Analysis of Mixed Traffic Flow in Urban District Using Multi-Agent Model

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Abstract: In Japan, several modes use the sidewalk extensively apart from pedestrians. The existence of this mixed traffic in the sidewalk causes confusion and increase conflicts between users. As a result, the sidewalk is not used effectively and eventually leads to the decreased amenity of the sidewalk users. It is therefore necessary to introduce measures and tools for analysis and evaluation in considering equality and enhancing the comfort and safety of all sidewalk users. The purpose of this study is to develop a tool for analyzing mixed traffic flow and use this tool to evaluate the measures and the impact of each mode's behavior on other modes. Study method is to build multi-agent simulation model and to evaluate measures and the impact of the mode's behavior using simulation model. As a result, it became possible to analyze quantitatively the effectiveness of measures and the impact of the mode's behavior.

Key Words: *traffic simulation, multi-agent model, mixed traffic flow*

1. Introduction

In Japan, there are several modes that use the sidewalk extensively apart from pedestrians. For example, there are bicycles, wheelchairs, baby carriages and push carts to name a few. The existence of this mixed mode in the sidewalk causes confusion and increase conflicts between users. As a result, the sidewalk is not used effectively and eventually leads to the decreased amenity of the sidewalk users. Another concern is the recent increase in usage of bicycles due to environmental issues and health consciousness. This could possibly cause much deterioration of sidewalk user's amenity. In addition, it is envisioned in the near future that a new type of mode will appear as a reflection of an aging society's pursuit for mobility. This includes the wide-spread use of motorized wheelchairs and personal transporters such as Segway HT, a two-wheeled self-balancing transportation device.

With these circumstances, confusion and conflicts will be aggravated and cause the user's amenity to deteriorate more. It is therefore necessary to introduce measures and tools for analyses and evaluation, considering equality and enhancing the comfort and safety of all sidewalk users.

2. Purpose of the study

The purpose of this study is to develop a tool for mixed traffic flow analyses and use this tool to evaluate the measures and the impact that each mode's behavior has on other modes.

3. Study methodology

The adopted methodology is to a build multi-agent simulation model for analyses of mixed traffic flow and to evaluate measures and the impact of the mode's behavior has on others using simulation model.

3.1 What is Multi-agent model?

The agent is used in various senses in many fields. In this research, agent is a practice actor that recognizes neighboring environmental states, judge it depending on the situation autonomously, act and produce effect on the environment. Multi-agent model is the system that allows a lot of autonomous agents to coexist. It is used for dispersion (cooperation) problem solving or the emergence of various kinds of complicated phenomena. The behavior of the whole system is built from interaction of the agents. From this feature, each agent itself has only a simple function but it becomes possible to reproduce complicated phenomenon by the fact that the interacting agents operate mutually. Judging from the above, this study adopted multi-agent concept as the basis for building the simulation model.

In this study each mode is considered as the agent. Complex traffic flow is reproduced by the fact that each mode acts from information from its environment and its own behavior.

4. Simulation model building

4.1 Multi-agent simulator – Artisoc

In this research, multi-agent simulator artisoc is used for construction of the simulation model. Artisoc is a simulator specialized in multi agent simulation that KOZO KEIKAKU ENGINEERING Inc developed. Artisoc has various features including the following:

- Various functions for building multi-agent simulation.
- Easy of use in agent generation, arrangement and movement.
- Rule format is similar to visual basic a simple and widely used programming language.
- A GUI allows setting of simulation output.
- Readily available online tutorials for beginners.

This features were the deciding factor for choosing Artisoc for this study.

4.2 Mode parameters

This research used results from existing researches that calculated each mode's parameters by processing images in the animation recorded from a walking experiment inside school campus (figure1). The resulting parameters used in this study are shown below.

Figure 1 Sidewalk experiment

Table 1 Mode parameters

average speed	pedestrian	1.55(m/s)
	bicycle	2.23(m/s)
	Elderly pedestrian	0.7(m/s)
	wheelchair	0.89(m/s)
avoidance speed	pedestrian	0.6(m/s)
	bicycle	0.85(m/s)
	Elderly pedestrian	0.3(m/s)
	wheelchair	0.3(m/s)
cross-purposes area	for pedestrian of bicycle	(x,y)=(0.21[m],6.3[m])
	for elderly pedestrian of pedestrian	(x,y)=(0.54[m],3.48[m])
	for wheelchair of pedestrian	(x,y)=(0.22[m],6.2[m])
	for wheelchair of bicycle	(x,y)=(0.21[m],6.3[m])
	other than those above	(x,y)=(0.54[m],8.9[m])
passing area	all modes	(x,y)=(0.6[m],2.0[m])
rate of decrease	all modes	60%

＊As for x left and right of mode, as for y front distance of mode is displayed.

