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Intelligent transport systems — The use of simulation models for evaluation of traffic management systems — Input parameters and reporting template for simulation of traffic signal control systems

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Intelligent transport systems — The use of simulation models for evaluation of traffic management systems — Input parameters and reporting template for simulation of traffic signal control systems

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Foreword

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The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

Introduction

Many kinds of signal control systems are used in the world. Some systems are based on simple time-of-day control while some systems are operated in real time, adaptively controlled in accordance with changing traffic conditions.

When adopting a new signal control system in the field, simulations are often used to evaluate its effect. However, although traffic conditions vary considerably in each country and area, simulations can be operated only with some limited conditions. Some control systems and algorithm achieve good performance only in specific conditions, and sometimes simulations are operated assuming virtual road networks for studying a new algorithm.

By disclosing simulation conditions, it becomes possible to learn whether the signal control systems are applicable to many conditions or good in particular conditions, and whether the conditions are practical or the simulation is for theoretic quality assessment. Thus, this Technical Report aims to provide guidelines for disclosing simulation conditions and results in order to evaluate and compare various signal control systems.

For a fair evaluation of signal control systems from simulation results, this Technical Report describes minimum necessary items of conditions of simulation that shall be disclosed. The items of simulation results cannot be regulated because various kinds of results are created depending on simulators, so this Technical Report shows some examples of simulation results.

Intelligent transport systems — The use of simulation models for evaluation of traffic management systems — Input parameters and reporting template for simulation of traffic signal control systems

1 Scope

This Technical Report provides guidelines for disclosing simulation conditions and results when evaluating the performance of signal control methods, focusing on algorithm that establishes signal timings based on traffic conditions. The following are the main aims of the evaluation of signal control systems:

a) to evaluate the quality of the algorithm in various traffic conditions;

b) to evaluate the validity of the algorithm for specific applications (types of intersection);

c) to establish a fair comparison of the algorithm versus other existing algorithms or other types of control systems;

d) to evaluate the results of the implementation of a signal control system objectively.

When claiming and/or comparing the performance of signal control systems from simulation results, it is necessary to clarify simulation conditions and results so that third parties can objectively judge its fairness and reasonability.

This Technical Report describes minimum necessary items of conditions that shall be disclosed to ensure fair evaluation and does not describe maximum possible items.

2 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

2.1
additional lane
added lane which is branched from another *lane* (2.6)

2.2
clearance time
time between signal phases during which an intersection is not used by any traffic

Note 1 to entry: It is expressed in seconds.

2.3
cycle
complete sequence of signal indications

2.4
cycle length
time required for a complete sequence of signal indications

2.5
detection area
area where a vehicle detector can count and/or determine the presence of a vehicle

2.6
lane
marked part of a road that is wide enough to accommodate one vehicle

2.7
link
union of separated two points on the road, tied by single or plural *lanes* (2.6)

2.8
lost lane
lane (2.6) which is merged into another *lane* (2.6)

2.9
occupancy
percent of time that a detector indicates a vehicle is present over a total time period

2.10
phase
signal controller timing unit associated with the control of one or more movements

2.11
saturation flow rate
equivalent hourly rate at which vehicles can traverse an intersection approach, assuming a constant green indication at all time and no loss time

Note 1 to entry: It is expressed in vehicles per hour or vehicles per hour per lane.

2.12
split
time assigned to a *phase* (2.12) during coordinated operations

Note 1 to entry: It may be expressed in seconds or percent.

2.13
time-of-day control
signal timing plans associated to specific hours of the day associated with fluctuations in demand

2.14
vehicle detector
device used to count and/or determine the presence of a vehicle

3 Categories of targeted signal control method

In this Technical Report, the simulation conditions shall be classified in the following categories according to the main purpose of the targeted signal control method:

a) signal control for isolated intersection;

b) area traffic control.

4 Signal control for isolated intersection

4.1 Simulation condition

4.1.1 Simulator

By disclosing simulator being used, it becomes possible to indicate whether the simulator is suitable for evaluating the functions of targeted signal control and to guarantee reproducibility of the evaluation. For this purpose, the following items about simulator information shall be disclosed:

a) manufacturer of the simulator;

b) product name;

c) version.

