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**A Methodology and Measure of Performance
for the Evaluation of Commuters Information Systems**

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Abstract

The objective of this paper is to prove the effectiveness of variable message sign information on recurrent congestion using different measurements of effectiveness.

To show the benefits of the information systems, we have built a new methodology. We took advantage of the data collected during a national strike which shut down the variable message signs. By comparing these data to a set of “normal” days we can evaluate the impact of information systems on congestion level.

We present a way to measure the effectiveness of information systems. For the evaluation of information effectiveness we use both qualitative and quantitative measurements. This allows us to finally give a financial assessment of information systems for commuters. Our study is based on an 80 km long suburban network in Lyon. We show that the benefits of an information system can be evaluated between 0.7 and 1 M€ per year (between 0.9 and 1.3 M US \$ per year).

INTRODUCTION

Providing road users with travel time information is a usual measure to mitigate congestion. This is especially true in suburban highway networks. The devices to collect and dispatch information (Variable Message Signs, data collection system, Traffic Management Centers) require a lot of work and a lot of money. Decision makers need to know the real impact of each of their policies and to measure the returns on the investments. Methods are available to compute cost and benefits of such systems (1), but the information systems benefits assessment process proposed in (2) is not commonly diffused. We will propose here an evaluation methodology of the impact of information on the level of congestion which is encountered in typical weekday by an urban highway network.

To evaluate the impact of information, we need to:

1. Compare the situation with and without information for one network with a given level of demand;
2. Measure the level of congestion.

In this paper, we will use data collected with the automatic procedure in the vicinity of the city of Lyon. This city is halfway between the North and the South of France and has less than 1.5 million inhabitants. We had a unique opportunity to evaluate precisely the impact of information systems on congestion thanks to a strike of the workers of "Coraly" (3), the local traffic management center. This strike was on Tuesday the 4th of October 2005. We will compare flows and travel times automatically measured on that day with similar data measured on other Tuesdays of the year 2005-2006

To make the comparison, several measurements of efficiency will be used:

- Total travel time (product of instantaneous flows and travel times);
- Percentage of travel time spent in congestion.

The different parts of this paper will be as follows. We will first present the Lyon's suburban highway network, its control system and the input data. Secondly we will justify the measurements of efficiency that allowed us to assess the congestion experienced by road users and the benefits of the traffic management center. The building of the days' sample will then be explained. We will end this paper presenting our results and their analysis.

1. INPUT DATA

Lyon has a suburban highway network of about 2*80 km long. Because of the central position of the region, both in France and in Europe, long distance heavy vehicles are numerous on those highways. Many commuters are also using the highway network. In this study we will concentrate on the impact of the information system on those local users.

The traffic control center is called “Coraly” (3). This system is in charge of ensuring safety and good traffic conditions along this network. Quantitative information is collected by means of inductive loop detectors, transmitting mean flows, mean flow speeds and mean occupancy every 6 minutes. A total number of 150 cameras record traffic situation and location of incidents. All information is transmitted to and stored in a management center.

Information is provided to road users by means of Variable Message Signs (VMS), an internet site and radio broadcast flashes every half an hour during peak period. This radio network is not very famous and therefore the main source of en route information for commuters is VMS. The positions of the VMS are shown in the Figure 1.

We chose the four facilities (A/ to D/) highlighted on the Figure 2. On each of them VMS give to road users, at their entry point in the facility or during their journey along this facility travel time information from the VMS position until the end of this facility. Each week day an amount of 300,000 to 600,000 vehicles use those four facilities. The middle part of the network is a toll highway. It does not belong to any of the facilities studied here. The four facilities are summarized in the Table 1.

| Letter | Origin and destination of the facility | Free flow travel time (min) | Length (km) | Number of lanes |
|--------|--|-----------------------------|-------------|------------------------------|
| A | Manissieux - Noeud des Iles | 10 | 13.625 | 2 |
| B | Beynost - Croix Luizet | 4 | 5.951 | 3 and 2 |
| C | Les Essarts - Laurent Bonnevey | 4 | 5.451 | 3 |
| D | Limonest - Fourvière | 5 | 7.671 | 3 and 2 (ends with a tunnel) |

Table 1: Characteristics of the four facilities.