4.3 Simulation algorithm

Algorithm of simulation which is used in this research is shown below

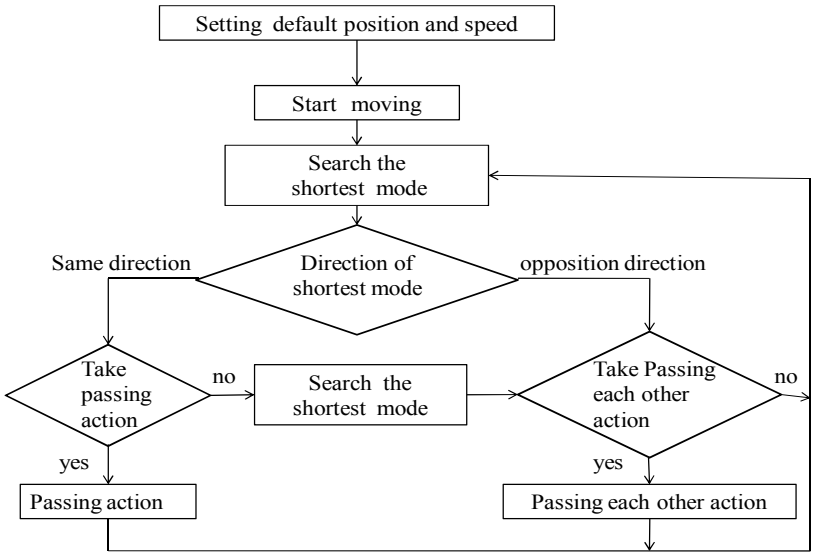

Figure 2 Basic mode algorithm

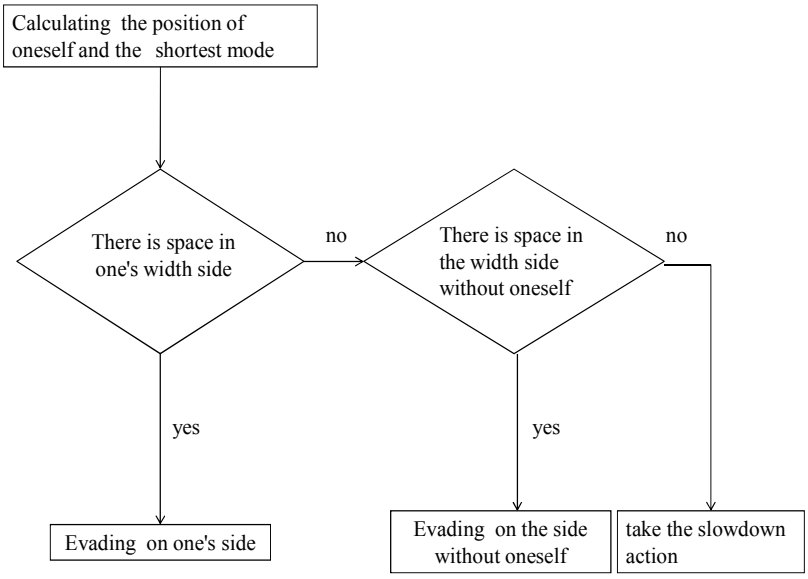

Figure 3 Evading algorithm

4.4 Setting evaluation item

This study sets three items to evaluate whether the sidewalk was used safely and comfortably. Evaluation items are shown below.

- Number of slowdown action
- Number which is penetrated to personal space

＊personal space is space to feel unpleasantly when no familiar person approach. This

research defines that circumference of each mode' personal space is about 40 cm.

- Number of conflict

Using algorithm, parameter and evaluation items mentioned above, Simulation is developed by artisoc. Execution time of simulation is set 30 seconds and Execution step of simulation was set to a one-tenth second. Evaluation items are counted per one-tenth second and displayed by graph. Size of each mode is set circle of a radius of 40 centimeters as a limitation of the software.

