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ISOLATED VS COORDINATED RAMP METERING STRATEGIES: FIELD EVALUATION RESULTS IN FRANCE

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1 INTRODUCTION

Severe traffic congestion is the daily lot of drivers using the motorway network, especially in and around major cities and built-up areas. On intercity motorways, this is due to heavy traffic during holiday weekends when many people leave the cities at the same time, or to accidents or exceptional weather conditions. In the cities themselves, congestion is a recurrent problem. The control measures which are produced in a coordinated way to improve traffic performance include signal control, ramp metering and route guidance. With respect to the ramp metering techniques, one successful approach, for example, is the ALINEA strategy (Haj-Salem et al, 1990, 1995, Papageorgiou, et. al, 1991) which maintains locally the density on the carriage way around the critical value. Nevertheless, due to the synergetic effect of all metered on-ramps (they interact on each other at different time scale) the coordinated strategy could be more efficient than a local strategy.

In this paper, some field trials, conducted in the southern part of Ile de France motorway in Paris are presented. Field trials have been design and executed over a period of several months in the aim of investigating the traffic impact of ramp metering measures. More specifically, the field trials, reported in this paper, include a comprehensive data collection from the considered network (A6W motorway) over several weeks with isolated and coordinated ramp metering strategies. The main objectives of the field trials were the development, the test and the evaluation of the traffic impact of new isolated and coordinated strategies.

This paper is organized as follows: section 2 is dedicated to the test site description. Section 3 concerns the brief description of the candidate strategies. The last section 4 is focused on the description of the used criterion on one hand and the other hand the field results analysis.

2 FIELD TEST DESCRIPTION

The traffic management of "Ile de France" motorway network is under both main authorities: the Paris City "Ville de Paris" authority operates the Paris inner urban network and the ring way and the DIRIF "Direction interdépartementale de la Région d'Ile de France" authority operates the motorway network around Paris city (A1 to A13). The DIRIF motorway network covers around 700 km including A1 to A13 motorways. Since 1988, DIRIF has launched a project called "SIRIUS: Service d'Information pour un Réseau Intelligent aux USagers" aiming at optimising the traffic conditions on the overall "Ile de France" motorway network in terms of real-time traffic control strategies such as ramp metering, automatic incident detection, speed control, lane assignment, traffic user's information/guidance (travel time display) etc.).

The particular motorway network considered in this field evaluation study is in the southern part of the Ile de France motorway network (A6W, figure 1). The considered site is one among the most critical areas of the Ile de France motorway network. The total length covers around 20 km including several on/off ramps.

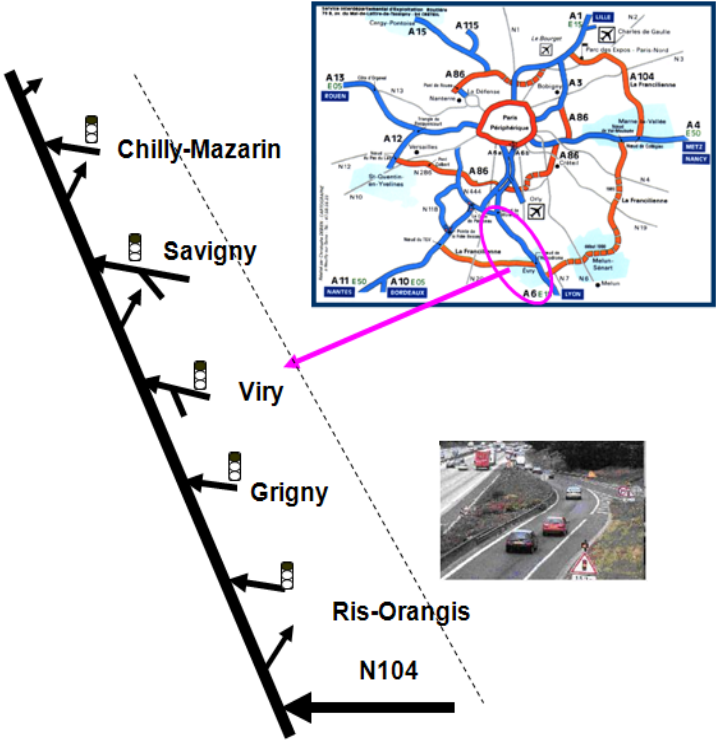


Figure 1. Field test site

Morning and evening peak congestions extend over several hours and several kilometres. A recurrent congestion in the morning peak period typically starts around the on ramp Chilly and it spreads subsequently over several kilometres on A6W motorway axis. The considered motorway axis is fully equipped with measurement stations. The field test covers around 20