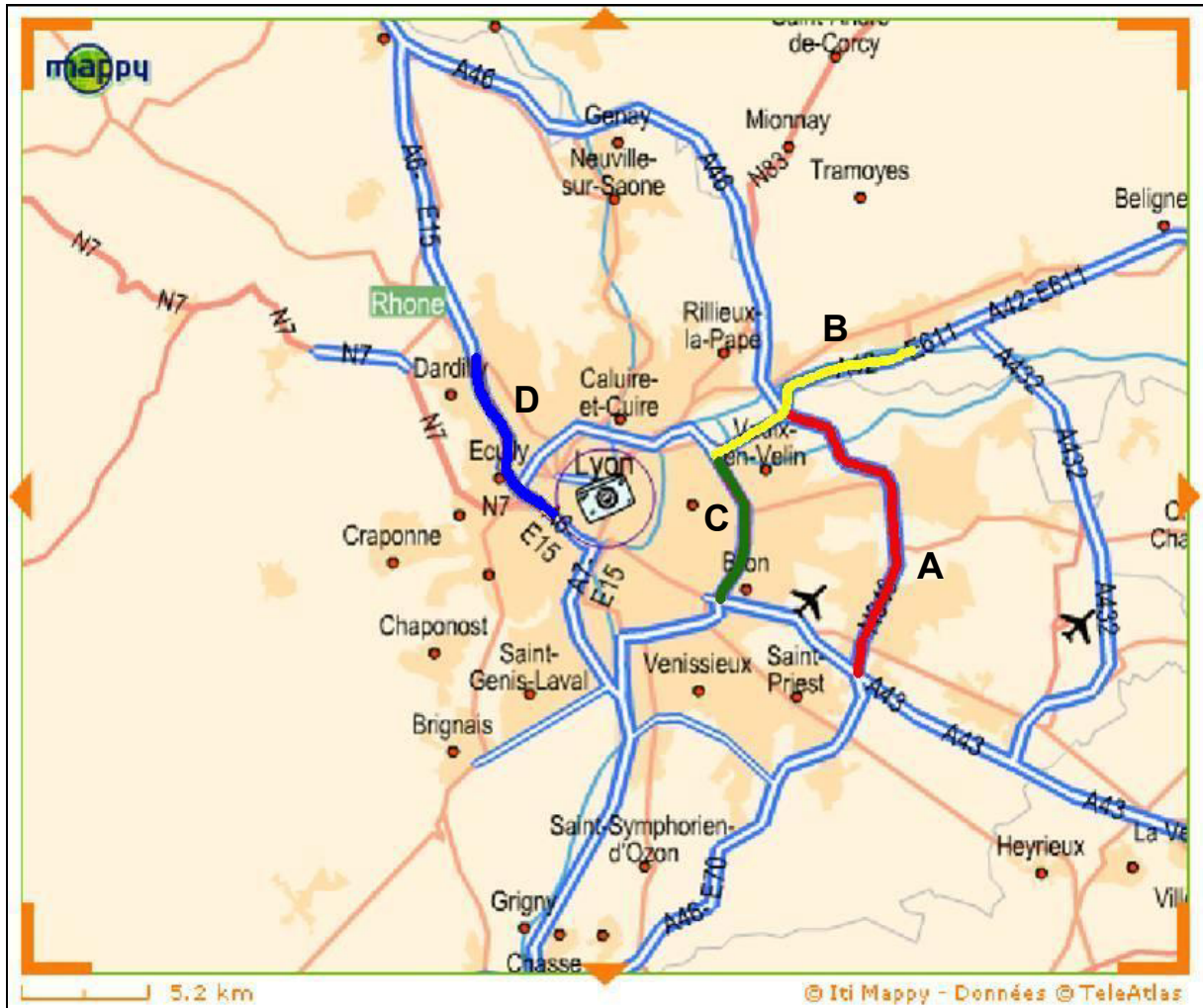


Figure 2: Schematic map of the city of Lyon. The four facilities used in this paper for evaluation are colored. Facilities A and C are chosen Northbound; congestion occurs on them either in the morning or evening peak. Facilities B and D are chosen from the suburbs towards the center of the town and are mainly congested in the morning. Please note that facility D ends at a tunnel (the Fourvière Tunnel) and is the most congested part of the network.

