Title

Travel Times on Changeable Message Signs in District 4

Authors

Margulici, JD

Chiou, Bensen

Yang, Samuel

et al.

Publication Date

2007

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

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CCIT Research Report
UCB-ITS-CWP-2007-3

california center for innovative transportation
UNIVERSITY OF CALIFORNIA, BERKELEY

ISSN 1557-2269

The California Center for Innovative Transportation works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

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JD Margulici – Senior Development Engineer, CCIT
Bensen Chiou – Senior Development Engineer, CCIT
Samuel Yang – Associate Development Engineer, CCIT
Jeff Ban – Post-Doctoral Researcher, CCIT
Brian Huey – Graduate Student Researcher, CCIT

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This work was performed by the California Center for Innovative Transportation, a research group at the University of California, Berkeley, in cooperation with the State of California Business, Transportation, and Housing Agency's Department of Transportation, and the United States Department of Transportation's Federal Highway Administration.

January 2007

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Final Report – July 2006

<u>Prepared by:</u>

JD Margulici
Senior Development Engineer, CCIT

Bensen Chiou
Senior Development Engineer, CCIT

Samuel Yang
Associate Development Engineer, CCIT

Jeff Ban
Post-Doctoral Researcher, CCIT

Brian Huey
Graduate Student Researcher, CCIT

<u>For:</u>

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

Project Fact Sheet

Title:	Travel Times on Changeable Message Signs in D4
Sponsor:	Caltrans Division of Traffic Operations
Executing organization:	California Center for Innovative Transportation 2105 Bancroft Way Berkeley, CA 94720 Phone: (510) 642-4522 – Fax: (510) 642-0910
Execution period:	6/1/2004 – 6/30/2006
Contract amount:	$89,990
Principal investigator:	Professor Pravin Varaiya EECS Department, UC Berkeley
Center Director:	Hamed Benouar CCIT Director
Project manager:	JD Margulici, Senior Development Engineer CCIT
Administrative Officer:	Anne Crowe, Assistant Director CCIT
Additional investigators:	Bensen Chiou, Sr. Development Engineer, CCIT Samuel Yang, Asc. Development Engineer, CCIT Brian Huey, Graduate Student Researcher, CCIT Xander Mitman, Asc. Development Engineer, CCIT Jeff Ban, Post-Doctoral Researcher, CCIT David Lewkowitz, Grd. Student Researcher, CCIT Yvonne Leung, Jr. Development Engineer, CCIT Marika Benko, Staff Research Associate, CCIT

Acknowledgements

The project team wishes to thank the many contributors to this project. Success was only made possible by the active participation of all the stakeholders.

By spelling out names, one always takes the risk to forget somebody and to end up with the opposite of the intended effect. On the other hand, not taking risks amounts to doing nothing! Therefore, with great apologies to anyone who may be forgotten, the team particularly recognizes the following individuals:

- **David Lively** of Caltrans Traffic Operations, who made the project possible and offered his unconditional support at all times;
- **Alan Chow**, who managed the project on District 4 end with incredible care and attention;
- **Charles Price** of District 4, who provided great insights and pushed the envelope to insure ultimate success;
- **Sean Campbell** of Caltrans DRI, who deployed more efforts than any of the team members in updating the SOCCS software;
- **Benjamin McKeever**, who was the 511/Travinfo liaison but contributed his time and thinking well beyond this role;
- **Hector Garcia** of District 4, who was our constant interlocutor and went out of his way to help us succeed;
- **Kane Wong** of District 4, whose assistance in understanding the needs of the project was invaluable;
- **Tom Saul** of PB Farradyne, who generously shared his knowledge and experience throughout the project;
- **Hamed Benouar**, Director of CCIT, who is no less than a beacon in the night for the lost transportation engineer!

And also **Albert Yee**, then Deputy Director for Operations and Maintenance at District 4, **Miguel Gomez** at District 4, **Melanie Crotty** and **Carol Kuester** at MTC, **Russ Elovitz** of PB Farradyne, **Fred Dial**, **Carol Wilbon** and **Zoe Bayar** at Caltrans Traffic Operations, and finally the rest of the **CCIT staff**. A special mention goes to **Chao Chen**, who started as the project manager before leaving CCIT.

Report Content

This report is organized as a collection of stand-alone documents. A 2-page summary is provided that outlines the project steps and results. The rest of the documents include three reports of evaluation activities that were conducted as part of the project, one implementation report focused on network modeling, and two manuals that were developed to accompany the software that was delivered to District 4.

The three evaluation reports are as follows:

- A data evaluation that took place prior to going live with the signs (15 p.)
- An analysis of the impact of signs on freeway speed (18 p.)
- An analysis of a satisfaction survey that was distributed to commuters (22 p.)

The implementation report is titled:

- Network Construction and Route Generation (27 p.)

And the two manuals are:

- MITTENS – System Architecture and Operating Rules (18 p.)
- MITTENS – Software Design and System Administration (39 p.)

In addition, the following appendices are provided:

- Project presentation in slide show format (14 p.)
- A project narrative written for communication purposes (3 p.)
- Meeting minutes (38 p.)
- Field elements and system configuration (10 p.)
- Bibliography (6 p.)

Project Summary

Real time traffic information on changeable message signs (CMS) has gained popularity in urban areas where congestion and incidents frequently affect the reliability of trip times. Signs have been used to broadcast information about downstream delays, incidents and travel times in a corridor. Under normal conditions, trip time is the most practical information that commuters can use to assess traffic, alleviate their stress, and ultimately make decisions on their route. Being aware of driving times to popular destinations, travelers may be able to choose an alternate route early if it appears that their intended route is too congested. Moreover, signs are the most effective mean to communicate real-time, relevant information to motorists. Unlike a radio broadcast, signs target drivers passing a given location, so that the message is highly likely to be of interest to those drivers. On-demand media such as phone or internet-based services require the user to operate a specific device, which is more fastidious and potentially hazardous.

The California Department of Transportation (Caltrans) owns and operates about one hundred CMS in the San Francisco Region from its Traffic Management Center (TMC). The local Caltrans district, District 4, had long been willing to leverage this investment to provide more useful information to motorists. CCIT Task Order 13 consisted in implementing, deploying and evaluating an automated system to relay travel time information to the district's CMS. The implementation started in October, 2004, through a partnership piloted by CCIT, and involving Caltrans' Division of Research and Innovation (DRI), Caltrans District 4, and the Metropolitan Transportation Commission (MTC).

The main technical component of the project consisted in creating the missing link between MTC's Travinfo system, which provides data for 511, and the District's TMC. In order to manually control the display on the signs, TMC operators use SOCCS, a piece of software developed by DRI. CCIT integrated Travinfo and SOCCS by developing MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). MITTENS is a stand-alone software system designed to host a description of a freeway network, let operators configure commuter routes and sign displays, process link travel time information, and generate messages. DRI updated SOCCS in order to manage message priorities: while travel time messages from MITTENS are displayed by default, they are overridden by operator-input messages.

MITTENS relies on MTC's Travinfo for travel time predictions. These predictions are based on real-time traffic data collected by toll tag readers (FasTrak program) and by Caltrans' embedded loop traffic detectors. Predictions are updated every minute and are reported on the signs accordingly. MITTENS also applies filters to the estimated travel time estimates, so that bad or suspicious data doesn't get reported on the signs.

From May through October, 2005, a pilot deployment allowed the project partners to evaluate the system's robustness and public acceptance. For this pilot deployment, 2 signs were operated on Interstate 80 eastbound (CMS 078) and westbound (CMS 070) in Berkeley, CA. Trials were conducted with either 2 or 3 destinations on each sign. The destinations were San Francisco Downtown, San Francisco Airport, and Oakland Airport westwards, and the Carquinez Bridge, Fairfield and Novato eastwards. Therefore, the scope of the CMS pilot project evaluation encompassed a total of 6 routes.

The evaluation of the pilot deployment was broken down into 3 components:

- A pre-pilot evaluation found that the overall system produced available, reliable data of satisfactory accuracy.

- A traffic impact study found that the continuous use of CMS to display travel information may have had a limited impact on driving speed. The study concluded to an average speed reduction of 3 Mph for one sign, and no significant slowdowns for the other sign. Anecdotal evidence suggests that slowdowns, if any, wear out over time, but this could not be demonstrated by the study.

- A survey of 953 Bay Area commuters determined that the public responded very positively to the system. Only 10% of the respondents rated it negatively with respect to usefulness and information accuracy.

Concurrently with the evaluation, the project was expanded to include a total of 19 signs. This expansion was completed days before the start of the 12th World Congress on Intelligent Transportation Systems, which took place in San Francisco in early November, 2005. The system has been operating in this configuration since then.

In order to provide District 4 with autonomous control of the system, two manuals were produced that document MITTENS' architecture, design and administration. However, control of the software remains crude. Graphical User Interfaces will be developed to enhance system interaction for both TMC operators and TMC engineers. This work is part of a follow-up project, CCIT Task Order 1009. In the end, the district will gain fully autonomy for both the operations and the administration of the system. This will enable them to generalize its deployment to the reminder of their changeable signs.

Another effort that was undertaken in Task Order 13 is the effective modeling of the freeway network and determination of the shortest routes between 2 points. MITTENS processes the description of the network provided by Travinfo as a flat set of links into a searchable graph.

For the future, MITTENS will be upgraded to allow deployment in other Caltrans districts and to test alternative technologies and processing techniques to calculate travel times. These efforts are also part of Task Order 1009.

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Data Evaluation Report

July 2006

Prepared by:

Brian Huey
Graduate Student Researcher, CCIT

JD Margulici
Senior Development Engineer, CCIT

For:

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

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Glossary

511/Travinfo:	Traveler information system operated by MTC in the SF Bay Area
Caltrans:	California Department of Transportation
CCIT:	California Center for Innovative Transportation
CMS:	Changeable Message Sign
DOT:	Department of Transportation
DRI:	Caltrans Division of Research and Innovation
HOV lane:	Lane reserved for High-Occupancy Vehicles
ITS:	Intelligent Transportation Systems
MITTENS:	Software that generates travel time messages for freeway signs
MTC:	Metropolitan Transportation Commission
SF:	San Francisco
SFO:	San Francisco International Airport
SOCCS:	Software that controls the CMS from the TMC
TMC:	Transportation Management Center
VDS:	Vehicle Detection Station

Background

The California Department of Transportation (Caltrans) owns and operates about one hundred Changeable Message Signs (CMS) in the San Francisco Region from its Traffic Management Center (TMC). The implementation of an automated system to display travel times on those CMS started in October, 2004, through a partnership piloted by the California Center for Innovative Transportation (CCIT), and involving Caltrans' Division of Research and Innovation (DRI), the local Caltrans district (District 4, or D4), and the Metropolitan Transportation Commission (MTC).

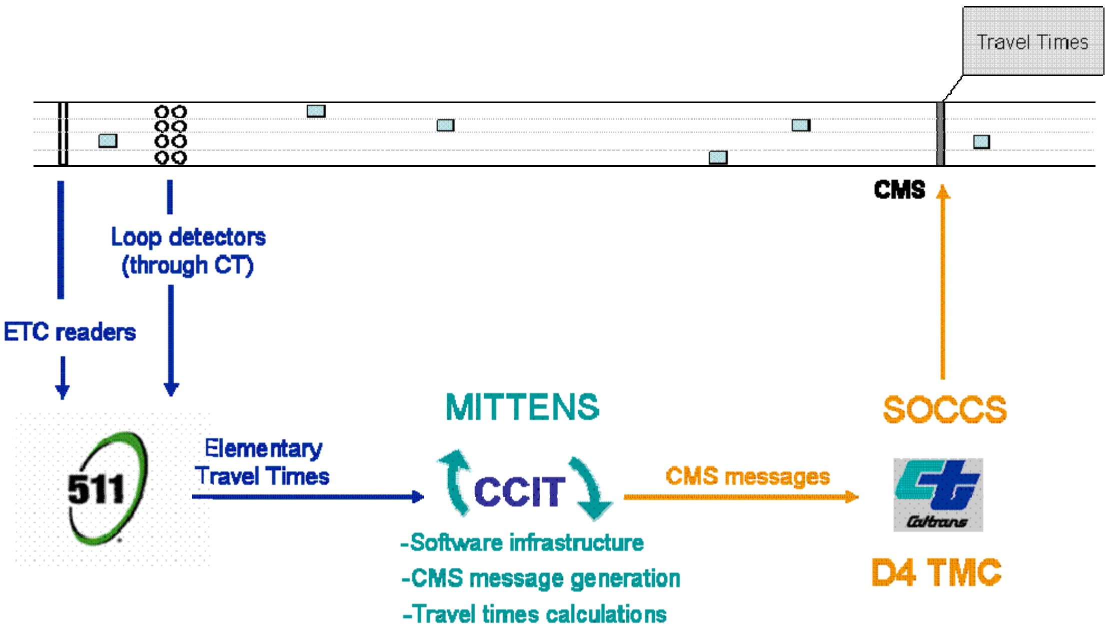


Figure 1 - Travel Times on CMS in District 4: Schematic Data Flow

The project consisted in creating the missing link between MTC's Travinfo system, which provides data for the regional 511, and the District's TMC. In order to manually control the display on the signs, TMC operators use SOCCS, a piece of software developed by DRI. CCIT integrated Travinfo and SOCCS by developing MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). MITTENS is a stand-alone software system designed to host a description of a freeway network, let operators configure commuter routes and sign displays, process link travel time information, and generate messages.

MITTENS relies on MTC's 511/Travinfo for travel time predictions. These predictions are based on real-time traffic data collected by toll tag readers (FasTrak program) and by Caltrans' embedded loop traffic detectors. Predictions are updated every minute and are reported on the signs accordingly. MITTENS also applies filters to the estimated travel time estimates, so that bad or suspicious data doesn't get reported on the signs. Figure 1 presents the schematic data flow for the whole system.

Starting on May 2nd, 2005, a pilot deployment allowed the project partners to evaluate the system's robustness and public acceptance. For this pilot phase, 2 signs were operated on Interstate 80 eastbound (CMS 078) and westbound (CMS 070) in Emeryville and Berkeley. Trials were conducted with either 2 or 3 destinations on each sign. The destinations were San Francisco Downtown, San Francisco Airport, and Oakland Airport westwards, and the Carquinez Bridge, Fairfield and Novato eastwards, for a total of 6 routes. Based on the success of the pilot phase, additional CMS were activated just before the 12th World Congress on Intelligent Transportation Systems in November of 2005. The total number of active signs stands at 19 since then, with further deployment under way.

Evaluation purpose

An evaluation of MITTENS was conducted during the months of March and April 2005, prior to the start of the pilot phase. The goal of the pre-pilot evaluation was to ensure that the quality of the travel time estimates meets required standards and that the travel time values are consistent with those delivered by the 511 system.

Data quality is the primary requirement that needs to be considered by transportation agencies that wish to provide commuters with travel time estimates. For this project, however, data quality was a mere matter of verification. The data is provided by MTC's 511/Travinfo, a regional system which has operated for several years and has benefited from considerable investments. Before MITTENS was developed, 511/Travinfo traveler information was available on the internet and via a phone server. Because of its large exposure to the public, the data quality is assessed on an on-going basis. Nonetheless, quality varies among different corridors in the Bay Area. It was therefore important to take a thorough look at the data used for the six routes included in the pilot phase, in addition to verifying data integrity end-to-end.

The quality of the data was evaluated using three metrics: availability, validity and accuracy. These metrics are consistent with federal guidelines regarding ITS data assessment[1]. Availability measures system uptime. Validity refers to the level of confidence that can be placed in the data. Validity measures the likelihood that an estimate produced by the system results from correct measurements, although these measurements may inherently lack precision. Invalid data can be the result of problems with traffic detectors or bugs in software systems. Finally, accuracy refers to the quality of the estimates themselves, under nominal conditions. Travel times are statistical in nature, as different drivers starting at a given location at the same time may experience different travel times. One may define actual travel times as the mean of the trip times for vehicles that start traveling on a given route at a given time, but even this definition can

[1] Federal Highway Administration "Traffic Data Quality Measurement – Final Report" Source: http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14058_files/index.htm, September, 2004.

be questioned, and furthermore, it still doesn't make actual travel times measurable by any practical means. In general, accuracy is measured by comparing estimated travel times to realized trip times collected by probe vehicle runs.

In addition to verifying data quality, this evaluation tracked differences between information drivers would be able to retrieve from the 511/Travinfo internet or phone system and what would be displayed on the signs. Even though the data source is the same, several factors may contribute to discrepancies. First, the routes are defined in a slightly different manner. 511/Travinfo routes are defined between 2 locations taken from a defined set. By contrast, MITTENS routes originate from the exact location of a CMS, which may not correspond with 511/Travinfo locations. Second, the processing may differ slightly. MITTENS' algorithm for route travel time calculation was borrowed from the 511/Travinfo system but the implementation is independent. Additionally, the filters applied to the travel time estimates before they are broadcast are a bit different. For instance, messages on the signs only get refreshed if the travel time value slides by 2 minutes or more.

Methodology

Data was collected for roughly one month between March and April. However, because the MITTENS system was continually being developed and altered, not all data was available. The period of 18 days between March 28 and April 14, 2005 was used for the analysis because it was deemed the most consistent.

There were two sets of data used for the study. The first set of data came from the 511/Travinfo system and consisted of travel time estimates for the six routes under evaluation in exact one-minute intervals. This data also included information about the quality of the estimates, which primarily depends on the amount of current detector data collected to produce them. The second set of data was the travel time estimates generated by an off-line instance of MITTENS. The MITTENS data provided travel time estimates for the six routes, in one-minute intervals. Two forms of the estimate were presented in the data logs: a calculated estimate and the filtered value that would be shown on the sign. These two values may differ due to functional requirements. For example, the displayed travel time changes only if the estimate deviates from the last estimate by more than two minutes[2]. To complement the two data sets, 26 probe vehicle runs were conducted by the 511/Travinfo program on the six routes being evaluated. MTC operates an ongoing evaluation in order to monitor the data quality of 511/Travinfo. The time of the run and the realized trip times were recorded. This data was used to assess the overall accuracy of the travel time estimates.

Using the aforementioned data, quality metrics were assembled. Availability was measured by counting the number of travel time estimates observed in the data set and dividing it by the number of expected records. Validity is a lot more difficult to assess

[2] This filter is applied to reduce the processing load on SOCCS.

quantitatively because no analytical criteria can be establish to discriminate individual records. Validity was assessed qualitatively by plotting the travel times over time and placing the resulting plots under the scrutiny of professional opinions from Caltrans District 4 staff. One consistency check looks for major outliers or nonsensical estimates. In addition, travel times variations through the day should present peaks and valleys consistent with usual traffic patterns. Finally, accuracy was measured by comparing the travel time estimates from Travinfo/511 with the probe vehicle data.

Data accuracy

Logs of the messages posted by MITTENS over the 18-day period showed that availability varied in the beginning, becoming most consistent as MITTENS was adjusted and bugs were fixed. Over the entire 18-day period, there were 156,671 total records out of 233,280 for an availability rate of only 67%. However, much of these problems were ameliorated by software adjustments and establishing a more consistent network connection between the 511 and MITTENS servers. Eliminating the earlier periods, availability was 91% for a five-day period from April 11 to April 15. Traveler information is a useful but non-critical application, and this number was deemed adequate for the pilot phase. System uptimes have been a lot higher during actual operations, although a specific number is not available.

Validity was examined visually by plotting a route's average travel times for each minute in the day. The Appendix shows the plots for the six routes. The period of observation lasted from March 29 to April 4. The shape and values appear realistic and consistent with expectations. This indicates that the signs would have displayed valid estimations throughout the observation period. The routes displayed on the westbound CMS for San Francisco Downtown and San Francisco Airport both show peaks corresponding to the morning and evening commute, since both routes are heavily frequented in the morning as job centers, as well as at night as places of residence. Only one peak in the evening is observed for the eastbound routes to Hercules and Fairfield. This is because these are mainly suburban locations that attract little traffic in the morning, but are major destinations in the evening as people return home. Novato, the third eastbound route, exhibits significant variability but no pronounced peaking throughout the day. Somewhat similarly, the Oakland Airport route is subject to erratic travel times throughout the day, but with a more distinct peak in the evening. This peak is likely due to southbound traffic on I-880, which intensifies in the evening commute hours as many suburban commuters drive to predominantly residential areas such as Fremont and San Leandro.

Accuracy was measured by comparing the 26 probe vehicle runs with estimates from 511. Table 1 shows the dates and times of the probe vehicle runs, as well as the differences between the estimated and realized travel times.

Table 1 - Differences between probe and 511 travel time estimates (minutes)

Date	Time	Probe	511	Difference
Route 7001: SFO				
3/11	9:01am	48.6	45.1	3.5
3/15	5:41pm	44.9	42.5	2.4
3/24	1:05pm	24.5	23.1	1.4
3/29	5:45pm	30.4	30.4	0
Route 7002: Oakland Airport				
3/11	6:07pm	18.1	19.3	-1.2
3/15	9:10am	16.4	18.8	-2.4
3/15	9:10am	16.4	19.3	-2.9
3/21	1:02pm	12.9	12.5	0.4
3/21	1:02pm	12.9	13	-0.1
4/1	8:21am	16.1	16.8	-0.7
4/1	8:21am	16.1	17.7	-1.6
Route 7003: Downtown San Francisco				
3/11	9:01am	37.6	28.7	8.9
3/15	5:41pm	28.2	21.1	7.1
3/24	1:05pm	13.3	11.6	1.7
3/21	12:11pm	23.9	25.6	-1.7
3/29	5:45pm	16.1	14.6	1.5
Route 7801: Hercules				
3/11	7:35am	10.8	10.8	0
3/15	4:32pm	18.9	17.8	1.1
3/24	11:59am	10.8	10.5	0.3
3/29	4:37pm	15.8	14.3	1.5
Route 7802: Fairfield				
3/11	7:35am	28.9	27.6	1.3
3/15	4:32pm	38.4	36.6	1.8
3/24	11:59am	31.2	27.9	3.3
3/29	4:37pm	34.5	32	2.5
Route 7803: Novato				
3/11	4:55pm	36.7	36.2	0.5
3/15	7:24am	32.3	27.6	4.7

A discrepancy of 15% between the prediction and the actual time is considered acceptable by industry standards. 21 out of 26 records fall within a range of 15%. The two records that exhibit higher deviations were associated with the Berkeley - San Francisco Downtown route, during the morning and afternoon peaks. This route is especially subject to variability because of the crossing of the Bay Bridge toll plaza and high peak-traffic volumes. Records on this route exhibit discrepancies of 25% or less. The overall accuracy of the 511/Travinfo data was considered sufficient to be brought onto freeway signs in the light of these satisfactory, though limited, observations.

Comparisons between 511 and MITTENS

Logs from 511/Travinfo and MITTENS were compared for a whole week spanning March 29 to April 4, 2005. Records of the travel time values for each of the six routes during times ranging from 5:00 AM to 9:00 PM were matched, resulting in over 25,000 matched records. The average, standard deviation, 90th and 99th percentile values of the differences between matched records were assembled.

Table 2 establishes that the estimates from both systems are within 1 minute 90% of the time, except for route 7001 to SFO Airport and route 7803 to Novato. In the case of route 7001, there is a systematic bias of roughly 1’30” due to the fact that the CMS 070 is located a little less than 2 miles away from University Avenue, where the corresponding 511/Travinfo route originates. On the other hand, the same bias was surprisingly absent on routes 7002 and 7003. This absence could not be determined as of the start of the pilot phase, but the difference was considered small enough that the project moved ahead regardless. Since then, further investigations in partnership with 511/Travinfo staff and consultants have revealed a slight error in how these two routes were initially modeled in MITTENS, which was fixed.

The difference observed on route 7803, as well as the larger differences that occur 1% of the time or less (as seen under the 99th % column in Table 2), were explained by time offsets between 511 and MITTENS. When the travel time estimates are rapidly changing, a slight delay can create a gap, even though both systems are tracking the trend. In a few instances, the Travinfo system exhibited very large variations (i.e. in the tens of minutes), which further skewed the results. Nonetheless, for the first four routes that initially went live during the pilot phase, namely to SFO, SF Downtown, Hercules and Fairfield, the differences were 4.3 minutes or less 99% of the time.

Table 2 - Differences between 511 and MITTENS estimated travel times (min:ss)

RouteID	Average	StDev	90th %	99th %
7001	01:26	01:06	02:58	04:16
7002	00:32	00:46	00:53	03:16
7003	00:45	00:28	00:58	02:25
7801	00:24	00:18	00:49	01:40
7802	00:27	00:20	00:51	01:50
7803	00:49	01:26	01:33	05:48

Table 3 shows similar results using MITTENS' display values. The display values are the ones that are communicated to the public after the calculated estimates are filtered. Messages are filtered in a few different ways. First, a minimum travel time for each route is determined using the posted speed limit on each segment. When the estimates for a route are lower than the minimum value, that minimum value gets displayed. This avoids encouraging speeding. Second, the maximum travel time for each route is the smaller of ten times its minimum travel time or 99 minutes. Large values will mostly tend to be inaccurate, and by the time they are reached, traffic would be so bad that other messages would replace the travel time postings on the freeway signs. When the travel time estimates for a route is larger than the maximum value, no value gets displayed. Lastly, displayed values are only updated when the calculated estimate has deviated by at least two minutes. This disposition spares some processing resources on the SOCCS machine, which is a legacy computer with limited computing power.

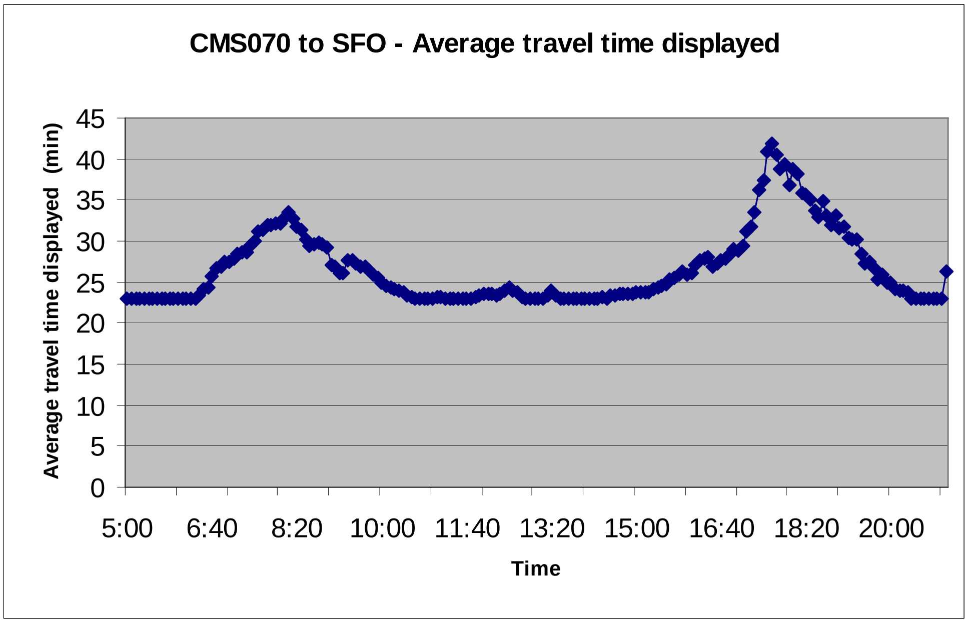
Table 3 - Differences between 511 and MITTENS displayed travel times (min:ss)

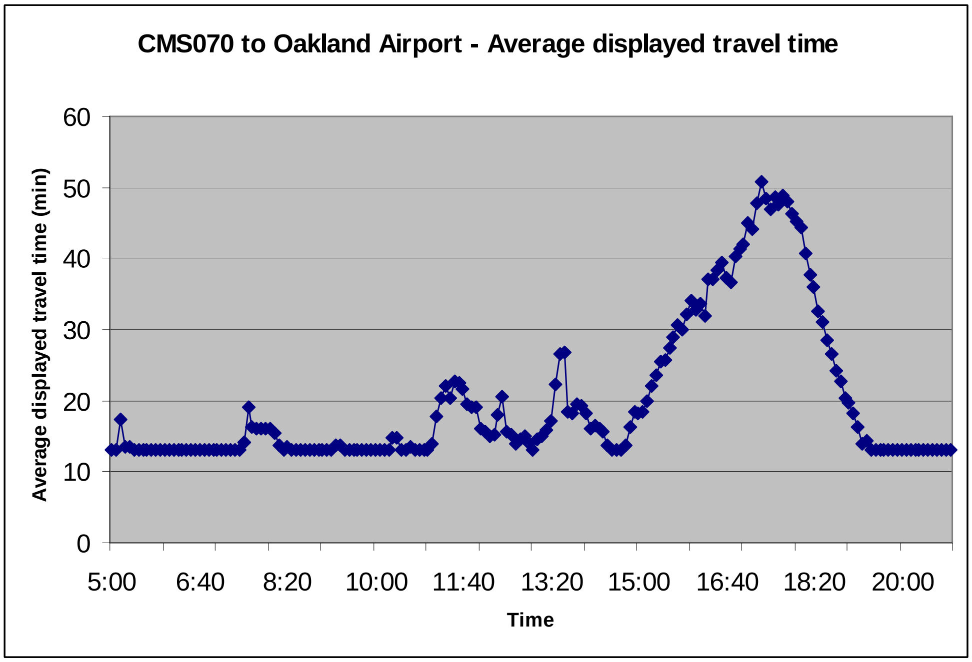
RouteID	Average	StDev	90th %	99th %
7001	02:05	00:40	02:58	04:23
7002	00:32	00:47	00:53	03:37
7003	00:34	00:28	00:58	02:29
7801	00:31	00:19	00:54	01:15
7802	00:31	00:22	00:56	01:37
7803	00:46	01:26	01:03	06:11

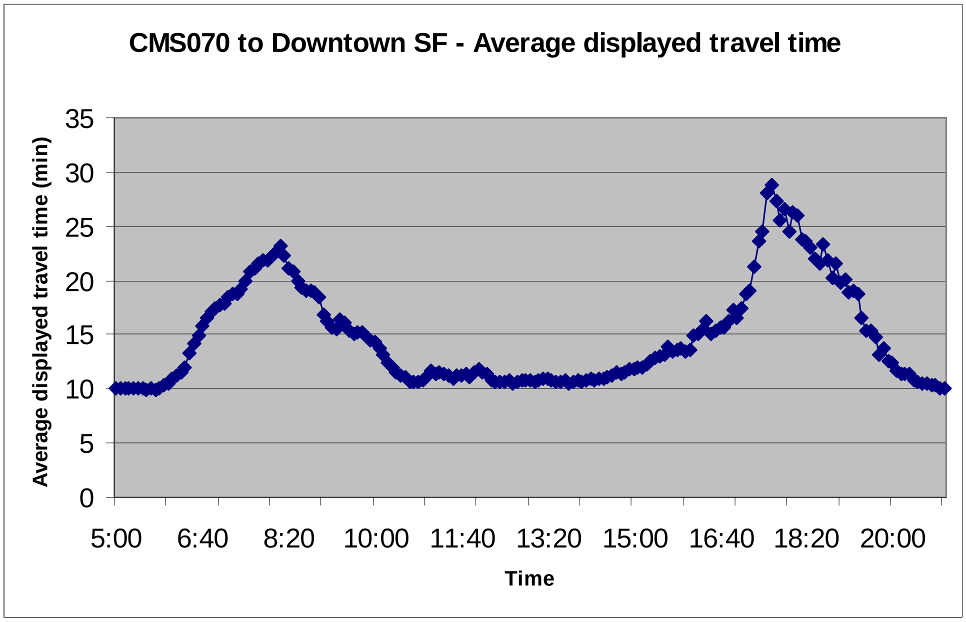
Summary

The data assembled during the evaluation period showed that the travel time estimates that would be displayed on the two CMS selected for the pilot phase would be adequately available, valid and accurate. Accuracy was evaluated based on a limited number of samples due to the high cost of probe vehicle runs. Nonetheless, 511/Travinfo has been credited for the quality of their system, which meant that the data could be reasonably trusted. One additional concern was that the public would not receive mixed signals from the 511 systems and the CMS. This was unlikely, since both systems use the same data source. Some slight differences inherently exist between both systems and were noted in the evaluation. Yet, the range and frequency of the differences were not a cause of worries for system stakeholders.

