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Advanced Demand Signals -II scheme

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Abstract— **This paper describes the advanced demand signals -II (ADS-II) scheme that can output signal phases based on both pedestrians' demands and drivers' demands, and also presents the basic performance evaluation of the ADS-II scheme. Firstly, we propose the ADS-II scheme, which is an improvement of the ADS scheme that controls signals using vehicles' location information, in order to output signal phases appropriate for demands both of pedestrians and vehicles. Secondly, a constructed pedestrian model is introduced to the conventional microscopic traffic simulator including the ADS scheme for performance evaluations of both pedestrians and vehicles. Finally, in terms of efficiency, basic performance of the ADS-II scheme is compared with that of the best basic coordinated signal control scheme by this simulator and results show that the ADS-II scheme is superior.**

I. INTRODUCTION

Intersections are important bases for human and thing's transportation. There are many people living in the neighborhood and passing through intersections. There are various demands such as the realization of the smooth and safe traffic flow and the improvement of environmental conditions in intersections used by many people. Based on these demands, various researches on traffic signal controls have been done [1]-[13]. These are researches to evaluate the smooth of traffic flow, the traffic safety and the influence on regional environment. Researches to smooth traffic flow have been undertaken [1]-[6]. Researches on traffic safety have been carried out [7]-[11]. Researches to evaluate regional environment have been investigated [12]-[13].

These schemes are classified broadly into two categories by technologies used for control. One is a category of the schemes that use traditional technologies. This scheme controls signals based on the travel demand that is collected by prior traffic survey and sensors such as traffic counters and cameras. All traffic signal control schemes discussed in the above references use traditional technologies. Some of them have been applied to actual streets. The other is the category of the scheme that uses technologies that will be implemented in the future. The advanced demand signals (ADS) scheme, which is proposed in [14], is the control scheme that uniquely decides the signal phase using the vehicle information of current positions and directions of travel on the assumption that infra can collect this information. We assume that this information is given when ITS platforms such as "EUPITS[15]" develop. [16] describes work on real-time and seamless communication. Additionally, [17] is a investigation of real-time and high-precision positioning. These researches show the realizability of them.

Basic performance evaluation of the ADS scheme and its application to actual streets have been studied. Studies of the ADS scheme for basic performance evaluation are carried out in [14], [18]-[21]. The construction of a microscopic traffic simulator and performance comparisons between the ADS scheme and the coordinated control scheme are described in [14][18]. In [19], after a new simulator is built based on the simulator [18], the performance of the ADS scheme is compared with that of the basic coordinated control scheme and results show the ADS scheme is superior. In [20], we improve the simulator [19] for performance evaluations on various road environments and the performance of the ADS scheme is compared with that of a coordinated control scheme in some road conditions and in some traffic conditions. There is the study on the performance comparisons between the ADS scheme and a coordinated control scheme using some evaluation indexes in several traffic conditions in [21]. Additionally, studies of the ADS scheme for application to actual streets are undertaken in [22]. The road environment is modeled after a part of root 463 in Japan and the performance of the ADS scheme is compared with that of a coordinated control scheme in [22].

In these conventional studies of the ADS scheme, the average idling time per vehicle by the ADS scheme drastically is smaller than that by the coordinated control scheme in the off hour condition. The average idling time per vehicle is defined as the average time spent traveling at less than 2m/s for vehicles. Particularly, in such a condition as few vehicles exist in the rural area, the average idling time per vehicle using the ADS scheme has been reduced by less than 90%.

However, the conventional ADS scheme appropriately can not output signal phases based on both demands of pedestrians and complicated demands of vehicles. Additionally, the conventional ADS scheme can not output the right-turn arrow signal depending on the current traffic condition. In this paper, the advanced demand signals -II (ADS-II) scheme that can output signal phases based on their demands is proposed, the basic performance of efficiency for both drivers and pedestrians in an urban intersection is evaluated.

Pedestrians' behavior at intersections is studied in [23]-[29]. However, it is difficult to construct a general pedestrians' behavior model because the pedestrian's road crossing behavior is complicated. In this paper, in order mainly to evaluate comfort of both pedestrians and drivers, we construct a simple pedestrian model based on [11], introduce the model to a conventional simulator of the ADS scheme and evaluate the basic performance of the ADS-II scheme.