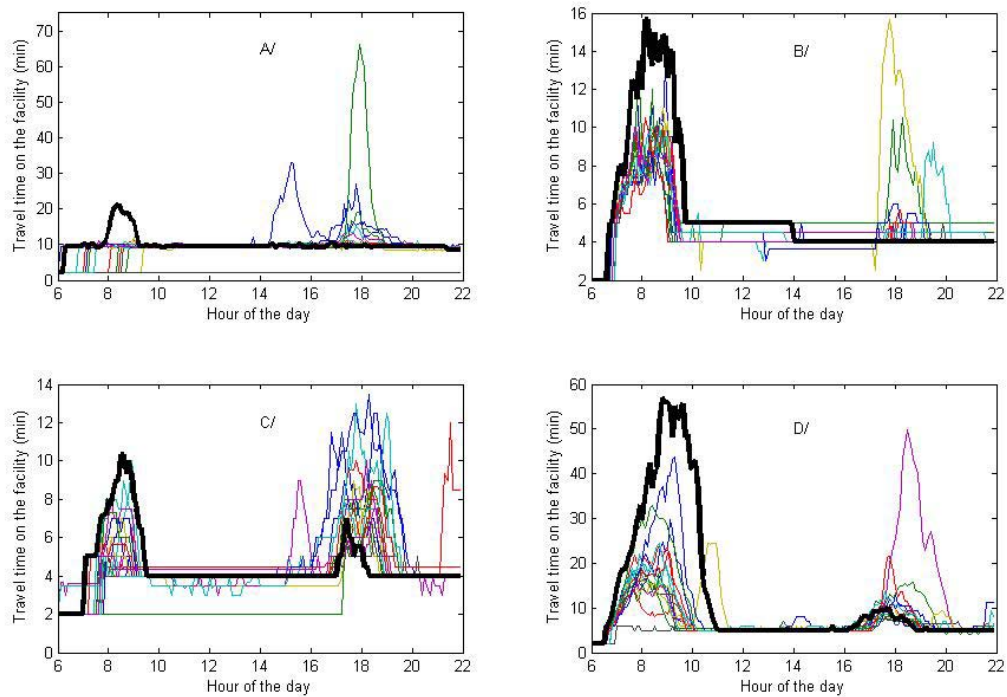


Figure 3: Travel times for the four chosen facilities for the 19 studied days. We can notice that D/ is the most congested facility in morning peak, that both morning and evening peaks create problems for route C/ which is a ring road. A/ is a facility highly used by trucks, and is less exposed to morning or evening congestion, except when incidents occur. The bold line corresponds to the results obtained the 4th of October, 2005.

We present in Figure 3 the travel times computed by the system on the basis of mean flow speed, measured for 19 days of September 2005 to February 2006. Flows are also collected by inductive loops. In this study we use one flow loop measurement corresponding to one facility. The loop associated with the facility is the one where daily traffic flow is the heaviest (see Figure 4).

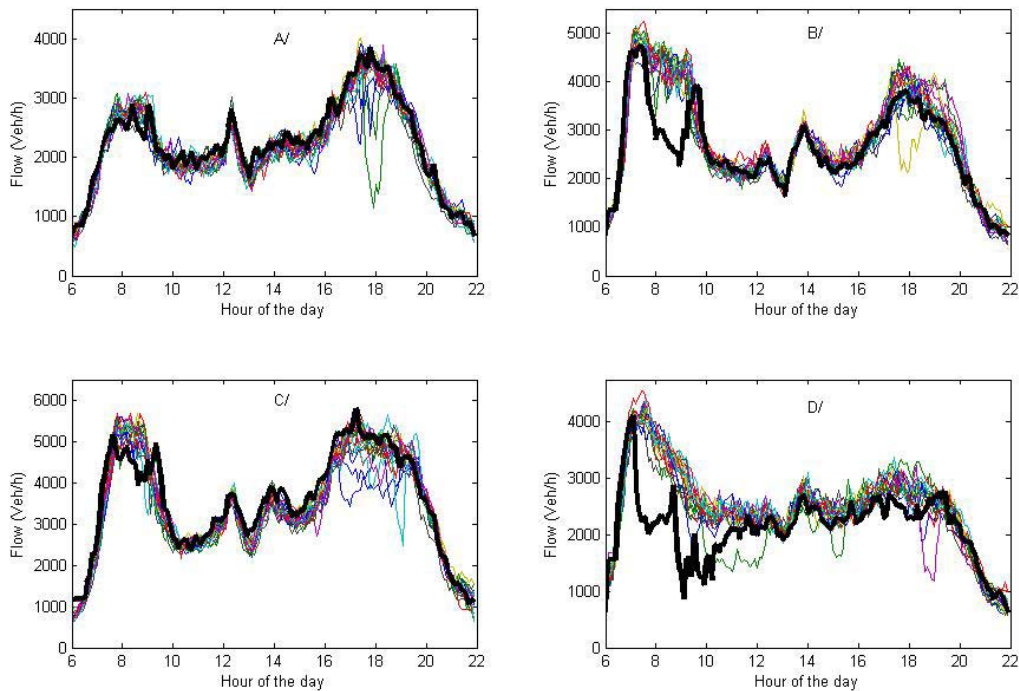


Figure 4: Measured flows for the four chosen facilities during the 19 studied days. The bold line corresponds to the results obtained the 4th of October, 2005.

2. MEASUREMENT OF EFFECTIVENESS

Objectives of this measurement

The main goal of this paper is to evaluate the impact of displaying information through VMS for commuters. With opinion polls one can have an insight of how drivers evaluate information. Such surveys were conducted on the Lyon's highway network and always found that users have a positive opinion of information display and of its accuracy (4, 5).

For this study we focus on the impact that travel time information has or has not on congestion. Therefore we need a measurement of congestion. We will recall hereafter the difficulties that lie with this definition. The two components we want to evaluate are:

- Congestion experienced by users. This can be seen as a qualitative evaluation. We need to know how much road users suffer from congestion, not only in terms of the total waste of time, but also by measuring how much congestion a typical user of a given facility will experience on a given day;
- Total amount of time spent by the road users of a city with and without information. With the help of a usual value of time (in France (6) and (7) are commonly used), we

can give a monetary evaluation of this time. Total travel time is usually also a first step to account for other external elements (pollution, noise, stress...).