Appendix: Travel time plots by route






CMS070 to Downtown SF - Average displayed travel time
Average displayed travel time (min)
35
30
25
20
15
10
5
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5:00
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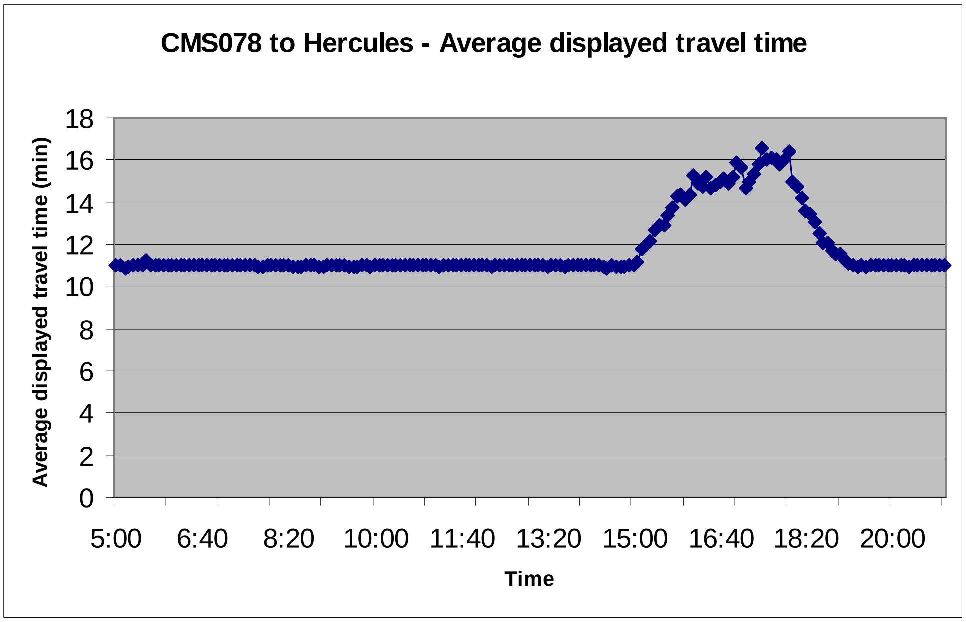
20:00
Time


CMS078 to Hercules - Average displayed travel time
Average displayed travel time (min)
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16
14
12
10
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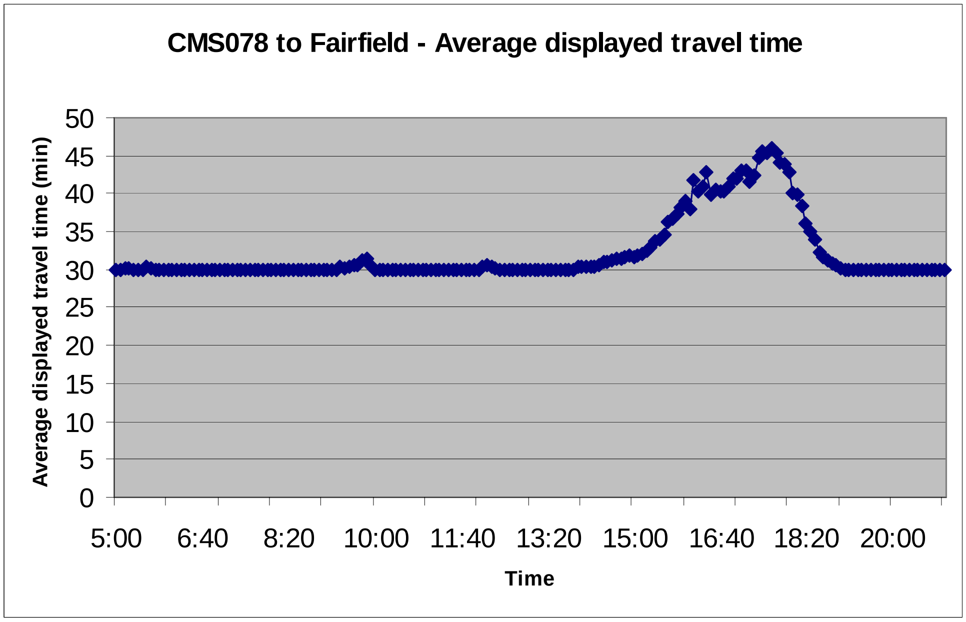
Time


CMS078 to Fairfield - Average displayed travel time
Average displayed travel time (min)
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10
15
20
25
30
35
40
45
50
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6:40
8:20
10:00
11:40
13:20
15:00
16:40
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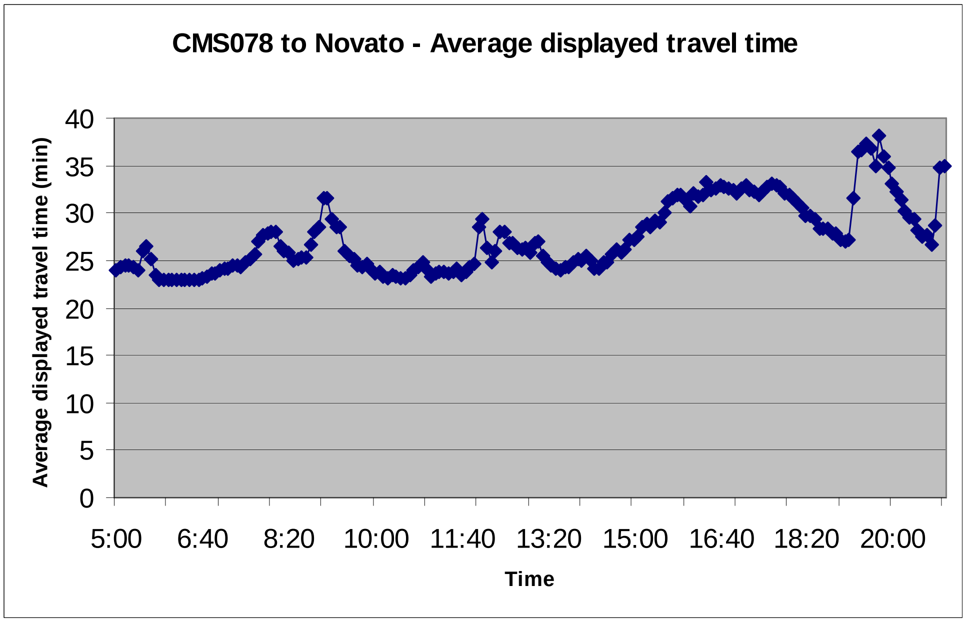
20:00
Time


CMS078 to Novato - Average displayed travel time
Average displayed travel time (min)
0
5
10
15
20
25
30
35
40
5:00
6:40
8:20
10:00
11:40
13:20
15:00
16:40
18:20
20:00
Time

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Traffic Impact Study

July 2006

Prepared by:

Brian Huey
Graduate Student Researcher, CCIT

JD Margulici
Senior Development Engineer, CCIT

For:

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

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Glossary

511/Travinfo:	Traveler information system operated by MTC in the SF Bay Area
Caltrans:	California Department of Transportation
CCIT:	California Center for Innovative Transportation
CMS:	Changeable Message Sign
DOT:	Department of Transportation
DRI:	Caltrans Division of Research and Innovation
HOV lane:	Lane reserved for High-Occupancy Vehicles
ITS:	Intelligent Transportation Systems
MITTENS:	Software that generates travel time messages for freeway signs
MTC:	Metropolitan Transportation Commission
SF:	San Francisco
SFO:	San Francisco International Airport
SOCCS:	Software that controls the CMS from the TMC
TMC:	Transportation Management Center
VDS:	Vehicle Detection Station

Background

The California Department of Transportation (Caltrans) owns and operates about one hundred Changeable Message Signs (CMS) in the San Francisco Region from its Traffic Management Center (TMC). The implementation of an automated system to display travel times on those CMS started in October, 2004, through a partnership piloted by the California Center for Innovative Transportation (CCIT), and involving Caltrans' Division of Research and Innovation (DRI), the local Caltrans district (District 4, or D4), and the Metropolitan Transportation Commission (MTC).

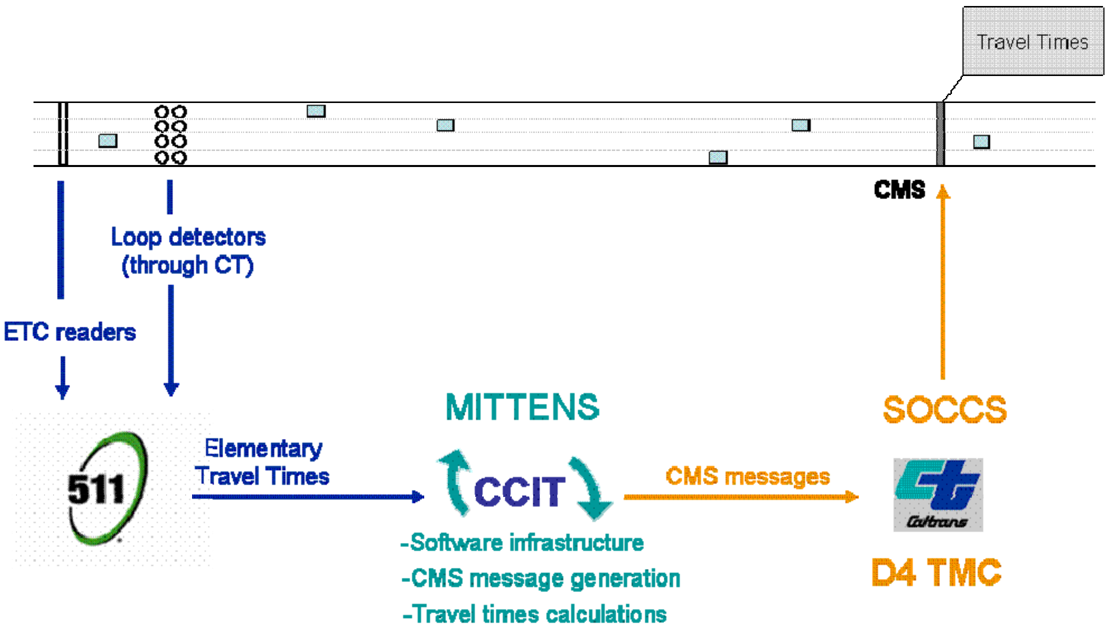

Figure 1 - Travel Times on CMS in District 4: Schematic Data Flow

The project consisted in creating the missing link between MTC's Travinfo system, which provides data for the regional 511, and the District's TMC. In order to manually control the display on the signs, TMC operators use SOCCS, a piece of software developed by DRI. CCIT integrated Travinfo and SOCCS by developing MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). MITTENS is a stand-alone software system designed to host a description of a freeway network, let operators configure commuter routes and sign displays, process link travel time information, and generate messages.

MITTENS relies on MTC's 511/Travinfo for travel time predictions. These predictions are based on real-time traffic data collected by toll tag readers (FasTrak program) and by Caltrans' embedded loop traffic detectors. Predictions are updated every minute and are reported on the signs accordingly. MITTENS also applies filters to the estimated travel time estimates, so that bad or suspicious data doesn't get reported on the signs. Figure 1 presents the schematic data flow for the whole system.

Starting on May 2nd, 2005, a pilot deployment allowed the project partners to evaluate the system's robustness and public acceptance. For this pilot phase, 2 signs were operated on Interstate 80 eastbound (CMS 078) and westbound (CMS 070) in Emeryville and Berkeley. Trials were conducted with either 2 or 3 destinations on each sign. The destinations were San Francisco Downtown, San Francisco Airport, and Oakland Airport westwards, and the Carquinez Bridge, Fairfield and Novato eastwards, for a total of 6 routes. Based on the success of the pilot phase, additional CMS were activated just before the 12th World Congress on Intelligent Transportation Systems in November of 2005. The total number of active signs stands at 19 since then, with further deployment under way.

Purpose and methodology

Questions have been raised by traffic engineers about the possibility that dynamic messages cause drivers to reduce speeds in order to read the information, thereby restricting traffic flow and potentially increasing congestion. The same concern is raised in a report by the Federal Highway Administration on travel time message implementation, with the authors noting that "the experience of more than one DOT surveyed showed that (…) in regions where the information is new, DOTs should expect that motorists would slow down to read the signs, since they are unfamiliar with the abbreviations used."[1] This traffic impact study addressed this question by gathering traffic and environment data nearby the two signs selected in the pilot phase and analyzing the effect messages have on speed using multivariate regression modeling.

The aim of the analysis was to isolate the impact of displaying messages on vehicle speed immediately upstream of a sign. In order to do this, a model was developed that estimates speed based on the following factors:

- Congestion level
- Time of day (peak vs. non-peak)
- Weather
- Data quality
- CMS activation

[1] U.S. Department of Transportation Federal Highway Administration "AMBER, Emergency, and Travel Time Messaging Guidance for Transportation Agencies." May 27, 2004.

The model is a multivariate regression. It was calibrated using loop detector data provided by the Freeway Performance Measurement System (PeMS). PeMS is a statewide repository for detection data on California freeways. Loop data nearby the locations of CMS 078 and CMS 070 was retrieved for the months of May and June in both 2004 and 2005. The pilot phase started on May 2, 2005. Therefore, the two-month period in 2005 was used as the treatment group (CMS active), while the corresponding two month-period in 2004 before was used as the control group (CMS inactive).

Controlling for the changing level of congestion near each sign was one of the concerns in the process of developing the model. Providing the best estimation of congestion's effect on speed is necessary to obtain an unbiased estimate of the effect of the CMS activation. The difficulty stems from the circular causality relationship between congestion levels and speed, whereby congestion causes speed to drop, but slowdowns due to the CMS may also result in congestion. In order to break away from that circularity, it was assumed that the effect of the CMS activation, if any, would be of a limited magnitude. In particular, it would be unlikely that slowdowns caused by the CMS would spill back very far upstream. 1 mile was considered, rather arbitrarily, as a reasonable buffer size for that purpose. This meant that the congestion levels 1 mile upstream of each sign were considered to be unaffected by the presence of a message. On the other hand, traffic conditions 1 mile upstream of a sign were assumed to be reflective of the conditions at the location of the sign itself, had no message be displayed. This was seen as an acceptable assumption for the two signs in the pilot phase, because there are no known bottlenecks within the 1-mile segments leading to those signs. Therefore, traffic conditions at either end of those segments would be similar most of the time.

Quantitatively, loops provide occupancy (spatial density), volume and speeds as 30-second averaged values. Occupancy is a good measure of congestion levels. Therefore, occupancy 1 mile upstream of each sign was chosen as the explanatory variable to reflect the effect of congestion on speed nearby the sign. Both upstream volume and upstream speed were considered as alternatives and finally abandoned. In traffic theory, the relationship between volume and speed is not functional, unlike the relationship between occupancy and speed. For a given traffic volume, there may be two speed values: free flow speed or some lower speed reflecting congestion. Speed not being a function of volume, volume was discarded. Upstream speed was also considered as an explanatory variable, but was found to be poorly correlated with downstream speed. This may be because speed is inherently more volatile than occupancy. Figure 2 depicts the causality relationships between the various traffic variables upstream and downstream.

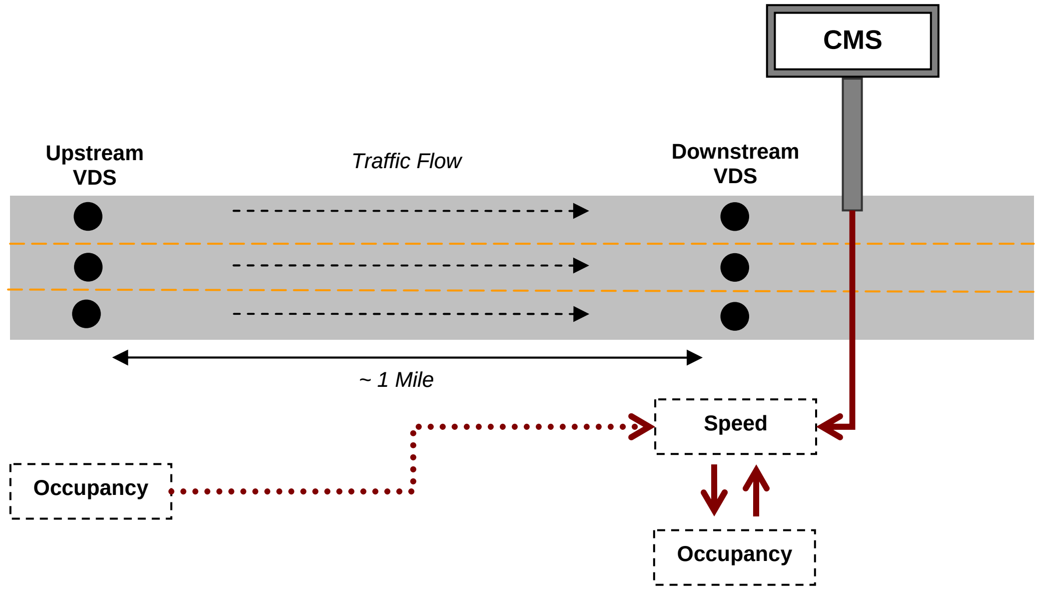

Figure 2 - Upstream and downstream measurements for traffic impact analysis. There is a circular relationship between occupancy and speed at the downstream VDS. The upstream occupancy explains downstream speed insofar as the congestion levels tend to be the same at both locations.

The rationale for the time-of-day variable is that traffic conditions and driver behavior can be very different during peak hours as opposed to non-peak hours. Although the congestion level is already modeled in the regression, the time-of-day variable may capture less tangible parameters that can impact drivers' speed, therefore improving the quality of the model. The peak period was defined as weekdays from 6am to 10 am and from 4pm to 7 pm. The corresponding variable is a dummy variable taking a value of 1 during peak period and 0 otherwise.

For weather, precipitations data for the two periods considered in the model was used. Although the rainy days are few in May and June in California, the precipitation variable is used to control for drivers slowing down because of wet pavement and poor visibility.

The data quality variable accounts for the level of confidence that can be placed in the loop data. This is described in more details in the next section. Finally, the variable corresponding to the CMS activation is evidently a dummy variable, taking a value of 1 when the sign is active and 0 otherwise.

The regression analysis was first performed on the whole data set. It was then observed that the effect of the messages on speed may not be uniform at different levels of congestion. In free flow conditions, drivers may choose to slow down significantly. On the other hand, in bumper-to-bumper traffic, little effect is expected as commuters have ample time to read messages. Therefore, a second regression model was run that controlled for different levels of occupancy, not only in terms of its explanatory power on speed, but also in terms of its effect on the impact of the CMS. Dummy variables for high, medium and low traffic occupancies were added to the regression. The coefficients on these variables were meant to rectify the estimated CMS effect with regards to congestion. The three different occupancy intervals are 0-5%, 6-15% and 16% and above. The cutoff points were determined by examining speed-occupancy diagrams and from prior knowledge of sensible occupancy ranges[2]. The first interval corresponds to free flow traffic, the 6-15% interval corresponds to intermediate states between free flow to congestion, and the 16%+ interval corresponds to heavy traffic.

Data

As previously mentioned, the loop data was gathered from PeMS. Four vehicle detector stations on I-80 were chosen to gather data for the analysis: the two upstream stations closest to each CMS and two stations located approximately one mile upstream of each CMS. Table 1 and Figure 3 show the locations of the four Vehicle Detection Stations (VDS), and other nearby stations. Table 1 features absolute postmile for these elements, and relative distance from each sign. The upstream station selected for the University Avenue sign is only .6 mile away from the sign. This is because all other stations further upstream were either inactive or producing unreliable data according to PeMS.

Table 1 - VDS and CMS Locations

Location	Postmile	Distance from CMS
CMS070 - Westbound CMS	9.89	0.00
VDS: 400803 - Ashby Ave.	9.90	0.01
VDS: 400009 - Upstream from Ashby	10.94	1.05
CMS078 - Eastbound CMS	11.50	0.00
VDS: 400612 - University Ave.	11.45	0.05
VDS: 401198 - Upstream from University	10.89	0.61

[2] "PeMS 5.4 – Frequently Asked Question 6.1"
Source: http://pems.eecs.berkeley.edu/Help/index.phtml?content=faq, July 21, 2005.

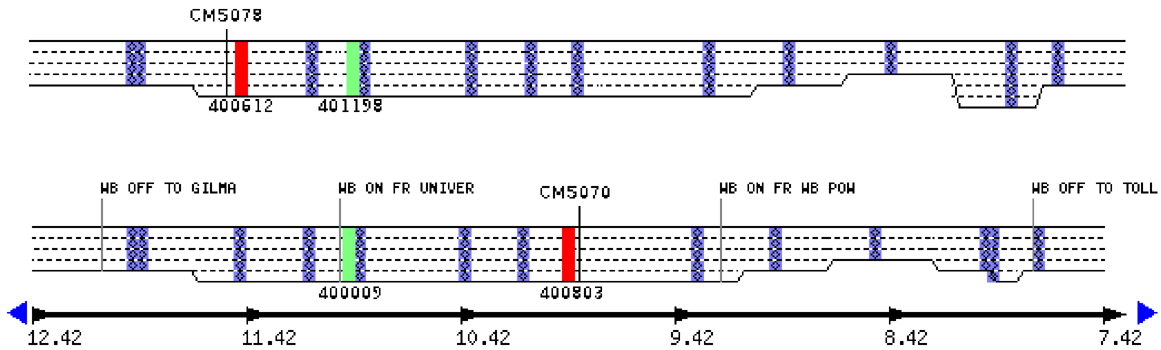

Figure 3 - Map of CMS and VDS along I-80

Hourly samples of data from all four stations were gathered for the months of May and June of 2004 and 2005. Data from 2004 was used as a control group (CMS inactive) while the data from 2005 was used as the treatment group (CMS active). The dataset was constructed from speed data at the downstream detector stations and occupancy data at the upstream detector stations. Descriptive statistics of the datasets are presented in Table 2, which is displayed in the Appendix. These do not, by themselves, show a clear effect of the travel time messages on speed. Looking across both signs, in either May or June, and in the three occupancy intervals defined in the previous section, one finds some of the average speeds in 2005, when the CMS were active, to be statistically less than the average speeds in 2004, the control group. However, there isn't a consistent difference throughout the data, and the 2005 speeds happen to be greater in some instances, such as at the eastbound sign location, in the month of May for the 0-5% occupancy level. Moreover, the average differences between speeds are less than the standard deviations of the corresponding speed samples by a factor of 3 or more, which forbids any meaningful conclusion. These preliminary results provide a reason for a more robust method of measuring the CMS effect on drivers.

PeMS features imputation procedures designed to fill in missing loop data or replace data that is blatantly incorrect. Although imputed data may be better than no data in most situations, imputed data cannot be trusted to the same extent as data that is obtained directly from the field. A scatter plot of speed vs. occupancy for the whole data set makes the imputed data stand apart from the direct data. This reveals that the imputation procedures have inherent flaws. In the regression models, a dummy variable was employed to control for imputed data.

Hourly precipitation data nearby the two signs was gathered from Weather Underground (http://www.weatherunderground.com), a website featuring national weather data.

Model

The model used for the traffic impact analysis is a multivariate ordinary least square regression. The functional form is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$$

where

$Y =$ Speed (mph) near CMS

$X_1 =$ CMS dummy (CMS On $= 1$, CMS Off $= 0$)

$X_2 =$ Upstream occupancy (%)

$X_3 =$ Precipitation (inches per hour)

$X_4 =$ Time of day dummy (Peak $= 1$, Off Peak $= 0$)

$X_5 =$ Imputed dummy (data imputed $= 1$, otherwise $= 0$)

$\varepsilon =$ Error term

The coefficients β_n measure each individual variable's effect on speed, controlling for all other variables in the model. For continuous variables such as upstream occupancy and precipitation, β_n represents the change in speed given a unit change in X. For dummy variables, β_n represents the speed change when $X = 1$. The regression was run four times with the four following data subsets:

- Eastbound direction, May 2004/2005 (noted EM1)
- Eastbound direction, June 2004/2005 (noted EJ1)
- Westbound direction, May 2004/2005 (noted WM1)
- Westbound direction, June 2004/2005 (noted WJ1)

As noted in the methodology section, it was anticipated that the CMS will affect speed in different magnitudes under different traffic conditions. In order to verify this phenomenon, another model was developed where the CMS effect on speed is separated according to three different occupancy intervals: 0-5%, 6-15% and 16% and above. The revised model is shown as equation 2 in the Appendix. Four additional regressions were run accordingly, with the same subsets as for equation 1. These for runs are noted EM2, EJ2, WM2 and WJ2, respectively.

Results

The regression results are presented in Table 3 and Table 4, both located in the Appendix. Regression coefficients were tested at the 95% confidence level, meaning that coefficients deemed significant have a probability of 95% or more of being non-zero. Coefficients which do not meet this criteria are statistically insignificant and are marked by an asterisk (*) in the results tables. The number of observations and the adjusted R^2 values are also presented for each regression. The R^2 correlation coefficient is a measure of the amount of variability in the model's dependent variable that is captured by the explanatory variables in the model. The adjusted R^2 is a refinement of the R^2 coefficient that controls for sample size and takes the number of explanatory variables into account, making it easier to compare different models. An adjusted R^2 value of 1 means that the explanatory variables fully capture the variations of the dependent variable, while a value of 0 signals an absence of correlation.

The adjusted R^2 values for the different regression runs vary between 0.34 and 0.38 in the eastbound direction, with sample sizes around 1400, and between 0.15 and 0.18 in the westbound direction, with sample sizes between 1100 and 1200. These values are rather low, indicating that the model as a whole does a mediocre job of capturing speed variations throughout the day based on the explanatory variables. Given the inherently chaotic nature of traffic, this is hardly surprising. Although correlation has some bearing on the strength of the model, a model with a low R^2 does not necessarily mean there is a better model available. Ultimately, it is the predictive power of each explanatory variable that makes most of the value of the model.

