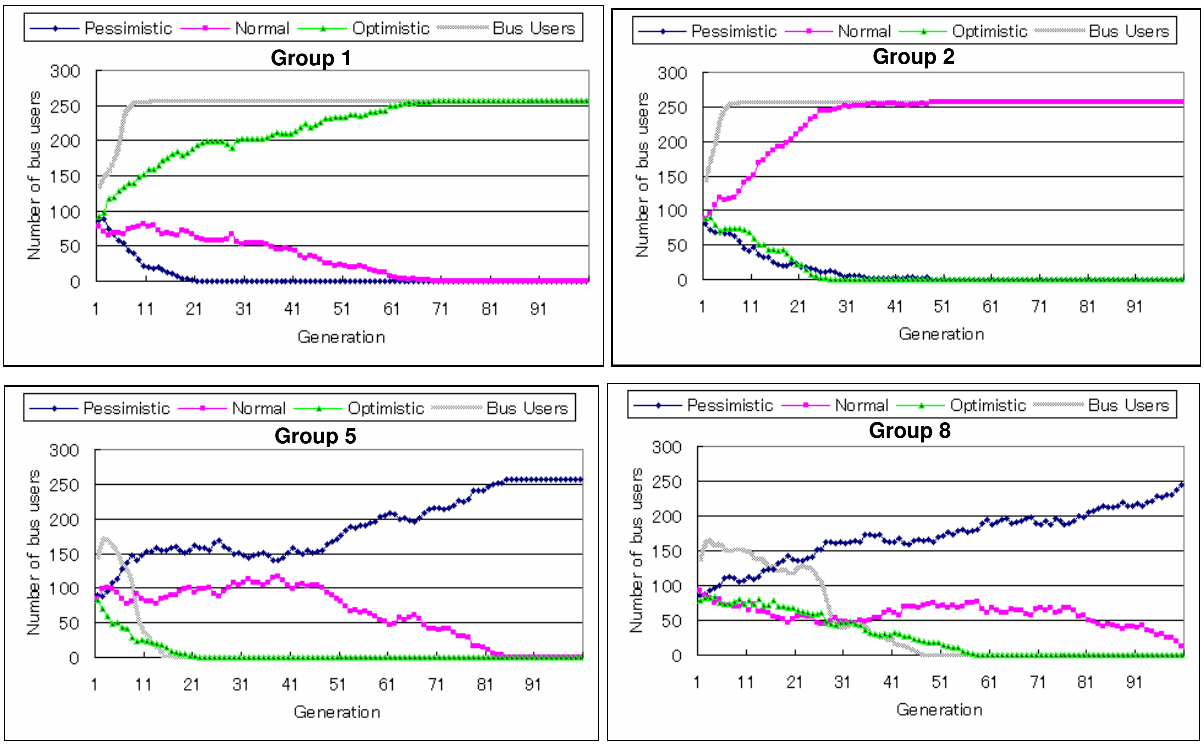

Figure 11: Dynamics of behaviours within a group (α=0.4)

A group dominated by pessimistic behaviour is represented by Group 5 and 8. These groups have similar results, total cooperation and only optimistic curve existed. Group 8 has longer processes before finally all group members chose defection. Cooperation level decreased highly after Generation 20's and all defection at Generation 40's.

These results prove that the conformist transmission might be able to stabilize cooperation when it is strong enough compared with payoff-biased transmission. By using a complex process of interactions among agents, a combination of payoff-biased and conformist transmissions, and also other emergent components, high level of cooperation can be achieved.

Path-dependence

For α=0.4, the result is path-dependence since the final result depends on the process (see Figure 12). Different random numbers' seeds used for simulation run would give different evolutionary path and finally give different final results. The system's behaviours depend on the past states of the system. For α=0.0, the paths for each run are slightly different in the beginning, but same final result could be achieved, showing that it is non path-dependence.

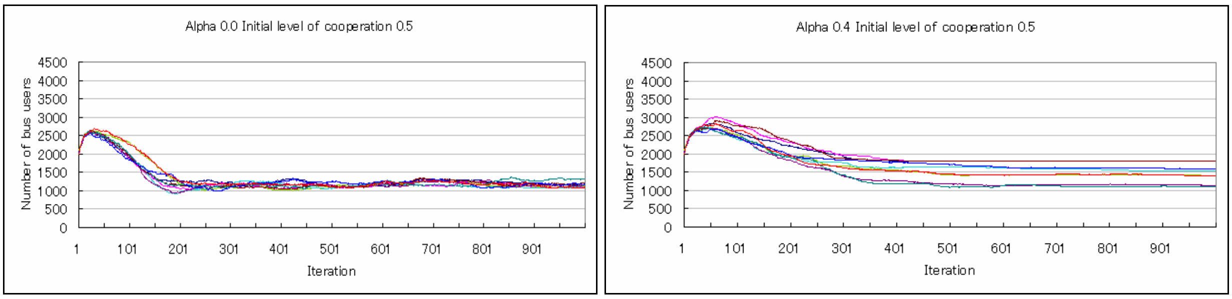

Figure 12: Non path-dependence (left) and path-dependence (right)

Effects of group size

Studying effects of group size, we run simulation with different size of group size, ranging from 64 to 1024. (see Figure 13). Different dynamics of the system could be observed from macro level, such as the cooperation level in the system, except for initial level of 0.8 that gave the same result for all cases. Referring to our main case of group size 256, we found several differences of the system's behaviour.