State of the art

The main effect of information systems is on congestion and on reliability. For many years, in order to measure congestion, only one indicator has been used in the US (as well as in France).

The FHWA used “hours of delay per 1,000 vehicle miles traveled (VMT) whereas the French government used (and still uses) “HKM” which is a length of congestion multiplied by the duration of the congestion and the number of lanes.

Using just one measure does not allow for showing the two dimensions of congestion which are amplitude (the number of people concerned by the congestion) and seriousness (how long they are delayed).

With such a unique measure, you cannot show the effects of your policy, particularly on urban networks where recurrent congestion occurs.

After discussion (8), the FHWA replaced their indicator with three new measures:

- Congested Travel (percentage of travel under congested conditions),
- Travel Time (percentage of additional travel time needed for an individual to make a trip in peak periods), and
- Traveler Delay (average number of hours during which drivers are delayed in traffic per year).

These three measures are developed in the Texas Transportation Institute’s (TTI’s) Annual Mobility Report (9), (10). An update of the values was made recently (11), but the same methodology is used.

The French government has appointed a group of experts whose work aims at defining and validating new measures. One of the difficulties lies in the number of congestion definitions (as shown by Bertini (12)). Indeed, congestion definitions given by traffic managers depend on the type of network they are in charge of. This leads to a very high number of measures available (13) to make our evaluation of the impact of displaying information on congestion.

In our case we need a set of MOEs, each one able to gather one aspect of the whole daily congestion observed each day of the sample. Please note that because we deal only with commuters, we consider that the day begins at 6 am and ends at 10 pm.

A new way of evaluating congestion is also to measure the reliability of travel times. This is particularly of interest if one wants to compare an infrastructure and a traffic management center to another one. In our case, this is not relevant, because we have only one day in the sample of days without information display.

Qualitative evaluation of congestion: percentage of time traveled in congestion

We want an evaluation of the effect of travel time information on individual comfort. In this purpose, we use the percentage of time spent in congestion. We define here congestion as traveling along the facility at a speed lower than 30 km/h.

Recall that travel time is defined by the traffic management center as $tt^f(i) = \sum_s \frac{L_s}{V_s(i)}$:

Where:

i is the period index (each period is of 6 minutes, from 6am to 10 pm).

S is the segment index of the segment composing the facility f .

$V_s(i)$ is the speed measured at the station i during the previous 6 minutes.

L_s is the length of the segment assigned to the data collection station.

Here we define the facility speed as the ratio between the length of the facility and the facility travel time. Our qualitative evaluation of the impact of information availability during one day is based on the following equation:

$$\%Tt_{congestion}^f = \frac{\sum_{i=6h}^{10h} tt^f(i) \times Q^f(i) \times \delta_{Congestion}^f(i)}{\sum_{i=6h}^{10h} tt^f(i) \times Q^f(i)},$$

where $\delta_{congestion}^f(i)$ is equal to 1 if speed is lower than 30 km/h on facility f , equal to 0 otherwise. $Q^f(i)$ is the flow measured during period i in the loop detector considered as representative of the flow circulating on facility f .

Quantitative evaluation of congestion: daily total travel time

For the quantitative evaluation of congestion we use the total travel time. Here total travel time for one day is defined as (with the same notations than above):

$$TTT^f = \sum_{i=6am}^{10pm} tt^f(i) \times Q^f(i).$$

We can then multiply this travel time value by a value of time to access to a measurement of the amount of money collectively lost.

3. METHODOLOGY

Evaluating the impact of travel time information, both in terms of comfort provided to users and in amount of wasted time, leads to comparing the situation with and without information. The evaluation paradox is that where no information is available for the user, no information is available for evaluation purposes.

The “before and after studies” collect data during months **firstly** without information, **secondly** with information and then compare the two situations with the help of some of the above mentioned MOEs. The difficulty with that type of study is to allow for the “natural” evolutions of the transportation system related to economic, sociological or behavioral changes.

The method we use in this paper is based on the analysis of the traffic MOEs for regular Tuesdays of the last fall 2005 and winter 2006, compared with a day on which neither travel time nor event based information was given to road users (2005, 4th of October). This last situation is due to a strike that implied traffic management control operators. Even if loops data were collected, as operators must validate information before it is displayed on VMS, no information was provided on that day. This was for us an outstanding opportunity.