The regression results show varying effect of the CMS activation on speed. The range of the corresponding coefficients is -4.28 mph to -2.36 mph in the eastbound direction and -2.27 to +0.91 mph in the westbound direction. The statistical significance of these coefficients, as determined by their p-value, also varies. The sign of the coefficients for the eastbound runs are statistically significant, except for those determined in runs EM2 and EJ2, in the case of the higher occupancy (16%+). In the westbound direction, the coefficients are mostly not established with enough statistical confidence, except for those in runs WM2 and WJ2 for the medium occupancy (6-15%). A qualitative assessment of these results leads to conclude that the activation of CMS078 (eastbound) generally caused slowdowns of about 3 mph, although this may not be true during congested periods, and that the activation of CMS070 (westbound) did not have a clear or measurable effect. In the case of the eastbound sign, the data shows a rather uniform slowdown, indicated by the fact that the CMS activation coefficients have low standard deviations and roughly similar values across different congestion levels in models EM2 and EJ2. It is important to notice, as one could wrongly assume that the 3 mph speed decrease is an average that masks much more pronounced slowdowns. The data seems to indicate otherwise.

There is no noticeable trend in the evolution of the CMS activation coefficients. One would generally expect slowdowns following the activation of the system, followed by a gradual dissipation of the effect. The apparent speed decrease is roughly constant in the eastbound direction between May and June, while no significant conclusion can be drawn for the westbound sign in either May or June.

The regression coefficients for the other explanatory variables are mostly aligned with expectations and statistically significant. The intercept coefficient is slightly above speed limit (82-84 mph eastbound and 72-75 mph westbound), and most coefficients are negative, thereby decreasing speed. The weather variable is the only one that does not behave according to expectations. Its coefficients are not established with statistical significance in the eastbound direction, while they are positive in the westbound direction.

The difference in results between the eastbound and westbound signs is difficult to interpret. In general, factors that can explain differences between the effects of different signs could include the following:

- Usefulness of messages: people are more likely to slow down to read the signs if they know that the information is going to help them.

- Legibility: complexity of abbreviations used in the message, position of the sign respective to the roadway, fitness of the CMS bulbs, are all factors affecting legibility and therefore the amount of attention required to read a message.

However, it is hard to discriminate CMS070 and CMS078 based on these factors. The westbound sign displays travel times to San Francisco going over the Bay Bridge and seems useful to more people at any time of the day than the eastbound sign. This was confirmed by a user survey. On the other hand, someone with intimate knowledge of both sites could argue that the westbound sign is more easily readable than the eastbound sign. Its actual orientation is north, which means that the sunlight does not impair readability. The westbound sign faces the opposite direction and the incoming sunlight affects contrast and therefore the legibility.

Summary

This study used large amounts of data to conduct a before-and-after analysis of the effects of continuous CMS activations on driving speed. While first-order, descriptive statistics were not conclusive, a multivariate regression model was assembled to isolate the effect of CMS activation from other major factors affecting freeway speed. Out of two locations that were studied, one showed an apparent 3 mph speed reduction that is relatively uniform, except at high levels of congestion when the effect is less clear. No conclusions could be established for the other location, and speculations as of why a difference exists incriminate sign legibility as a potential cause. Overall, the effect on speed appears to be limited. To the extent that the effect wears out over time, a 3 mph speed reduction in the first 2 months seems acceptable.

Further work could include looking at speed changes associated with the CMS over a longer time period to examine whether or not slowdowns dissipate as drivers become more accustomed to seeing the signs. User feedback and anecdotal evidence seem to imply that this is the case.[3, 4] In addition, work on how drivers perceive the signs may shed light on the disparate result of the eastbound and westbound signs.

[3] Richards, Gary "Trying to get the message out: Don't slow to read message board" San Jose Mercury News, November 4, 2005.
[4] Kleinbaum, Josh "Talkin' bout my destination: Drivers split on value of traffic time signs on freeways" Los Angeles Daily News, November 2, 2005.

Appendix

Table 2 - Summary statistics of hourly speeds (mph)

at the eastbound (CMS 78) and westbound signs (CMS 70)

Eastbound	**May**				**June**			
		2004	2005	Difference		2004	2005	Difference
Entire set	Average	65.08	59.18	-5.90	Average	60.60	57.40	-3.20
	Std	19.22	22.08		Std	20.63	21.66	
	N	422	371		N	376	425	
Occ (0-5%)	Average	68.97	75.08	6.10	Average	76.49	70.90	-5.58
	Std	17.74	13.31		Std	12.45	18.05	
	N	57	43		N	39	40	
Occ (6-15%)	Average	66.63	59.34	-7.29	Average	62.47	60.03	-2.44
	Std	18.48	22.41		Std	20.90	21.27	
	N	319	258		N	254	291	
Occ (16%+)	Average	49.53	48.82	-0.72	Average	47.41	43.51	-3.91
	Std	19.16	19.26		Std	14.83	17.21	
	N	46	70		N	83	94	

Westbound	**May**				**June**			
		2004	2005	Difference		2004	2005	Difference
Entire set	Average	68.06	66.31	-1.75	Average	66.84	64.81	-2.03
	Std	12.07	14.11		Std	13.62	12.65	
	N	409	361		N	362	387	
Occ (0-5%)	Average	69.33	67.47	-1.87	Average	66.05	68.27	2.22
	Std	15.49	17.44		Std	20.19	16.54	
	N	93	76		N	60	80	
Occ (6-15%)	Average	71.02	71.68	0.66	Average	71.38	68.46	-2.92
	Std	7.55	4.99		Std	7.47	9.25	
	N	221	157		N	187	164	
Occ (16%+)	Average	60.16	59.37	-0.79	Average	61.04	59.23	-1.81
	Std	13.41	15.72		Std	13.33	10.99	
	N	95	128		N	115	143	

Std: Standard deviation N: Sample size

Models formulation

Equation 1 - Regression model for entire dataset

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon$$

where

$Y =$ Speed (mph) near CMS

$X_1 =$ CMS dummy (CMS On $= 1$, CMS Off $= 0$)

$X_2 =$ Upstream occupancy (%)

$X_3 =$ Precipitation (inches per hour)

$X_4 =$ Time of day dummy (Peak $= 1$, Off Peak $= 0$)

$X_5 =$ Imputed dummy (data imputed $= 1$, otherwise $= 0$)

$\varepsilon =$ Error term

Equation 2 - Revised regression model for three occupancy scenarios

$$Y = \beta_0 + \beta_1 (X_1 * X_2) + \beta_2 (X_1 * X_3) + \beta_3 (X_1 * X_4) + \beta_4 X_5 + \beta_5 X_6 + \beta_6 X_7 + \beta_7 X_8 + \varepsilon$$

where

$Y =$ Speed (mph) near CMS

$X_1 =$ CMS dummy (CMS On $= 1$, CMS Off $= 0$)

$X_2 =$ Occupancy dummy 1 (Occ 0 - 5% $= 1$, otherwise $= 0$)

$X_3 =$ Occupancy dummy 2 (Occ 6 - 15% $= 1$, otherwise $= 0$)

$X_4 =$ Occupancy dummy 3 (Occ 16%+ $= 1$, otherwise $= 0$)

$X_5 =$ Upstream occupancy (%)

$X_6 =$ Precipitation (inches per hour)

$X_7 =$ Time of day dummy (Peak $= 1$, Off Peak $= 0$)

$X_8 =$ Imputed dummy (data imputed $= 1$, otherwise $= 0$)

$\varepsilon =$ Error term

Regression results

Table 3 - Results of runs EM1, EM2, EJ1 and EJ2 corresponding to CMS 078

Eastbound	May				June			
	EM1		EM2		EJ1		EJ2	
Intercept	**82.91**		**82.91**		**83.30**		**83.19**	
	(0.65)		(0.65)		(0.63)		(0.62)	
Data Imputed	**-6.97**		**-7.01**		**-0.08**		**-0.08**	
	(0.64)		(0.64)		(0.01)		(0.01)	
Occupancy	**-125.10**		**-125.13**		**-147.59**		**-146.05**	
	(9.76)		(10.53)		(8.87)		(9.64)	
Time of Day	**-11.75**		**-11.7**		**-9.99**		**-10.04**	
	(1.19)		(1.19)		(1.24)		(1.24)	
Weather	**-1.32**	*	**-1.21**	*	**-30.58**	*	**-31.19**	*
	(10.41)		(10.69)		(29.13)		(29.46)	
CMS Activation	**-3.22**				**-3.44**			
	(0.93)				(0.97)			
CMS Activation			**-2.36**				**-3.96**	
Occupancy 0-5%			(1.07)				(1.59)	
CMS Activation			**-3.58**				**-3.16**	
Occupancy 6-15%			(1.14)				(1.15)	
CMS Activation			**-2.6**	*			**-4.28**	*
Occupancy 16%+			(2.98)				(2.32)	
N	1474		1474		1430		1430	
R^2	0.35		0.34		0.38		0.38	

Bold values are coefficients. Values in parenthesis are standard errors.

Asterisks mark coefficients not statistically significant at the 95% confidence level (p-value > 0.05).

Table 4 - Results of runs WM1, WM2, WJ1 and WJ2 corresponding to CMS 070

Westbound	May				June			
	WM1		WM2		WJ1		WJ2	
Intercept	**74.23**		**74.118**		**72.68**		**72.29**	
	(0.63)		(0.63)		(0.64)		(0.67)	
Data Imputed	**-4**		**-4.27**		**-4.64**		**-4.67**	
	(0.55)		(0.53)		(0.67)		(0.67)	
Occupancy	**-53.03**		**-50.48**		**-40.31**		**-34.61**	
	(6.59)		(7.18)		(5.33)		(6.47)	
Time of Day	**-4.2**		**-4.51**		**-4.97**		**-5.25**	
	(0.89)		(0.90)		(0.85)		(0.86)	
Weather	**8.81**		**9.91**		**15.48**	*	**16.26**	
	(3.51)		(3.65)		(11.67)		(12.14)	
CMS Activation	**0.46**	*			**-0.27**	*		
	(0.67)				(0.68)			
CMS Activation			**-1.68**	*			**-0.47**	*
Occupancy 0-5%			(1.32)				(1.25)	
CMS Activation			**-2.65**				**0.91**	
Occupancy 6-15%			(0.56)				(0.81)	
CMS Activation			**-1.51**	*			**-2.27**	*
Occupancy 16%+			(1.71)				(1.26)	
N	1115		1115		1183		1183	
R^2	0.17		0.18		0.15		0.15	

Bold values are coefficients. Values in parenthesis are standard errors.

Asterisks mark coefficients not statistically significant at the 95% confidence level (p-value > 0.05).

California Center for Innovative Transportation

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Commuter Survey Report

July 2006

Prepared by:

Brian Huey
Graduate Student Researcher, CCIT

JD Margulici
Senior Development Engineer, CCIT

For:

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

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HOV lane:	Lane reserved for High-Occupancy Vehicles
ITS:	Intelligent Transportation Systems
MITTENS:	Software that generates travel time messages for freeway signs
MTC:	Metropolitan Transportation Commission
SF:	San Francisco
SFO:	San Francisco International Airport
SOCCS:	Software that controls the CMS from the TMC
TMC:	Transportation Management Center
VDS:	Vehicle Detection Station

Introduction

The California Department of Transportation (Caltrans) owns and operates about one hundred Changeable Message Signs (CMS) in the San Francisco Region from its Traffic Management Center (TMC). The implementation of an automated system to display travel times on those CMS started in October, 2004, through a partnership piloted by the California Center for Innovative Transportation (CCIT), and involving Caltrans' Division of Research and Innovation (DRI), the local Caltrans district (District 4, or D4), and the Metropolitan Transportation Commission (MTC).

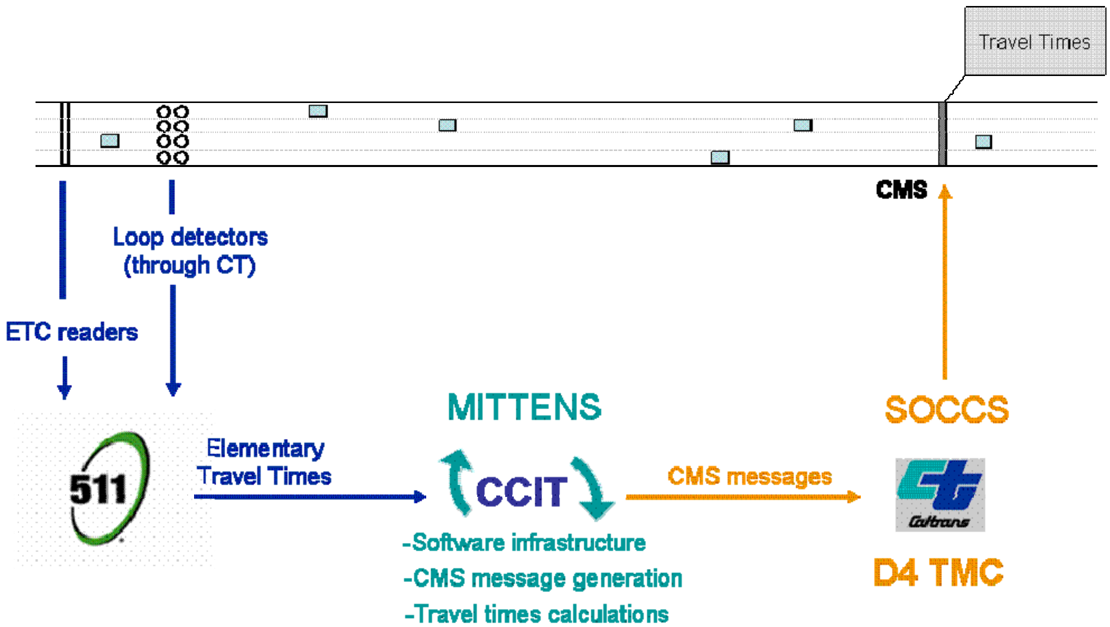


Figure 1 - Travel Times on CMS in District 4: Schematic Data Flow

The project consisted in creating the missing link between MTC's Travinfo system, which provides data for the regional 511, and the District's TMC. In order to manually control the display on the signs, TMC operators use SOCCS, a piece of software developed by DRI. CCIT integrated Travinfo and SOCCS by developing MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). MITTENS is a stand-alone software system designed to host a description of a freeway network, let operators configure commuter routes and sign displays, process link travel time information, and generate messages.

MITTENS relies on MTC's 511/Travinfo for travel time predictions. These predictions are based on real-time traffic data collected by toll tag readers (FasTrak program) and by Caltrans' embedded loop traffic detectors. Predictions are updated every minute and are reported on the signs accordingly. MITTENS also applies filters to the estimated travel time estimates, so that bad or suspicious data doesn't get reported on the signs. Figure 1 presents the schematic data flow for the whole system.

Starting on May 2nd, 2005, a pilot deployment allowed the project partners to evaluate the system's robustness and public acceptance. For this pilot phase, 2 signs were operated on Interstate 80 eastbound (CMS 078) and westbound (CMS 070) in Emeryville and Berkeley. Trials were conducted with either 2 or 3 destinations on each sign. The destinations were San Francisco Downtown, San Francisco Airport, and Oakland Airport westwards, and the Carquinez Bridge, Fairfield and Novato eastwards, for a total of 6 routes. Based on the success of the pilot phase, additional CMS were activated just before the 12th World Congress on Intelligent Transportation Systems in November of 2005. The total number of active signs stands at 19 since then, with further deployment under way.

As a part of the CMS pilot project, a survey was developed and distributed to collect and analyze the public's reaction. The primary goal of the survey was to obtain insights about their how the project was perceived. In particular, the survey examined three areas: general feedback about the project, specifics regarding the messages and the signs, and suggestions for improvement.

Between the launch of the pilot in May 2005 and the survey in October 2005, local media coverage and anecdotal responses regarding the sign were mixed. One driver wrote in to the San Jose Mercury News, "I love the new lighted highway signs that tell how much time it will take to get from point A to point B. It saves me a phone call to 511." On the other hand, a survey that was conducted for a similar project in the Los Angeles area revealed that "about half of the 275 respondents said they liked the signs and half didn't." People voiced concerns in the news media about drivers slowing down to read the signs: "Right before University Avenue is an electronic sign … Miraculously, five seconds after passing the sign I go from 20 to 65 mph." Although the questions of whether drivers slow down to read the sign was not explicitly asked in the survey – the phenomenon was deemed too difficult to articulate in such a brief survey – the survey did ask if the travel time messages provided too much information to read while driving. More generally, survey respondents were also invited to write in comments or suggestions about anything regarding the CMS.

Survey Methodology

A 12-question form was developed that covers respondent demographics and a mix of general and specific, as well as multiple-choice and open-ended questions. The form was posted online on the 511.org website hosted by MTC, and paper copies were printed for direct distribution. A printout of the questionnaire is presented in the Appendix.

There is an inherent difficulty in attempting to obtain a sample from drivers who traverse a particular corridor. The only time one is able to identify the target audience is while they are driving, which doesn't lend itself to any practical means of distributing surveys. One possible solution, however, was to distribute paper questionnaires to motorists stopping to pay the toll at the Bay Bridge toll plaza. The toll plaza is a mandatory stopping point (except for FasTrak users) and many vehicles that take the bridge drive there from I-80 where the signs activated for the pilot were located. The idea was rejected by Caltrans due to concerns about safety and increased delays at the toll plaza. A multi-channel approach was developed as an alternative.

In order to drive commuters to the online survey, two channels were employed. An advertisement on the 511.org home page encouraged the web site visitors to take the survey. Since the website is a popular resource for regional transportation information, it was expected that the CMS pilot project would be familiar to many users of the website. The second channel leveraged the FasTrak toll transponder program. FasTrak users were encouraged to take the online survey via an advertisement on their monthly billing statement.

The paper surveys were distributed at casual carpool locations throughout the East Bay. Casual carpooling is a phenomenon that began in the Bay Area; it refers to drivers picking up riders, usually at a designated meeting spot, in order to fulfill the vehicle occupancy requirements to enter the carpool lane and avoid toll charges. Both parties benefit from the carpool since the driver faces less congestion and no toll, while the rider receives a free ride to their commute destination. Casual carpooling has been successful in large part because of the effort to create casual carpool meeting locations and advertise them over the internet, so that drivers and riders can quickly and easily find one another. Since meeting spots usually have large queues of either vehicles or people waiting for rides, it presented an opportunity to distribute surveys to commuters whose destinations could easily be identified.

The online survey was operational for the entire month of October 2005, with 511.org advertising the survey on its homepage for two weeks. In addition, advertisements were mailed with FasTrak billing statements for two weeks in October. At the month's end there were 560 responses. The casual carpool surveys were conducted in the morning, 6:30 – 9:30 am for East Bay meeting points, and in the afternoon, 2:00 – 4:00 pm for San Francisco meeting points. These correspond with regular commute patterns in and out of the downtown San Francisco business district. Both inbound and outbound commutes were surveyed because, although the population is expected to be overall the same, individuals may elect to adopt the system in one direction and not the other. Surveying both directions would then increase the sample size. Table 1 details the location and dates of the casual carpool surveys. Approximately 1400 surveys were distributed over the entire survey period with 393 returns, a return rate of 28%. San Francisco was sampled twice due to the large number of people at the meeting point, and because it was the only eastbound casual carpool location.

Table 1 - Casual carpool survey locations and dates

Location	Survey Dates
North Berkeley	10/18
Albany/El Cerrito	10/20
San Francisco	10/20 and 10/27
Vallejo	11/3

Survey Response

Mail-in survey responses were gathered from mid-October until December 3rd, approximately one month after the last casual carpool survey date. Data from the casual carpool surveys were entered into a database along with the online surveys, for a total response of 953 entries. As a reference, a sample size of 953 produces a margin of error of roughly 3% at the 95% confidence level. This means that the 95% confidence interval of a 50/50 split response to a yes/no question is +/-3%. For results that are more divided, the confidence interval shrinks. However, since the sample was not obtained in an entirely random fashion, the margins of error may be slightly higher.

The responding population meets the criteria of the study. The main goal of the survey was to collect data from those who use the signs often enough to have formed an opinion in order to get feedback and suggestions for improvement. While the distribution channels do not fully guarantee that those taking the survey have seen the signs, the questionnaire contains a control question which asks precisely that. Only 3% of those who took the survey had not seen the signs. 52% of respondents “always see the signs” and 32% “often see the signs.” In addition, 63% see the signs on their regular commute.

Figure 2 shows survey responses by zip code. Aside from a few very distant zip codes, most of the survey respondents lived in the Bay Area. Figure 2 shows that the highest concentration of survey responses was located near the active signs in the east bay. This is desirable because it is likely that these survey respondents read the messages frequently and that their responses reflect the target population.

The distribution of commute origins and destinations shows that most commuters originate from the East Bay – Alameda and Contra Costa Counties are the most frequently cited origins, and San Francisco is the most frequently cited destination. Trips from the East Bay to San Francisco characterize the morning commute as seen in the results of Question 4. The reverse commute, from San Francisco to the East Bay, is also reflected in the data. Of those who responded at the San Francisco casual carpool location, East Bay to San Francisco origin-destination pairs comprised 82% of the total, with Solano County making up 67%. This is significant because the eastbound travel time messages refer to places in Solano County, namely the Carquinez Bridge and Fairfield.

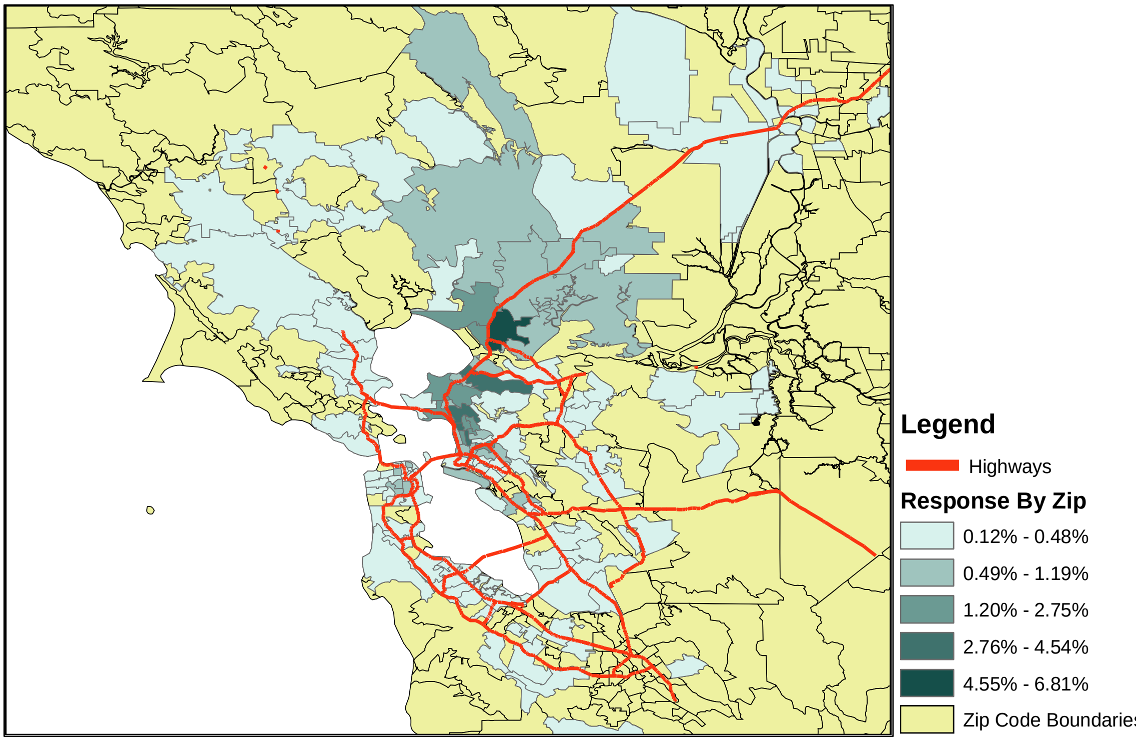
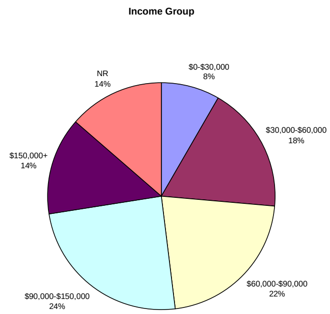


Figure 2 - Survey response by zip code (Bay Area Region)

It was also important to ensure that the sample adequately reflects the population of commuters in the region at large. The demographic questions regarding age and income were compared to similar figures in the 2004 American Community Survey of the San Francisco-Oakland-San Jose CMSA. Figure 3 shows the distributions for both surveys by age and income. Ages of the survey respondents are distributed towards the middle intervals since those who read the CMS most are commuters working full time, professional jobs. The sample deviates from census survey results at the tail ends of the age intervals because those 18-25 and 65 and above are a relatively small portion of the commute population. Income results in the CMS survey roughly corresponds to the census survey. The one outlier is the $90,000 – $150,000 interval which is 9% larger in the CMS survey than the census survey. A possible explanation for this disparity is that commuters tend to be higher income earners because they are the ones who are able to live far from their job centers, use a vehicle to access their employment area and afford parking costs. There was also a large non-response rate of 14% on the income question, which may hide further upwards bias.



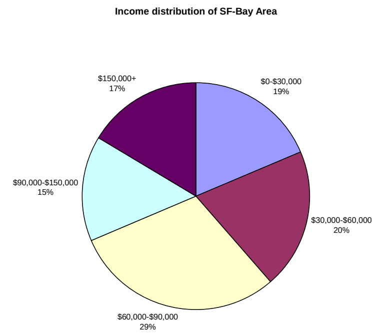


Figure 3 - Income comparisons: i) sample and ii) population

Source: 2004 American Household Survey

Survey Results

Comprehensive survey results can be found in chart format in the Appendix. Throughout the survey, respondents showed steady support for the CMS travel times. For instance, on a scale of 1 to 5 (5 being the highest), 70% of the respondents answered with 4 or 5 to question 5 asking, “How useful do you consider the travel time messages to be?” Likewise, 82% of respondents replied that they like the current travel time destinations. When asked about any difficulty reading the signs, 75% responded with a 1 or 2 on a 1 to 5 scale with 1 being least difficult. In addition, users expressed their satisfaction by writing in comments on the survey. One respondent commented, “The signs are useful. The more info we have the better we can adjust our travel patterns.” Another mentioned that, “knowing the estimated time even it it's a LONG time reduces driver anxiety dramatically.”

The survey asked respondents which travel time messages they have seen. Responses indicated that westbound travel time messages were seen more frequently than the eastbound ones. San Francisco Downtown was the most frequently seen travel time message, followed by San Francisco Airport. The Carquinez Bridge travel time was the most seen eastbound message. The least seen message was Novato. This suggests that drivers acquire information selectively, although the message design is probably influential. Both San Francisco Downtown and the Carquinez Bridge happen to occupy the first line of the message on the signs where they are featured, which makes them easier to read. By design, destinations are displayed by order of increasing distance.

The questionnaire also posed more in-depth questions about the messages. On a scale of 1 to 5, where 5 is most accurate, 58% of users said the accuracy of the signs was 4 or 5. The survey also inquired about users’ perception of the update rate. Although individual users have no way to observe first-hand what the update rate is, they may form an opinion from driving by the signs day after day. Current posting rules limit variability by imposing a minimum value and by only refreshing messages for drifts that are 2 minutes or greater. In order to determine if the update rate was perceived as adequate, the survey asked respondents if they felt the travel time messages were being updated “very frequently”, “somewhat frequently” or “not frequently enough.” 42% of respondents said they thought the signs were updated “somewhat frequently.” 27% of users said they didn’t know. The propensity to respond with the intermediate answer, “somewhat,” or to admit to not knowing, may indicate that the signs are being updated at a reasonable rate. If commuters strongly fell that the messages were not updated frequently enough, one can expect that they would have voiced their concern.

Several questions addressed the issue of message legibility. Illegible signs cause discomfort and ruin their own purpose; they may also distract drivers, with possible consequences on safety and traffic flow. A study of a Southern California CMS which surveyed drivers found that 28% considered the signs to be a distraction.[1] Question 7 directly asked the survey respondents to rate how difficult it was to read the signs on a scale of 1 to 5, with 1 being least difficult. The majority of respondents said they had no difficulty reading the signs – 50% chose 1 and 25% chose 2. Legibility is influenced not only by environmental factors such as the sign location and light bulbs fitness, but also by the messages themselves. This was one of the concerns with adding a third destination on the messages during the pilot phase. Question 9 asked respondents if they three travel time messages were providing too much information to read while driving. Again, the respondents did not feel that it was a problem – 84% said “no.”