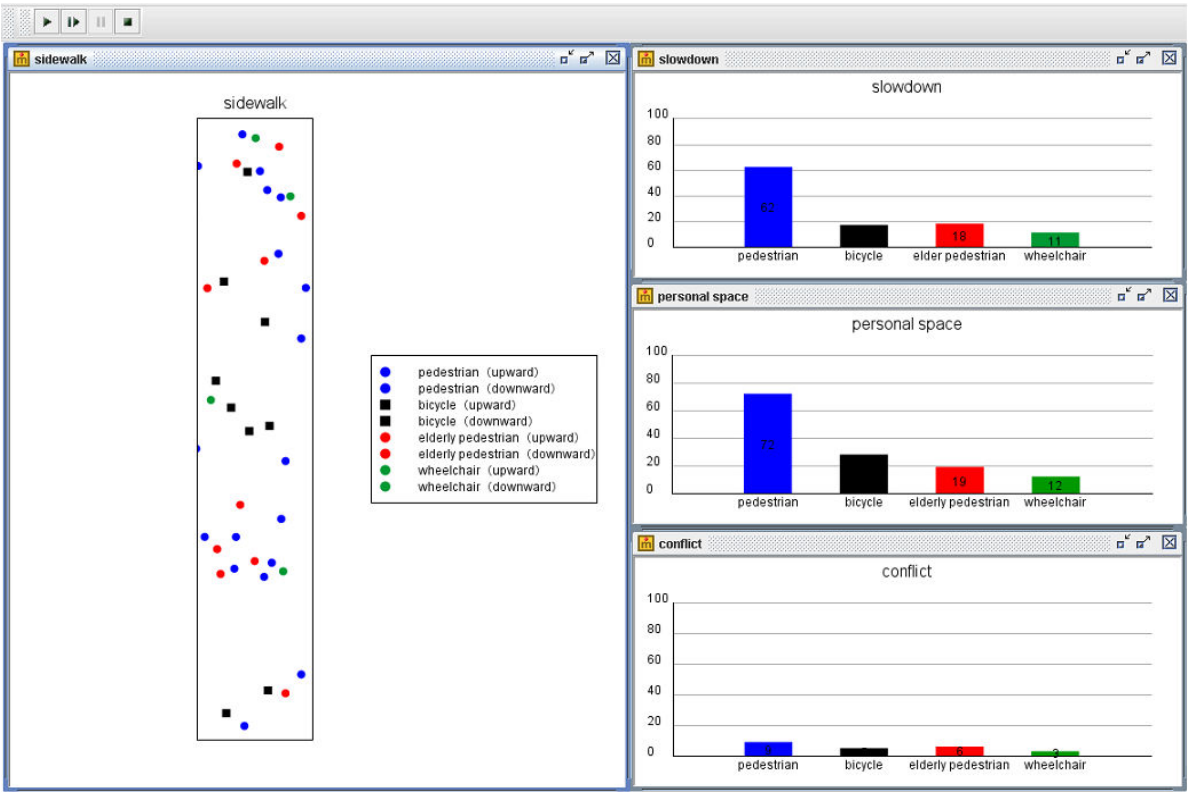

Figure 4 Simulation screen shot

5. Analysis of mixed traffic flow using simulation model

This section describes the analysis of mixed traffic flow using simulation model. Each result is the average of 100 trials with varying starting position of each agent. Scenarios where created such that simulation of different strategies can be examined and that effects of each mode can be observed.

5.1 Scheme1 One lane per mode

For all modes to comfortably and safely use the sidewalk, it is thought that combining modes with similar characteristics and considering it as one mode group to be assigned for each lane is a more effective approach. The characteristic considered are speed, weight, size and behavior of each mode. It is hypothesized that modes having almost the same characteristics can coexist in the same lane and that modes with different characteristic would cause conflict and that coexistence will be difficult.

5.1.1 Grouping modes with similar characteristic

Firstly, the four modes considered are pedestrian, bicycle, old pedestrian and wheelchair. The

method of grouping is to simulate only two different modes; isolating one mode and combining the other modes then analyze the effect of each of the combined mode to the isolated mode. The size of the sidewalk is 5m in width, 30m in length. The number of each mode is 15. Simulation results are shown below.