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The remainder of this paper is therefore organized as follows: Section 2 describes the conventional ADS scheme, the traffic simulator used in the conventional studies on the ADS scheme and the conventional evaluation indexes; the construction of a simple pedestrian model, the model validation and new evaluation indexes are explained in Section 3; the ADS-II scheme is explained in Section 4; the performance of the ADS-II scheme is compared with that of the coordinated control scheme in Section 5; the conclusion is presented in the final section.

II. ADS SCHEME, CONVENTIONAL TRAFFIC FLOW SIMULATOR AND EVALUATION INDEXES

A. ADS Scheme [14]

The ADS scheme is proposed under the assumption that intersections are for vehicles only. The outline of the ADS scheme is shown in Fig.1.

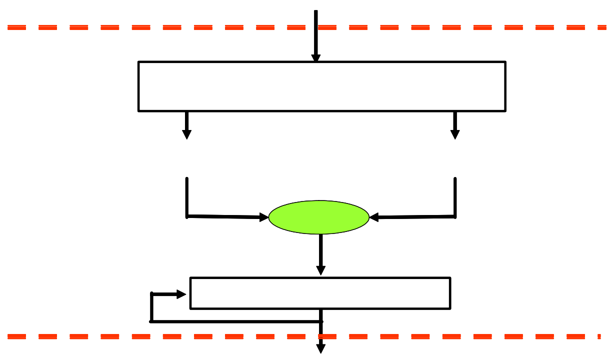

Fig. 1. Outline of the ADS scheme

The ADS scheme is the scheme that outputs appropriate phase information for the current traffic condition by using vehicles' location information. Vehicles' location information is input to the demand function, and then two evaluated values that desire green signals on a main roadway and those on an intersecting roadway are output in the ADS scheme. Additionally, a result of a comparison of two evaluated values is input to the phase determination subsystem then phase information is output. The evaluated value for the green signals on the main roadway and that for the green signals on the intersecting roadway are calculated by (1) and by (2), respectively. We assume that drivers on a main roadway and drivers on an intersecting roadway desire the green of the main roadway and that of the intersecting roadway, respectively. The phase determination subsystem controls the order of phases.

$$f_i^{(m)} = c_{i-1} \sum_{j^{(m)}} f_{i-1,j}^{(v)} + \sum_{j^{(m)}} f_{i,j}^{(v)} + c_{i+1} \sum_{j^{(m)}} f_{i+1,j}^{(v)} \quad (1)$$

$$f_i^{(c)} = c_{i-1} \sum_{j^{(c)}} f_{i-1,j}^{(v)} + \sum_{j^{(c)}} f_{i,j}^{(v)} + c_{i+1} \sum_{j^{(c)}} f_{i+1,j}^{(v)} \quad (2)$$

$$f_{i,j}^{(v)} = \begin{cases} 0, & (d_{i,j} > r_i^{(v)}) \\ 1/(d_{i,j})^n, & (d_{i,j} \le r_i^{(v)}) \end{cases} \quad (3)$$

i intersection number;
j vehicle number;
$j^{(m)}$ vehicle in the main roadway;
$j^{(c)}$ vehicle in the intersecting roadway;
n order of demand function;
$f_i^{(m)}$ evaluated value that desire green signals on the main roadway at intersection i;
$f_i^{(c)}$ evaluated value that desire green signals on the intersecting roadway at intersection i;
c_i cooperation coefficient that means the strength of the cooperation of adjoining traffic signals at intersection i;
$d_{i,j}$ relative distance between vehicle j and the center at intersection i;
$r_i^{(v)}$ communication range at intersection i;
$f_{i,j}^{(v)}$ demand of vehicle j at intersection i.

In the ADS scheme, there are four parameters, that is, the communication range, the cooperation coefficient, the order of the demand function and the minimum green time.

The communication range means that how far range from a center of an intersection is targeted when the signal phase is decided. As the communication range becomes long, the phase is decided by more vehicles' location information.

The cooperation coefficient is a parameter to cooperate traffic signals at adjoining intersections. For instance, when a traffic signal on the main roadway at intersection i is green, the value that multiplies the cooperation coefficient and the evaluated value for the green phase on the main roadway at intersection i together is added to both the evaluated value for the green phase on the main roadway at intersection (i-1) and that at intersection (i+1). The larger the cooperation coefficient becomes, the stronger the cooperation of adjoining traffic signals becomes. In the case that the cooperation coefficient is 0, each traffic signal is controlled by oneself. However, vehicles' location information makes adjoining traffic signals cooperate.