This new method presents two potential methodological limits:

1. We have to suppose that the day corresponding to traffic management operator’s strike is representative of the behavior of the network if no information would be available for some reason during a longer period. That particular day without information should not have encountered some abnormal traffic situation, except the lack of information. Of course because of the lack of people near TV screen reporting exceptional incident, we can have no proof of this “regular” behavior. But, we can see that traffic flow was at a normal level on most of the facilities.
2. One must keep in mind that using a network with VMS and no information display is not exactly the same as using a network where no information devices are present. Indeed, the presence of information devices, especially for commuters, encourages the regular use of information. On the other hand, VMS signs are not the only way of individually evaluating travel conditions: users use queue length (is it usual to see a queue at this exit? If not, why not use surface network today; and cell phone calls can be used to know what is happening on the road and what to expect

A more practical limit of the study is that on the same day, the transit network workers where also on strike and about half of the hundred lines of city buses were not working. This could imply an increase in demand, especially for the center facilities and therefore an increase in total travel time.

But, most of the transit lines concern the center part of the city. On three of the four facilities (A/, B/, and D/) concerned, the use of bus lines does not represent a credible alternative. In table 2, one may notice that facility A/ has a total amount of flow absolutely compatible with mean value. Concerning facilities B/ and D/ one would have predict an increase of total daily flow if transit strike would have increase the use of individual car. On the contrary, the flow was decreasing. This can be explained by rerouting on surface network, due to unusually high travel times, unusually high travel times probably due to lack of information.

The facility C/ is the most central one and a ring road. This is the facility where transit lines represent a real alternative to car use. Logically, facility C/ encounter a significant increase of the total flow. But the total travel time (see table 4) is compatible with the mean value.

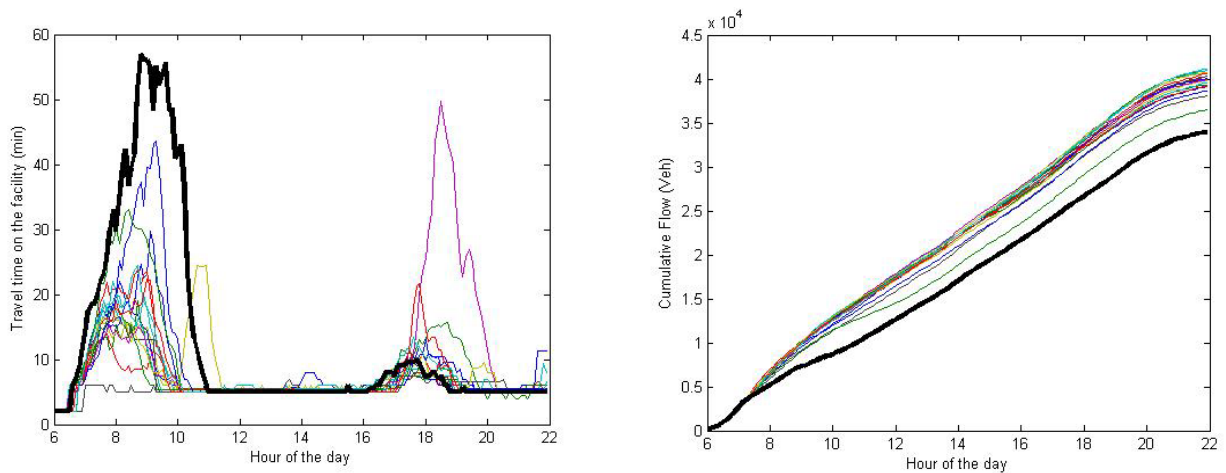


Figure 5: Left: travel times and, right, cumulative flow curves for facility D/, for the 19 considered Tuesdays. The bold line corresponds to the results obtained the 4th of October, 2005. Note that when, on that day, congestion rises to an unusual level (at about 8 am), the cumulative flow curve increases at a lower level than on other days. This is mainly due directly to unusual congestion, but the fact that distance with the total flow is never covered is due to the rerouting of some users faced to this congestion.

4. RESULTS AND ANALYSIS

Building the sample of representative days

We have explained in the section “input data” how we chose the four facilities presented in Figure 2. We also have to build a sample of days to make the comparison of MOEs presented above with and without information. We chose the six month period comprised between the beginning of September 2005 and the end of February 2006. In this period, the network faces a traffic that is very similar to the one observed on October 4th.

We exclude holiday periods because during those periods the long distance traffic is heavier and local commuters demand is lower. Let us recall that our objective is to evaluate the impact of information systems for commuters.

In the sample for some of the facilities, incidents may have occurred. We keep them in the sample because on this type of network, incidents are so frequent that one can't exclude them from the sample without reducing it drastically. We will conclude below that the impact of incidents is less important than the one of the lack of information.