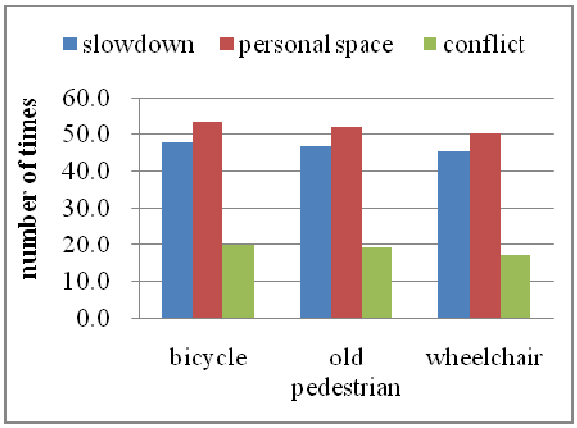

Figure 5 pedestrian

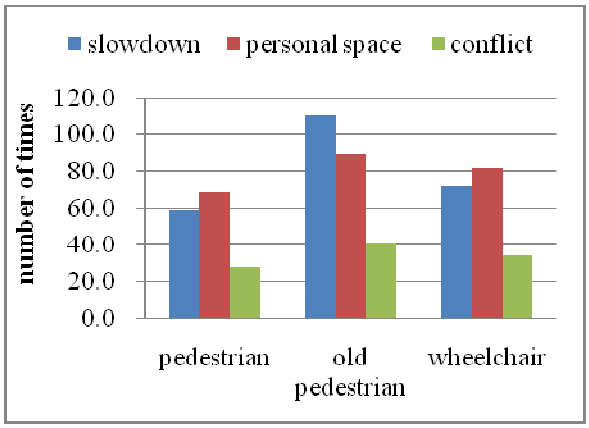

Figure 6 bicycle

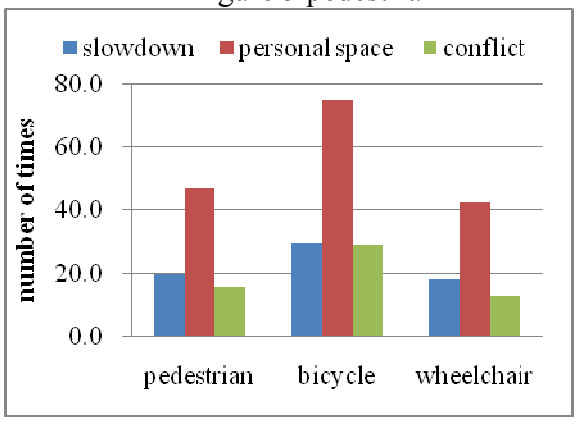

Figure 7 old pedestrian

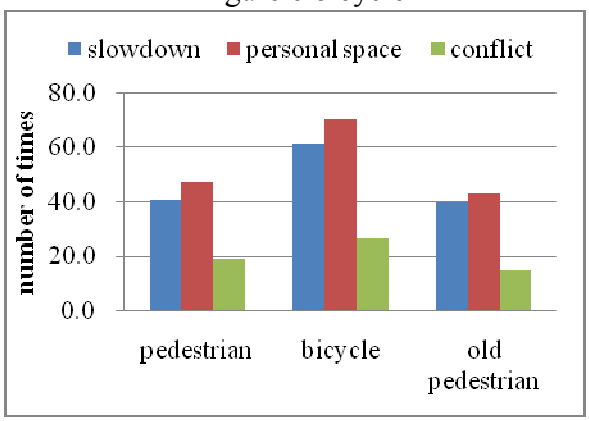

Figure 8 wheelchair

From the simulation results, pedestrian doesn't have a big effect on other three modes with almost the same values (figure1). Bicycles are affected strongly by old pedestrian and wheelchair in comparison with the pedestrian (figure2). In the same way old pedestrian and wheelchair are affected strongly by bicycles. For this reason, old pedestrian and wheelchair are different from bicycle. Their characteristics greatly differ and it is thought that their coexistence in the same lane is difficult. In addition when the effect the bicycle receives from pedestrian and the effect received by old pedestrian and wheelchair from pedestrian are compared, the effect received by senior citizen and wheelchair from the pedestrian is small. It is supposed that pedestrian's characteristics are similar to old pedestrian rather than that of the bicycle. From the above-mentioned analysis, two groups were determined - pedestrian, old pedestrian and wheelchair are grouped into one and the mode bicycle is considered as another group.

5.1.2 Allocating lanes for each group

Two groups are distributed to different lanes and the effect is analyzed. To physically divide the lane into 2, a block was installed 2 meters from the right side of the sidewalk having a width of 5m and 30m in length. Pedestrian, old pedestrian and wheelchair are distributed to the lane 3m wide and bicycle is distributed to the lane 2m wide. The number of each mode is 10. As an initial condition, a simulation was performed where the 10 agents of each mode was

distributed on the sidewalk 3m wide and 30m long without the separating blocks. Simulation results are shown below.