It is important to calibrate simulation models to validate the simulation results. An example of the criteria for the calibration can be found in "Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software" by The Federal Highway Administration. The validation of simulation models are out of scope of this Technical Report, but simulation models should be disclosed.

4.1.2 Road network

The following items shall be disclosed as road network conditions under simulating:

a) number of links;

b) number of lanes (and number of additional lanes and lost lanes, if it exists);

c) length of links (in meters);

d) direction of each link (should be illustrated with arrows in figures);

e) geometry of links (how each link is connected to other links and intersections).

If each link can be used by particular vehicles (e.g. dedicated buses, bicycles), then the vehicle types shall be disclosed.

4.1.3 Vehicle detector

Generally, signal control systems are thought to achieve better performance as more detectors are installed, but the cost of installing detectors increases with the numbers of detectors. Moreover, there are some areas in the field where detectors are difficult to install. Thus, by disclosing the detector conditions, it becomes possible to evaluate the cost effectiveness of the targeted system and to let third parties know whether the conditions are practical or if the simulation is for theoretic quality assessment.

For this purpose, the following items shall be disclosed for detector conditions under simulating:

a) location of vehicle detector (can be shown as Figure A.1);

b) detection area (e.g. square measure, shape);

c) items collected with vehicle detectors for signal control (e.g. traffic volume, occupancy);

d) lane usage for vehicle detector (e.g. right turn only, right turn plus through);

e) when using information collection methods other than a detector (e.g. probe data), then their outline and collection items;

f) when using information collection methods that are not feasible to use in the field, then their outline and collection items.

4.1.4 Traffic conditions and simulation time

The effect of the signal control system depends on traffic conditions, so the conditions and the variations over the time of the simulation shall be disclosed.

For this purpose, the following items shall be disclosed for traffic flow conditions under simulating:

a) types of demand (vehicle types and their percentages of total vehicle demand);

b) public transit (routes and volume, in case of evaluating the influence of public transit);

c) pedestrians (crosswalk and volume, in case of evaluating the influence of pedestrians);

d) traffic demand (input traffic volume of each link and turning ratio at the intersection);

e) vehicle generation distribution (e.g. uniform distribution, Poisson distribution);

f) saturation flow rate (vehicles/lanes/green timing);

g) average speed (km/hour);

h) simulation time (seconds);

i) simulation resolution (how many steps per second calculations are operated);

j) pre-simulation time (the time to create initial traffic conditions before simulation evaluation, excluding simulation time).

Traffic conditions should be general enough so that third parties can rationally evaluate the performance and compare it to other algorithm. Each traffic control system will have its strong traffic conditions and weak traffic conditions. The performance of signal control under changing traffic conditions is essential. Therefore, input traffic volume should be changed cyclically to be normal, near saturated, and over saturated in order to prove the signal control system is applicable to all these conditions, or good in particular traffic conditions, and to show the performance under changing traffic conditions.

4.1.5 Signal control

The performance of signal control depends on clearance time, cycle length, upper and lower limits of split, and other conditions, so those conditions shall be disclosed. When using the time-of-day control method without vehicle detectors as the reference system, its periods of transition between time of day plans and the details of timing within those periods shall be disclosed. For these purposes, as a condition of signal control at the intersection, the following items shall be disclosed if applicable:

a) phase pattern (these conditions can be disclosed as Figure A.3):

   1) variable or fixed;

   2) sequence;

   3) constrained conditions (in case of variable);

b) clearance time:

   1) variable or fixed;

   2) initial clearance time, upper limit and lower limit (in case of variable) or fixed clearance time (in case of fixed) (in seconds);

c) cycle length:

   1) variable or fixed;

2) initial cycle length, upper limit and lower limit (in case of variable) or fixed cycle length (in case of fixed) (in seconds);

d) split:

1) variable or fixed;

2) initial split, upper limit and lower limit (in case of variable) or fixed split (in case of fixed) (in seconds or percent);

e) other signal control parameters:

1) contents;

2) variable or fixed;

3) constrained condition (in case of variable);

f) priority control (in case of implementation):

1) type of vehicle to give priority to (transit vehicle, emergency vehicle, heavy vehicle etc.);

2) priority rules.