The order of the demand function is a parameter for weighting. The shorter the distance between the vehicle and the center of intersection becomes, the larger the evaluated value becomes when the order of the demand function is not 0. When the order of the demand function is 0, all evaluated values of vehicles within the communication range are equal. The evaluated value of a vehicle stopped over the stop line is equal to that of a vehicle stopped on the stop line.

Additionally, the minimum green time means the constant period that the green phase must be kept once the traffic signal becomes green. When the phase is simply controlled by the evaluated values, there is a possibility that the direction of the right of way may change frequently depending on the traffic conditions, and the traffic flow may reach a standstill, because the phase is decided every second in the

ADS scheme. Therefore, the minimum green time prevents the traffic flow from reaching a standstill.

Since the ADS scheme uses communications such as other traffic signal control schemes, the ADS scheme can give the right to public vehicles and emergency vehicles flexibly. There is no need of flashing phases for vehicles in the ADS scheme, drivers easily understand traffic signal light, and unexpected collisions can be reduced.

B. Conventional Simulator of Study on the ADS Scheme

1) Street Model:: The street in this simulator includes intersections equipped signals. The traffic signals are assumed to be on stop lines. The street width is 3.5 m and the distance from the stop line to the shoulder of the intersecting street is 4.5 m. In the simulator, the number of intersections, the number of lanes and the link length can be adjustable. The simulator can have the right turn bays according to need (shown in Fig. 2).

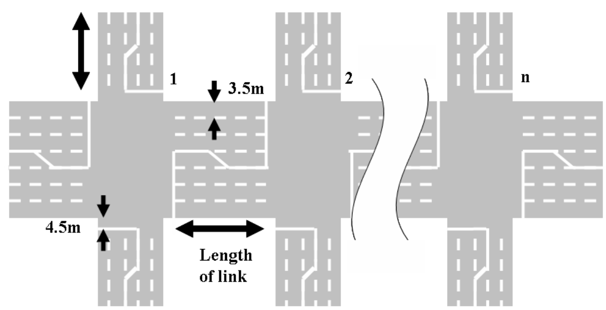

Fig. 2. Street Model

2) Vehicle Model and Driving Model [19][20]:: All the vehicles are assumed to be passenger cars. The vehicle length is 4.5m and the width is 1.7m. Each vehicle is operated by a driver who makes judgments on the ambient traffic conditions while driving. The entry of vehicles into the evaluation area is assumed to be a Poisson distribution. Assuming that ideal running conditions are maintained in the region outside the evaluation area, the minimum vehicle distance is set in the entrance to the evaluation area depending on the velocity. When a vehicle enters with a distance less than the minimum vehicle distance, it waits in a vehicle pool and then enters after the minimum distance is assured. In this case, the average value generated by a Poisson distribution does not change and the vehicles are flowing even if the vehicle stays in the pool temporarily. When a vehicle starts moving from a standstill, the delay is given by a normal distribution with a mean of 0.8s and a standard deviation of 0.5s. If it is less than 0.5s or more than 1.1s, it is truncated at 0.5s and 1.1s, respectively. Additionally, right or left turn is chosen with a probability of 10% on the main roadway and right or left turn is chosen with a probability of 40% on the intersecting roadway at the time when the vehicle enters each link. Lane change is chosen only when there is no vehicle making right or left turn from the right or left turn lane in the next intersection. Also, in consideration of actual driving, to avoid the prevention of straight motion by right-turning vehicles or left-turning vehicles, the performance of lane change is chosen at a probability of 80% by a straight-moving vehicle. The lateral displacement during lane change is 1m/s and with an acceleration of 0m/s^2. If the driver judges that the vehicle is too close to the intersection to change lane and turn right and left.