One of concerns stemming from message legibility is the potential effect on driver attention and, consequently, on vehicle speed. The impact of the signs on traffic speed was assessed quantitatively as part of a parallel study, using loop detector data and regression analysis. The effect was found to be tangible but limited (3 mph) for one sign, and probably insignificant for the other. This result can be correlated with the survey responses to the questions regarding legibility, which showed overall satisfaction. Yet, slowdowns caused by the signs, whether perceived or real, are a phenomenon that is reported by respondents in the write-in portion of the survey: “The signs are great but they cause traffic slowdowns...so I don't know how you can remedy this but it is really a pain sometimes...especially when the sign is used for messages other than traffic-related (e.g. Don't Drink and Drive)” It is interesting to notice the linkage established between the adverse effect of the sign activation and the usefulness of some messages other than travel times, similarly reflected in other comments: “I find it extremely annoying on the Bay Bridge to have a posting telling me to buckle up or to tune my radio to 840 and then the radio only gives me generic information. The amount of congestion caused by bad drivers reading the signs tends to back the bridge up for quite some time.” The travel time messages are not directly targeted by the comments, suggesting that their usefulness at least balances any perceived disadvantage and creates a status quo.

[1] Parentela, E and N. Eskander. “Effectiveness of Changeable Message Signs CMS) On Los Angeles Freeways” Institute of Transportation Engineers, 2001 Spring Conference and Exhibit, Washington, DC, 2001.

It is possible that the messages cause only a small portion of drivers to slow, but that behavior is noticed by other drivers. This would explain the results from questions 7 and 9: even though a small portion of people may have found the messages hard to read or overloaded with information, the effect could have been observed and felt by others. Travel time messages, as well as any other “out of the ordinary” structure on highways may require some time for users to get accustomed to. Some respondents mentioned that the slowdowns have become less frequent over time as people got used to the messages.

The survey contained two write-in questions. The first one asked the survey participants to suggest other destinations they would find useful. Table 2 shows the most requested destinations and the frequency with which they were mentioned. One interesting point is that some of the requested destinations are far outside of the region surveyed. For instance, Sacramento lies in a different metropolitan region. A general guideline for the CMS is to limit the distance of the routes being displayed to about 20 miles. Longer routes result in less accurate predictions because they require forecasting further into the future, and have less of a reach because the proportion of drivers going from the sign location to a given destination decreases with the distance to that destination.

Table 2 - Top 10 requested alternative CMS destinations

Destination	Frequency	Distance (miles)
1 - San Jose	30	51
2 - Sacramento	21	76
3 - Hayward	20	21
4 - San Rafael	14	16
5 - San Mateo Bridge	13	21
6 - Vallejo	12	20
7 - Palo Alto	10	41
8 - Walnut Creek	8	18
9 - Hercules	4	13
10 - Daly City	2	17

The second write-in questions called for general comments and suggestions. There were three main comments that respondents frequently made. The most popular comment, with 21 occurrences, reflected confusion regarding the definition of travel times given the evident difference between High-Occupancy Vehicle (HOV) lanes and general-purpose lanes. Those who use the HOV lane thought that the travel time predictions overestimated their actual travel time, while some people who drove in general-purpose lanes thought the travel time predictions underestimated their travel time, particularly in the west bound direction: “[I] Can't be sure if the East Bay to San Francisco times are based upon carpool, FasTrack [sic] or toll-paying. The times posted only seem a reality to a driver who DOESN'T stop at the toll plaza. They seem unrealistic to any other driver.” The second most frequent comment was that drivers slowed to read signs, and this was discussed above. 15 occurrences of that comment were collected. The third most frequent comment, with 9 occurrences, was that the travel time messages and/or CMS were a waste of money. These comments were usually made in conjunction with overall dissatisfaction with the accuracy of the travel times or the fact that they were slowing down traffic. Some thought the money could be spent better: “A big time waste of money. Use that money to fix potholes and freeways.”

Summary

The survey was a useful tool to gauge the public’s opinion on the posting of travel time messages on CMS. The sample taken was large enough to provide excellent statistical confidence in the results. The sample also seemed very representative of the target population since 97% of respondents had seen the signs, and a large proportion of them had their residence located near the study corridor. The demographic data collected in the survey roughly reflected the demographics of the region at large, with some bias towards older, wealthier persons.

The most important results of the survey are as follows:

- The survey effort returned a sample of 953 respondents, corresponding to a margin of error of approximately +/- 3%.

- The majority of survey respondents found the travel times useful and accurate; only 10% of respondents gave them a negative rating in respect to usefulness and accuracy. 82% of respondents said that they liked the current travel time destinations. Respondents did not have strong opinions about the update rate. Some expressed confusion about the data source, rightfully assuming that travel times differ on HOV and general-purpose lanes.

- The messages were generally not considered difficult to read while driving, even with 3 destinations displayed. Difficulty reading the sign may still be a reason for causing traffic slowdowns that are anecdotally reported by some of the respondents.

- The destinations displayed on the signs appeared well chosen, although individual people list alternative destinations that they can personally relate to when asked about their preferences.

Appendix

- Survey questionnaire
- Survey results, question by question

CMS TRAVEL TIMES SURVEY

ID#________

You are invited to take a quick survey regarding your opinion of the travel time messages displayed on the Changeable Message Signs (CMS) on I-80. Your information will be kept strictly confidential and you can return the completed survey using the pre-paid envelope attached. Thank you!

1. Have you seen the travel time signs on I-80?
   - ☐ I have never seen the signs *
   - ☐ I always see the signs.
   - ☐ I often see the signs.
   - ☐ I sometimes see the signs.

   *** If you checked this box you may stop taking the survey.**

2. Which travel time message(s) have you seen? Check all that apply:
   - ☐ SF Downtown
   - ☐ SFO
   - ☐ Oakland Airport
   - ☐ Carquinez Bridge
   - ☐ Fairfield
   - ☐ Novato

3. Are the travel time messages located on your regular commute?
   - ☐ Yes
   - ☐ No
   - ☐ I don't commute

4. When you last saw a travel time message, where were you traveling from and to?

	FROM:	TO:
Alameda County	☐	☐
Contra Costa County	☐	☐
San Francisco County	☐	☐
San Mateo County	☐	☐
Santa Clara County	☐	☐
Solano County	☐	☐
Other	☐	☐

Please rate on a scale of 1 (worst) to 5 (best):

5. How useful do you consider the travel time messages to be?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

   Least Useful → Most Useful

6. How accurate do you find the travel time estimations?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

   Least Accurate → Most Accurate

7. How difficult was it to read the sign while driving?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

   Least Difficult → Most Difficult

8. Do you get the impression that the travel time messages are updated:
   - ☐ Very frequently
   - ☐ Somewhat frequently
   - ☐ Not frequently enough
   - ☐ I don't know

9. Does displaying three travel time messages on one sign provide too much information to read while driving?
   - ☐ Yes
   - ☐ No
   - ☐ I don't know

10. Do you like the current travel time destinations?
    - ☐ Yes
    - ☐ No
    - ☐ I don't know

11. Please suggest any other destinations that you would find useful.

    ____

    ____

12. Please share with us any comments/suggestions you may have.

    ____

    ____

    ____

Your Age Group:
- ☐ 18 – 25 years
- ☐ 26 – 35 years
- ☐ 36 – 50 years
- ☐ 51 – 65 years
- ☐ 65 + years

Your Household Income:
- ☐ $ 0 - $30,000
- ☐ $ 30,000 - $ 60,000
- ☐ $ 60,000 - $ 90,000
- ☐ $ 90,000 - $150,000
- ☐ $ 150,000 +

Your Zipcode: _ _ _ _ _ - _ _ _ _

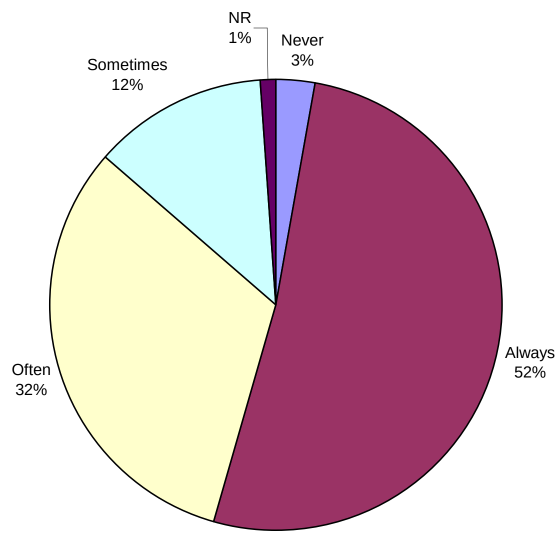
Thank you for participating!

Caltrans

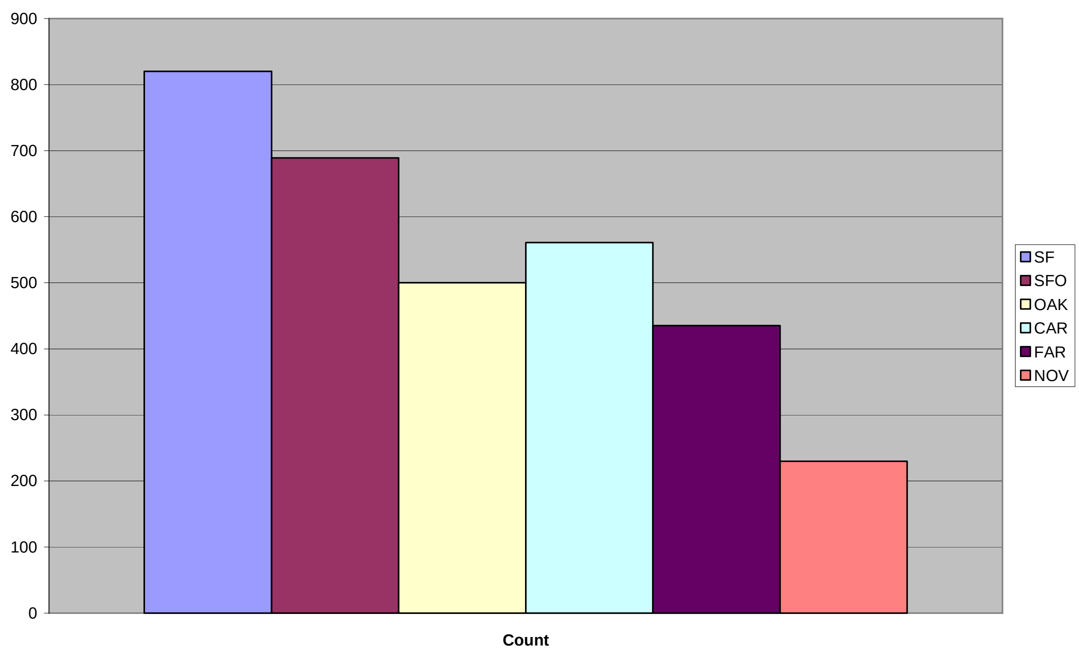
California Center for Innovative Transportation

511

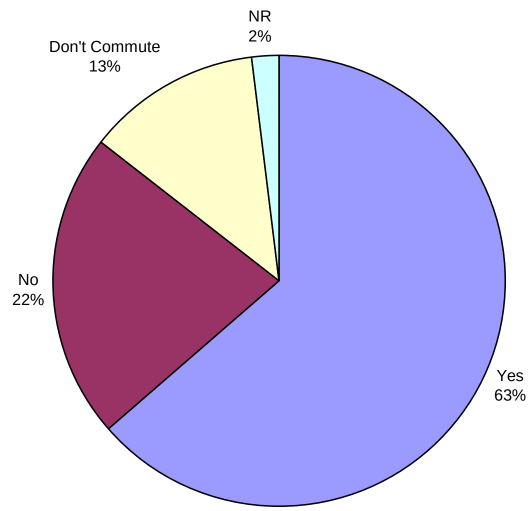
Q1 - "Have you seen the travel time signs on I-80?"



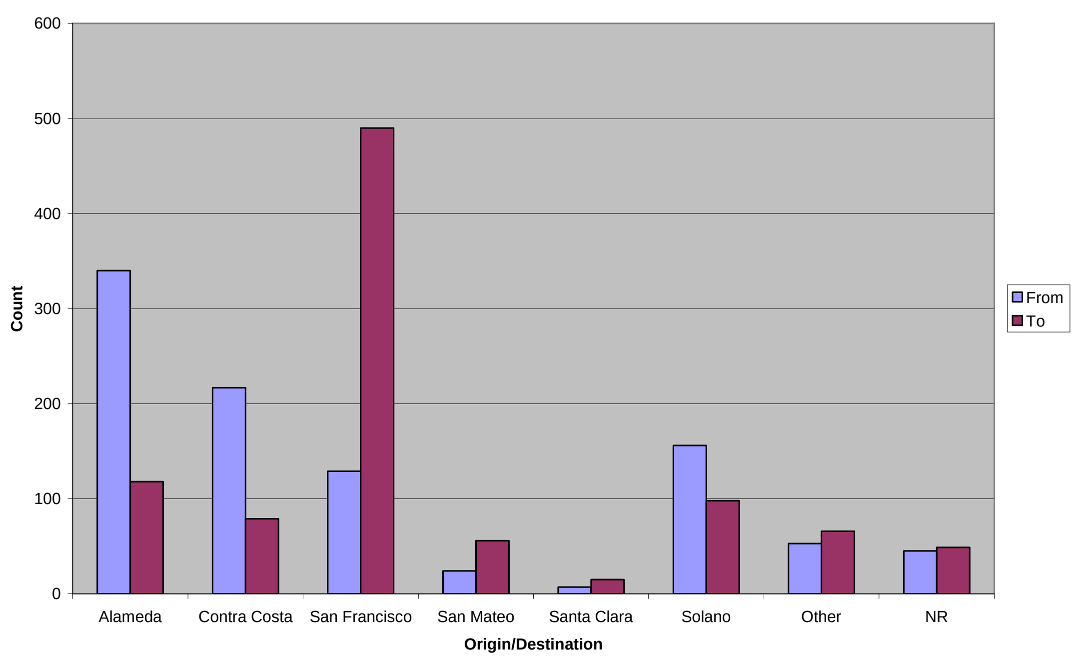
Q2 - "Which travel time message(s) have you seen? Check all that apply"



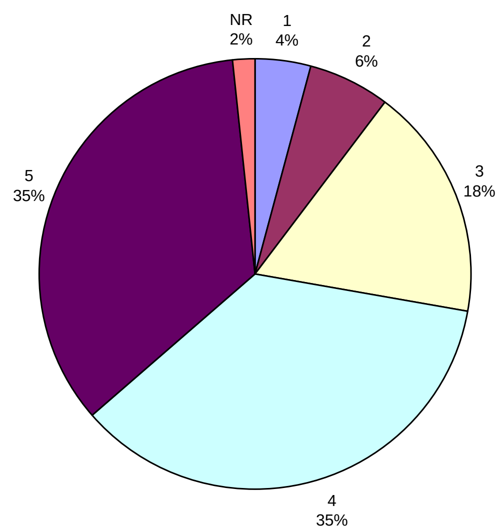
Q3 - "Are the travel time messages located on your regular commute?"



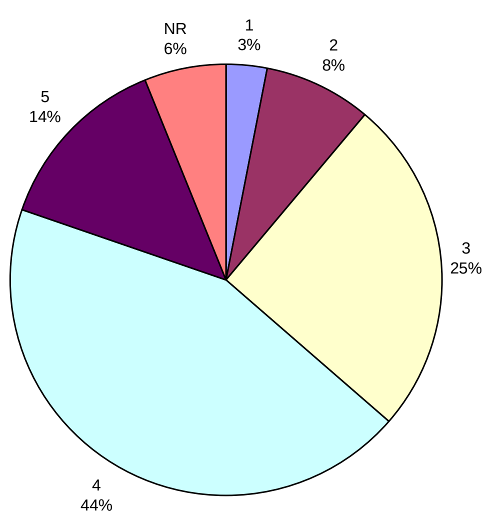
Q4 - "When you last saw a travel time message, where were you traveling from and to?"



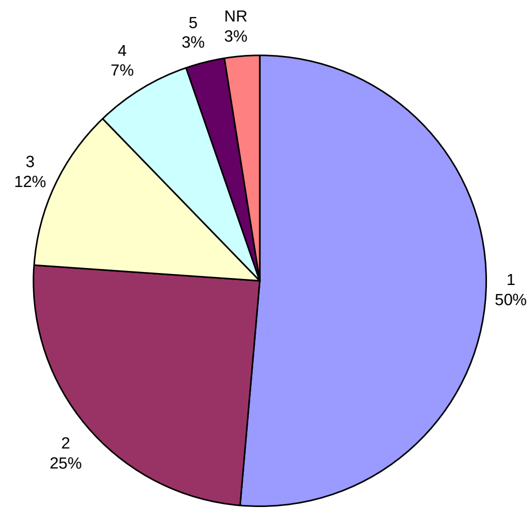
Q5 - "How useful do you consider the travel time messages to be?" (1 - Least useful, 5 - Most useful)



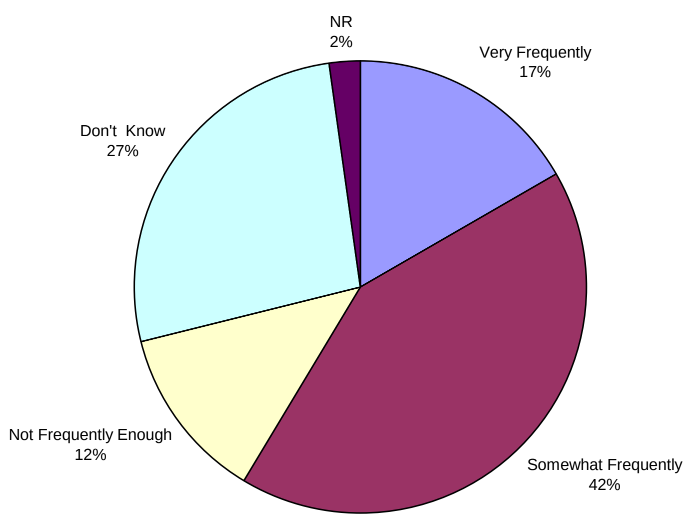
Q6 - "How accurate do you find the travel time estimations?" (1 - Least accurate, 5 - Most accurate)



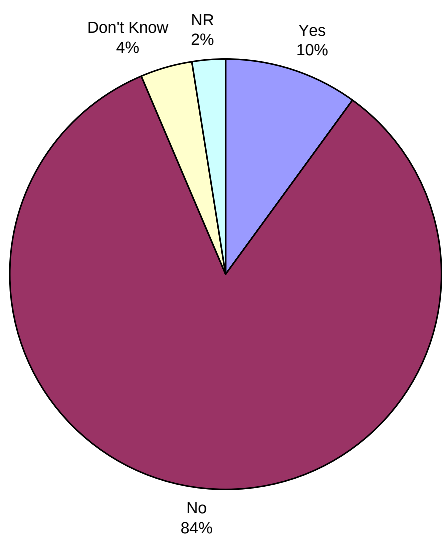
Q7 - "How difficult was it to read the sign while driving?" (1 - Least difficult, 5 - Most difficult)



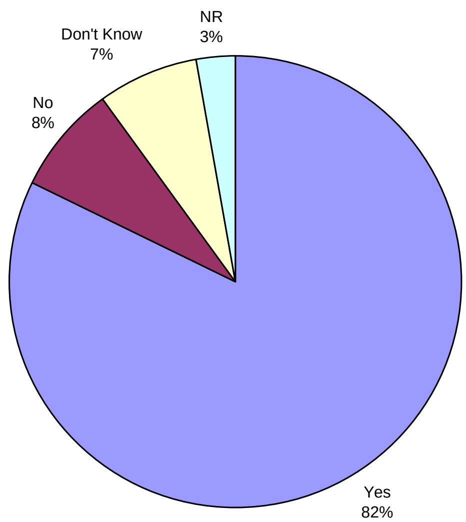
Q8 - "Do you get the impression that the travel time messages are updated:"



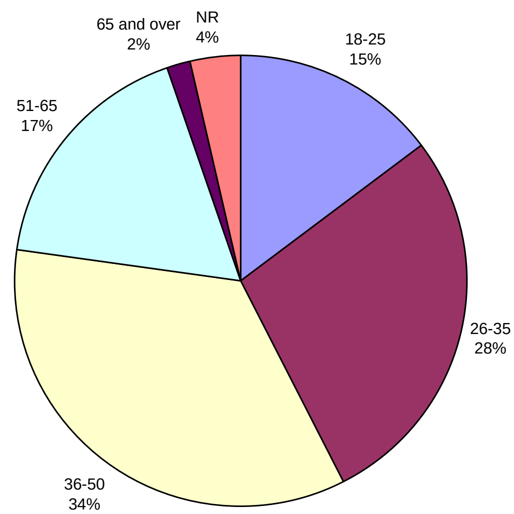
Q9 - "Does displaying three travel time messages on one sign provide too much information to read while driving?"



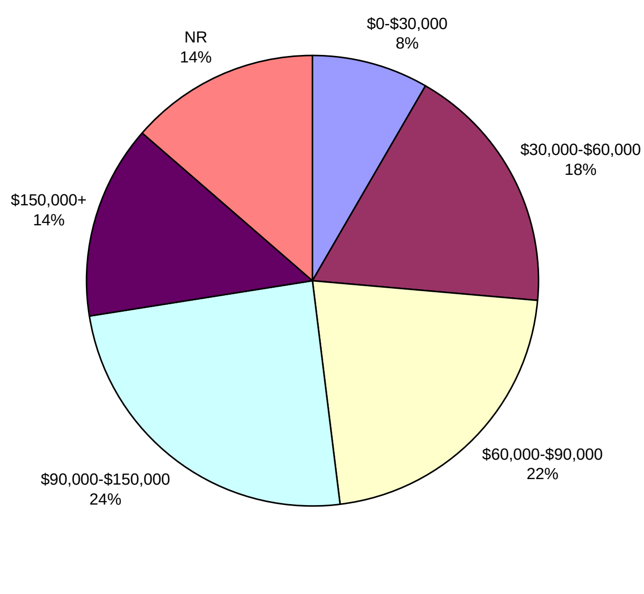
Q10 - "Do you like the current travel time destinations?"



Age Group



Income Group



California Center for Innovative Transportation

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Network Construction and Route Generation

December 2005

Prepared by:

Samuel Yang
Graduate Student Researcher, CCIT

For:

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

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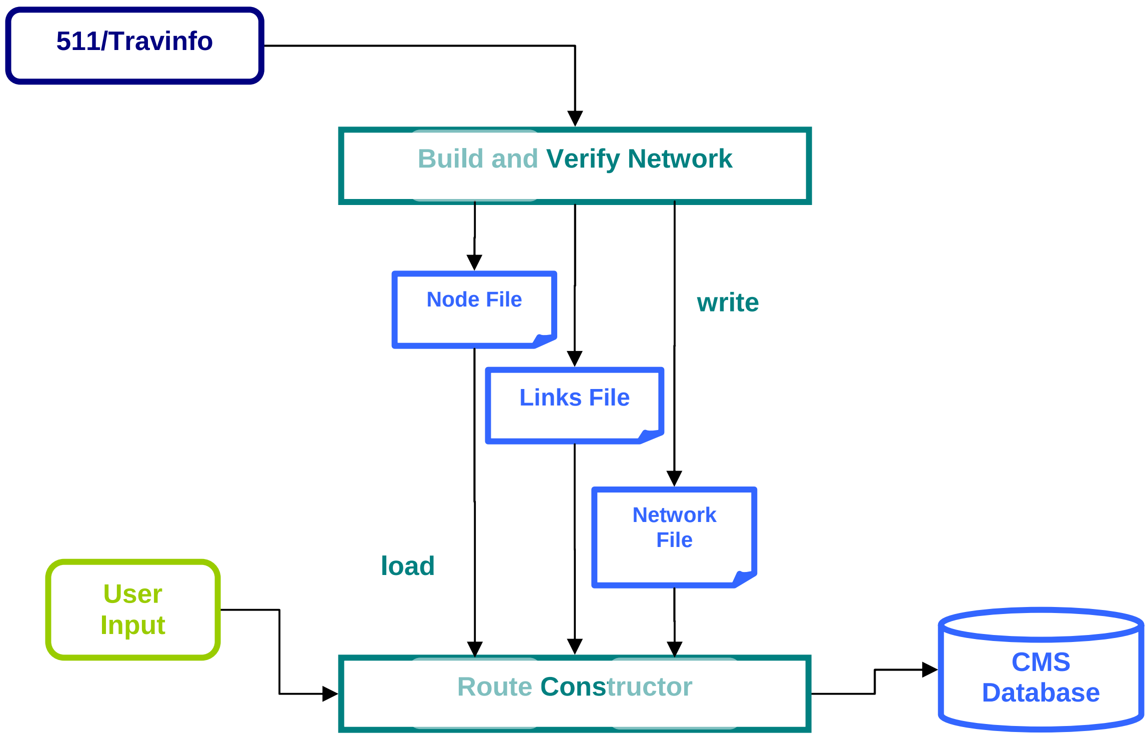


Figure 1 – System Overview

In the CMS Travel Time project, travel times for specific destinations are displayed on the CMS. The travel times are calculated by summing together link travel times along a given route. We would like an automated way to construct routes for any origin to destination. We accomplish this by first constructing a network and then using a routing algorithm called Double Dijkstra to find the routes from the link definitions between an origin and a destination. Once the routes are found, they must be written in a format for the CMS Database to understand. How these tasks are implemented is discussed below. Please see the MITTENS documentation for more information regarding the link definitions.

Building the Network

The Problem of Building the Network

In general, the link definitions provide thorough coverage of the Bay Area's freeway network and include moderate coverage of some of the major surface streets. However, there is no explicit indication in the link definitions which define link connections. In other words, each link definition contains information regarding itself and does not contain information regarding its relationship to neighboring links.

LINK_NAME	ROAD_NUMBER	LINK_LENGTH	LINK_SPEED_LIMIT	ON_STREET_NAME	FROM_STREET_NAME	TO_STREET_NAME	START_LATITUDE	START_LONGITUDE	END_LATITUDE	END_LONGITUDE	FWY	ACTIVE
142025	27769	55	104	I-238 S	I-580 E	I-580 W	37.68966	-122.104	37.68945	-122.103	238	1
140015	8360	55.77321	104	CA-85 S	CENTRAL EXPY	W EVELYN AVE	37.39175	-122.069	37.39127	-122.069	85	0
502055	58828	55.7829	201	US-101 N	CA-37 E	CA-37 W	38.07987	-122.546	38.08027	-122.546	101	0
196000	749	55.86204	56	AIRPORT PKY	US-101	E BROKAW RD	37.37226	-121.92	37.37186	-121.92	#N/A	0
195010	749	55.86216	56	AIRPORT PKY	E BROKAW RD	US-101	37.37186	-121.92	37.37226	-121.92	#N/A	0
119845	58828	58	104	US-101 N	CA-37 E	CA-37 W	38.07987	-122.546	38.08027	-122.546	101	1
300850	58831	58	104	US-101 S	CA-92 W	CA-92 E	37.55334	-122.296	37.55293	-122.296	101	1

Table 1 - Some of the 511/Travinfo Links

Link definitions provide information regarding: the link name, the road name, the length of the link, the speed limit, the street that the link is on, the nearest exits at the start and end point, and the geographic start and end points (Please see Table 1). Further work has been done to construct the 'active' field. The 'active' field is '1' when travel times are reported for the given link and '0' when travel times are not reported.

Solution – Making Connections between Links

Before routes can be constructed from the links, a network must be built. The network will define how the links are connected to other links. Using the information in the link definitions, nodes will be created, and the links will connect the nodes. Nodes can be connected to multiple links thus creating a connection between the links. The figure below shows how multiple links may share the same node and thus are connected.

The following sections will discuss the data entities and the process flow that is needed to build the network.

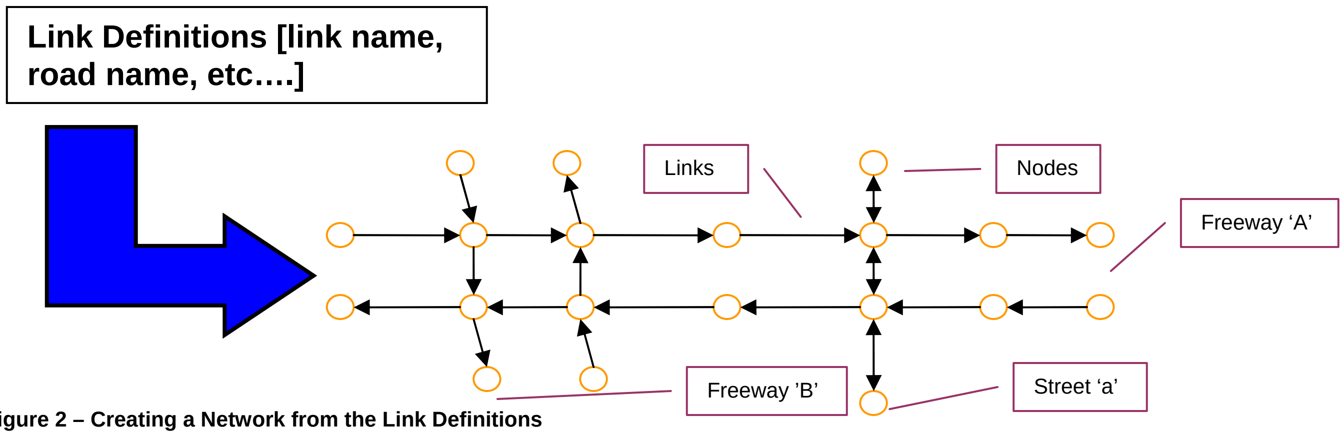


Figure 2 – Creating a Network from the Link Definitions

The Current Set of Links

The current set of link definitions used to build the network uses only freeway link definitions. As mentioned above, the link definitions also include surface street definitions, but these are excluded from the network. Also excluded are 'duplicate' links. The 'duplicate' links exist for some link definitions and are intended to be used for carpool lanes but for now no travel times are ever reported for these links. The link definitions are in the file: `links_noStreet_noCarpool.csv.`

Building the Network - Data Entities

Figure 3 shows the data entities that are used in constructing the freeway/street network. The object, Network has a Links object which stores the link definitions. Links also has Nodes which is a list of instances of Node.