km length and includes 33 measurements stations (loop detectors) available on the carriageway, located around 500 m from each other. Each measurement station provides traffic volume, occupancy and speed measurements. The on-ramps and off-ramps are fully equipped also. In particular at each on-ramp, two measurement stations are installed: the first one is located at the nose of the ramp behind the signal light which used for the realised on-ramp volume measurements and the second at the top of the on-ramp which used for the activation of the override tactic when the control is applied.

3 CANDIDATE STRATEGY DESCRIPTIONS

The implemented strategies are the following:

1. No control
2. ALINEA
3. VC_ALINEA (Variable Cycle ALINEA)
4. Coordination (CORDIN)

3.1 ALINEA strategy

ALINEA is based on a feedback philosophy and the control law is the following:

$$r_k = r_{k-1} + K (O^* - O_k)$$

where r_k and r_{k-1} are on-ramp volumes at discrete time periods k and $k-1$ respectively, O_k is the measured downstream occupancy at discrete time k , O^* is a pre-set desired occupancy value (typically O^* is set equal to the critical occupancy) and K is a regulation parameter. The feedback law suggests a fairly plausible control behaviour: If the measured occupancy O_k at cycle k is found to be lower (higher) than the desired occupancy O^* , the second term of the right hand side of the equation becomes positive (negative) and the ordered on-ramp volume r_k is increased (decreased) as compared to its last value r_{k-1} . Clearly, the feedback law acts in the same way both for congested and for light traffic (no switchings are necessary).

3.2 VC_ALINEA Strategy

The basic philosophy of Variable Cycle ALINEA (VC_ALINEA) is the computation of the split as control variable instead of the green duration. The main objective of VC_ALINEA is to apply different cycles with respect to the on-ramp traffic demand and the traffic conditions. The split is defined as: $\alpha = G/C$, where G is the green duration, C is the cycle duration. The VC_ALINEA control law is derived from ALINEA and has the following form:

$$\alpha(k) = \alpha(k-1) + K' [\hat{O} - O_{out}(k)]$$

Basically, the derivation of VC_ALINEA control law (see EURAMP Deliverable D3.1) consists to convert the computed ALINEA on-ramp volume $r(k)$ in green (or flashing amber) duration. This conversion is based on the measurement of the maximum on-ramp flow (q_{sat}). In case of ALINEA, the calculated green time is constrained by the minimum and the Maximum green. Similarly, the split variable as a control law (α) is constrained by two limits also: the maximum cycle C_M duration and the minimum cycle duration C_m . This means that α is varying between α_{min} and α_{max} where

$$\alpha_{min} = G_m / C_m$$

$$\alpha_{max} = G_M / C_M$$

Where:

G_m and G_M are the fixed minimum green and maximum green durations respectively.
 C_m and C_M are respectively the Minimum and Maximum cycle duration:

With $r_k = \frac{G_k}{q_{sat}}$ we have: $G_k = G_{k-1} + \frac{K_R}{q_{sat}}(\hat{o} - o_{k-1}^{out})$ (1)

G_k : Calculated Green duration.
 q_{sat} : Maximum output flow on the ramp.

Dividing equation (1) by C_k , we obtain the following VC_ALINEA control law:

$$\alpha_k = \alpha_{k-1} + \frac{K_R}{q_{sat} C_k}(\hat{o} - o_{k-1}^{out})$$
 (2)

The range of control variable α is defined by:

In a fluid condition:

$$\alpha \geq \alpha_{thr} \Leftrightarrow \left\{ \begin{array}{l} G = \alpha(G + A + R_{min}) \\ R = R_{min} \end{array} \right\} \Leftrightarrow \left\{ \begin{array}{l} G = \left(\frac{\alpha}{\alpha - 1} \right) (A + R_{min}) \\ C = G + A + R_{min} \end{array} \right\}$$