TABLE I
WALK SPEED

	Sidewalk	Crosswalk		
		Number of lines is less than 6	Number of lines is 6	Number of lines is greater than 6
Green	2m/s	1.5m/s		
Flushing	2.5 or 0 m/s	2m/s	2.5m/s	3m/s
Red	1 or 0 m/s	2m/s	2.5m/s	3m/s

C. Conventional Evaluation Indexes [19][21]

The average idling time per vehicle, the average vehicle driving speed and the maximum vehicle idling time are used as evaluation indexes in the conventional study on the ADS scheme. The average idling time per vehicle is defined as the average time spent traveling at less than 2m/s of vehicles entering into the evaluation area until pass. Then the average vehicle driving speed is defined as the average speed of vehicles entering into the evaluation area. It is inadequate for some vehicles to wait a long time by a traffic signal control scheme in the case of actual driving. Therefore, the maximum vehicle idling time is defined as the maximum idling times for vehicles per intersection, and then it is used as an evaluation index.

III. PEDESTRIAN MODEL AND NEW PERFORMANCE INDEXES

A. Construction of a Pedestrian Model and Model Validation

The entry of pedestrians into the evaluation area is based on Poisson distribution. The number of generation points of pedestrians is 8 as shown in Fig 3. The distance between a generation point and a crossing end point is set to 50m without depending on the number of lanes. A pedestrian selects own walk speed (table 1) depending on the pedestrian signal. Based on [11], the walking speed of crosswalks is set. If a signal for pedestrians is green or within 6s of flashing, the pedestrians waiting in the crossing start points determine to cross a street. Also, pedestrians on the crosswalk keep crossing a street without returning even if the signal becomes a pedestrian flashing or a pedestrian red. Based on the data surveyed in actual streets in [11], the pedestrian model constructed is verified. Table 2 shows parameters of both the streets and the traffic signal control in [11].

In this paper, we evaluate the average time that pedestrians wait without crossing a street. Therefore, using above parameters, the timing of pedestrians' crossing start in the model constructed is simulated. The result is shown in Fig.4. (S) is the results simulated by our simulator when parameters in

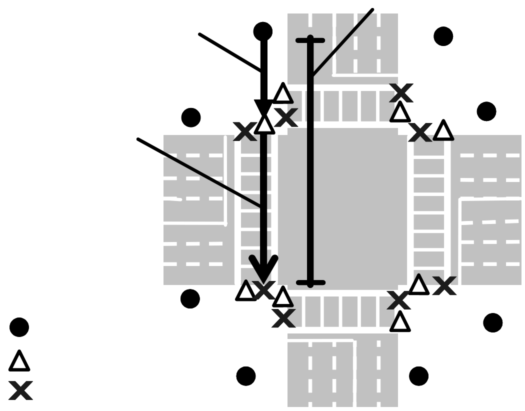

Fig. 3. Pedestrian Model

TABLE II
PARAMETERS OF INTERSECTIONS

Intersection Name	Pedestrian Green[s]	Pedestrian Flushing[s]	Length of Crossing[m]	Cycles[s]
Jiyu	26	5	10.0	91
Tashiro	40	7	17.7	150
Imaike	36	8	22.1	140
Gokiso	45	9	25.7	140

Table 1 are used. (A) is the data surveyed in actual streets. This result shows that my pedestrian model is valid.

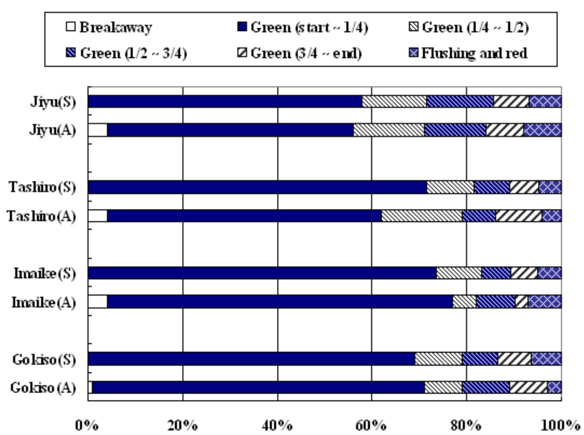

Fig. 4. Timing of Pedestrians' Crossing Start

B. New Performance Indexes

Evaluation indexes for pedestrians are needed to evaluate the comfort of pedestrians. Here, the average idling time per pedestrian is defined as the average time that pedestrians wait without crossing a street. Additionally, it is inadequate for some pedestrians to wait a long time by a traffic signal control scheme in the case of actual driving. Therefore, the maximum pedestrian idling time is added as an evaluation index. The maximum pedestrian idling time is defined as the maximum idling times for pedestrians per intersection. In the conventional studies on the ADS scheme, the average idling time per vehicle is set to the average of all idling time spent in the evaluation area because system performance for only drivers is evaluated. In this paper, the average idling time per vehicle is defined as the conventional average idling time per vehicle divided by the number of intersections crossed so that the average idling time per vehicle is easily compared with the average idling time per pedestrian. Additionally, in order to evaluate efficiency in an intersection, the average idling time per person is defined as the average idling time per person and it is also used as a performance index. Here, the average idling time per person is calculated on the assumption that there are two persons in a vehicle.