Setting the signal control conditions, such as clearance time, cycle length, and upper and lower limit of split as impractical values to gain better performance shall be avoided.

4.1.6 Simulation system configuration

The information about the composition of the simulation system indicates how much processing and communication delays in the field are reflected to the simulation. Therefore, the following items shall be disclosed concerning how the simulator and the signal control system are linked (via API, via communication interface, etc.).These items can be disclosed as Figure A.5.

a) Structure of the device and the software of the simulator and the targeted signal control system.

b) Data flow of the device and the software of the simulator and the targeted signal control system.

4.2 Methods of presenting simulation results

Evaluation of simulation results is essential for simulation experiments. Therefore, the following items as the results of simulation shall be disclosed so that third parties can evaluate them fairly. Detailed contents of each item should be able to be used to rationally evaluate the characteristics of signal control methods.

4.2.1 Signal control parameter

Parameters of signal controls during simulation shall be disclosed so that the behaviour of the simulation and the values of evaluation index in 4.2.2 are proved to be appropriate, and so that the simulation result do not serve as outputs from black boxes.

For this purpose, the time change of following variables as the results of signal control simulation at intersection shall be disclosed:

a) order of phases;

b) cycle length (in seconds);

c) split (in seconds or percent);

d) other signal control parameters.

4.2.2 Evaluation index

Simulation results shall be quantified according to the purpose of the target system and disclosed as evaluation indexes in order to simplify the evaluation of simulation results by the third parties. Also, the formulas of the evaluation indexes also shall be disclosed so that the indexes are appropriate for the targeted system and so that evaluation indexes do not serve as outputs from black boxes. The number of runs of simulations shall be disclosed, and when the simulations are operated plural times, coefficient of variation should be disclosed. If outliers are removed when calculating evaluation index, the policy or formula for rejecting outliers shall be disclosed.

For this purpose, the following items as evaluation indexes used to evaluate the results of simulation shall be disclosed. See A.2.2.2 and A.2.2.3, which shows examples of disclosing formulas of calculating CO_2 emissions and global man hour loss.

a) Definition of information for calculation of evaluation index, measurement method

b) Definitional identity of evaluation index

c) Range of scope (link, section etc.)

d) Value of evaluation index

Evaluation of the effectiveness of the signal control system will be based on different criteria, in order to give an integrated and global vision of the performance, but also relevant aspects such as the environment or economics. Thus, the indicators will be classified according to the following criteria.

4.2.2.1 Impact on traffic flow

The impact on traffic flow can be quantified using simulation. Table 1 indicators are the examples of results (some other items can be disclosed).

Table 1 — Examples of impact on traffic flow

Items	Description
Travel time combined	Sum of the travel time of all the approaches that configure the intersection (total. or avg. per vehicle)
Travel time per approach	Segregated travel time for each approach (tot. or avg. per vehicle)
Delay combined	Sum of delays of all the approaches that configure the intersection (total. or avg. per vehicle)
Delay per approach	Segregated delay for each approach (total. or avg. per vehicle)
Maximum delay combined	Maximum delay all the approaches that configure the intersection (can be calculated for each vehicle type and pedestrian)
Maximum delay per approach	Maximum delay for each approach (can be calculated for each vehicle type and pedestrian)
Queue length	In distance
Congestion length time	Duration of congestion (considered in queue exceeding a minimum threshold)
Number of stops	Total. or avg. per vehicle
Stop duration	Total. or avg. per vehicle
Reduction in the variance of acceleration/deceleration	Monitoring the smoothness of traffic flows
Reduction in the delay on under-saturated approaches at oversaturated intersections	To avoid overestimated efficiency in main approaches but penalizing in excess the secondary approaches

All these indicators will be considered, taking into account the dynamism of the traffic flow, aggregating values on a time interval basis and taking maximum values and duration for the approaches and global value. The mean, max, and deviation values shall then be considered as the evaluation variables.