And, in a congested condition:

$$\alpha < \alpha_{thr} \Leftrightarrow \left\{ \begin{array}{l} G = G_{min} \\ R = \frac{G_{min}}{\alpha} - (A + G_{min}) \end{array} \right\} \Leftrightarrow \left\{ \begin{array}{l} G = G_{min} \\ C = \frac{G_{min}}{\alpha} \end{array} \right\}$$

3.3 Coordinated strategy (CORDIN)

The main philosophy of CORDIN strategy is to use the storage capacities of the upstream on-ramps in case of apparition of downstream congestion of the controlled on-ramp. Under critical on-ramp queue constraint, an anticipation of the control is applied at the upstream on-ramps of the head of the congestion. This means that the level of the traffic improvement in case of the application of CORDIN strategy is much related to the geometry of each on-ramp

and particularly to the storage capacity. CORDIN is a based rule coordinated strategy using ALINEA strategy first and anticipating the control action. It consists in the following steps:

1. Application of ALINEA to all controlled on-ramps -> control sets \underline{U}_{al} .
2. Find the location of the head of the congestion by testing if the first on-ramp (r_i) where ALINEA is active ($O_i > 0.9 \hat{O}_{i,cr}$) and the queue constraint not active.
3. For every upstream on-ramp $r_{up} = r_i+1, \dots, Nb_Ramps$: if the queue constraint of the on-ramp (r_{up}) is NOT active then correction of the ALINEA command according to $U_{coor} = \alpha_1 U_{al}$ if $r_{up} = r_i+1$ and $U_{coor} = \alpha_2 U_{al}$ for the other upstream ramps, where (α_1) and (α_2) are parameters to be calibrated; otherwise do nothing.
4. Application of the new coordinated control sets on the field
5. Wait the next cycle time
6. Go to step 1.

Figure 3 depicts one example of the applied correction parameters (α_1, α_2) after a detection of the head of the congestion (MASTER on-ramp).

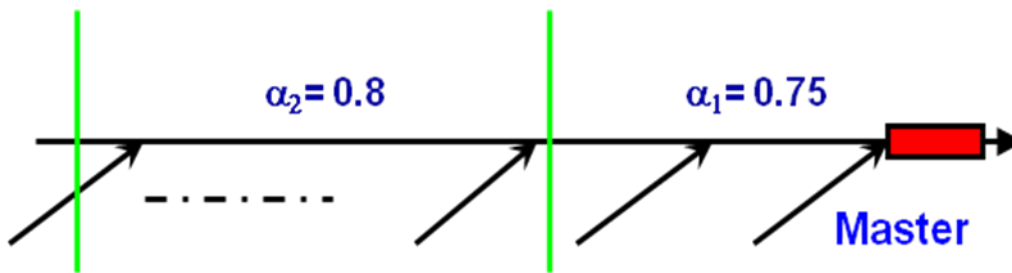


Figure 3: Example of CORDIN parameters

For each control strategy, the characteristics of the cycle time are the following: cycle duration = 40 Sec, Max_green= 30 sec, Min_green =10 sec, Amber= 5 sec

4 EVALUATION RESULTS

4.1 Available data

The different strategies have been applied in weekly alternation ALINEA, VC_ALINEA, CORDIN and no control respectively over the period from the middle of September 2006, until the end of January, 2007, and to perform subsequently, comparative assessments of the traffic impact. Full 140 days of collected data were stored in the SIRIUS database. Screening the collected data was firstly necessary in order to discard days which include major detector failures. Secondly, all days with atypical traffic patterns (essentially weekends and holidays) were discarded. Thirdly, in order to preserve the results comparability, all days including significant incidents or accidents (according to the incident files provided by the Police) were also left out.

This screening procedure eventually delivered 11, 10, 11 and 9 days of data using No control, ALINEA, VC_ALINEA and CORDIN strategies respectively. In order to minimize the impact of demand variations on the comparative evaluation results, the selected days were averaged for each strategy.