IV. PROPOSAL OF THE ADS-II SCHEME

A. ADS-II Scheme

Assuming that much location information is utilizable on the ITS platform such as EUPITS, the ADS-II scheme is proposed. On the assumption that much location information for pedestrians is obtained by cameras equipped at intersections or by communications, this information is used in the ADS-II scheme. Differently from the ADS scheme, the ADS-II scheme is able to output signal phases based on both demands of pedestrians and complicated demands of vehicles. Additionally, the ADS-II scheme can output the right-turn arrow signal depending on the current traffic condition. The outline of the ADS-II scheme is shown in Fig.5.

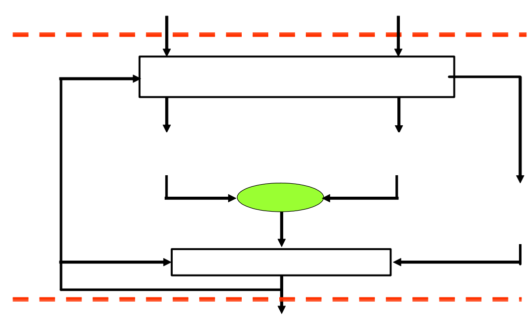

Fig. 5. Outline of the ADS-II scheme

In the ADS-II scheme, the input values are location information for vehicles and pedestrians. The output value is the signal phase information in this scheme. Both vehicles' location information and pedestrians' location information are input to the demand function, and then an evaluated value for keeping the current phase and that for changing the current phase are output. Additionally, a result of a comparison of two evaluated values is input to the phase determination subsystem. Finally, this subsystem uses the information whether a right-turning vehicle exists in the right turn bay and two evaluated values, and then the phase information is output. For example, when a right-turning vehicle does not exist in the right-turn bay, the right-turn arrow signal is skipped. In the conventional ADS scheme, the minimum green time is a parameter to prevent the direction of the right of way from being change frequently. Based on results in [21], the minimum green time is set to 5s in the case that no pedestrian exists at the intersection in the ADS-II scheme. Additionally, based on [30], the minimum green time is the period depended on the length of the pedestrian crosswalk in the case that pedestrians exist at the intersection in the ADS-II scheme. For instance, if the length of the pedestrian crosswalk is w[m], the minimum green time is w[s]. In order to output signal phases based on both demands of pedestrians and complicated demands of left-turning vehicles and right-turning vehicles, the conventional demand function used by the ADS scheme is extended.

The demand function of the ADS-II scheme is explained in IV.B.

B. Extension of Demand Function

The conventional ADS scheme decides the signal phase depending on only vehicles' demands. However, a minimum cycle length is restricted by a pedestrians' crossing time because pedestrian is an important element in coordinated control schemes. Therefore, the ADS-II scheme decides the signal phase depending on both vehicles' demands and pedestrians' demands. Furthermore, the signal control paradigm of the ADS-II scheme is shifted from that of the ADS scheme. As mentions above, in the ADS scheme, we assume that vehicles on a main roadway and vehicles on an intersecting roadway desire the green of the main roadway and the green of the intersecting roadway, respectively. However, in the case of the actual driving environment, all vehicles whose the phase is green do not desire to keep. For example, if the traffic volume of both pedestrians and vehicles coming from the opposite direction is high, it is difficult to turn right during the green phase. In this case, right-turning vehicles desire to change the current phase to the right-turn arrow signal when the signal is green. If it is difficult to turn left, left-turning vehicles want to change the current phase to the phase that does not allow pedestrians to walk and allows vehicles to move when the signal is green. Therefore, in the ADS-II scheme, demands of pedestrians and those of vehicles are judged based on the rule shown in Fig.6 in order to output more appropriate phases for these demands.