4.2.2.2 Impact on the environment

Main pollutants that can be taken as environmental variables are in Table 2:

Table 2 — Examples of impact on the environment

NOx	Nitrogen oxides
CO2	Carbon dioxide
VOC	Volatile organic compound
PM	Particulate matter

Consider the aggregate values obtained per approach, or globally at intersection level or area level, expressed in mass divided into length (in SI units: kg/km).

4.2.2.3 Economic impact

The economic impact on drivers can be quantified using simulation. Indicators in Table 3 can be defined.

Table 3 — Examples of economic impact

Fuel consumption per intersection	Aggregate of all approaches to the intersection
Global fuel consumption along corridor	Aggregate of all intersections if coordination is tested
Global man hour loss along corridor	Aggregate of all intersections if coordination is tested

See Table A.4 which is an example of calculating global man hour loss in a day.

4.2.3 Target for comparison

When comparing the simulation results with other signal control methods, disclose the information of the reference signal control method based on the items in 4.2.2. Setting the signal control conditions unfavourable for reference system to make the performance of targeted control system relatively better shall be avoided.

5 Area traffic control

5.1 Simulation conditions

5.1.1 Simulator

Items that shall be disclosed are the same in 4.1.1.

5.1.2 Road network

Items that shall be disclosed are the same in 4.1.2.

For evaluating the performance of area traffic control, road network should be appropriate for evaluating the effects of the coordinated control which adjusts offset and the side effects of it.

5.1.3 Vehicle detector

Items that shall be disclosed are the same in 4.1.3.

5.1.4 Traffic condition

Items that shall be disclosed are the same in 4.1.4.

a) Hourly traffic demand

b) Either following 1) or 2), or its combination

   1) Origin-destination traffic volume (by vehicle type)

   2) Input Traffic volume of each link and turning ratio at each intersection

5.1.5 Signal control

In addition to the items in 4.1.5, the following shall be disclosed. When each traffic signal is configured individually, then each parameter for each traffic signal shall be disclosed.

a) Offset

   1) Discrimination of intersection offset, link offset

   2) Direction

   3) Variable or fixed

   4) Assignment phase

   5) Initial offset value, upper limit and lower limit (in case of variable) or fixed offset (in case of fixed) (seconds)

b) Sub-area configuration

   1) Variable or fixed

   2) Minimum unit of sub-area (in case of variable)

5.1.6 Simulation system configuration

Items that shall be disclosed are the same in 4.1.6.

5.2 Methods of presentation of simulation results

5.2.1 Signal control parameters

In addition to the items in 4.2.1, the following shall be disclosed:

a) offset (link offset to adjacent intersection);

b) sub-area.

5.2.2 Evaluation Index

Items that shall be disclosed are the same in 4.2.2.

Annex A
(informative)

Example of simulation conditions for evaluation of signal control systems performance (in case of area traffic control)

A.1 Simulation condition

A.1.1 Simulator

XXXSIM Ver. 1.0 (XXX products)

A.1.2 Road network

a) Number of intersections: 5 (critical intersection 1, ordinary intersection 4)