Small group sizes, such as 64 and 128, gave many equilibrium points that depend on initial levels of cooperation. Higher initial level resulted in higher level of cooperation at the equilibrium point. When the group size is small, choices of group members become homogeneous in an early process and converge to total cooperation or defection within each group. In all initial levels, Group size of 64 converged earlier than that of 128. So that levels of cooperation for the former case are higher than those of the latter case.

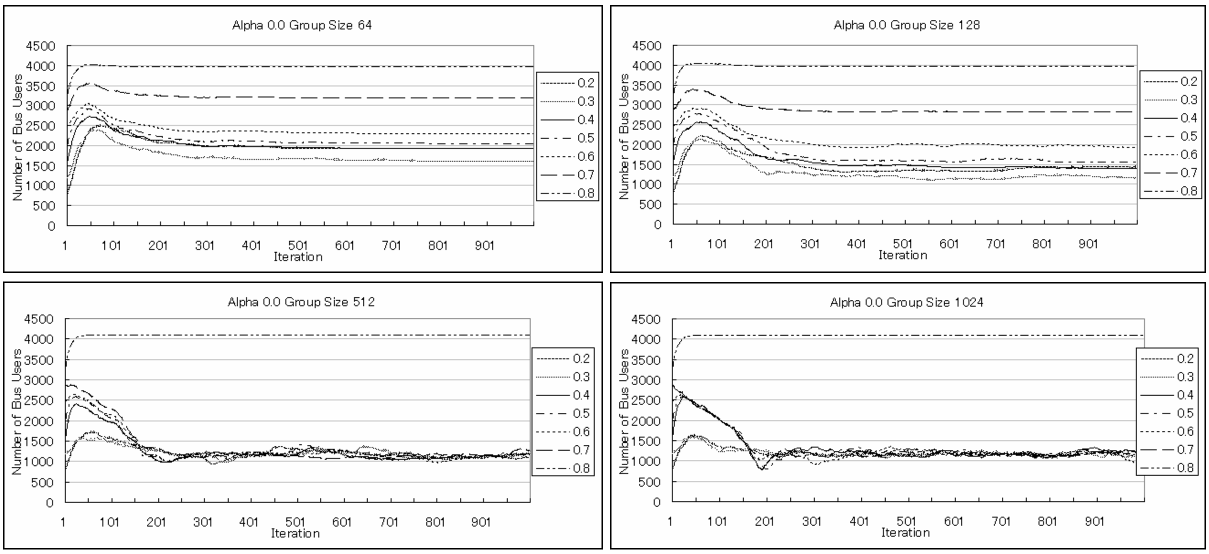

Figure 13: Dynamics of cooperation level for group size = 64, 128, 512 and 1024

It can be inferred that initial levels of cooperation did not give any difference to global behaviour of the system when the size of group is big. But for small group sizes, initial level of cooperation is very important on determining the global behaviour of travellers.

5. Conclusion

A simulation model of multiagent learning for commuters' mode choice was built and applied to examining behaviour of commuters. The same user equilibrium point as predicted by conventional analysis can be reached and stabilized, by interaction process among travellers and by behavioural-change process of each traveller. Outside the system, there is no central or external rule that organizes objective function of the system. The equilibrium is a result of self-organization and complex process among travellers.

Based on the phenomenon within a group, it could be inferred that cooperation level is highly related to the existence of type of expectations within a group. Domination of pessimistic agents would make a group converges to all defection and the appearance of optimistic agents is very important to pioneer cooperation within a group. This also shows that the global behaviour of all agents may make the system converge to the equilibrium point, although local behaviours within a group converge to their own convergent point.

When the strength of conformist transmission is relatively high (0.4), once a type of expectations becomes common then it will quickly dominate and homogenize a group. Within a group, if optimistic agents were quite common and the conformist transmission were strong enough, then optimistic type would spread through all group members and the maximum level of cooperation could be achieved. The only chance for 'cooperative type', like optimistic type, to spread is by dominating the group as fast as possible, without giving a chance for 'selfish type', like pessimistic type, to spread with the help of payoff-biased transmission. Once a type spreads widely enough then it will dominate the group.

High strength of conformist transmission also produces path-dependence of the system. Evolutionary path determines the end result of simulation. And also there is high importance of the size of group to the system behaviour. Smaller size of group makes the group easily homogenized. Behaviour of a number of members will give more influence in a small group than in a big group. The existence of opportunistic expectations' type gave a significant different to the system behaviour, since there is a chance for an agent to get higher payoff by 'free-riding', a typical characteristic of opportunist. Basically within a group, agents with this type prefer cooperation than defection, but they prevent the group to converge to all cooperation, since they are better off 'free-ride' when they observe a high fraction of cooperation inside the group.

There are three conditions that enable cooperation as a possible outcome. The first is beliefs and expectations. This study assumes that travellers have bounded rationality since they do not directly choose mode based on payoff they receive, but based on the expectation of their actions to affect others. The second is limited information. Grouping among travellers, as a way to represent employer-based interactions, limits travellers' knowledge about behaviours of other groups' members. They can observe the behaviour of all their close neighbours, instead of all group members. The third is the conformist transmission. When travellers do not feel economic rationality as a must, they should observe other kinds of learning process such as conformist transmission, which is formed as a motivation to copy majority behaviour of a group

It can be concluded that emergent phenomenon of the system may favour cooperation, if there is strong conformist transmission. This gives insight to the possibility of solving the dilemma by incorporating employer-based TDM measure, after we understood behaviour of travellers within a group and revealed that there is a chance of eliciting cooperation.

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