Point

The Point object holds a geographical location. It can compare two points using the functions: isEqual, isRoughlyEqual, and isInVicinity.

Node

The Node object stores a list of tuples. Each tuple is constructed from information in the link definitions and a Point: (‘on_street_name’, ‘from_street_name’, Point). For example, a node created from a link on the 580 may have the tuple (‘I-580 E’, ‘W GRAND AVE’, Point).

Two nodes can be compared using the isEqual function. Two nodes can be merged by using the addAttributes function where the attributes from node A can be merged with the attributes of node B. The ‘Node’ object can also be assigned an ID.

Nodes

The Nodes object stores a list of multiple instances of ‘Node’.

Link

The Link object stores the information provided in the link definitions as well as start and end Node objects.

Links

The Links object is a dictionary of Link objects with the ‘link_name’ (see Table 1) as the key. It also holds a Nodes object which is a list of all the Node objects that are in the Link objects. The build( ) function uses makeStreetAndRampLists( ), makeNodeList( ), makeNode( ), searchAndAdd( ), and doesExist( ) to construct the network.

Network

The Network object is a dictionary of Node objects. For each Node ID stored, the Network object stores the Link objects whose start node is that Node. For example, Figure 2 shows the entry for Node 1 and Node 3. Node 1 is connected to Node 2 by Link ‘link_name_12’ whose length is 2 and connected to Node 3 by Link ‘link_name_13’ whose length is also 2. Node 3 is connected to Node 1 by Link ‘link_name_31’ whose length is 3 and connected to Node 2 by Link ‘link_name_32’ whose length is 1.

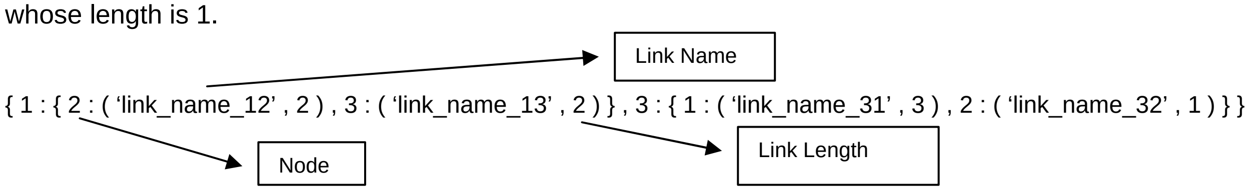


Figure 2 – Example of the network object

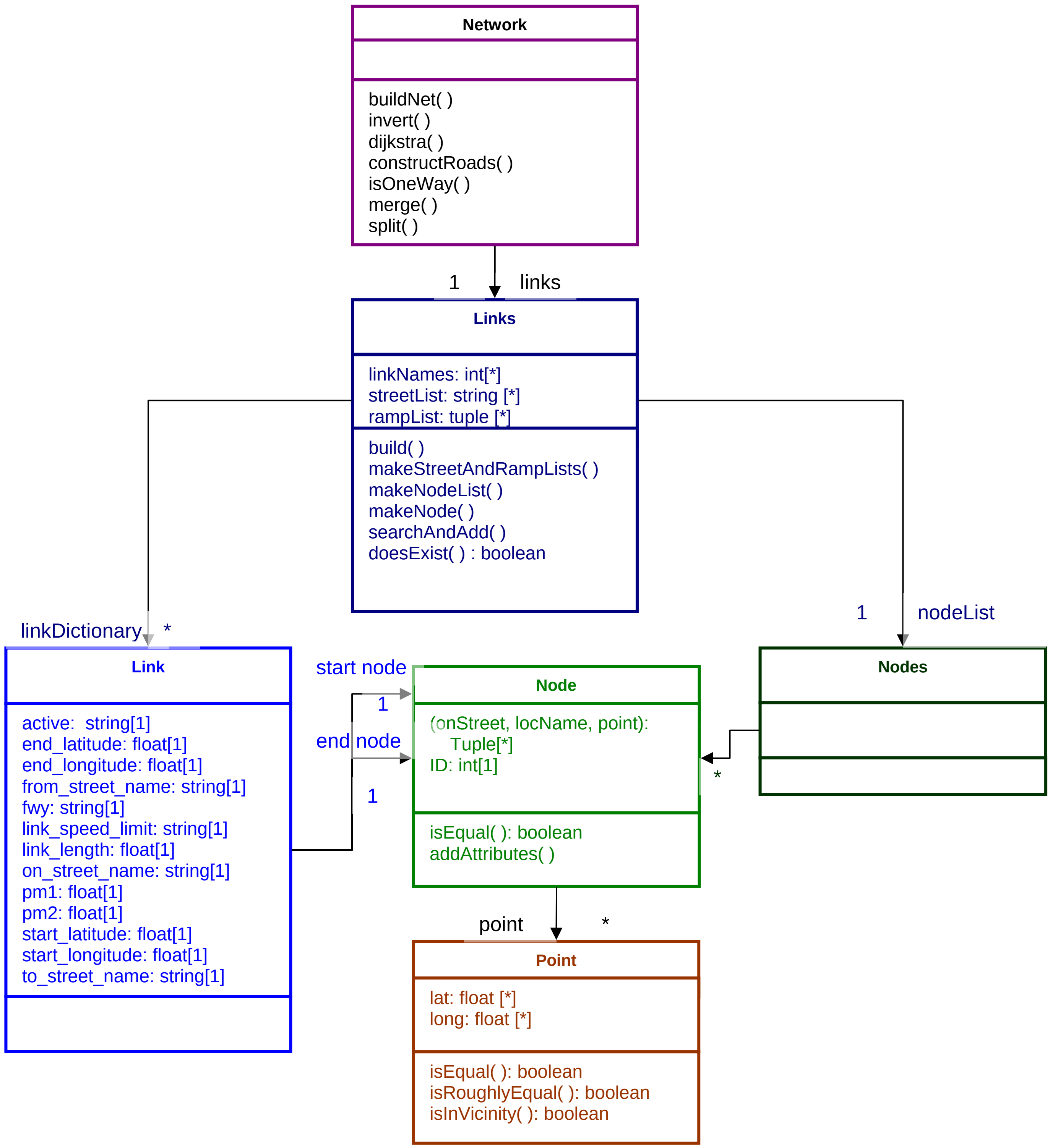


Figure 3 - The data entities and their relationships

Building the Network - Process Flow

The 511/Travinfo link definitions are read in from a file and placed in Links.linkDict. Lists of the ramps and freeways reported in the link definitions are created as Links.rampList and Links.streetList. These lists are used in creating the nodes and are reported in the diagnostic files. The process then enters a loop in Links.makeNodeList( ), where the bulk of the network creation takes place. The loop analyzes each link and assigns new or existing nodes at the start and end of each link. Links.makeNodeList( ) calls Links.makeNode( ) which creates a start Node and an end Node from the link definitions as described above. Links.searchAndAdd( ) is then used to determine if the two Node objects already exist in the Nodes object, Links.nodeList. If they do not already exist, then they are added to the Nodes object and they are assigned to the link as the “start node” or “end node.” If they do exist in Links.nodeList, then the nodes found in Links.nodeList are assigned to the link as the “start node” or “end node” and the just-created Node objects are deleted. More detail is shown below in Figure 4.

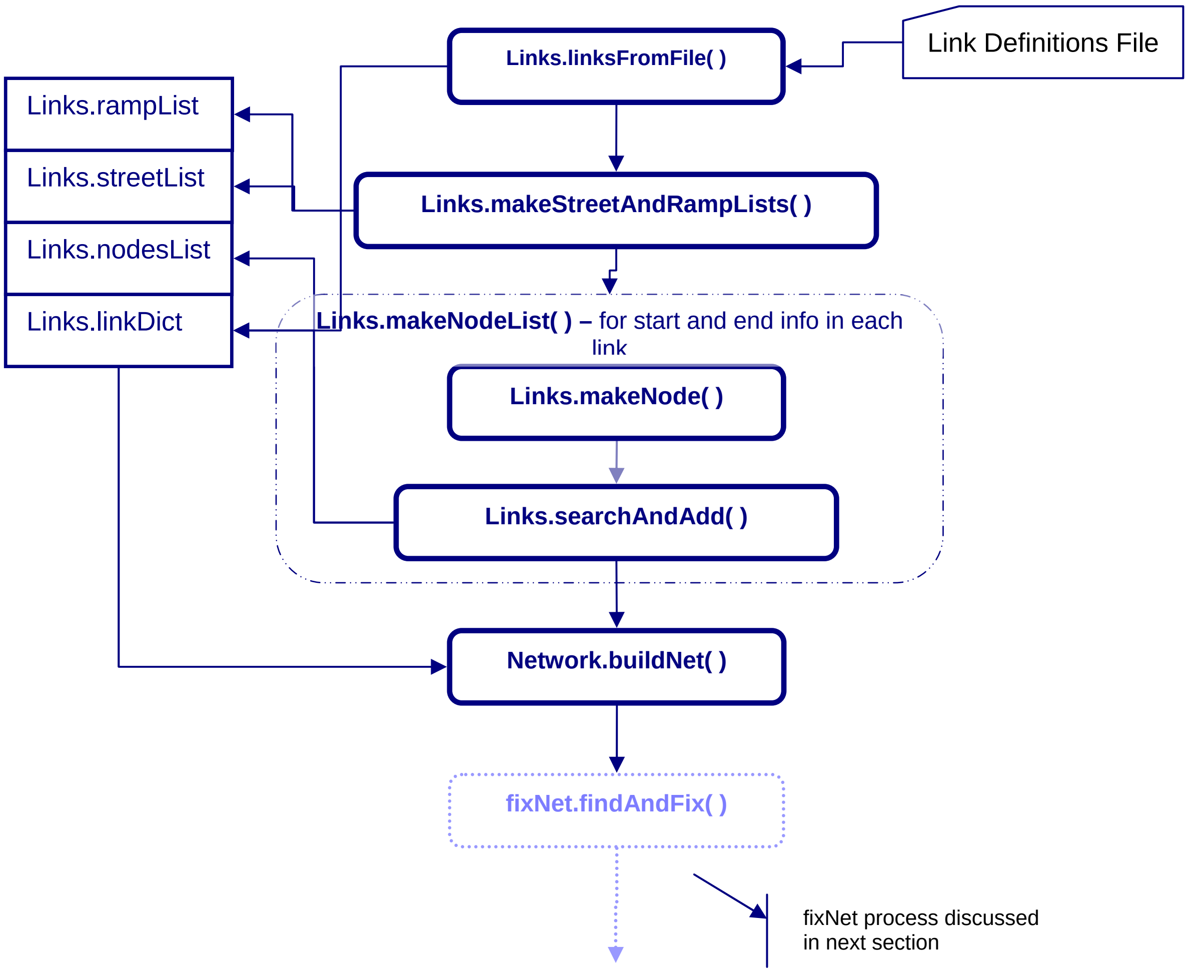


Figure 4 – Building the Network Process Flow (In Bold)

In the two following sections, two critical methods, Links.doesExist( ) and Node.isEqual( ) are described in detail. Both of these methods are used in the Link.searchAndAdd( ) method.

Links.doesExist( )

Links.searchAndAdd( ) passes a newly created Node object, for example, Node A to Links.doesExist( ). Node A is then compared to every Node object in Links.nodeList. Links.doesExist( ) calls Node.isEqual( ) to compare two Node objects. If the two objects are equal, then the index in the Nodes object is saved. If more than one Node object is found to be equal to Node A, then a warning will be issued to the user. Once Links.doesExist( ) has searched all of Links.nodeList, it returns the index of the equal Node to Links.searchAndAdd( ). Please see the figure below for more details.

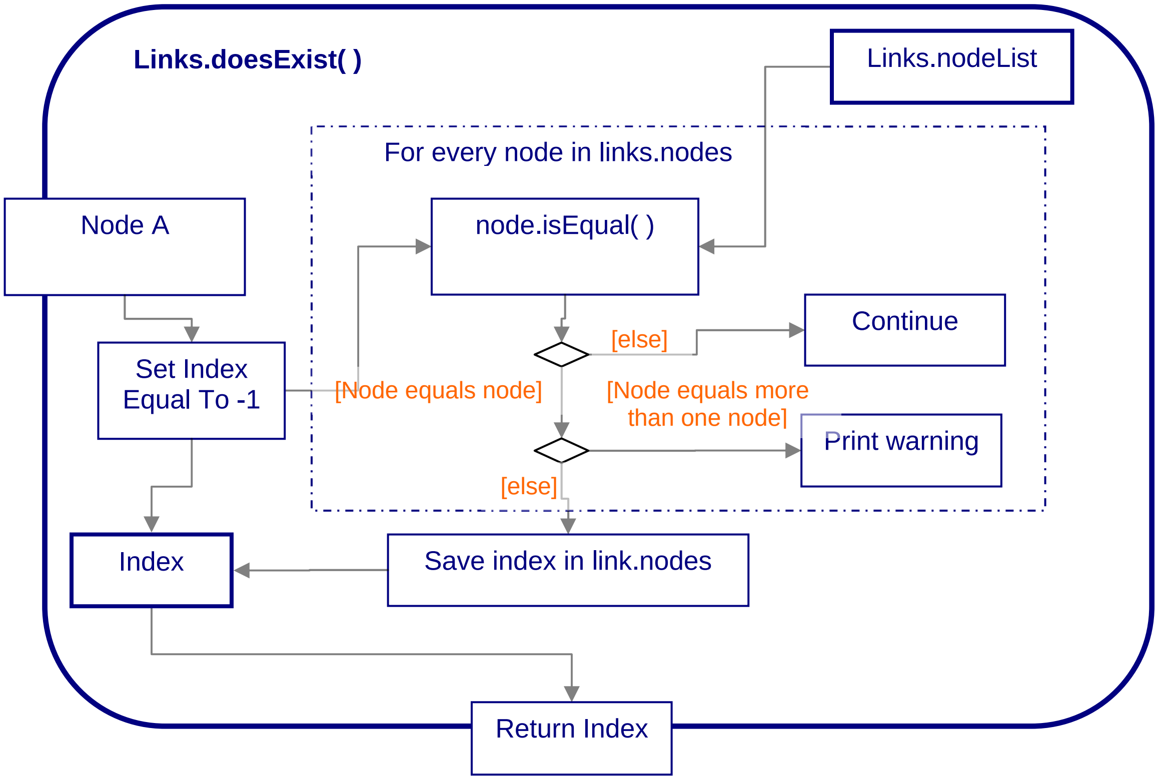


Figure 5 – Process for testing if a node already exists

Node.isEqual( )

Node.isEqual( ) determines if two Node objects are the same. If two node objects are the same, this means, that the links, from which the nodes have been created, are connected. There are 4 types of connections that occur in the network and each case must be tested:

1. Typical Case

This corresponds to two consecutive links on the same street. The Point, onStreet and locName are all equal. When two Point objects are equal, this means that the square of the difference between the latitudes and the longitudes are within some tolerance. The tolerance level is a constant defined in the Point class.

Link Defs

102570	27809	1152	104	'I-80 W'	'ASHBY AVE'	'POWELL ST'	37.84833	-122.298	37.83807	-122.296
102560	27809	2096	104	'I-80 W'	'UNIVERSITY AVE'	'ASHBY AVE'	37.86681	-122.304	37.84833	-122.298

Node A: (I-80 W, ASHBY AVE), (37.84833, -122.298)
node: (I-80W, ASHBY AVE) , (37.84833, -122.298)

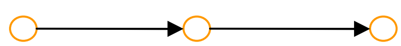


Figure 6 – Topology of the typical case

2. Ramps

This case corresponds to the ramps, where Node A’s onStreet specifies that it is a ramp, Node A’s locName is equal to the other node’s onStreet, and their Points are equal. The example below provides more detail.

Link Defs

401000	54036	2543	88	'I-880 N-I-80 W Ramp'	'I-880 N'	'I-80 W'	37.81715	-122.296	37.82375	-122.319
107510	27818	1525	88	'I-880 N'	'I-580 W'	'I-80 E'	37.81715	-122.296	37.82918	-122.294

Node A: ('I-880 N-I-80 W Ramp', 'I-880 N'), (37.81715, -122.296)
node: ('I-880 N', 'I-580 W'), (37.81715, -122.296)

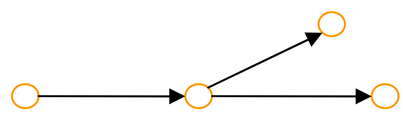


Figure 7– Topology of the ramps

3. Ramps
These cases correspond to the ramps, where node's onStreet that it is a ramp, node's locName is equal to Node A's onStreet, and their Points are equal. The example below provides more detail. The topology is the same as in Figure 7.

Link Defs

107510	27818	1525	88	'I-880 N'	'I-580 W'	'I-80 E'	37.81715	-122.296	37.82918	-122.294
401000	54036	2543	88	'I-880 N-I-80 W Ramp'	'I-880 N'	'I-80 W'	37.81715	-122.296	37.82375	-122.319

node: ('I-880 N-I-80 W Ramp', 'I-880 N'), (37.81715, -122.296)
Node A: ('I-880 N', 'I-580 W'), (37.81715, -122.296)

4. Junctions

This case corresponds to junctions where no ramps are defined in Links.rampList. If the two Node objects have roughly the same Point (Point.isRoughlyEqual( )) and Node A's onStreet is equal to node's locName and node's onStreet is equal to Node A's locName, then they are equal. For two points to be roughly equal means that the tolerance used in the typical case (1) has been increased. The parameter rampFlag is set false to indicate that the two freeways are not connected with a ramp. An example case follows.

LinkDefs

105235	27793	941.0001	104	'I-580 E'	'CA-13 N'	'CA-13 S'	37.78385	-122.183	37.78091	-122.174
122065	8291	41.15273	104	'CA-13 S'	'I-580 W'	'I-580 E'	37.78627	-122.179	37.78606	-122.18

Node A: ('I-580 E', 'CA-13 S'), (37.78385, -122.183)
node: ('CA-13 S', 'I-580 E'), (37.78606, -122.18)

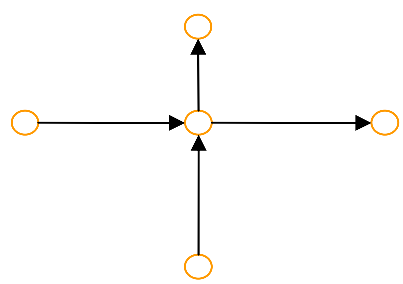


Figure 8 – Topology of the ramps

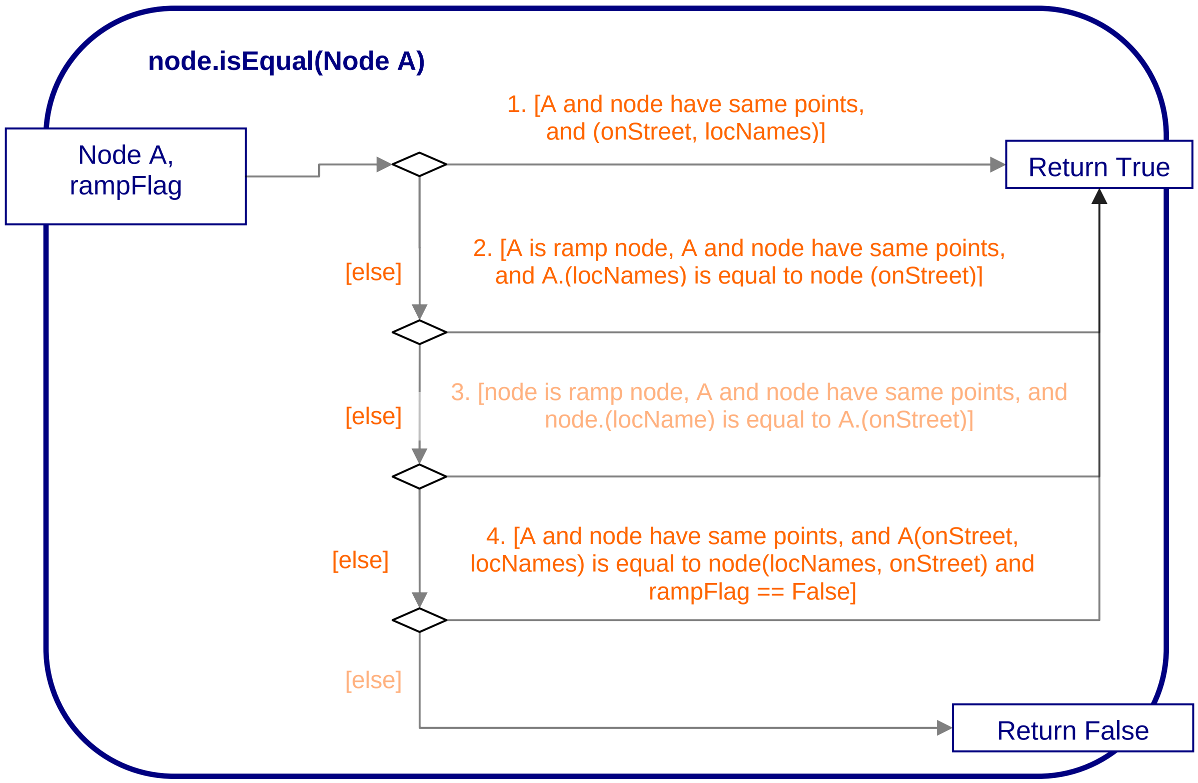


Figure 9 – Comparisons used to determine if two nodes are equal

Files Used

Table 2 lists the files that are used in building the network.

File	Description
`point.py`	Defines the Point object
`node.py`	Defines the Node object
`nodes.py`	Defines the Nodes object
`link.py`	Defines the Link object
`links.py`	Defines the Links object
`network.py`	Defines the Network object
`buildAndFixScript.py`	The script that builds the network
`Links_noStreet_noCarpool.csv`	Link definitions

Table 2 – Files used in building the network

Verifying and Fixing the Network

The Problem with Verifying and Fixing the Network

As noted in the section titled ‘The Problem With Builiding the Network’, the link definitions do not contain any information about a link’s connections to its neighbors. The preceding section covered the first attempt at solving this problem by creating and assigning nodes to each link. When multiple links share the same node, then a connection is made. Determining whether or not two links share the same node is performed in the node.isEqual( ) method (please see section above). It turns out that this method is incomplete due to the inconsistencies in the link definitions and there are still gaps in the network. Previous testing has shown that gaps do not occur along a given freeway. The gaps only occur at the junctions, which are where two or more freeways intersect.

Resolving the gaps in the network consists of finding each junction, looking for gaps in the junction, and if gaps are found, to fix the gaps. Fixing the gaps mainly involves merging two or more nodes together. The difficulty in fixing the network is finding where the gaps are and identifying which nodes need to be merged in order to fix the gap.

The gaps are identified by finding each junction and classifying it according to a set of categories. Following this, specific fixing methods are applied to each type of junction in which there are gaps. In special cases, where it is too difficult to automate the gap fixing, user input is required.

The following section describes the various junctions that are found in the network and their solution. The data objects and process flow that are involved in verifying and fixing the network are then described.

The Junctions

A junction is a connection between two or more freeways. Gaps occur in the junctions when two freeways that should connect are not connected. Gaps are identified by examining all the nodes associated with a given junction to see what the connections are. Because there are a variety of ways for a junction to a gap, the best way to fix the junctions is to firstly categorize all the junctions according to their topology and then apply specific fixing methods to each type.

The following figures will provide examples for each type of junction. There are nine types of junctions: Complete Junction Definition (this is the typical case), Exits with Different Names, Unmatching Points, End of Freeway Junction, Asymmetric Links, Missing Connection, Incomplete Junction Definition, Triple Junction and Ramp. Included with the example, is the way to fix the junction to obtain the proper connectivity. Table 3 summarizes the different types of junctions encountered and the type of solution that is used as the fix. The types of solution are either None, Auto or Manual. None indicates that no fix is needed – all connections are made in the junction. Auto means that there is a specific method to automatically fix the gaps in the junction. Manual means that user input is required to fix the gaps in the junction.

Quirk	Name	Solution
1	Complete Junction	None
2	Exits with Different Names	Auto
3	Unmatching Points	Auto
4	End of Freeway Junction	Auto
5	Asymmetric Links	Auto
6	Missing Connection	Auto
7	Incomplete Junction Definition	Auto
8	Triple Junction	Manual
9	Ramp	None

Table 3 – Types of junctions and type of solution

Complete Junction Definition

In a Complete Junction Definition there are four nodes shared by 12 links. In this case, the junction is complete and is not in need of fixing.

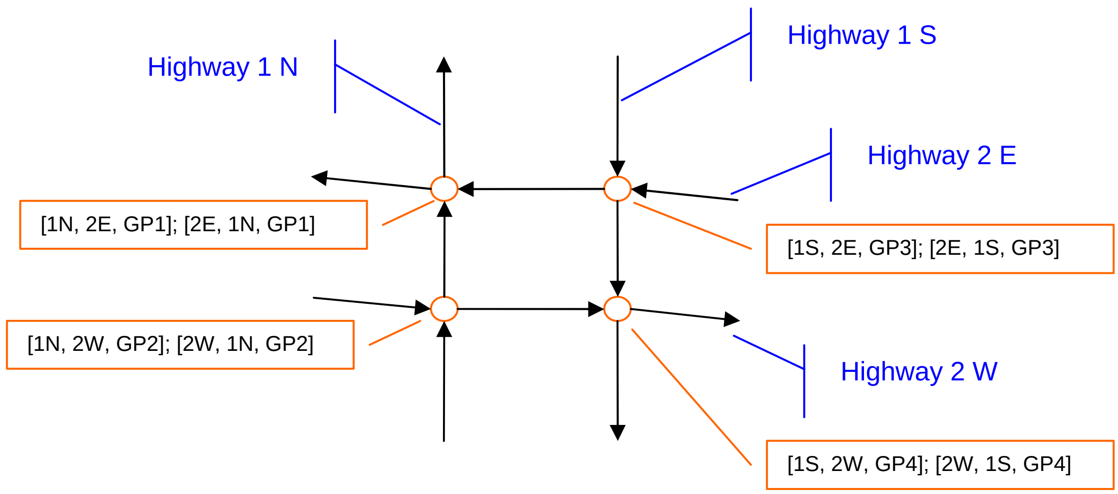


Figure 10 – A Complete Junction Definition with four nodes and 12 links. The nodes are shown in orange with their tuples of (onStreet, locName, point), the links are the black arrows connecting the nodes and the freeway names are shown in blue.

Exits with Different Names

The Exits with Different Names case is caused by the link definitions not having the proper 'from_street_name' or 'to_street_name.' Because these names are improperly defined, the nodes created from these links are not equal (Please see node.isEqual( ) above). There are six nodes found in the junction. The solution is to merge the necessary nodes together in order to make the connection. An example is shown below.

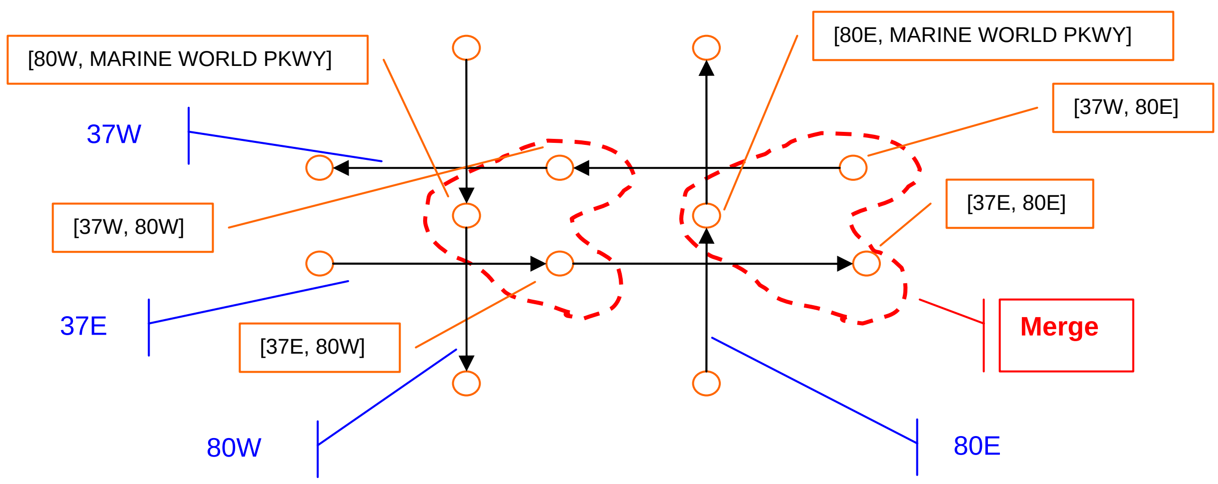


Figure 11 – An example of Exits with Different Names. For simplicity, the nodes are shown without their point. The merge of the six nodes into two nodes is show in red. Only the nodes involved in the junction are shown.