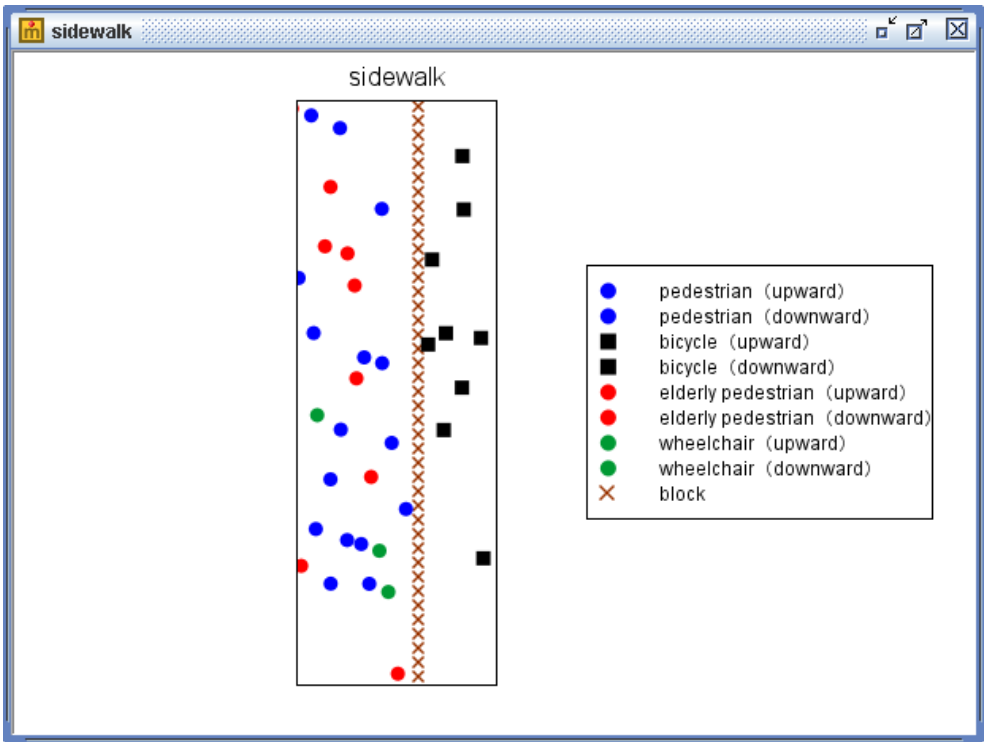

Figure 9 simulation

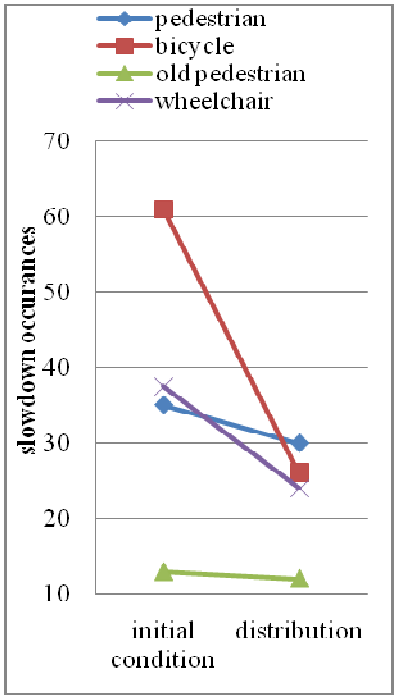

Figure 10 slowdown

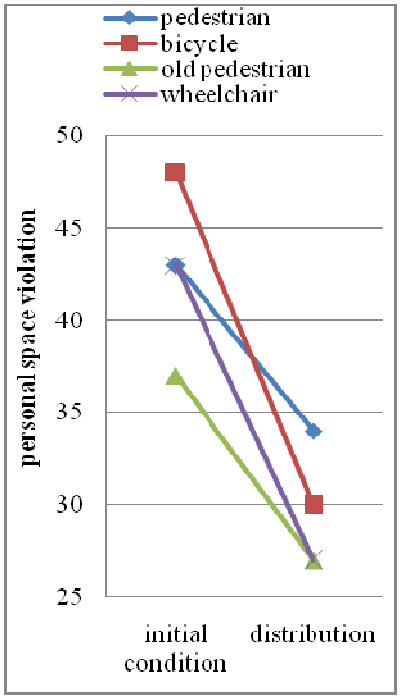

Figure 11 personal space

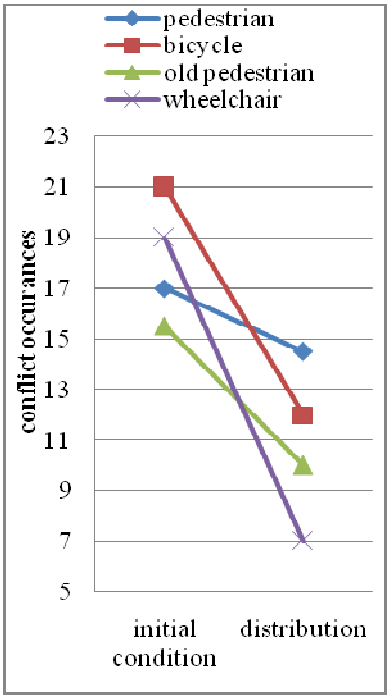

Figure 12 conflict

As figure10, 11, and 12 indicates, Numerical value of each evaluation items decreased for each mode. Looking accordingly at each evaluation item, slowdown is decreased greatly for bicycle. With regards to personal space, all modes decreased in the same way. The bicycle and wheelchair largely decreased conflicts. From the analysis above, this measure is effective.

The grouping of this scheme is similar to creating a bicycle lane and it may be said that having of a bicycle lane is effective in increasing amenity.

5.2 Scheme2 Priority is established between modes

Scheme1 is effective but enough width in sidewalk is necessary. In other words, introduction of Scheme1 is difficult on narrow and small sidewalks. Therefore it is necessary to think about a new measure.

From the analysis in scheme1, old pedestrian and wheelchair are different from bicycle in a characteristic greatly and it is thought that the coexistence in the same lane is difficult. For this reason, it is thought that some measures are necessary between these modes. It is thought that it is good to give clear priority between modes as a measure. When different modes take cross-paths and passing action in a narrow sidewalk, if it is predetermined clearly whether either mode will preferentially evade other, then coexistence in same lane is possible.
In this study, the sidewalk 3m wide and 30m long was retained but the passing area parameter of the bicycle and cross-path area for old pedestrian and wheelchair was increased 1.5 times as listed in Table2. The bicycle was made to preferentially evade old pedestrian and wheelchair. Because old pedestrian and wheelchair are weak compared to bicycle, this research set it so that a bicycle evades with precedence. Under these circumstances, a simulation with 8 agents for each mode was performed. As an initial condition, a simulation was also executed where the parameter was not changed. Simulation results are shown below.

Table 2 parameter change

	Bicycle(initial condition)		Bicycle(expand area)
passing area	(x,y) = (0.6[m],2[m])		(x,y)= (0.9[m],3[m])
cross-path area for old pedestrian	(x,y) = (0.54[m],8.9[m])	→	(x,y) = (0.81[m],13.6[m])
cross-path area for wheelchair	(x,y)= (0.18[m],8.9[m])		(x,y) = (0.27[m],13.6[m])