b) Number of links: 8

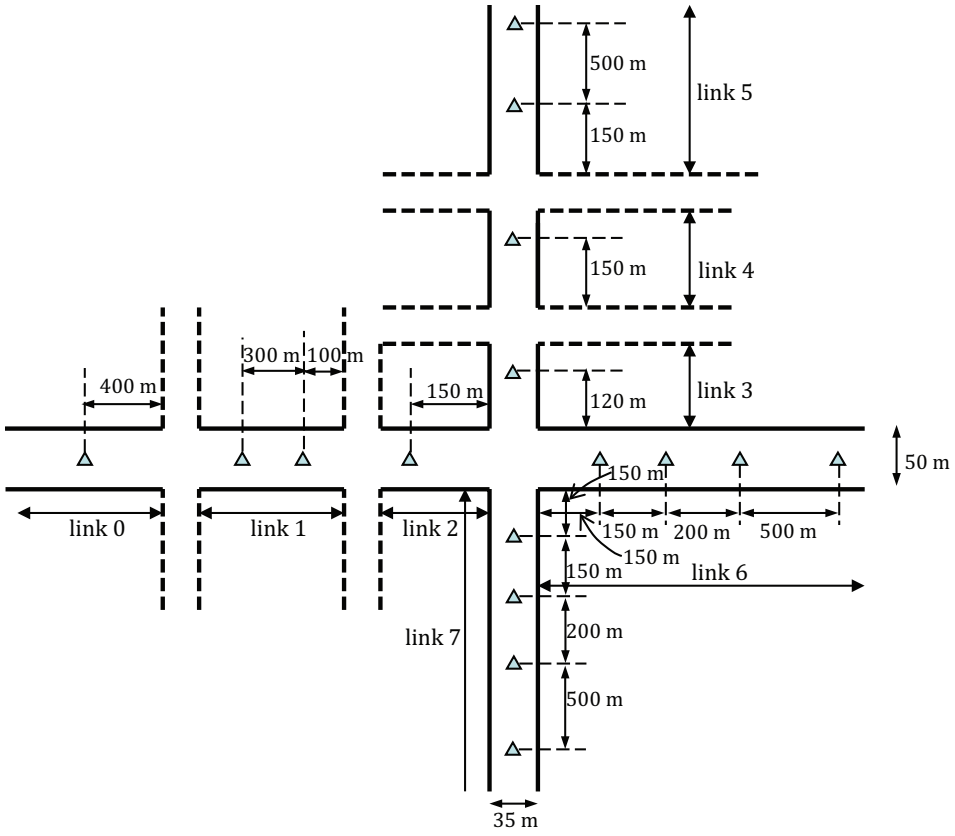
c) Length of link: (see Table A.1)

d) Number of lanes: (see Table A.1)

Table A.1 — Road network parameters

Link no.	0	1	2	3	4	5	6	7
Length of link (m)	900	400	200	150	200	1 150	1 500	1 500
Number of lanes	2	2	2	1	1	1	2	1

e) Network configuration (see Figure A.1)



Key

△ vehicle detector

Figure A.1 — Network configuration

A.1.3 Vehicle detector

a) Location of vehicle detector (see Figure A.1)

b) Detection area: cross-section (square measure = 0)

c) Items collected with vehicle detectors for signal control: traffic volume, occupancy

d) Information collection methods other than detector: none

A.1.4 Traffic conditions

a) Hourly traffic demand

   1) Vehicle generating links: link 0, 5, 6, 7

   2) Turning ratio: straight 100 %

b) Generating traffic volume (see Figure A.2)

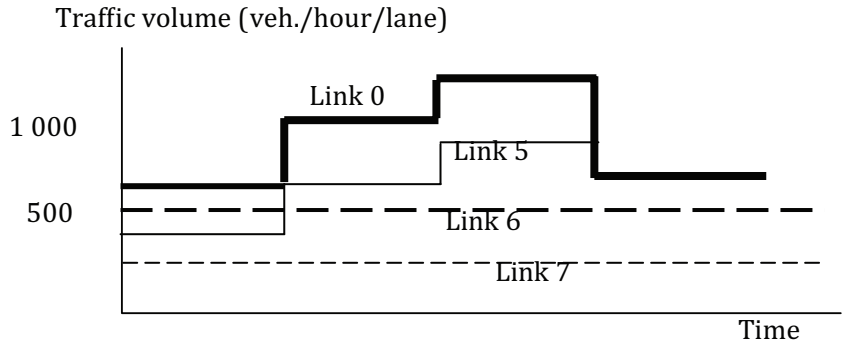


Figure A.2 — Traffic volume

c) Vehicle generation distribution: Poisson distribution

d) Saturation flow rate: 1 800 (vehicle/lanes/green timing)

e) Average speed: 50 km/h

f) Simulation time: 5 400 s

g) Pre-simulation time: 300 s

A.1.5 Signal control

a) Phase configuration: fixed (see Figure A.3)