From 26 Tuesdays in 6 months, we selected 19 days. They are presented on

Table 2 with the total flow (between 6 in the morning and 10 in the evening). Total flow is also presented on Figure 6.

| Year | Month | Day | Facility | | | |
|------|-------|-----|-----------------------------------|---------|---------|---------|
| | | | A | B | C | D |
| | | | Total flow between 6 am and 10 pm | | | |
| 2005 | 9 | 6 | 349 226 | 425 389 | 523 452 | 391 148 |
| 2005 | 9 | 13 | 356 740 | 457 341 | 549 441 | 409 675 |
| 2005 | 9 | 20 | 358 040 | 454 217 | 552 463 | 402 954 |
| 2005 | 9 | 27 | 366 958 | 454 569 | 560 512 | 409 884 |
| 2005 | 10 | 4 | 358 812 | 417 489 | 567 909 | 339 877 |
| 2005 | 10 | 11 | 358 222 | 443 747 | 561 230 | 398 580 |
| 2005 | 10 | 18 | 343 734 | 444 488 | 557 436 | 403 129 |
| 2005 | 11 | 8 | 357 127 | 452 702 | 552 122 | 400 129 |
| 2005 | 11 | 15 | 353 774 | 453 168 | 553 911 | 393 329 |
| 2005 | 11 | 22 | 356 448 | 459 905 | 562 577 | 406 554 |
| 2005 | 11 | 29 | 350 266 | 441 658 | 541 313 | 395 559 |
| 2005 | 12 | 6 | 352 965 | 469 663 | 548 570 | 399 150 |
| 2005 | 12 | 13 | 352 530 | 457 868 | 562 738 | 407 449 |
| 2006 | 1 | 3 | 337 644 | 417 521 | 511 874 | 380 865 |
| 2006 | 1 | 17 | 335 499 | 432 364 | 518 941 | 288 702 |
| 2006 | 1 | 24 | 326 408 | 434 131 | 534 103 | 386 338 |
| 2006 | 1 | 31 | 344 092 | 447 796 | 537 998 | 364 842 |
| 2006 | 2 | 7 | 340 875 | 443 412 | 535 746 | 391 797 |
| 2006 | 2 | 14 | 350 412 | 453 988 | 555 771 | 411 247 |
| Mean | | | 349 988 | 445 338 | 546 742 | 388 484 |
| Std | | | 9 839 | 14 390 | 15 971 | 29 739 |

Table 2: 19 selected days for the study with total flow for the 6am-10pm period. The day (October 4th) corresponding with the traffic operators' strike is highlighted.

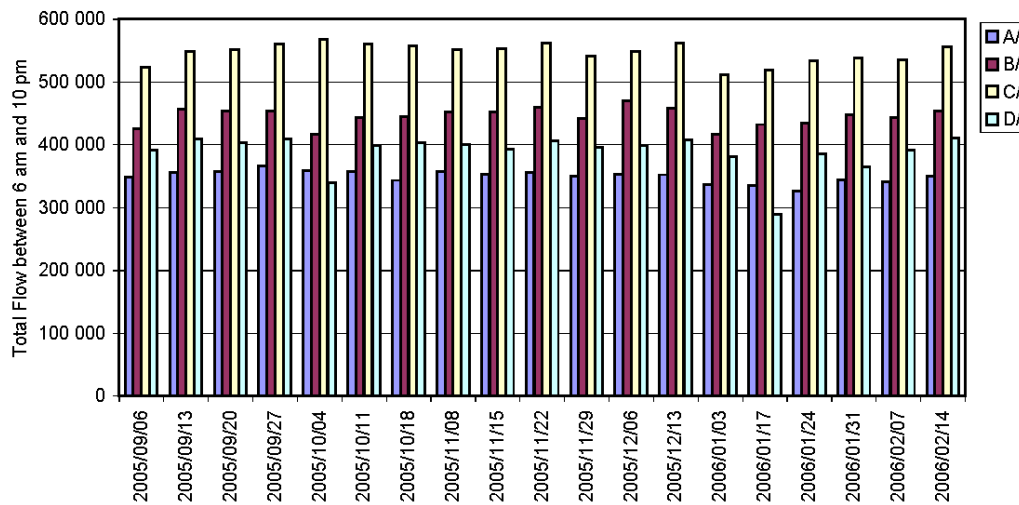


Figure 6: Total flow between 6 am and 10 pm for the 19 selected days. Except for the significant decrease of total flow for facility D/ on October 4th, the total flow is not different from the one of other days.

To conclude this explanation of our selection of the sample, we can state that the sample is composed of typical Tuesdays, with no increase of the flow for the day considered in the following part as the day without information (October 4th).

Qualitative evaluation of congestion: percentage of time traveled in congestion

We proposed above a qualitative measure of the average congestion suffered by users. This is the percentage of the total travel time that is traveled with a speed lower than 30 km/h. The next figure presents the results of this MOE for selected days and the four facilities. One can note that some congestion, due to incidents, occurs on some days. One can also note that congestion for the day without information is substantially above the one for other days.