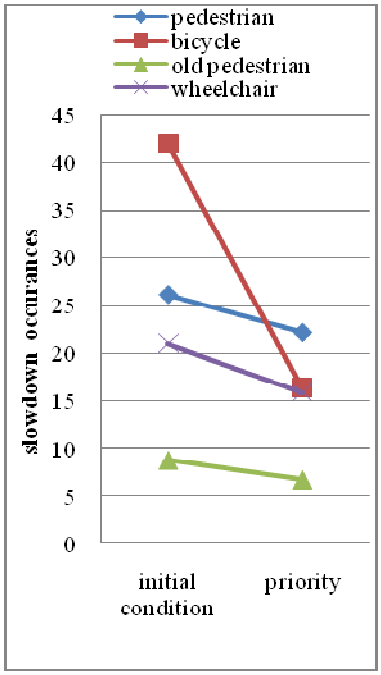

Figure 13 slowdown

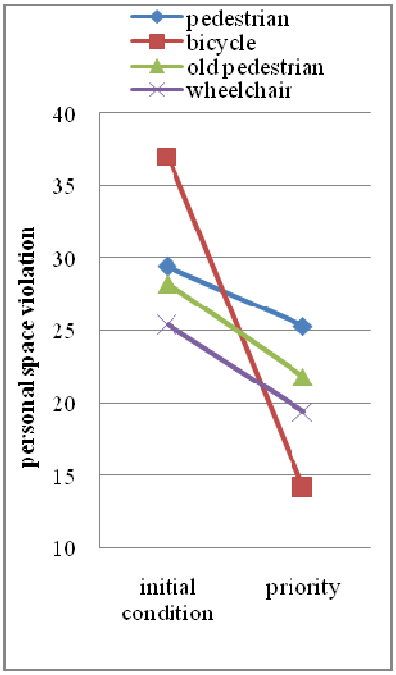

Figure 14 personal space

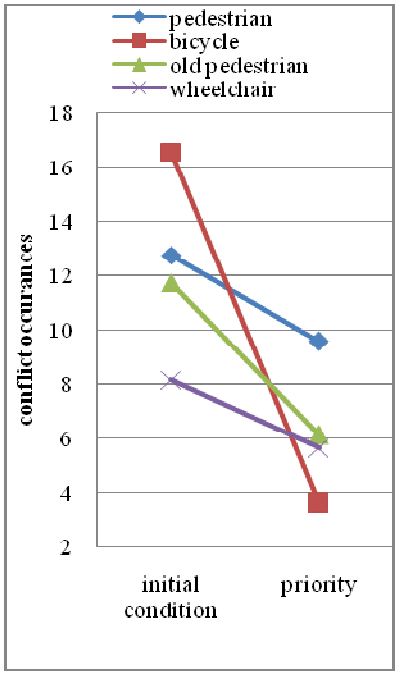

Figure 15 conflict

From simulation results (figure13, 14, 15) each evaluation item decreased value for the bicycle, old pedestrian and wheelchair. The decrease of evaluation item for bicycle is conspicuous. In addition, old pedestrian and wheelchair decreased by the same level on all of evaluation item unlike pedestrian when considering slowdown item. It is possible for bicycle to evade old pedestrian and wheelchair with ease. From analysis above, this measure is effective.

5.3 analyzing the impact of children and old pedestrian's behavior on other modes.

5.3.1 the impact children's behavior on other modes

Analyzing the influence of children to each mode is done by changing the parameter of pedestrian into young pedestrian. The parameter of young pedestrian is presumed from parameter of pedestrian. For young pedestrian, walk speed is slow and range of vision is narrow in comparison with pedestrian. It is thought that young pedestrian acts irregularly or random. Each parameter of young pedestrian is less 30% of that of pedestrian (table3). In addition each mode calculates shortest path in every simulation step, but the child set to move irregularly with 20% probability every simulation step.

Table 3 young pedestrian parameter

	young pedestrian
average speed	1.09(m/s)
avoidance speed	0.21(m/s)
cross-purposes area for bicycle	(x,y) = (0.37[m],6.23[m])
cross-purposes area for old pedestrian	(x,y) = (0.37[cm],2.4[m])
cross-purposes area for wheelchair	(x,y) = (0.15[m],4.3[m])
cross-purposes area for other than those above	(x,y) = (0.37[m],6.23[m])
passing area	(x,y) = (0.42[m],1.4[m])
rate of decrease	60%

In order to analyze the influence of young pedestrian on other mode, a simulation with 10 agents for each mode was executed. The size of the sidewalk is 5m in width, 30m in length. As an initial condition, simulation before the parameter modification is executed.