Unmatching Points

The Unmatching Points case is caused by the nodes with matching onStreet and locNames not having the same point. In other words, the only reason why the two nodes are not equal is because points are not equal. The solution is to merge the two nodes into one node.

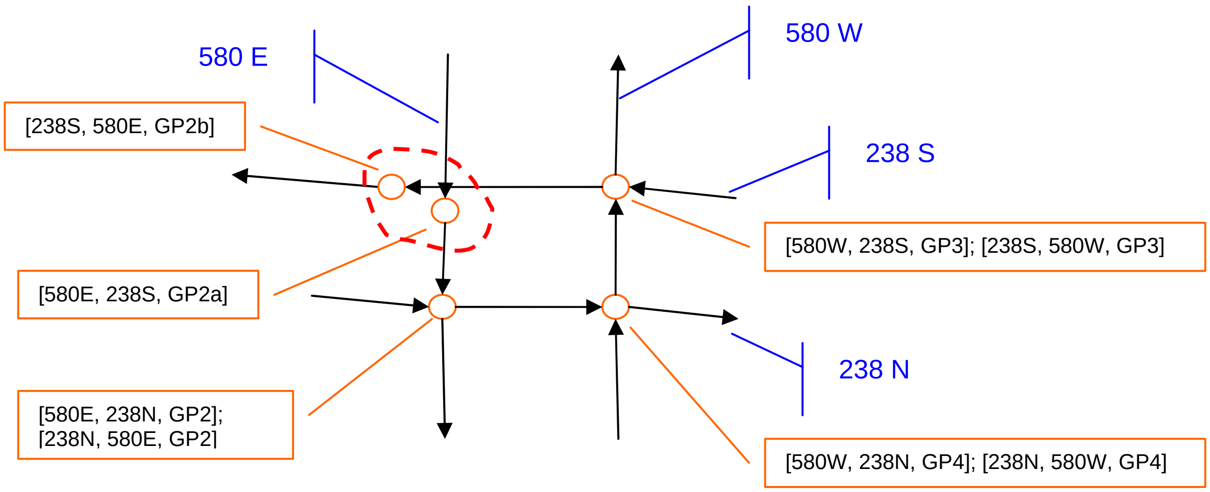


Figure 12 – An example of Unmatching Points. The merge of the two nodes is shown in red.

End of Freeway Junction

The End of Freeway Junction case is caused when there is no connection for two nodes in the junction because the freeway ends. In the example below, there are no nodes on the 680 North and South that correspond with the 24 East, 680 South and 24 East, 680 North Node objects. In other words, there are no Node objects with the following tuples: (680 North, 24 E) and (680 South, 24 E). This is because the link definitions ‘from_street_name’ and ‘to_street_name’ usually correspond to exit names on the given freeway. In this case, the 24 East ends at the 680, so therefore, there is no exit from the 680 to the 24 East.

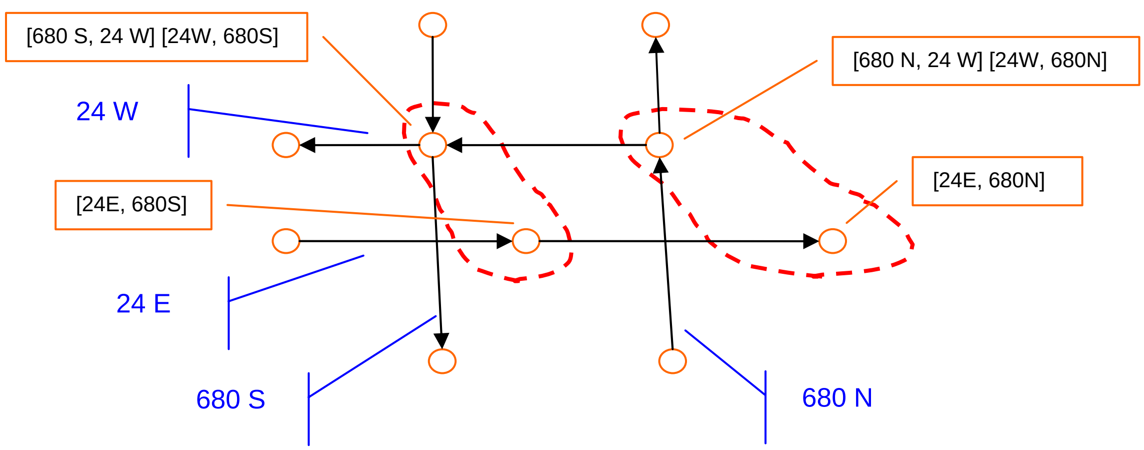


Figure 13 – An example of End of Freeway Junction.

Asymmetric Links

The Asymmetric Links case is similar to the End of Freeway Junction case except that there are more than two nodes for which there is no connection. In this case, all the nodes need to be merged together in order for the necessary connections to be made.

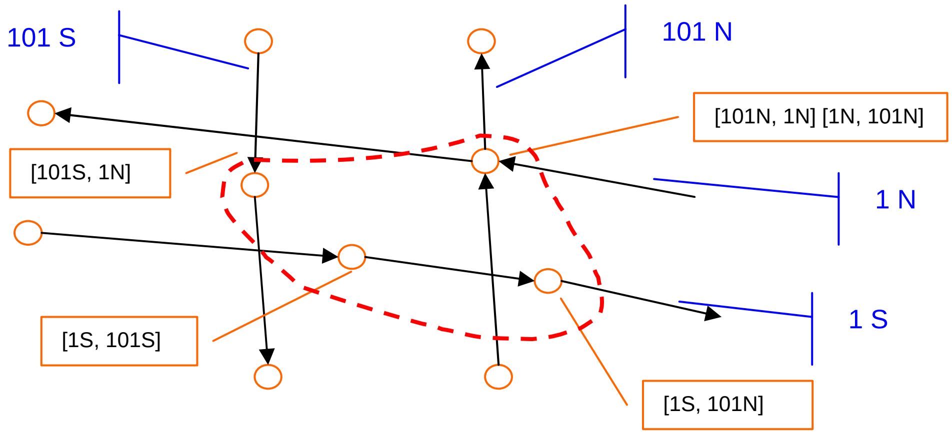


Figure 14 – An example of Asymmetric Links.

Missing Connection

The Missing Connection case is a junction where a freeway can only connect to the other freeway in one direction, and vice versa. In this case, there are only two nodes in the junction. As clearly seen below, in order to fully connect the junctions, the two nodes must be merged into one.

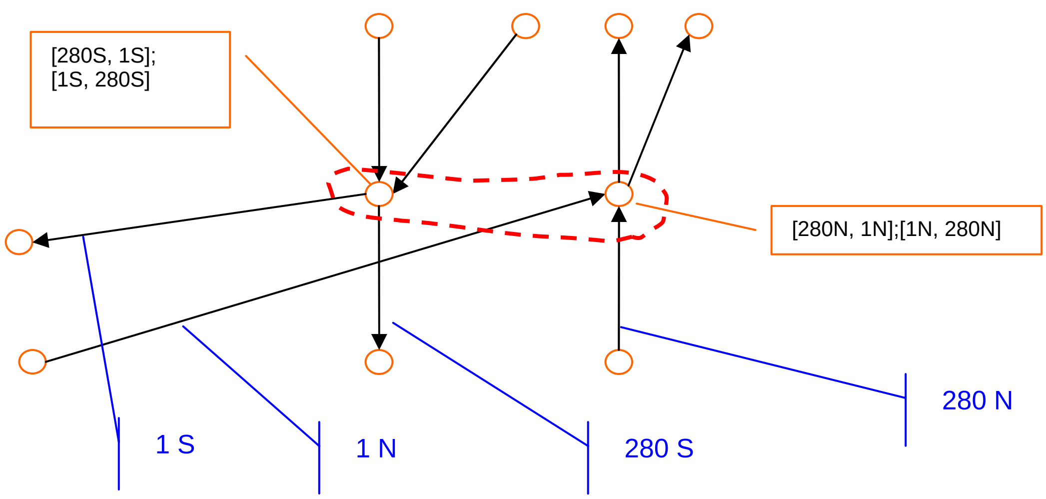


Figure 15 – An example of a Missing Connection

Incomplete Junction Definition

The Incomplete Junction Definition is similar to the End of Freeway and Asymmetric Links cases. Like the Asymmetric Link case, only one connection between the two freeways in the junction has been made in the net.Build( ) process (please see previous section). However, there are only three nodes in this junction. Please see the example below.

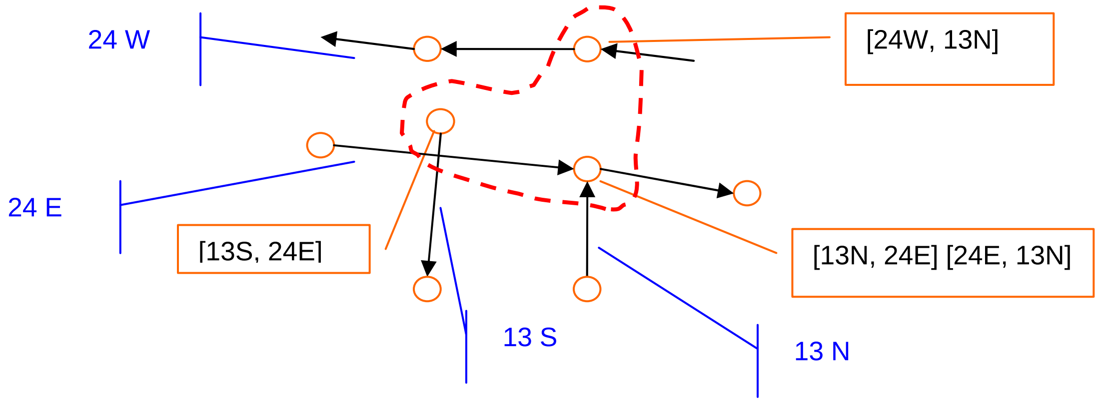


Figure 16 – An example of Incomplete Junction Definition

Triple Junction

The Triple Junction is the case where three freeways intersect. In the 511/Travinfo link definitions, there are four Triple Junctions. Each case has a particular topology with specific gaps that must be fixed. Below is an example of a triple junction.

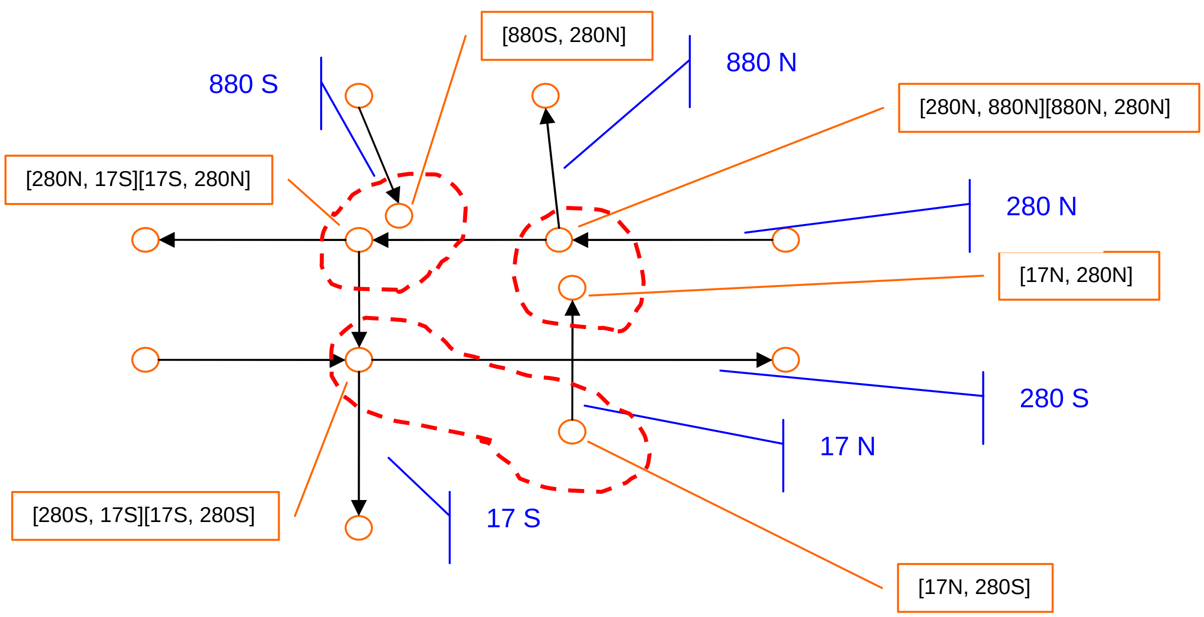


Figure 17 – Example of a Triple Junction

Ramp

In general, a ramp connects two freeways. In the 511/Travinfo link definitions, ramps are links that connect one freeway in a certain direction to another freeway in a certain direction. Most of the ramps are associated with a triple junction. For those ramps not associated with a triple junction, there are no gaps.

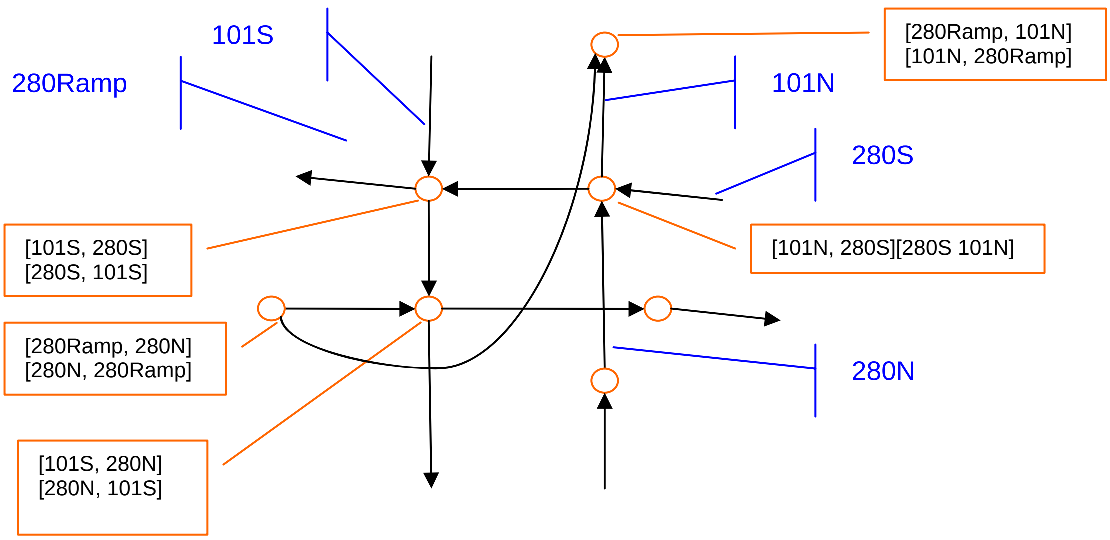


Figure 18 – Example of a junction with a Ramp

Objects Used in Verifying and Fixing the Network

There are two main objects that are used to verify and fix the network: netDiagnostic and fixNet. fixNet and netDiagnostic both have a copy of the Network object. netDiagnostic classifies the junctions according to the nine categories mentioned above, and fixNet fixes the gaps found by netDiagnostic.

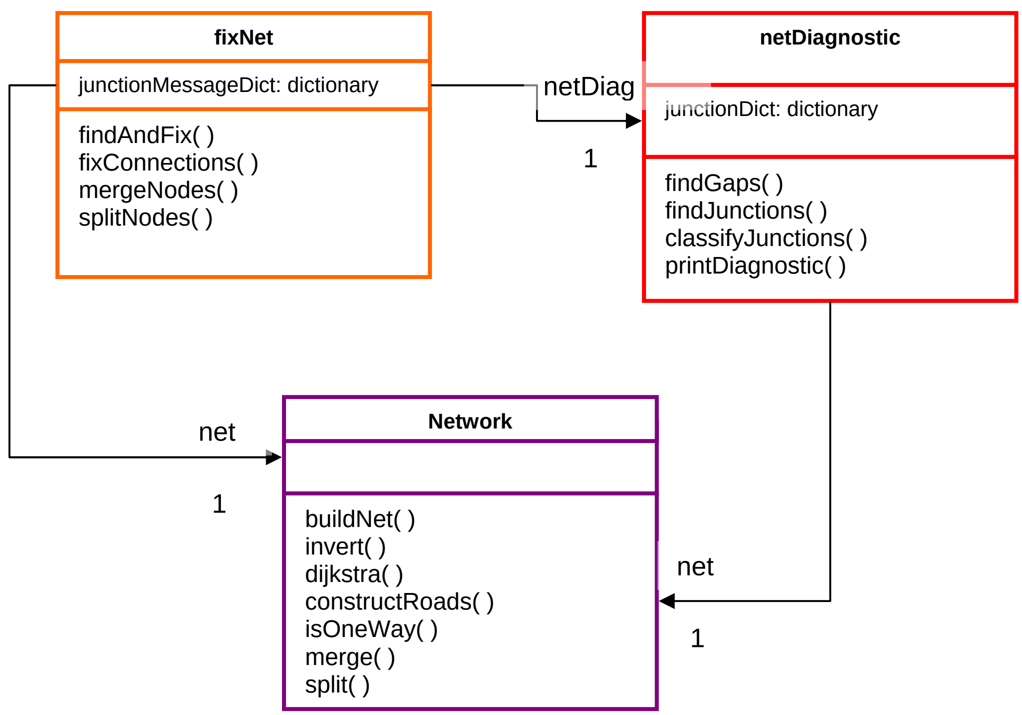


Figure 19 – The fixNet, netDiagnostic and Network objects

Verifying and Fixing the Network – Process Flow

The first step in verifying and fixing the network is to determine the gaps found in the network. After net.buildNet( ) has finished creating the preliminary network, a fixNet object is instantiated with network and immediately calls netDiagnostic to operate over the network. netDiagnostic finds the gaps by classifying the junctions and passes the results back to fixNet. fixNet then fixes the gaps that netDiagnostic has found by merging the pertinent nodes together. Since not all gaps can be fixed automatically, the user can modify the network manually using fixNet's merge and split functions. More information on manually manipulating the network is described below. Once the network has been completed, fixNet then prints a diagnostic file regarding the changes that there were made to the network. The final network is then printed in three files: the node file, the links file, and the network file.

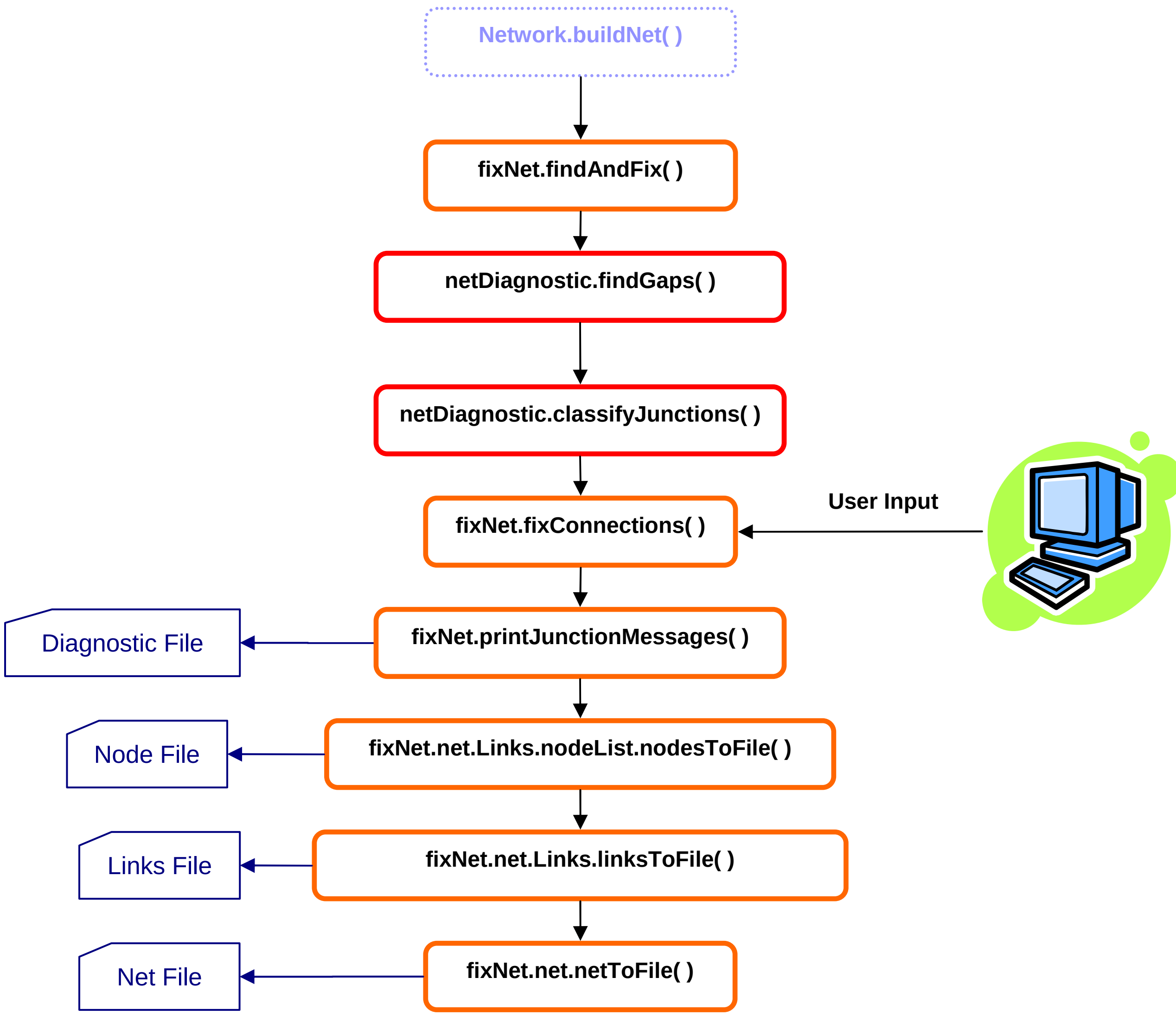


Figure 20 – Process Flow for Verifying and Fixing the Network

Files Used

File	Description
`fixNet.py`	Defines the fixNet object
`netDiagnostic.py`	Defines the netDiagnostic object
`buildAndFixScript.py`	The script that fixes the network
`fwayLists.txt`	Diagnostic file, contains list of ramps and freeways
`junctReport.txt`	Diagnostic file, contains all junctions found before fixing occurs
`FinalJunction.txt`	Diagnostic file, contains all junctions with the changes that were made during the fixing process
`FinalNodes.txt`	Network file, contains a list of the nodes in the network
`FinalLinks.txt`	Network file, contains a list of the links in the network
`FinalNetwork.txt`	Network file, contains a print out of the network object

Table 4 – Files used in fixing the network

Diagnostic Files

The diagnostic files are all printed in the Reports/ directory. There are three files: fwayLists, junctReport, and FinalJunction. Please see Table 4 for more details.

Network Files

The network files are all printed in the FinalNetwork/ directory. There are three files: FinalNodes, FinalLinks, and FinalNetwork.

Fixing the Junctions Manually

Merge and Split Functions

The merge and split functions allow the user to merge two nodes into one or split one node into two. The merge function takes two nodes as its argument and merges the two together. All relevant links and the network are updated. The split function takes one node as its argument and then asks the user for input regarding the new node. The user is presented with all the links which use the given node and is asked which of these links will use the new node. After the user supplies this information, the new node is created and assigned to the user-supplied links. The old node is adjusted accordingly and the Links and Network object is updated accordingly. After all merges and splits have been made, the user must write the network object to file in order to save the changes. Examples of how to use the functions are in manualMergeExample.py and manualSplitExample.py.

Triple Junctions

The Triple Junctions must be fixed by hand using the IDLE shell to manipulate the data objects. The diagrams below show how the Triple Junctions need to be fixed. For one Triple Junction, 580-24-980, no changes need to be made. The freeway links are shown in different colors in order to show the different freeways involved. The way to fix these junctions is to use the figures in combination with the FinalNodes file to identify the nodes that need to be merged. Once the nodes have been identified, use manualMergeExample.py to see an example of how to merge two nodes together. The example in manualMergeExample.py carries out the mergers for the Triple Junctions.

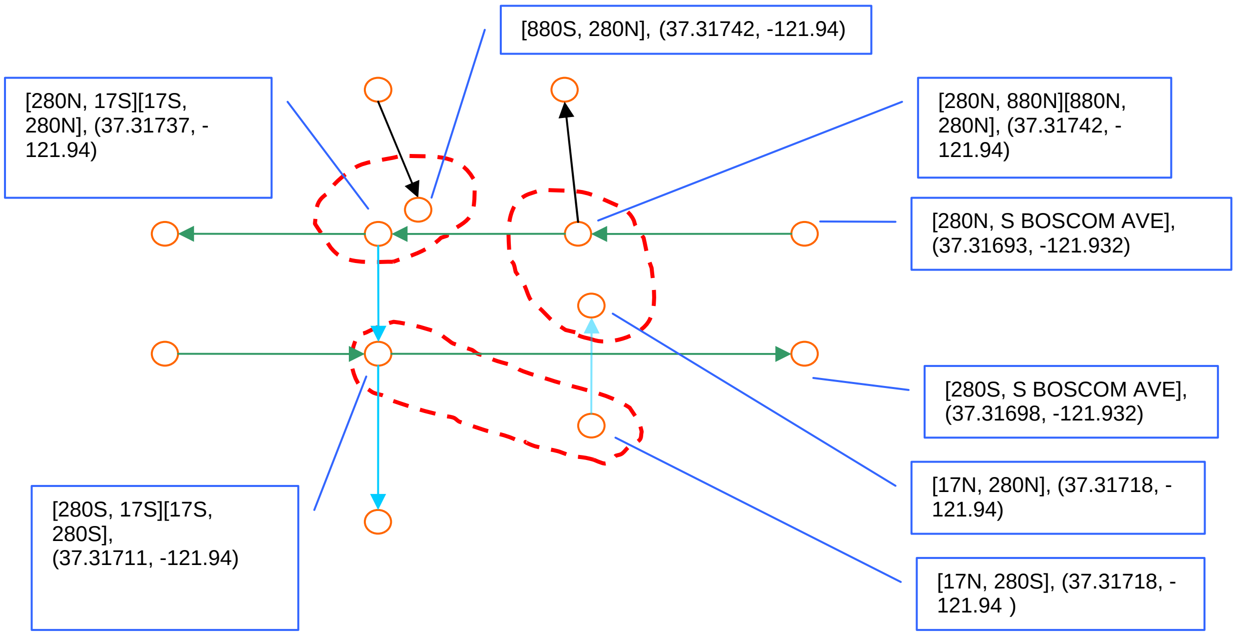


Figure 21 – The 880-280-17 Triple Junction. Three merges need to be made.

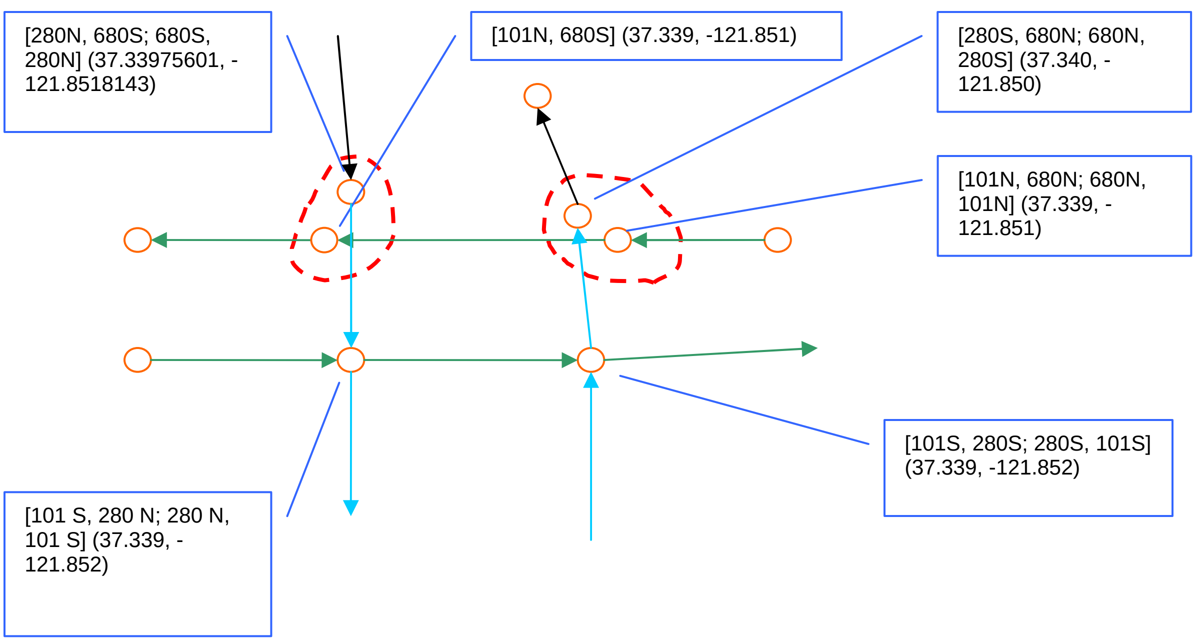


Figure 22 – The 680-280-101 Triple Junction. Two merges need to be made.