4.2 Assessments criteria

The evaluation procedure was based on a computation of several criteria for assessing and comparing the efficiency of the ramp metering installation. These criteria were calculated for each simulation run. The horizon of the simulation is fixed to the overall period (5:00 – 22:00), the morning peak period (6:00-12:00) and the evening period (17:00-21:00). The following quantitative criteria were considered for the evaluation of the control strategy:

1. The total time spent on the network (TTS) expressed in $vh \cdot h$
2. The total number of run kilometres (TTD) expressed in $vh \cdot km$
3. The mean speed (MS) expressed in Km/h
4. The travel time expressed in second from one origin to the main destination
5. Other environment criteria also were computed:
 - Fuel consumption (litres) (Jurvillier, 1982)
 - Pollutant emission of CO & Hydrocarbon (HC) expressed in kg (European project TR 1030, INRESPONSE, D91, 1998 ; ADEME, 1998)

The evaluation results were reported in the Deliverable D6.3 of EURAMP Project. In summary, the results obtained can be summarized as follows:

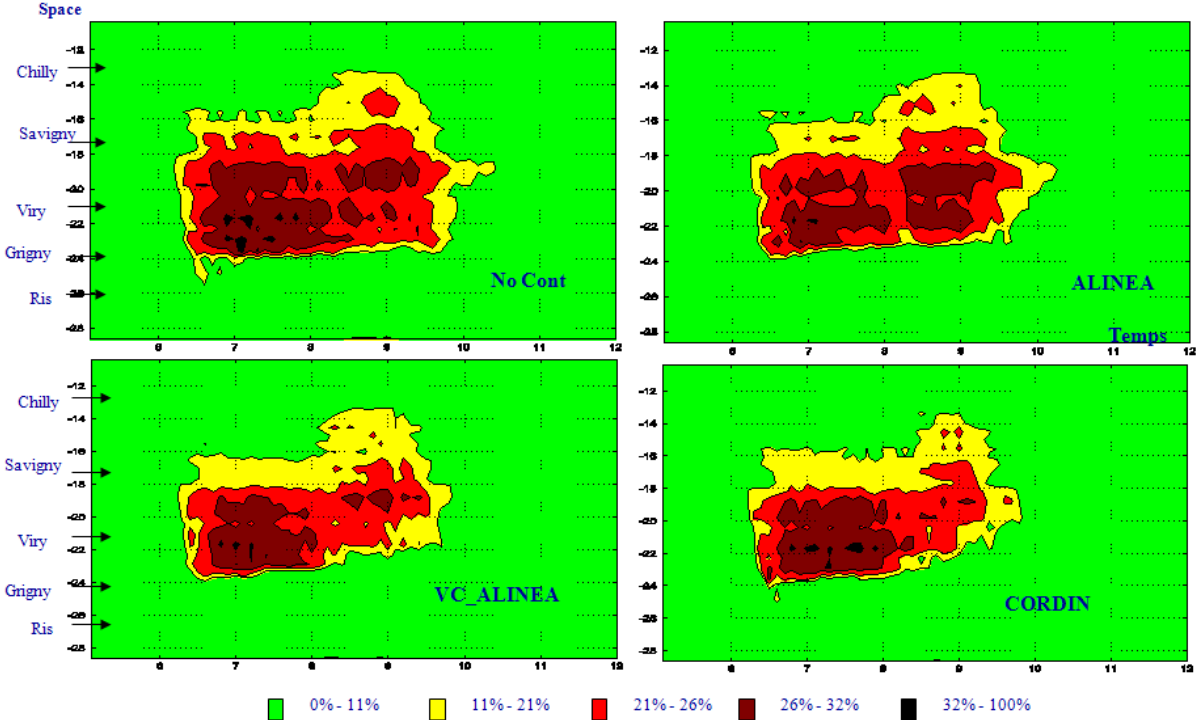


Figure 4: Congestion mapping of the 4 strategies

- It was found that ALINEA decreases the Total Time Spent (TTS) by 10% and increases the Mean Speed (MS) by 5%, compared with the No Control case.
- The VC_ALINEA seems to provide better results than ALINEA in term of the TTS index (12%). However, we observe that the TTD is decrease by 5% whereas for ALINEA, the TTD is decreases by 2% compared with the No control case.
- The CORDIN strategy provides change of 12%, 0% and 11% for TTS, TTD and MS respectively compared with the No control case.
- Figure 4 reports the congestion mapping of A6W and visually confirm these conclusions.
- With respect to the Total Travel Time (TTT), figure 5 depicts the obtained results. The CORDIN strategy gives better results than the isolated strategies. As far as the travelled distance increases, the gain in term of travel times increase also. The maximum gain of 17 % is observed for CORDIN strategy.