"o" means that keeping the current phase is desired. "x" means that changing the current phase is desired. "?" means that the demand is various according to the traffic condition. So, in the case of "?", left-turning vehicles or right-turning vehicles desire to change the current phase if right-turn or left-turn is difficult. Left-turning vehicles or right-turning vehicles want to keep the current phase if right-turn or left-turn is not difficult. Based on the above rule, the demands of pedestrians and those of vehicles are judged whether they desire to keep the current phase or they desire to change. Then, an evaluated value for keeping the current phase and that for changing the current phase are calculated both by (4) and by (5), respectively.

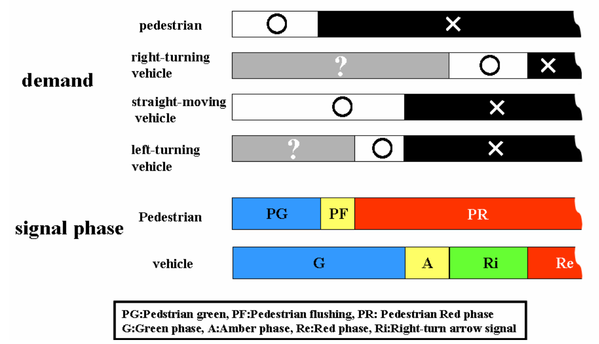

Fig. 6. Rule to judge demands

The ADS-II scheme calculates a demand for a vehicle using (3) of the ADS scheme. The ADS-II scheme calculates an evaluation value for a pedestrian using (6).

$$\begin{aligned} f_i^{(k)} &= c_{i-1}\Big(\sum_{j^{(k)}} f_{i-1,j}^{(v)} + \sum_{k^{(k)}} f_{i-1,k}^{(p)}\Big) + \Big(\sum_{j^{(k)}} f_{i,j}^{(v)} + \sum_{k^{(k)}} f_{i,k}^{(p)}\Big) \\ &\quad + c_{i+1}\Big(\sum_{j^{(k)}} f_{i+1,j}^{(v)} + \sum_{k^{(k)}} f_{i+1,k}^{(p)}\Big) \end{aligned} \tag{4}$$

$$\begin{aligned} f_i^{(c)} &= c_{i-1}\Big(\sum_{j^{(c)}} f_{i-1,j}^{(v)} + \sum_{k^{(c)}} f_{i-1,k}^{(p)}\Big) + \Big(\sum_{j^{(c)}} f_{i,j}^{(v)} + \sum_{k^{(c)}} f_{i,k}^{(p)}\Big) \\ &\quad + c_{i+1}\Big(\sum_{j^{(c)}} f_{i+1,j}^{(v)} + \sum_{k^{(c)}} f_{i+1,k}^{(p)}\Big) \end{aligned} \tag{5}$$

$$f_{i,k}^{(p)} = \begin{cases} 0, & (The\ distance\ walked\ is\ over \\ & the\ half\ length\ of\ the\ crosswalk), \\ p, & (The\ distance\ walked\ is\ not\ over \\ & the\ half\ length\ of\ the\ crosswalk). \end{cases} \tag{6}$$

$f_{i,k}^{(p)}$	demand of pedestrian k at intersection i;
k	pedestrian number;
p	pedestrian demand coefficient;
$f_i^{(k)}$	evaluated value for keeping the current phase;
$f_i^{(c)}$	evaluated value for changing the current phase;
$j^{(k)}$	vehicles that desire to keep the current phase;
$j^{(c)}$	vehicles that desire to change the current phase;
$k^{(k)}$	pedestrians that desire to keep the current phase;
$k^{(c)}$	pedestrians that desire to change the current phase.

V. PERFORMANCE EVALUATION

In this section, in order mainly to evaluate the foundational performance of the efficiency in the ADS-II scheme, the performance of the ADS-II scheme is compared with that

TABLE III
EXAMINED PARAMETERS

(a) Paremeters in the ADS-II scheme

Communication Range[m]	Cooperation Coefficient	Order of the Demand Function	Pedestrian Demand coefficient
100,200,300,400	0, 0.3, 0.6, 1	0, 0.1, 0.3, 0.5, 1	0, 0.5, 1, 3, 5

(b) Paremeters in the coordinated control scheme

Cycle [s]	Split	Offset[s]	Time Difference[s]
80,100,140,180,220	0.5,0.6,0.7,0.8,0.9	0	0, 5, 10