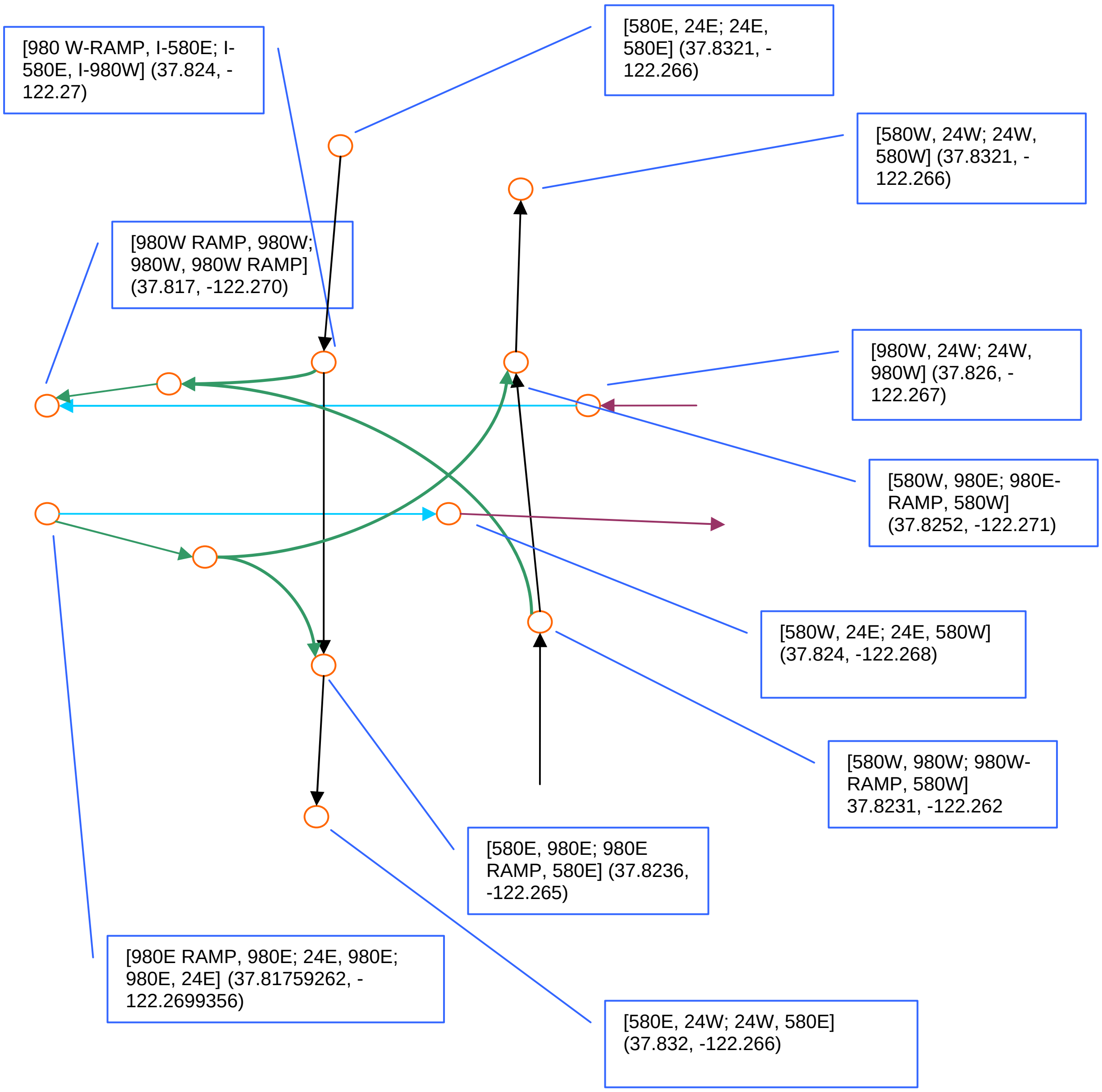


Figure 23 – The 980-580-24 Triple Junction. No merges need to be made.

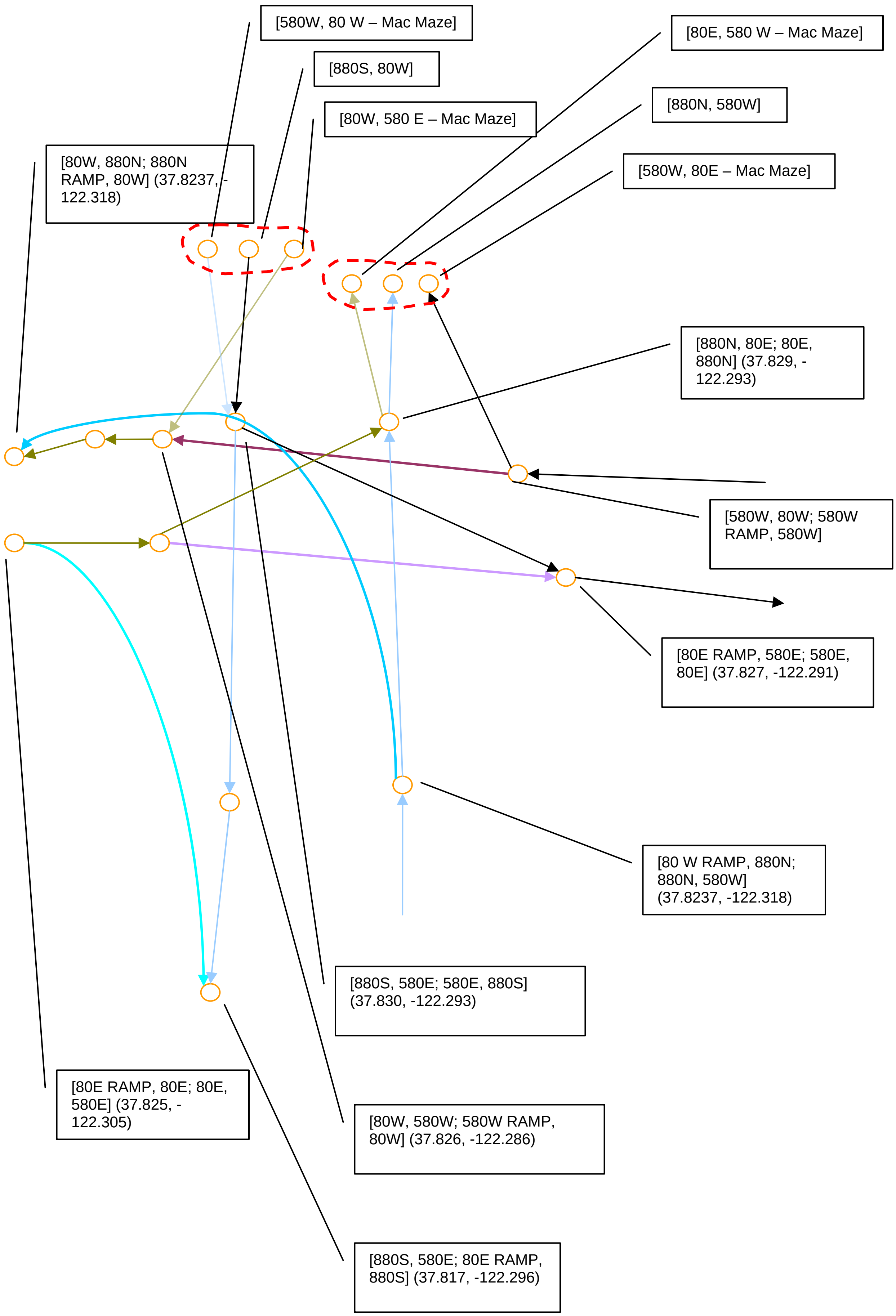

[580W, 80 W – Mac Maze]
[880S, 80W]
[80W, 580 E – Mac Maze]
[80E, 580 W – Mac Maze]
[880N, 580W]
[580W, 80E – Mac Maze]
[80W, 880N; 880N RAMP, 80W] (37.8237, -122.318)
[880N, 80E; 80E, 880N] (37.829, -122.293)
[580W, 80W; 580W RAMP, 580W]
[80E RAMP, 580E; 580E, 80E] (37.827, -122.291)
[80 W RAMP, 880N; 880N, 580W] (37.8237, -122.318)
[880S, 580E; 580E, 880S] (37.830, -122.293)
[80E RAMP, 80E; 80E, 580E] (37.825, -122.305)
[80W, 580W; 580W RAMP, 80W] (37.826, -122.286)
[880S, 580E; 80E RAMP, 880S] (37.817, -122.296)

Figure 24 – The 880-80-580 Triple Junction. Two merges need to be made.

Constructing Routes and Filling the CMS Database

Routes are a set of continuous links from a given origin and destination Node. The links in a given route are used by MITTENS to calculate travel times for that route (please see the MITTENS documentation). For the route to be used by MITTENS, the route must be defined according to the CMS Database. In terms of the CMS Database, a route is completely defined in three tables: CMS_TO_ROUTE, ROUTE_TO_LINK, and SEGMENT_TO_LINK (please see the MITTENS documentation).

The following section presents the interface for the user to interact with the Network object in order to construct routes and produce SQL script files that can be loaded into the CMS Database. The user provides a set of .csv files, where each file is a table in the CMS Database minus the route information. Routes are constructed according to the content of the files, and the route information is used to fill in the tables and produce the SQL script files.

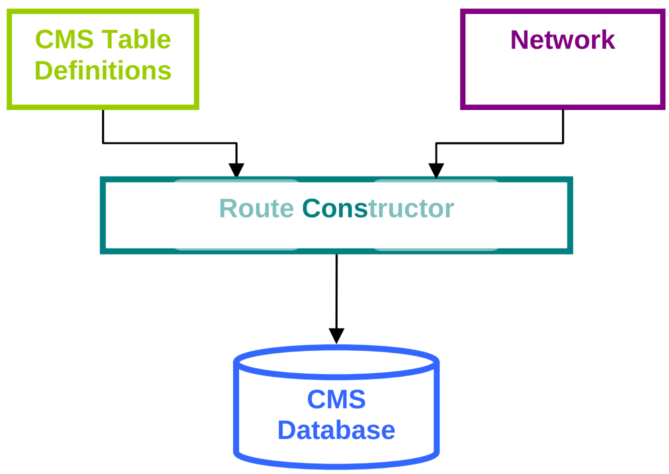


Figure 25 – Using the Network to fill the CMS Database

Objects Used in Constructing the Routes

There are five objects used in constructing the routes: Network, databaseOutput, routeConstructor, Roads and Road. The Network object is the built network as described in the previous sections, databaseOutput outputs the network data and the user’s .csv files in SQL scripts, and the routeConstructor interacts with the Network object to construct, select and filter routes. The Roads object, which is a list of a Road objects, is used to store the paths in the network between two nodes. Figure 26 shows the relationships between the data objects.

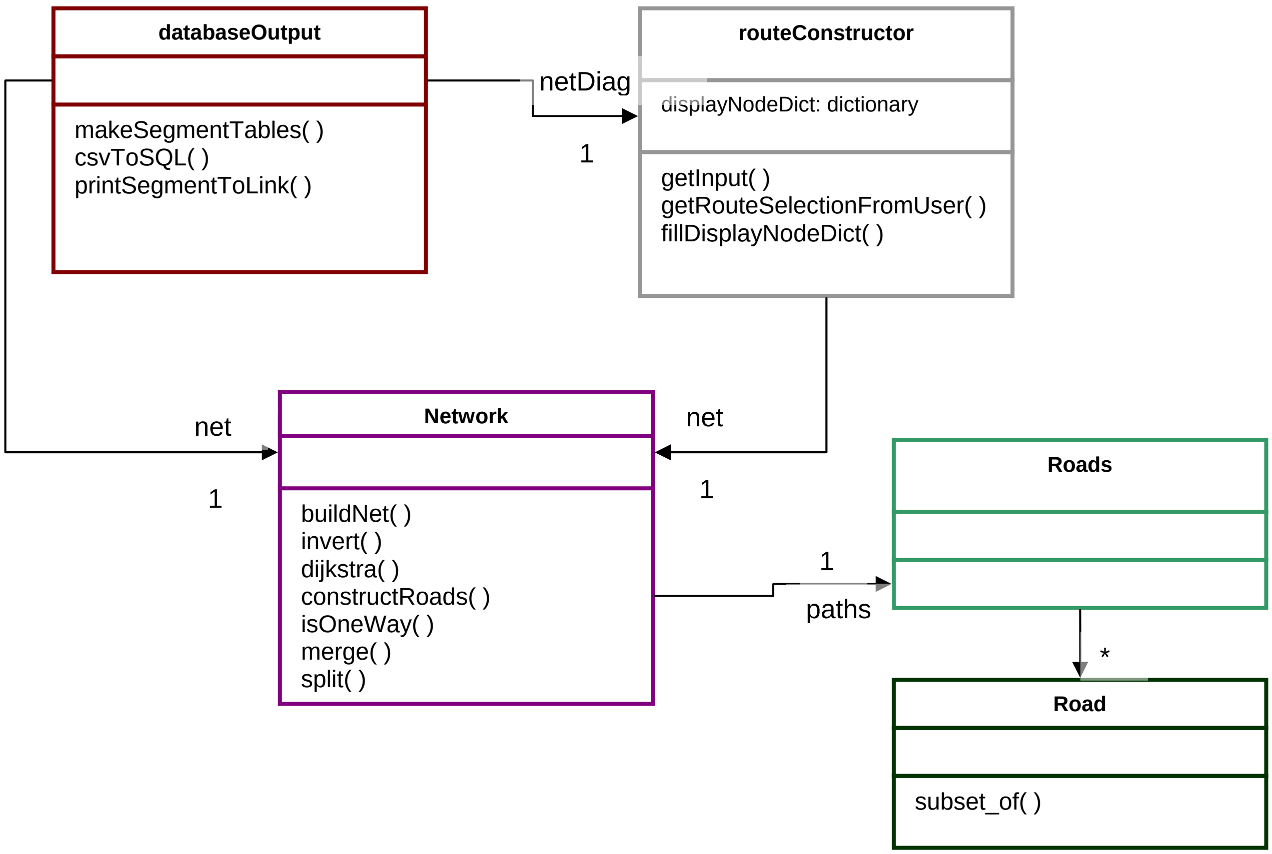


Figure 26 – Data Objects for Constructing the Routes

Process Flow in Constructing the Routes

The process flow in Figure 27 shows how the routes are created and the data is converted to SQL statements. The routeConstructor.getInput( ) first reads in the Network files and the .csv files that are the partial content of the CMS Database. routeConstructor.fillDisplayNodeDict( ) then looks for all the origin and destinations that are defined in the .csv files and uses the Network object to find multiple routes between them. The Network object creates routes using constructRoads( ) and dijkstra( ) which find the routes between any origin and destination Node using a variation of Dijkstra's shortest path algorithm called Double Dijkstra. The routes are written to the Route File. The user is then prompted to select a route from the Route File for each origin-destination. The databaseOutput object then fills the necessary tables using the route information and outputs the SQL script files.

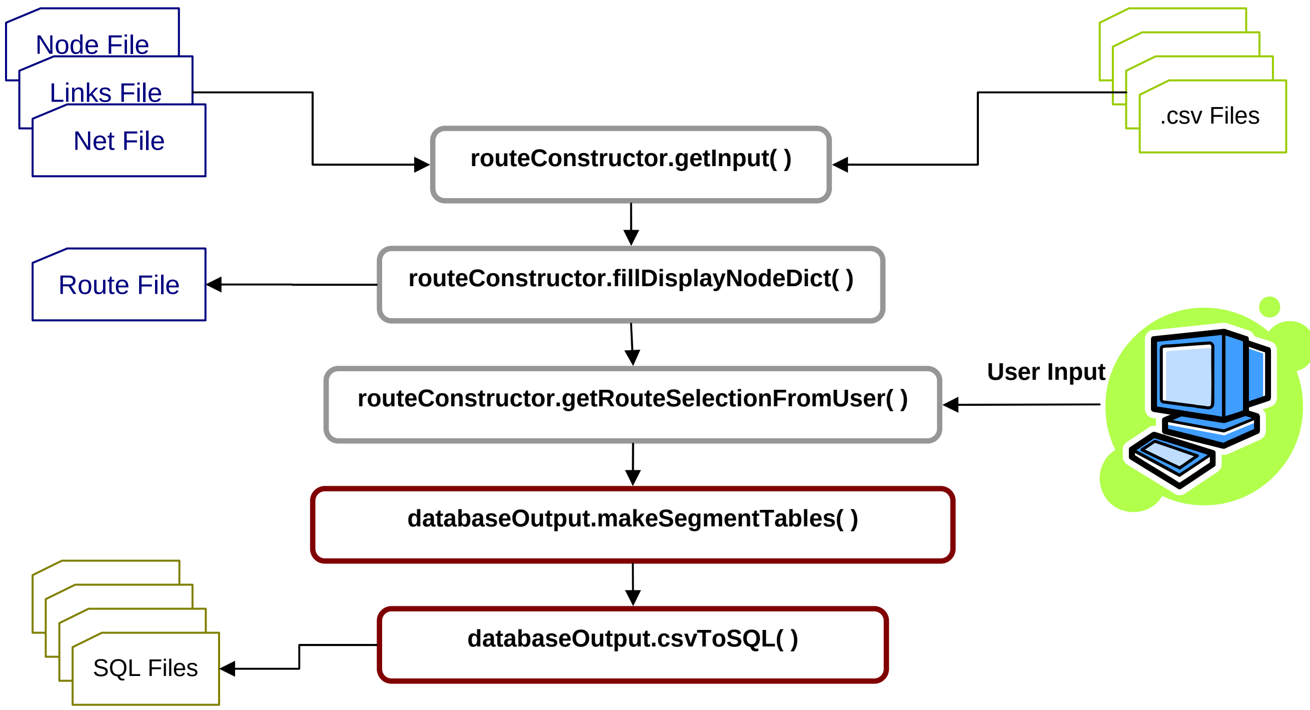


Figure 27 – Constructing the routes and producing SQL script files

Files Used

File	Description
`routeConstructor.py`	Defines the routeConstructor object
`Roads.py`	Defines the Road and Roads objects
`databaseOutput.py`	Defines the databaseOutput object
`routesToSQL.py`	Script to create the SQL output
`routes.txt`	Text file containing the route choices between a origin and destination

Table 5 – Files used in constructing the routes

Testing the Routes

A simple way of testing the travel times along the routes is to look at the distribution of the calculated route travel times. By analyzing the travel time log file, the mean, standard deviation and varying percentiles can be calculated for each route. These statistics give a good indication of the distribution of the travel times.

The main advantage of this process is that is collects the travel times in the log file and categorizes them according to each origin-destination. Once this has been accomplished then it is easy to calculate a variety of statistics and other indicators related to the travel times.

Cutting the Travel Time Log

Since the travel time log is usually quite large, fileparse.py can be used to cut the travel time log starting on a certain day. The smaller file can then be processed much faster.

Mean

The mean is calculated using the stats.py module.

Standard Deviation

The standard deviation is calculated using the stats.py module.

Percentile

The 10th, 90th, and 99th percentiles are reported. The function used to obtain the percentile is **`findPercentile`**. The percentile function that comes with stats.py returned percentiles that were different from those calculated in Excel. The percentiles calculated in **`findPercentile`** were much closer to those in Excel.

Maximum and Minimum – The maximum and minimum travel times are found and can be compared to the maximum and minimum travel times in the CMS Database to ensure that these constraints are enforced.

Files Used

File	Description
`pstat.py`	Defines the pstat object
`stat.py`	Defines the stat object
`fileparse.py`	Script the cuts the travel time log
`MVSTD.py`	Script that calculates the travel time stats
`d4cms.log`	Input Travel Time Log
`stats.csv`	Output file, contains the statistics for each route

Table 6 – Files used in testing the routes

Travel Times on Changeable Message Signs

in Caltrans District 4

System Architecture and Operating Rules

Version 1.1 – December 2005

Caltrans

California Center for Innovative Transportation

511™

Table of Contents

Applicable documents

- CCIT / Caltrans – MITTENS Travel Times Validation
- ITSA – Travel Time Messaging on Dynamic Message Signs (DMS) Workshop Summary
  `http://www.itsa.org/dms.html`
- FHWA – GUIDELINES FOR CHANGEABLE MESSAGE SIGN MESSAGES
  `http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=25&new=2`
- Texas DOT – DYNAMIC MESSAGE SIGN MESSAGE DESIGN AND DISPLAY MANUAL
  `http://tti.tamu.edu/documents/0-4023-P1.pdf`

Contact List

- Caltrans District 4 Project Manager

  Alan Chow
  alan_s_chow@dot.ca.gov
  (510) 286-4577

- Caltrans DRI SOCCS Lead Developer

  Sean Campbell
  sean_campbell@dot.ca.gov
  (916) 654-8868

- Metropolitan Transportation Commission – 511/Travinfo liaison

  Ben McKeever
  bmckeever@mtc.ca.gov
  (510) 817-3245

- CCIT Project Manager

  J.D. Margulici
  jdmargulici@yahoo.com
  (510) 642 5929

Project Overview

The CMS Travel Times Project objective is to display reliable travel times on freeway Changeable Message Signs (CMS) throughout the Bay Area (Caltrans District 4, or D4). The expectation is that drivers will benefit from knowing their estimated time of arrival and, under certain circumstances, be able to change their itinerary accordingly. Travel time data is provided by the 511/Travinfo system. It is generated from both 511/Travinfo Fastrak antennas and Caltrans inductive loops. The resulting information is displayed on Caltrans D4's current CMS park. CCIT is acting as the system integrator and has implemented software to link the 511/Travinfo data infrastructure with the signs.

Caltrans D4 already operates software to control the CMS display from the Traffic Management Center (TMC). The Satellite Operations Center Command System (SOCCS) was developed by Caltrans' Division of Research and Innovation (DRI) for that purpose. CCIT implemented The Messaging Infrastructure for Travel Time Estimates to a Network of Signs (MITTENS) to interface the 511/Travinfo system, SOCCS, and TMC operations. Figure 1 summarizes the data flow between 511/Travinfo, MITTENS and SOCCS. 511/Travinfo delivers travel times estimates on elementary freeway links through an internet-based messaging infrastructure. MITTENS processes the elementary travel times to compute travel times for a set of pre-defined routes, and then generates the CMS messages. The messages are then retrieved by SOCCS and sent to the signs.

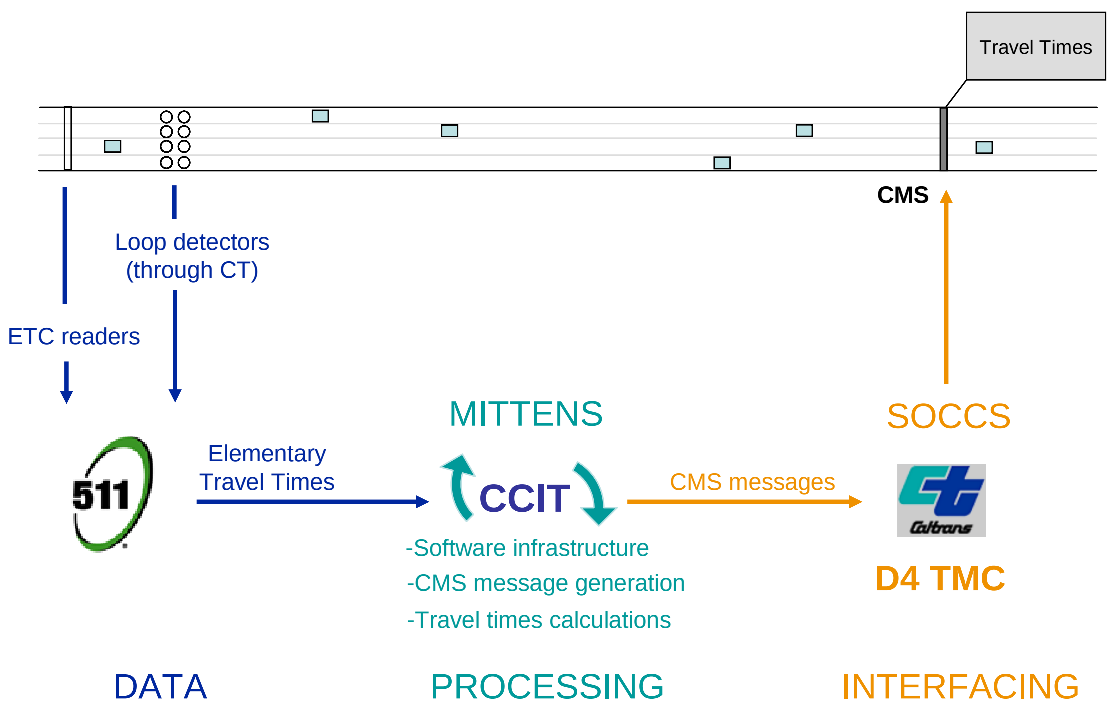


Figure 1 – System Overview

So far (as of June, 2005) the CMS Travel Time Project is operating on two signs on the I-80 in Emeryville. The software components are for the most part complete. Administrative tools have yet to be developed to give the TMC full control over the system. Once this is done, MITTENS will be handed over to Caltrans D4 and the coverage will be expanded throughout the district, based on needs assessment and data availability.

This document describes the system architecture and operating rules, including data sources, travel times computation, messages generation and display. The roles of the TMC operators and engineers in the target architecture are enumerated, based on future developments that will be implemented during FY 05-06. The final section covers the functional guidelines that govern the system and the message creation.

System Architecture

The architecture of the CMS Travel Time system is shown below in Figure 2. A thorough description of all the components follows Figure 2. This section also comprises a description of the user interfaces.

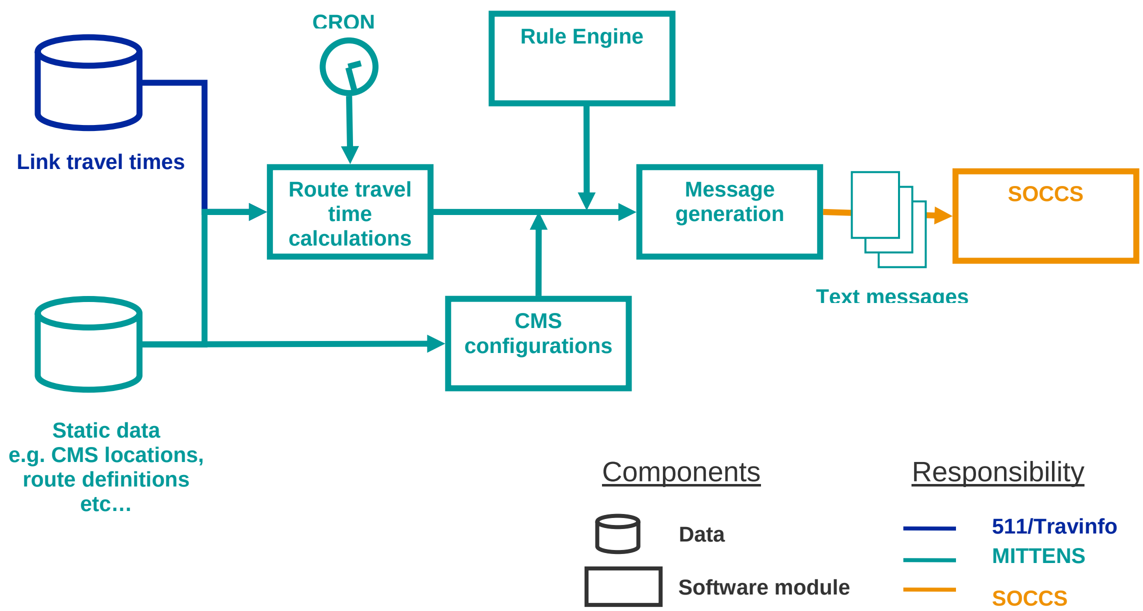


Figure 2 – Software Architecture

511/Travinfo

As seen in Figure 1, 511/Travinfo uses Fastrak antennas (Electronic Toll Collection tag readers, or ETC readers) and loop detectors to measure and estimate travel times. Loop detectors are embedded in the freeway pavement and can sense how fast a vehicle is moving over the loop. Fastrak antennas are mounted on highways signs and can track the progress of a specific vehicle by reading a given Fastrak transponder at different locations. Trip times are then estimated for a set of links. Links are elementary highway segments that are a few hundred feet to a few miles long. The link travel times are published by 511/Travinfo and are available on the Travinfo Open Messaging Service (TOMS) which is a Java Messaging Service.