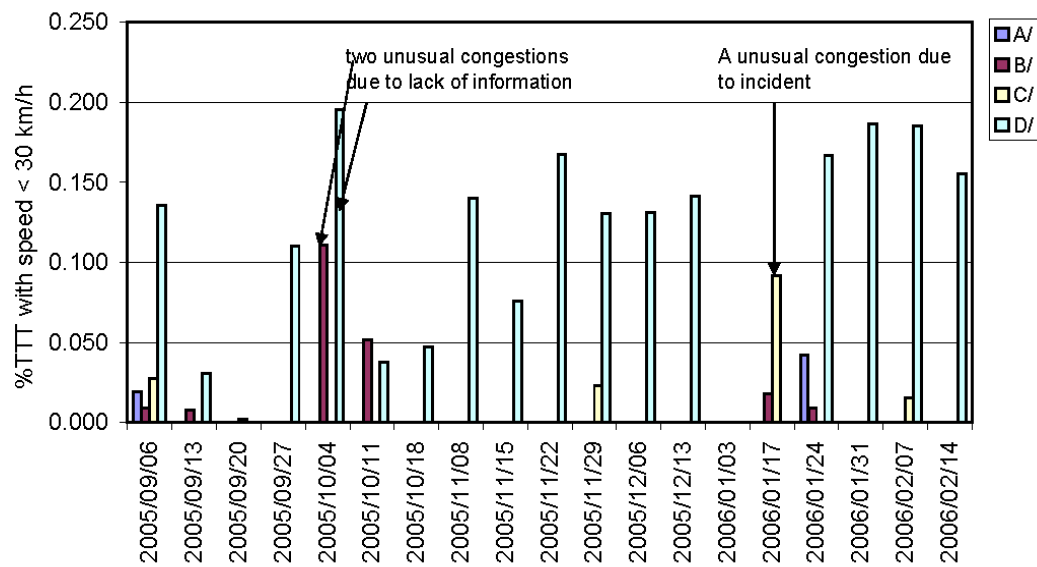


Figure 7: Percentage of total travel time spent with a speed lower than 30 km/h. For the day without information (4th of October), one can see that this percentage is higher for every facility than the percentage observed without incident. One can deduce that the provided information has a positive effect road users' comfort.

| Year | Month | Day | Facility | | | |
|------|-------|-----|---|--------|-------|--------|
| | | | A | B | C | D |
| | | | percentage of travel time with speed<30km/h between 6 am and 10 pm | | | |
| 2005 | 9 | 6 | 1.925 | 0.877 | 2.754 | 13.553 |
| 2005 | 9 | 13 | 0.000 | 0.781 | 0.000 | 3.088 |
| 2005 | 9 | 20 | 0.000 | 0.000 | 0.171 | 0.000 |
| 2005 | 9 | 27 | 0.000 | 0.000 | 0.000 | 11.047 |
| 2005 | 10 | 4 | 0.000 | 11.093 | 0.000 | 19.562 |
| 2005 | 10 | 11 | 0.000 | 5.182 | 0.000 | 3.783 |
| 2005 | 10 | 18 | 0.000 | 0.000 | 0.000 | 4.704 |
| 2005 | 11 | 8 | 0.000 | 0.000 | 0.000 | 14.015 |
| 2005 | 11 | 15 | 0.000 | 0.000 | 0.000 | 7.582 |
| 2005 | 11 | 22 | 0.000 | 0.000 | 0.000 | 16.772 |
| 2005 | 11 | 29 | 0.000 | 0.000 | 2.281 | 13.073 |
| 2005 | 12 | 6 | 0.000 | 0.000 | 0.000 | 13.120 |
| 2005 | 12 | 13 | 0.000 | 0.000 | 0.000 | 14.109 |
| 2006 | 1 | 3 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2006 | 1 | 17 | 0.000 | 1.768 | 9.146 | 0.000 |
| 2006 | 1 | 24 | 4.176 | 0.922 | 0.000 | 16.689 |
| 2006 | 1 | 31 | 0.000 | 0.000 | 0.000 | 18.640 |
| 2006 | 2 | 7 | 0.000 | 0.000 | 1.558 | 18.509 |
| 2006 | 2 | 14 | 0.000 | 0.000 | 0.000 | 15.508 |
| Mean | | | 0.321 | 1.085 | 0.837 | 10.724 |
| Std | | | 1.032 | 2.717 | 2.180 | 6.814 |

Table 3: Percentage of the total travel time traveled at a speed lower than 30 km/h. The day without information is highlighted. Note that total travel time is the travel time multiplied by the total flow of the facility.