TABLE IV
OPTIMUM PARAMETERS

(a) Paremeters in the ADS-II scheme

Main Road way[s]	Communi-cation Range[m]	Coopera-tion Coefficient	Order of the Demand Function	Pedestrian Demand coefficient
10	200	0.6	0.1	0
12	300	0.3	0.1	0.5
14	300	0.3	0.1	0.5
20	300	0	0.1	0.5
40	300	0	0.1	1
200	300	0	0.3	1

(b) Paremeters in the coordinated control scheme

Main Roadway[s]	Cycle [s]	Split	Offset[s]	Time Difference[s]
10	180	0.7	0	0
12	140	0.6	0	0
14	140	0.6	0	0
20	140	0.6	0	0
40	140	0.6	0	0
200	140	0.6	6	0

of a coordinated control scheme. Based on the consideration that the cost of time loss of each pedestrian should be equal that of each driver, we adopt an index that the smaller the average idling time per person becomes, the more effective the control scheme becomes.

A. Simulation Parameters

The street model simulated is shown in Fig. 7. Here, the ratio of the average vehicle headway time of the main roadway, that of the cross roadway and that of pedestrian generation period are set to 1:2:5. The all red is 2s, and the amber phase is 4s in both the ADS-II scheme and the basic coordinated signal control scheme. Additionally, based on [30], the pedestrian flushing in the main roadway and that in the intersecting roadways are 9s and 13s, respectively. The period of the right-turn arrow signal is 5s in both the ADS-II scheme and the basic coordinated signal control scheme. Here, 10000 vehicles entering into the evaluation area and pedestrians entering into the area during these vehicles leaved this area are used for evaluation.

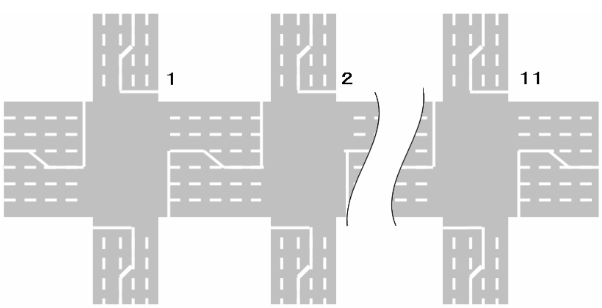

Fig. 7. Simulated Street Model

B. Performance Comparison

Firstly, parameters in the ADS-II scheme and those in the coordinated control scheme are examined (shown in table 3). Optimum parameters of the ADS-II scheme and that of the coordinated control scheme are shown in table 4. Here, "optimum control" in each scheme means the control that make the average idling time per person the smallest. Secondly, using the optimum parameters, the performance of the ADS-II scheme is compared with that of the coordinated control scheme by simulations (shown in Fig.8 - Fig.10).

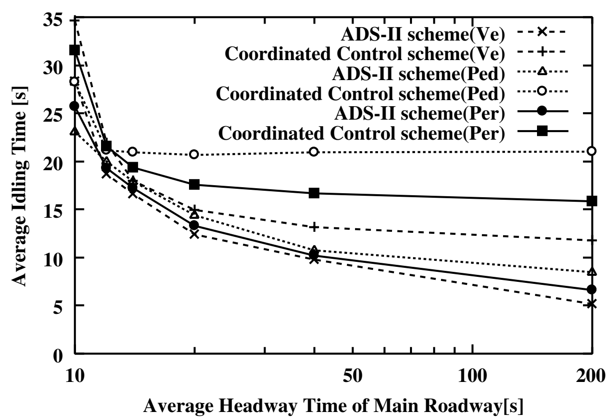

Fig. 8. Average Idling Time

Here, the time difference of the coordinated control scheme is the period that the vehicle's signal and the pedestrian's signal are green and red, respectively.