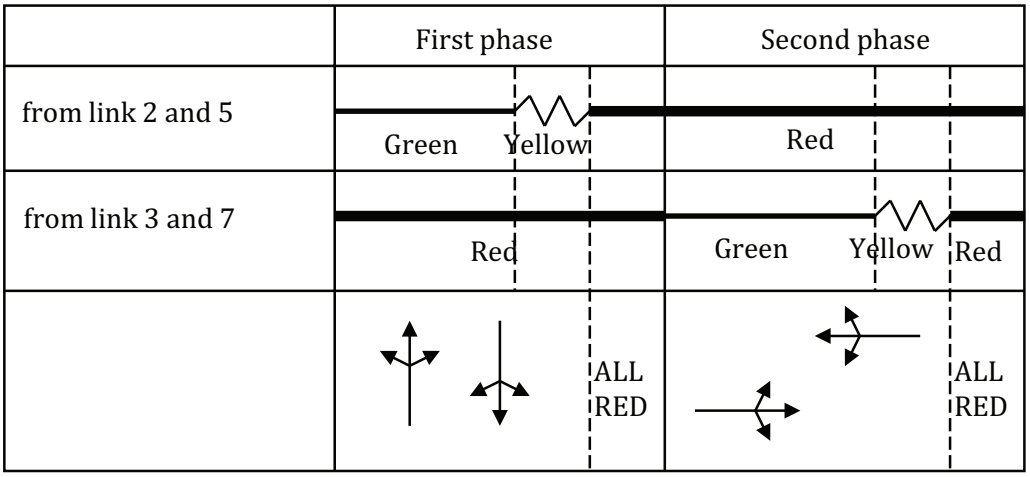


Figure A.3 — Phase sequence diagram

b) Clearance time: fixed, 10 s

c) Cycle length: variable, initial value 150 s, upper limit 150 s, lower limit 80 s

d) Split: critical intersection: variable, initial value 60 %:40 %, upper limit, lower limit

Ordinary intersection: fixed, 70 %:30 %

e) Link offset: Link 1, 2,4: variable, initial value 0 s, upper limit, lower limit

Link 3: fixed, 0 s

f) Sub-area: fixed

A.1.6 Simulation system configuration

See Figure A.4.

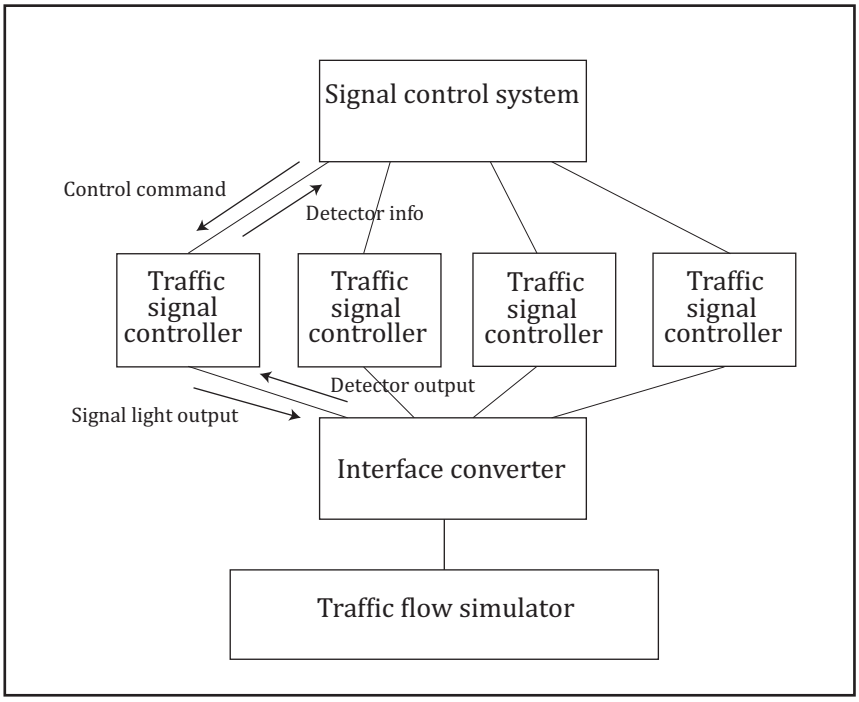


Figure A.4 — Simulation system configuration

A.2 Simulation results

Figure A.5, Figure A.6, Figure A.7, and Figure A.8 are simulation results.