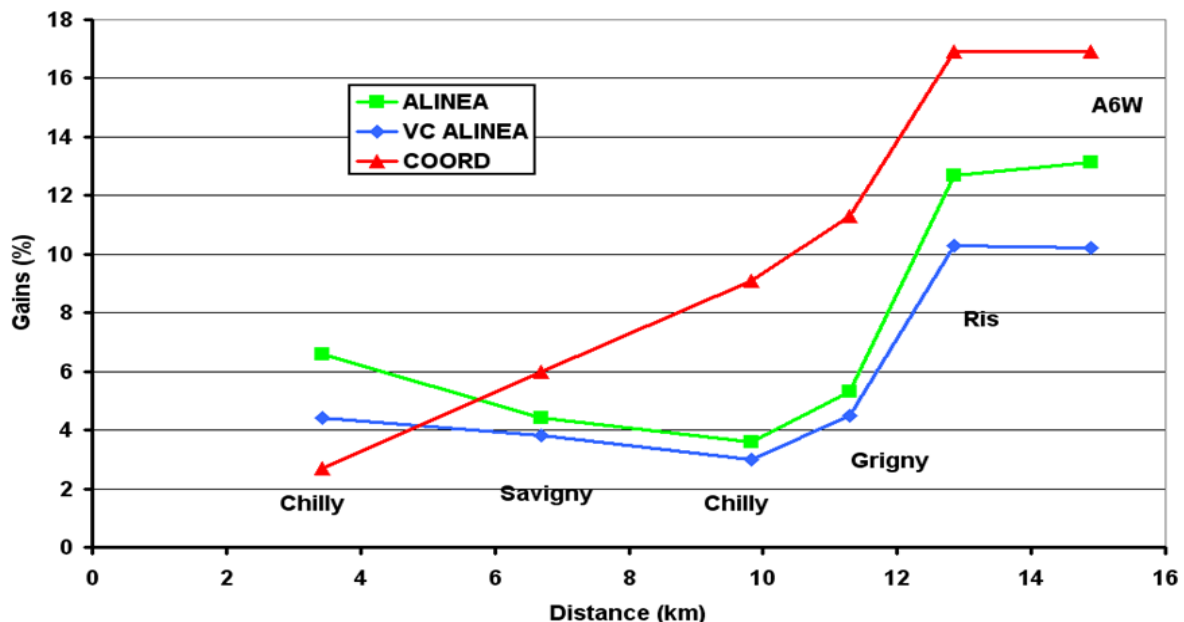


Figure 5. Gain = F_n(distance) of the candidate strategies

- The environment indices are based on the computation of the Fuel consumption and Pollution emission. With respect to the fuel consumption, compared with the No control case, the changes of -8 %, -5%, -8 % for ALINEA, VC_ALINEA and CORDIN respectively.
- The emission indices are decrease for all strategies. In particular, the gains of HC and CO indices are of - 6%, - 9% and -7% for ALINEA, VC_ALINEA and CORDIN respectively

By considering the TTS and TTD costs hypothesis in France, the results of the cost benefit analysis, with regard to the investments and the maintenance of the ramp metering system, indicated a collective benefit per year (250 of working days) of 2.4M€, 2.44M€ and 3.5 M€ for ALINEA, VC_ALINEA and CORDIN respectively.

5 CONCLUSIONS

The obtained results of this field trial are leads the DIRIF authorities to generalize the implementation of the ramp metering technique to the overall motorway network. Renewal of ACCES_1 system is decided current 2007. The new system is called ACCES_2 and it is implemented in SIRIUS current 2008.

The DIRIF authorities decided at the first step, to test and evaluated the ALINEA strategy on the East part of the Ile de France motorway network including 22 on-ramps. The second step consists to the extension of the generalization of ALINEA to 150 others existing on-ramps. The last step will concern the implementation of CORDIN strategy.

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