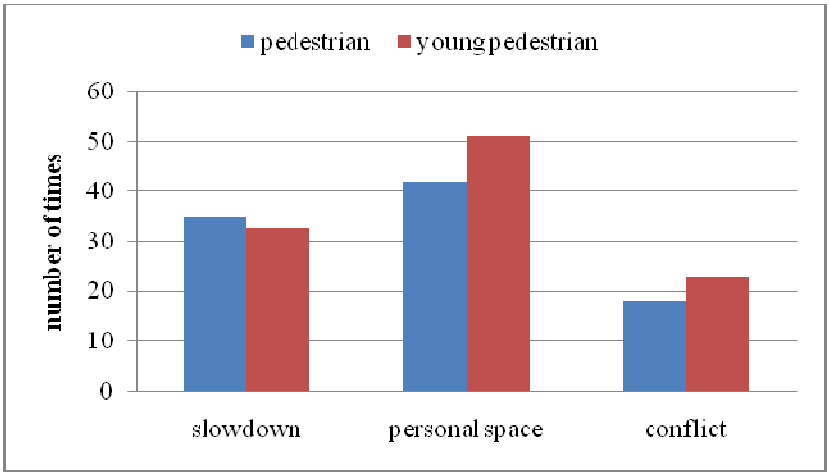

Figure 16 the effect of young pedestrian

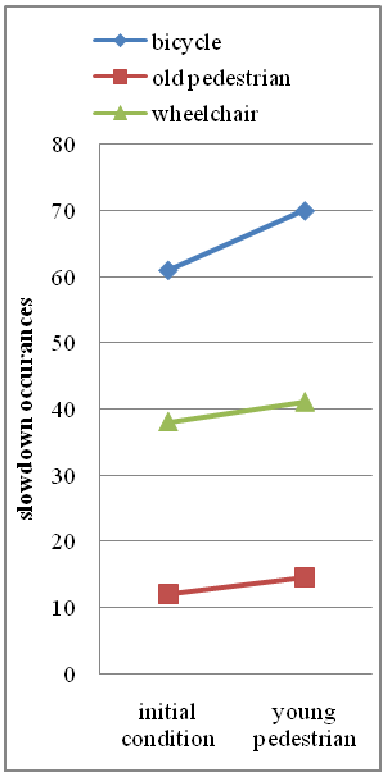

Figure 17 slowdown

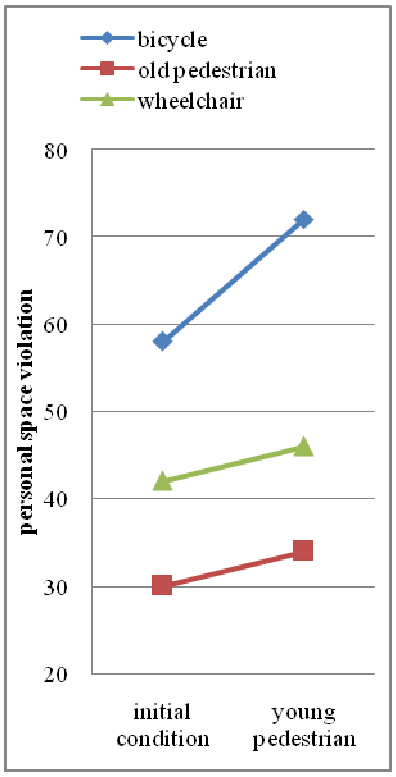

Figure 18 personal space

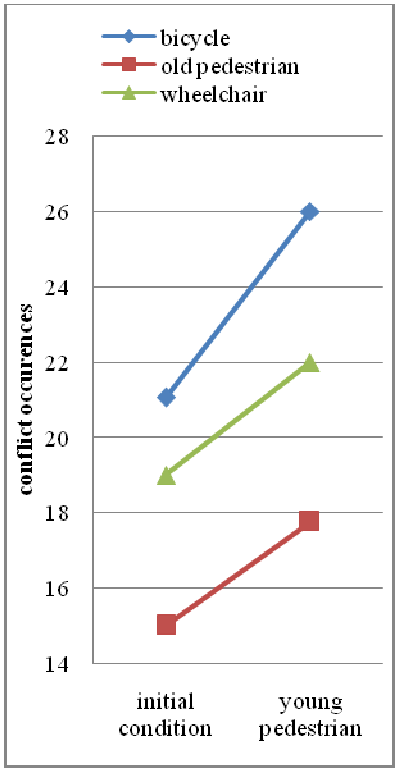

Figure 19 conflict

When pedestrian and young pedestrian are compared from the result of simulation (figure12), young pedestrian have few slowdown number of times. Conflict number of times is bigger than slowdown and personal space in comparison with pedestrian. It is thought that deceleration behavior occurs late due to narrow vision and irregular action as personal space and conflict number of times increased. Numerical value of each evaluation item increased at the same level for each mode. From mentioned above, it is said that young pedestrian has strong effect on other modes in comparison with pedestrian.

5.3.2 Effect of old pedestrian's deteriorated mobility

Old pedestrian's perception, reflex, and cognitive skill decreases the physical body deteriorates compared with the general adult. But old pedestrian in this simulation model does not have this characteristic, searching for the shortest mode every step (1/10 seconds). To reflect decreasing cognitive ability, perception and recognition power is decreased and its effect is analyzed. Decreasing cognitive ability is expressed as not to search of the shortest mode every one step with probability of 30%. The size of the sidewalk is 5m in width, 30m in length. A simulation with 10 agents for each mode is executed. As an initial condition, simulation before the parameter modification is executed. The results are shown below.