A.2.1 Signal control parameter

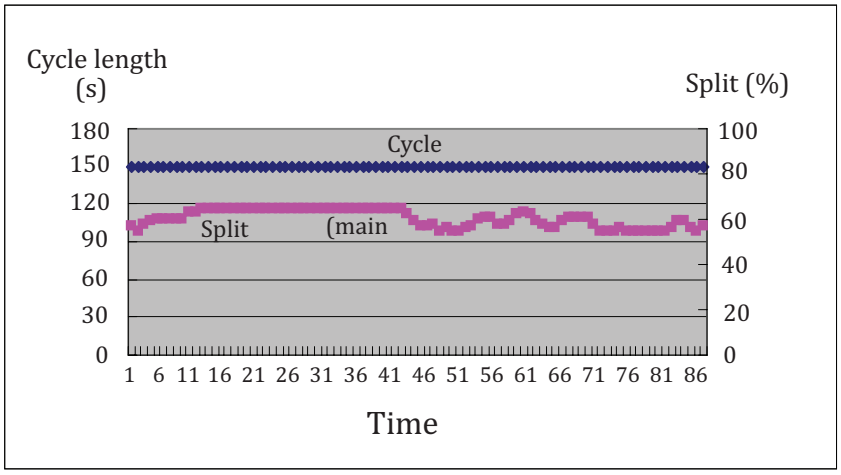


Figure A.5 — Cycle length and split of the reference control

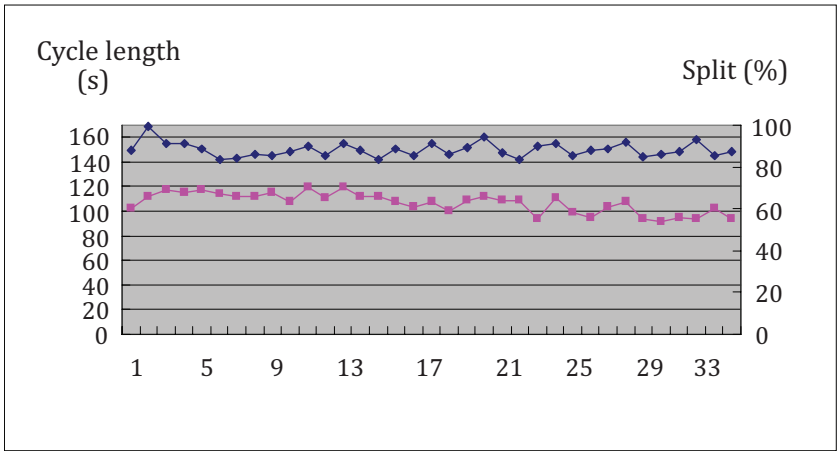


Figure A.6 — Cycle length and split of the proposed control

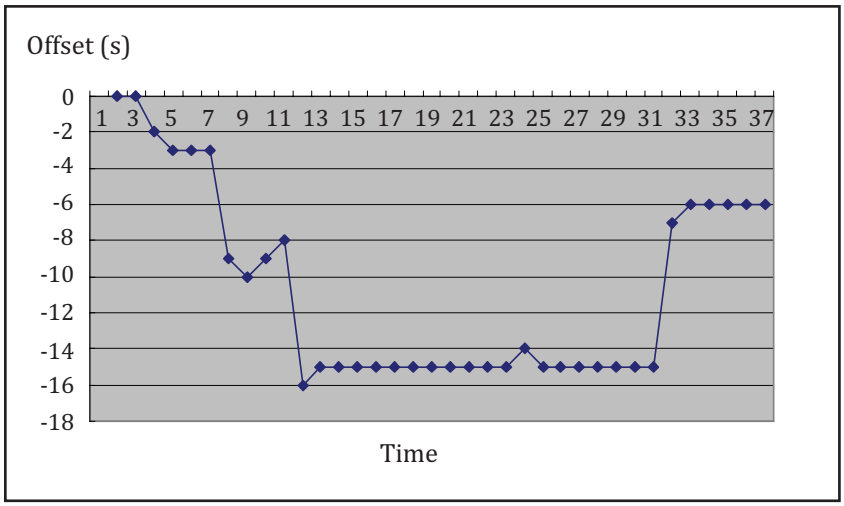


Figure A.7 — Offset of the reference control (link 2)

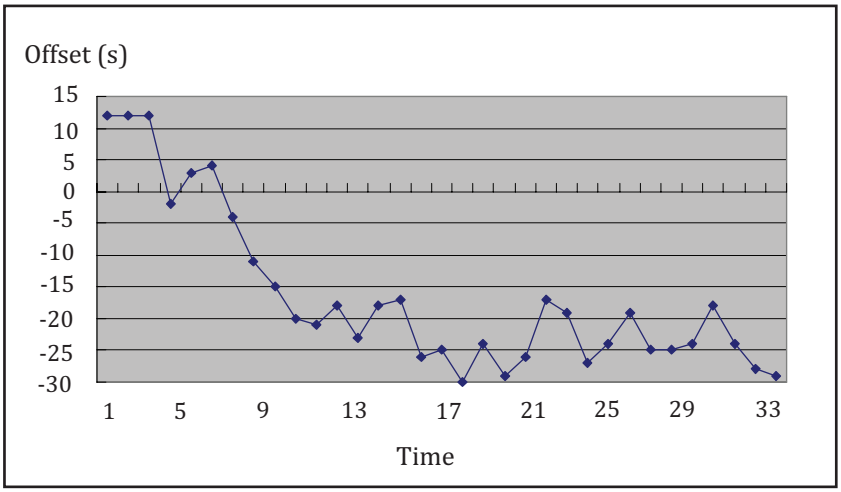


Figure A.8 — Offset of the proposed control (link 2)

A.2.2 Evaluation indexes

A.2.2.1 Impact on traffic flow

See Table A.2.

Table A.2 — Delay combined and number of stops

System	Delay combined (vehicle*sec)	Number of stops
Reference	160 000	3 000
Proposed	120 000	2 800

A.2.2.2 Impact on the environment

See Table A.3. Evaluation index: CO_2 emissions over the network E (g/m = kg/km)

$$E = 0{,}68 * T + 0{,}064 * L + 0{,}13\left(196{,}0 * S1 + 31{,}0 * S2\right)/H \quad \text{(A.1)}$$

Table A.3 — Evaluation index and information for calculation

System	E (kg/km)	T Travel time (h)	L Distance travelled (m)	S1 Number of stops at intersection	S2 Number of stops in congestion	H Total length of network (m)
Reference	67,9	560 000	5 500 000	3 000	1 500	12 000
Proposed	65,0	520 000	5 500 000	2 700	1 300	12 000

A.2.2.3 Economic impact

See Table A.4. Evaluation index: Global man hour loss over the network Y (yen/day)

$$Y = \left.\begin{array}{l} 1{,}8\left(\text{persons}/\text{vehicle}\right) * 2\,200\left(\text{yen}/\text{hour}\right) * \\ 12\left(\text{hour}/\text{day}\right) * \text{Delay combined}\left(\text{vehicles} * \text{sec}\right) \end{array}\right/ 5\,400 \quad \text{(A.2)}$$

Table A.4 — Evaluation index and information for calculation

System	Y (yen/day)	Delay combined (vehicle*sec)
Reference	1 408 000	160 000
Proposed	1 056 000	120 000

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