Quantitative evaluation of congestion: total travel time and collective cost of a day without information

Comparing total travel time without information displayed on VMS with mean total travel time when information is displayed permits us to evaluate precisely the extra congestion cost. Table 4 presents the total travel times, mean values for “regular” days and differences between values for the day without information and regular days.

| Year | Month | Day | Facility | | | | sum for all facilities |
|------------------------------------|-------|-----|---------------------------|-------|-------|-------|------------------------|
| | | | A | B | C | D | |
| | | | total travel time (hours) | | | | |
| 2005 | 9 | 6 | 6 968 | 3 586 | 4 564 | 5 421 | 20 540 |
| 2005 | 9 | 13 | 5 090 | 4 135 | 2 696 | 5 445 | 17 367 |
| 2005 | 9 | 20 | 5 082 | 3 425 | 4 049 | 4 664 | 17 221 |
| 2005 | 9 | 27 | 5 283 | 3 782 | 4 108 | 5 281 | 18 456 |
| 2005 | 10 | 4 | 6 092 | 4 070 | 4 483 | 6 743 | 21 390 |
| 2005 | 10 | 11 | 4 652 | 4 238 | 4 063 | 4 834 | 17 788 |
| 2005 | 10 | 18 | 4 792 | 3 576 | 3 998 | 5 010 | 17 377 |
| 2005 | 11 | 8 | 5 607 | 3 567 | 4 254 | 5 865 | 19 294 |
| 2005 | 11 | 15 | 5 170 | 4 208 | 4 173 | 4 728 | 18 280 |
| 2005 | 11 | 22 | 5 229 | 3 747 | 4 601 | 5 719 | 19 298 |
| 2005 | 11 | 29 | 5 791 | 3 756 | 4 942 | 5 102 | 19 592 |
| 2005 | 12 | 6 | 5 625 | 4 044 | 4 526 | 6 755 | 20 952 |
| 2005 | 12 | 13 | 5 383 | 3 670 | 4 041 | 5 770 | 18 866 |
| 2006 | 1 | 3 | 5 448 | 3 219 | 3 505 | 3 287 | 11 136 |
| 2006 | 1 | 17 | 5 814 | 3 726 | 4 958 | 3 106 | 17 606 |
| 2006 | 1 | 24 | 6 219 | 3 555 | 4 224 | 6 276 | 20 274 |
| 2006 | 1 | 31 | 5 377 | 3 748 | 4 238 | 6 067 | 19 432 |
| 2006 | 2 | 7 | 5 249 | 3 740 | 4 150 | 5 551 | 18 691 |
| 2006 | 2 | 14 | 5 596 | 3 671 | 4 132 | 5 946 | 19 346 |
| mean | | | 5 498 | 3 761 | 4 195 | 5 346 | 18 574 |
| std | | | 320 | 162 | 299 | 580 | 1 308 |
| mean of 18 regular days | | | 5 465 | 3 744 | 4 179 | 5 268 | 18 418 |
| std of 18 regular days | | | 529 | 267 | 508 | 933 | 2 130 |
| Values for day without information | | | 6 092 | 4 070 | 4 483 | 6 743 | 21 390 |
| Difference (hours) | | | 627 | 326 | 304 | 1 475 | 2 972 |

Table 4: Total travel times between 6 am and 10 pm for the four facilities and the 19 selected days. This table presents also mean and standard deviation for the total sample and for the “regular” days. One can deduce the amount of extra total travel time due to the lack of information.

The French typical value for the time spent traveling in a private car is 10 € (about 8.9 U.S. \$). Therefore we can give an evaluation of the total cost for the community of the lack of information during one day for the studied network and the considered facilities. This cost is of about 3000€ (near 2700\$).

Please note that the rerouting phenomenon observed on October 4th on facility D/, reduces the measured congestion. It also increases the congestion on the surface network, where it cannot be measured. Therefore we can't access any complete information for the congestion of the whole city for this particular day.

This result can be extended to the total highway network only with extreme caution. Indeed, half of the total gain is due to facility D/ which corresponds to a highway ending at a tunnel and connecting a highly populated part of the city to the center of the town. On regular days, this facility (less than 8 km long) corresponds to between a quarter and a third of the total time spent in congestion on the highway network of about 80 km. Therefore extending the result of the cost to the total highway network gives an amount of between 9,000 and 12,000€ gained when the traffic management center is in operation.

We can use this result further to make a rough estimation of the collective benefit of such a traffic management center - displaying information - at between 0.7 and 1 M€ per year (0.9 to 1.3 M US\$ per year). This extrapolation is based on the fact that information is useful not for every day of the week but mainly for Tuesdays and Thursdays and on the fact that there is heavy commuting traffic only for 40 weeks each year.

CONCLUSION

We developed here an original methodology for evaluating information system impacts on congestion. This evaluation is based on a qualitative estimation of the road users' comfort and on a quantitative estimation of the wasted time when no information is delivered.

We used this methodology on a part of the Lyon's highway network, thanks to a strike that deprived road users of information, but let the system automatically collect the loop data. The limit of the result is due to the sample size. On the one hand we found only 18 days comparable with the one with no information, on the other hand only one day composed this last sample.

Our methodology permits to go beyond the usual limits of 'before and after' studies. Indeed, our results are independent of any estimation of the evolutions of external conditions (demand, infrastructure improvement ...). The use of this methodology is possible in every city, provided that data are available for a day without information. This is possible either voluntary (switching down VMS travel time display for this experimental purpose) or not (when a strike occur). This is an effective way of demonstrating the positive impact of information display for commuters' travel times.

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