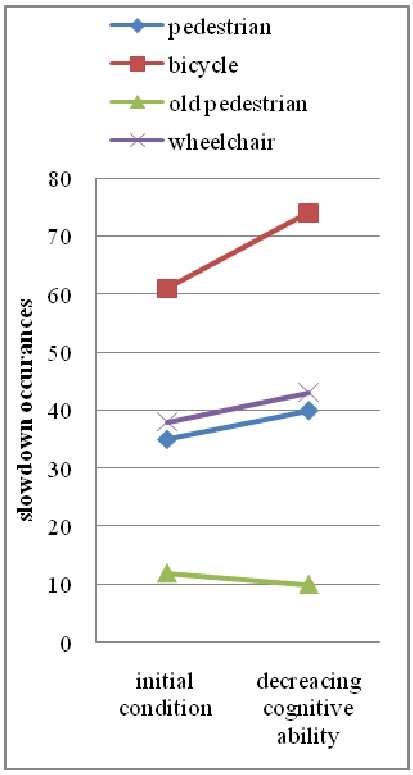

Figure 20 slowdown

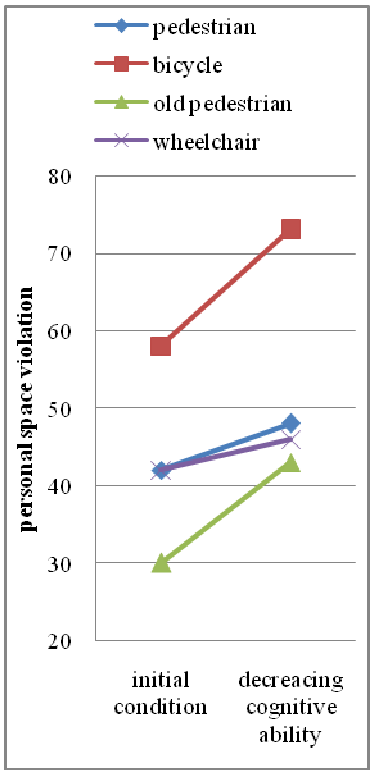

Figure 21 personal space

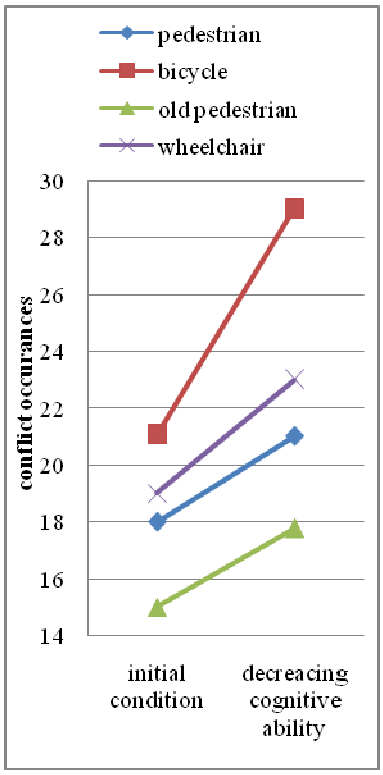

Figure 22 conflict

As for old pedestrian with deteriorated mobility and recognition, the slowdown number of times decreased. Personal space approach number of times and the collision number of times increased. Especially, increase of personal space number of times was considerable. It is thought that lag of the evasive action with the decrease of judgment occurred. Numerical value of each evaluation items increased for each mode. Numerical value of slowdown and personal space of bicycle in particular largely increased. From mentioned above, it is thought that old pedestrian has an influence to other modes particularly to bicycles.

5.4 Analysis and discussion point

From the analysis results using simulation model, the following were observed:
With regards to implementing measures for the comfortable and safety coexistence of each mode

- On sidewalks where various modes traverse and if there is enough width, grouping modes with similar characteristics and providing a separate lane for each group is effective.
- For the small sidewalk without enough width, comfort is secured by determining priority between modes with greatly different characteristic. In addition, the priority rule that it is desirable is to consider the vulnerable road user. In this case, bicycles should give way to senior citizens.

The effect of children and old aged pedestrians on other modes

- The young pedestrian with narrow field of vision, makes irregular moves requiring a big personal space and conflicts and collides with other modes frequently. It is said that the effect to other modes is bigger than pedestrian. To decrease this effect, it is necessary to devise of measure for young pedestrian.
- Old pedestrian with deteriorated motor, perception and reaction, conflicts highly to other mode's personal space and collide frequently because of searching for the shortest

distance mode is slow. Therefore, like a young pedestrian, it is necessary to think about measures to reduce their effect on other modes.

6. Conclusions

This research builds multi-agent model simulation. Effectiveness of measure and the influence of each mode to one another were analyzed quantitatively. From this result, it is thought that simulation model can be used as a tool for evaluating measures or schemes to be implemented and to analyze behavior of new mode. However, it is thought that there is a problem with using the parameter based on an intramural walk experiment for the sidewalk condition. It is thought that the parameter of each mode changes by width and traffic density of the sidewalk. Therefore, it is necessary to think about the calculation method of the parameter considered. In addition, there is room for improvement of the evaluation items. In this study, the weight of each evaluation items is treated equally but it is also a good argument to differentiate the weight value of the evaluation item depending on the type of mode. For instance, speed is much more important to bicycles than to pedestrians. And pedestrians would value personal space more than speed. Future topic improves each parameter to closely represent the real movement of modes and the weight of each evaluation items for realistic evaluation.

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