In the all simulated conditions, the average idling time per person in the ADS-II scheme is smaller than those in the coordinated control scheme. Additionally, the average driving speed in the ADS-II scheme is larger than those in the coordinated control scheme in these conditions. The maximum vehicle idling time and the maximum pedestrian idling time in the ADS-II scheme are smaller than those in the coordinated control scheme under most simulated conditions. The average idling time per persons by the ADS-II scheme is smaller than those by the coordinated control scheme in such high traffic volume as the average headway times that the main roadway is 10s. Particularly, the average idling time per pedestrian by the ADS-II scheme approximately decrease to 50% in the condition that the average headway time of the main roadway is 200s. Additionally, the maximum pedestrian idling time by the ADS-II scheme approximately is reduced 40% in this condition. This reason is that the

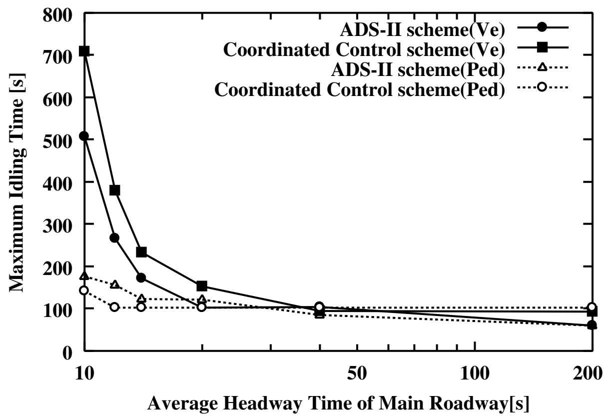

Fig. 9. Maximum Idling Time

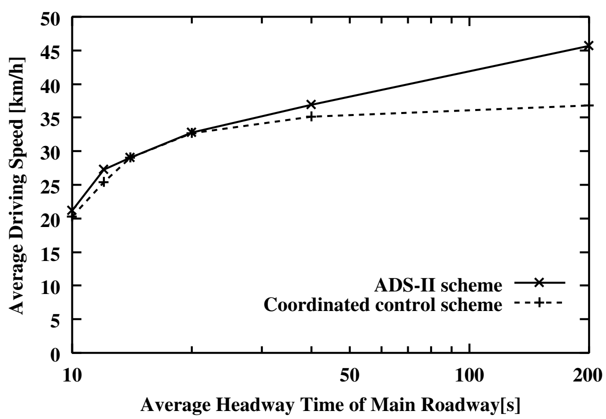

Fig. 10. Average Driving Speed

ADS-II scheme outputs signal phases based on pedestrians' demands. Therefore, the ADS-II scheme is expected that as the waiting times for pedestrians are reduced, the number of jaywalkers is smaller, and then the safety can be improved. The Figs. 8 and 9 show that as the traffic volume becomes low, the average idling time per person and the maximum idling time for both vehicles and pedestrians by the ADS-II scheme are smaller than those by the coordinated control scheme. However, these results show the average idling time per person and the maximum idling time for both vehicles and pedestrians approximately are constant by the coordinated control scheme in these cases. Therefore, it is found that the lower the traffic volume becomes, the larger the advantage of the ADS-II scheme becomes. Though the advantage of the ADS-II scheme may become larger in the low traffic volume as the off hour in a suburban area with a few lanes, this is the future topic of researches.

It is found that the ADS-II scheme is superior to the coordinated control scheme in both the high traffic volumes and the low traffic volumes.

VI. CONCLUSIONS

This paper has described the ADS-II scheme that can output signal phases based on both demands of pedestrians and demands of vehicles, and also has presented the basic performance comparisons between the ADS-II scheme and the basic coordinated control scheme and the utility of the ADS-II scheme. Firstly, we have proposed the ADS-II scheme, which is an improvement of the ADS scheme, in order to output signal phases appropriate for demands of pedestrians, straight vehicle, left-turning vehicles and right-turning vehicles. Secondly, after a simple pedestrian model has been constructed for system performance evaluations for both pedestrians and vehicles, the model has been validated. Thirdly, the performance of the ADS-II scheme has been compared with that of the coordinated control scheme by the simulator introduced this pedestrian model. The results showed that the average idling time per person in the ADS-II scheme is smaller than that in the coordinated control scheme in the all conditions simulated. Particularly, in the low traffic condition, the average idling time per person by the ADS-II scheme has been reduced by 50%. Additionally, the maximum idling time for vehicles and pedestrians by the ADS-II scheme has been smaller than that by the coordinated control scheme.

The future topics of researches will include the performance evaluation of the ADS-II scheme in the higher traffic volume such as a festival and that in the low traffic volume in a suburban area with a few lanes. We will evaluate the influence on regional environment of the ADS-II scheme.

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