TOMS feed is available over the internet on a subscription basis. Because the TMC Local Area Network (LAN) does not connect to the internet, 511/Travinfo graciously implemented a second instance of TOMS on a separate server, securely connected to the TMC LAN. When MITTENS first starts up, it subscribes to the service and the connection is established. If the connection is broken, MITTENS automatically attempts to reestablish the connection.

The 511/Travinfo system updates the travel times every minute. Changes in link travel times are therefore published on TOMS within a minute. All link travel times, changed or unchanged, are published by TOMS at 10 minute-intervals.

MITTENS

MITTENS is hosted on a PC running Linux connected to D4 TMC's LAN. It is functionally composed of five modules: the static data, the calculation module, the configuration module, the rule engine and the message generation module. This section first enumerates the data entities used in the application, followed by a description of the application modules.

Data Entities

Segments

Segments make up the mapping of the freeway network in MITTENS. Their lengths vary from a few yards to a few miles. The segments are defined by their start and end point, which locations are encoded using freeway, direction and postmile. Segments' attribute include the posted speed limit, which is the maximum legal speed on a section of freeway.

Links

Links designate the 511/Travinfo freeway links and are conceptually analogous to segments. They are not natively part of the MITTENS application but are used as the data source for travel time calculations. MITTENS hosts a fixed correspondence table between the segments and the links.

Routes

Routes are defined as a sequence of freeway segments. The route object also stores the route's attribute, namely its name, length, minimum travel time, maximum travel time and delta value. The route name is the name of the destination, and the length is the route's distance in miles. The minimum travel time, maximum travel time and delta value are used to keep the travel times within a reasonable range and are described in more detail in the Message Guidelines section.

CMS

CMS designate the signs in the system. CMS' attributes include their location and their model. The CMS location is defined as the city and county it is in, the freeway that it is on, and the post mile that it is located at.

Masks

Masks are the most abstract object in the system but they are also a very useful part of it. Masks define the display layout on a given CMS. In effect, a mask describes the content of each line of text for a CMS, which mixes static information (e.g. destination name) and dynamic information (e.g. travel time). Each mask is associated to a unique CMS, and conversely, each CMS is associated with a set of available masks. Another way to look at the masks is as a collection of preset displays, each one corresponding to a specific combination of routes.

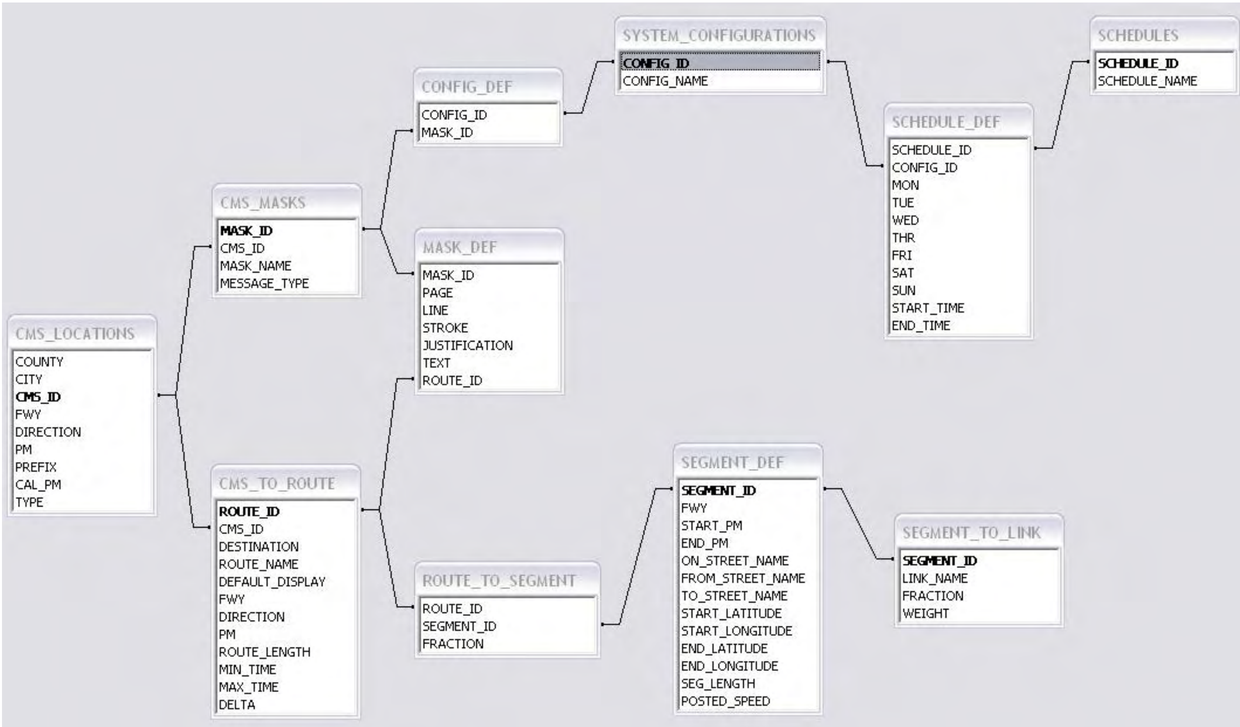


Figure 3 – Data architecture

<u>Configurations</u>

A configuration is a list of CMS – masks associations. Configurations list each CMS in the system once exactly, and associate it with one of its possible masks. The configuration is a way to group sets of CMS displays to pre-define a system-wide state.

<u>Schedules</u>

Schedules define the sequence of system configurations within a week. A schedule associates one configuration to each time of the week by storing the transition times. Schedules include down times, which are equivalent to a blank configuration in which none of the signs displays anything. The system can store several schedules, even though there can obviously only be one active schedule at a time.

Data Modules

<u>Static Data</u>

The static data is a MySQL database that holds the environment data (segments, routes, CMS, Masks, Configurations, and Schedules).

<u>Route Travel Time Calculation Module</u>

The travel time calculations occur every minute. First, the link travel times from 511/Travinfo are retrieved. For each route for which the travel time needs to be calculated, the calculation fetches the segments that make up the route. As mentioned above, each segment corresponds to a 511/Travinfo link. Once the routes' segments have been associated with the corresponding 511/Travinfo links, the calculation determines if current travel times are defined for all the links.

If all links travel times are defined, the route travel time is the sum of all the link travel times and is stored in a temporary table. If not all of the link travel times are defined, then no travel time is calculated.

Configuration Module

The configuration module retrieves the current mask for each CMS in the system and passes on the information to the message generation module.

Rule Engine

The rule engine applies certain constraints to the travel time messages. These rules are discussed more thoroughly in the Message Guideline section. In short, the rules define the valid range of the travel times, minimize the number of message transmissions, and ensure that travel times are current.

Message Generation Module

The Message Generation Module creates the text strings that are ultimately transmitted to the signs. Figure 4 shows the decisions involved with creating a message for each CMS in the system. The process loops through each route in every CMS – mask that is currently being displayed. First, the link travel times are examined to see if the route travel time can be calculated. If so, the travel time constraints, which are discussed in the "Message Guidelines" section, are applied. Once all the routes for a given mask are processed, either a CMS travel time message or a blank message is produced. Please see the "Blank Messages" section for more information.

One message is generated every minute for each CMS in the system. Messages are listed in the message file, in which each line is a record consisting of a message description for a particular sign, and is stamped with the time at which it is issued.

Within a record, fields are separated with a semicolon and appear in the order below:

TS;SN;MT;P1FT;P2FT;P1L1;P1L2;P1L3;P2L1;P2L2;P2L3;DT;

Where field definitions are as follows:

TS: Time Stamp. Dates the date and time at which the record is issued.

SN: Sign Number. An identifier designating the CMS to be addressed.

MT: Message Type. Specifies the display mode on the sign. Possible values include "Blank", "1 Page (Normal)", "1 Page (Flashing)", "2 Pages (Extended)".

P1FT: Page 1 Font Type. Choices include "Single Stroke", "Double Stroke".

P2FT: Page 2 Font Type. Choices include "Single Stroke", "Double Stroke".

P1L1: Page 1 Line 1. Message to be displayed on page 1, line 1. 16 characters for Single Stroke, 9 characters for Double Stroke. Note: if the number of characters is less than what is allowed on the line, SOCCS will automatically center the text.

P1L2: Page 1 Line 2.

P1L3: Page 1 Line 3.

P2L1: Page 2 Line 1.

P2L2: Page 2 Line 2.

P2L3: Page 2 Line 3.

DT: Display Time. Amount of time in seconds that a message displays each page. Most districts use between 2.2 and 3.0 seconds. This is not being used in the current system.

Example of individual record:

```
200401201701;CMS070;1 Page (Normal);Single Stroke;;TRAVEL TIME
TO;DWNTWN SF 29 MIN;SFO      23 MIN;;;;;
```

Even if the message for a CMS is a blank message, a line in the message file is still written that explicitly defines the blank message.

The computer that hosts MITTENS also hosts a web server, or CMS Travel Time Message Server (CTTMS). CTTMS makes the message file available via a simple http request. The message file is updated every minute with the latest messages.

As mentioned earlier, if the connection with TOMS is lost, MITTENS automatically attempts to reestablish connection. If, after a given wait time, MITTENS has not reestablished the connection, CTTMS generates blank messages for the CMS. That is, travel times will no longer be displayed on the CMS. The wait time is currently set to 10 minutes, but this value is configurable.

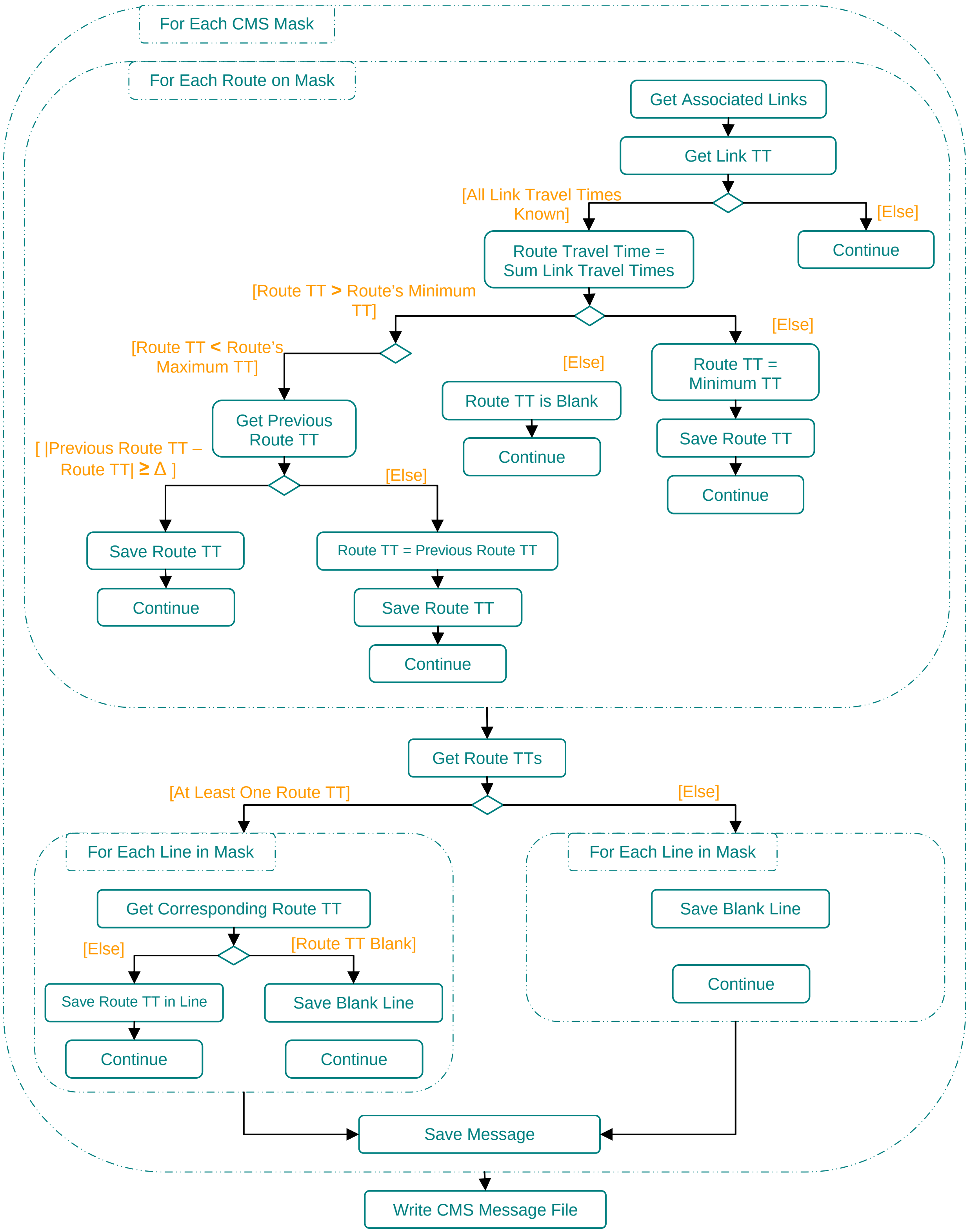


Figure 4 – Decision Tree for Creating CMS Messages

SOCCS

Like MITTENS, SOCCS is hosted on the D4 TMC LAN. SOCCS and MITTENS communicate through TCP/IP over the LAN. SOCCS communicates directly with the CMS using either a dial-up connection or GPRS modem.

Every minute, SOCCS fetches the message file from MITTENS using the http protocol. It then parses the file line by line and performs two comparisons at each line. First, SOCCS looks at the time stamp at the beginning of the line. If the time stamp has not changed since it last looked at the file, the line is discarded since SOCCS has already processed the corresponding message. If the time stamp on a given line is most recent, then SOCCS compares the corresponding CMS name and message to what is currently being displayed by that CMS. If there is no difference, the message is discarded. If there is a difference, then the message is put in a queue to be posted to the CMS. These comparisons minimize the number of transmissions to the CMS by ensuring that each transmission contains a new message.

A potential issue arises from the transmission time of each message. Currently, with only 2 signs being active, there is no problem with processing time. However, if the system is expanded, it may take longer than a minute to transmit all the new messages in a given minute. As this delay is compounded, SOCCS may end up posting a travel time that is no longer relevant (i.e. an old travel time). To solve this problem, SOCCS checks for a more recent update of a given route travel time before sending a message.

If SOCCS is unable to connect to the CTTMS, it will hold the current travel time messages for 10 minutes. After 10 minutes, SOCCS will send blank messages to the CMS. The amount of time that SOCCS waits for CTTMS to respond is configurable.

User Interfaces

In order to make the system fully effective, user interfaces are developed targeting two categories of users: TMC operators and TMC administrators. As of June, 2005, TMC operators can use SOCCS' existing Graphical User Interface (GUI) to turn the CMS travel times on and off. Two GUIs are planned that will allow TMC operators to have more control over the CMS displays, and TMC engineers to access and edit the static data held in MITTENS. Most of the data, including the routes, the CMS masks, and configurations will be modified through the administrator GUI. The two GUIs are discussed in more detail below.

Operator Interface

SOCCS GUI

The CMS operator is currently able to turn the CMS travel time messages off and on, either for an individual CMS or for all the CMS in the system.

Planned Controls – MITTENS GUI

The operator will be able to select travel time messages to display from a library of pre-formatted messages (in effect, by selecting a mask), via a web-based GUI. The GUI will connect to

CTTMS, but will be adopt the look and feel of the SOCCS GUI so that both GUIs will appear as one to the operator.

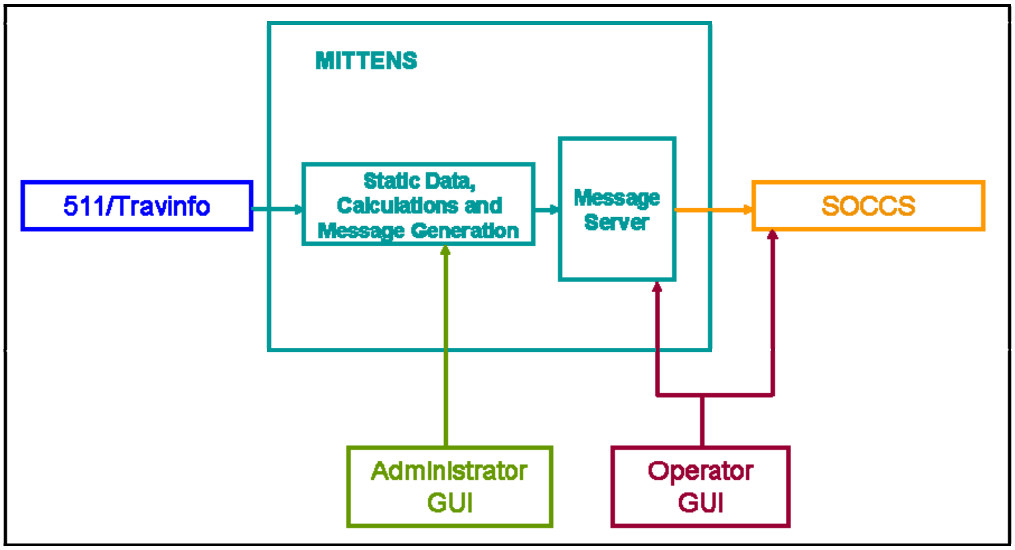


Figure 5 – Administrator and Operator GUI's to MITTENS and SOCCS

Administrator Interface

An administrator GUI is planned to manage the static data used by MITTENS (see 'Data Objects' section). The GUI will allow efficient and simple data management.

New Signs

The administrator is able to add new signs to the message system. The current system produces travel time messages for two CMS. However, this system can be easily expanded by adding new signs to the database.

Route Management

New routes can be added and existing routes can be modified. This also includes modifying route attributes like the minimum travel time, the maximum travel time, and the delta value, all of which are explained above.

The difficulty in adding new routes is that each route must be translated into a corresponding set of freeway segments. To address this problem, the planned GUI will allow the administrator to specify a start and end point, and the administrator will be given a list of possible routes. The selected route will automatically be translated into highway segments by a utility provided as part of MITTENS.

CMS Masks

Masks can be created and edited to control what combinations of routes can be displayed and how for a given CMS.

System-wide Configurations and Scheduling

System-wide configurations define sets of correspondences between CMS and CMS masks. Schedules automatically control configurations for different days and times. Configurations and schedules are strategic decisions but they can be modified tactically by the operator depending on the requirements of current traffic conditions.

Operating Rules

General Guidelines

A set of general guidelines has been adopted for the CMS travel time project. They drove decisions for the current 2-sign pilot. Some of the guidelines have been adapted from feedback from the national travel time conference that took place in Atlanta in March, 2005. These rules attempt to provide commuters with reliable and meaningful information on the CMS.

Format

The travel time messages are displayed on three lines with 16 characters per line. The first line is the title, “TRAVEL TIME TO” followed by the second and third line which display a destination and associated travel time, one per line. The diagram below shows the display format with the line numbers and the character numbers per line. All text is displayed upper case. Two spaces are needed to display the travel time, three spaces for “MIN”, two blanks to separate the words, leaving nine spaces available for the destination name. Figure 4 shows an actual CMS displaying a travel time message.

Table 1 – CMS Travel Time Format

Char. No. / Line No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		T	R	A	V	E	L		T	I	M	E		T	O	
2	S	F		D	W	N	T	W	N		1	0		M	I	N
3	S	F	O								2	3		M	I	N
	Destination (9 spaces)									*blank*	*(2 spaces)*		*blank*	*(3 spaces)*		

Figure 6 - Actual travel times displayed on a CMS

CMS Priority Rules

The CMS can be used to display law enforcement data, travel times, and other operator messages. The travel times are given the lowest priority among these messages. In other words, if a CMS will be used to display an AMBER Alert or an operator message, that message will override any displayed travel times. Furthermore, the operator is able to turn off the travel time messages.

Destination Choice

A general guideline is that 50% of the people who see a given sign should be going to or beyond the displayed destination. A survey of the current two sign system will confirm whether or not the displayed destinations adhere to this guideline. The current destinations were assumed to be common destinations or landmarks: SFO, SF Downtown, Hercules and Fairfield.

Route Distance

Routes, for which travel times are displayed, usually have their distance between four and 20 miles. As the distance increases, the estimated travel time is not as reliable since traffic conditions are more likely to change. Furthermore, the likelihood of a commuter traveling to a given destination decreases as the distance increases. Similarly, distances closer than four miles are not as meaningful since the commuter is so close to the destination. As indicated above, other considerations come into play, such as the popularity of certain landmarks. In the current pilot (June, 2005), two routes to SFO and Fairfield are 20 and 30-mile long, respectively.

Displayed Travel Time

Some Department Of Transportation (DOTs) recommend that commuters be provided with a range of travel times (e.g. 20-22 min). However, the current project relies on traffic information from 511/Travinfo and predicted travel times are 15-20% accurate 95% of the time. Furthermore, destinations themselves can be vague (e.g. SF Downtown), which is effectively equivalent to a time range. Also, the table above shows the space constraints on displaying the destinations and times. Displaying a range of times would not fit with the current format. Therefore, the current CMS travel time project only displays one time value per destination.

Signs Legibility: Number of Destinations and Abbreviations

The feedback at the national level is that displaying two destinations on a given CMS is effective, while displaying three destinations may be too many. In the current implementation, displaying three destinations is possible but the messages are limited to two. Suggested abbreviations used in the display can be found in [Dynamic Message Sign Message Design and Display Manual – Module 8].

Destination Ranking

For a given mask, the closest destination will be displayed first on the CMS. For example, on I-80 West bound, the travel time to downtown San Francisco is displayed before SFO.

Hours of Operation

Travel times are currently displayed seven days a week from 5am to 9pm. The hours of operation can be scheduled on a daily and hourly basis. See the “Operator Interface” section below.

Message Guidelines

Minimum and Maximum Values

In order to avoid travel times that are too fast or too slow, minimum and maximum travel times are used to confine the displayed travel times within an acceptable range. If the estimated travel time is less than the minimum travel time, the minimum travel time is displayed. However, if the estimated travel time is greater than the maximum travel time, the sign stops displaying the line that contains that route.

The minimum travel time for a particular route is calculated by adding together the minimum travel times along each segment in the route, which is the segment length divided by the posted speed limit for that segment. The maximum travel time is the lesser of two numbers: ten times the minimum travel time or 99 minutes. This maximum value is the default. As the system is used, a more accurate maximum travel time will be developed. Both the maximum and minimum travel times are configurable.

Preventing Message Toggling

Toggling generates unnecessary communications to the signs. A difference value is used to prevent messages from toggling between two travel times that are close in value (e.g. 15 min to 16 min to 15 min to 16 min). This difference value, termed delta (Δ), is computed as the absolute difference between the newly estimated travel time and the current displayed travel time. If the absolute difference is less than delta, than the current displayed travel time is not changed. The default delta is two minutes but is configurable. The following box summarizes the discussed relationship.

$$\boxed{\text{If } \left| \text{Estimated Travel Time} - \text{Displayed Travel Time} \right| \geq \Delta, \text{ then change the message}}$$

Blank Messages

There are a few cases in which blank messages may be produced which deal mainly with irregularities in the communication between the three entities: 511/Travinfo, MITTENS, and SOCCS. If a travel time cannot be computed because some of the link travel times from 511/Travinfo is unavailable, the line displaying the destination and time is blanked. If both travel times on a given CMS cannot be computed, then the whole sign is blanked. Furthermore, if MITTENS loses its connection to Travinfo’s messaging service for 10 minutes, then the CMS is blanked. Similarly, if SOCCS is unable to retrieve the MITTENS file for 10 minutes, then the CMS is blanked. Both of these times are configurable. Please see the architecture section for more information regarding system interfaces.

Travel Times on Changeable Message Signs

in Caltrans District 4

Chronicle / Chris Stewart

MITTENS Software Design and Management

Version 2 – December 2005

Applicable documents

- CCIT – Travel Times on Changeable Message Signs in Caltrans District 4 – System Architecture and Operating Rules

Contact List

- Caltrans District 4 Project Manager

  Alan Chow
  alan_s_chow@dot.ca.gov
  (510) 286-4577

- Caltrans DRI SOCCS Lead Developer

  Sean Campbell
  sean_campbell@dot.ca.gov
  (916) 654-8868

- Metropolitan Transportation Commission – 511/Travinfo liaison

  Ben McKeever
  bmckeever@mtc.ca.gov
  (510) 817-3245

- CCIT Project Manager

  J.D. Margulici
  jdmargulici@yahoo.com
  (510) 642-5929

Table of contents

Purpose of the Document

This document describes the software design and administration of MITTENS and MITTENS Monitor. MITTENS is the system which produces travel time messages for the Changeable Message Signs (CMS) based on data from 511/Travinfo. MITTENS Monitor supervises MITTENS' operations and has the ability to inform the administrator of MITTENS' operating status and to automatically restart MITTENS if needed.

A brief section covers the role of MITTENS and MITTENS Monitor in the CMS Travel Time system and how they interact. This is followed by a more detailed description of MITTENS and MITTENS Monitor. The last section of this document covers the administrator's role.

The MITTENS' software design section first gives an operational overview and then discusses MITTENS' inputs and outputs. The software data entities are then described in their relation to the inputs. The "Subsystems" section shows how the data entities are used and includes a thorough discussion of MITTENS' subsystems. The MITTENS Monitor section also starts with an operational overview, followed by its inputs and outputs. The subsystems are then described.

Finally, this document covers the administration of MITTENS and MITTENS Monitor. This section covers the configuration of the two systems, how to start and stop the two systems, and how to check their status.

This document is intended for a developer who wants to understand MITTENS' and MITTENS Monitor's software design or a system manager overseeing MITTENS. It is a supplement to the document, "Travel Times on Changeable Message Signs in Caltrans District 4 – System Architecture and Operating Rules," which describes the system architecture and operating rules and is the basis for what is described here. While it is assumed that the system architecture document has been seen by the reader, specific sections are explicitly referenced when necessary.

MITTENS and MITTENS Monitor System Overview

Figure 1 shows the main systems involved in the CMS Travel Time Project. MITTENS receives real-time traffic data from 511/Travinfo and produces travel time messages that are sent to SOCCS which controls the CMS. Since MITTENS needs to coordinate with several external systems such as the 511/Travinfo and databases, occasionally there are connection errors which prevent MITTENS from performing its tasks properly. MITTENS Monitor is specifically designed as an external error-recovery mechanism to mitigate such problems.

MITTENS Monitor supervises MITTENS operations. If MITTENS Monitor detects that MITTENS encountered some critical error, MITTENS Monitor takes appropriate action.

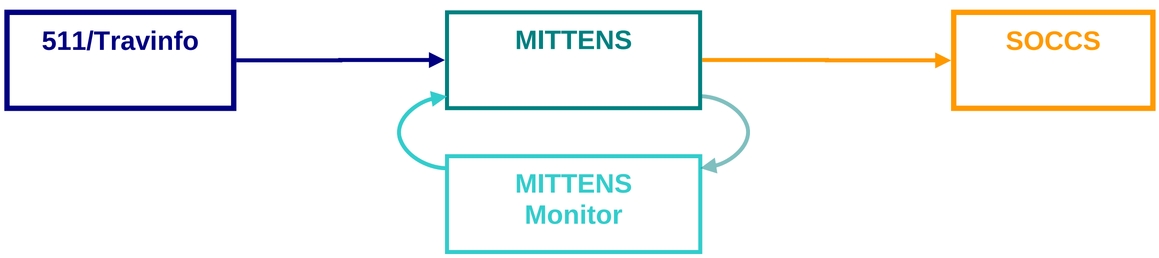


Figure 1 - System Overview of 511/Travinfo, MITTENS, MITTENS Monitor and SOCCS

Normally, system administrator starts MITTNENS Monitor which, in turn, starts MITTENS. But for debugging new MITTENS functionality, MITTENS can be started directly by system administrator without starting MITTENS Monitor first. For detail information on how to manage MITTENS Monitor and MITTENS, see section “Managing MITTENS and MITTENS Monitor”.

MITTENS Software Design

Operational Overview

In order to effectively function as the interface between 511/Travinfo and SOCCS, MITTENS has two operational stages: the Initialization Stage and the Message Stage. Figure 2 shows these two stages as well as the inputs and output of MITTENS. MITTENS is shown in green, 511/Travinfo is in blue and SOCCS is in orange.

The Initialization Stage occurs when MITTENS is started. This stage initializes the subsystems which operate during the Message Stage and loads static data from the CMS database into memory. It uses initialization data found in configuration files.

When the Initialization Stage has finished, MITTENS automatically enters the Message Stage. During the Message Stage, it receives messages from 511/Travinfo, processes the messages, and produces CMS messages, which are passed to SOCCS. During this stage, MITTENS uses the data supplied from 511/Travinfo and static data stored in memory to produce the CMS messages. At each step in the two stages, log files are automatically generated. These log files can be used to track MITTENS' progress and are used by MITTENS Monitor to supervise MITTENS' proper execution.

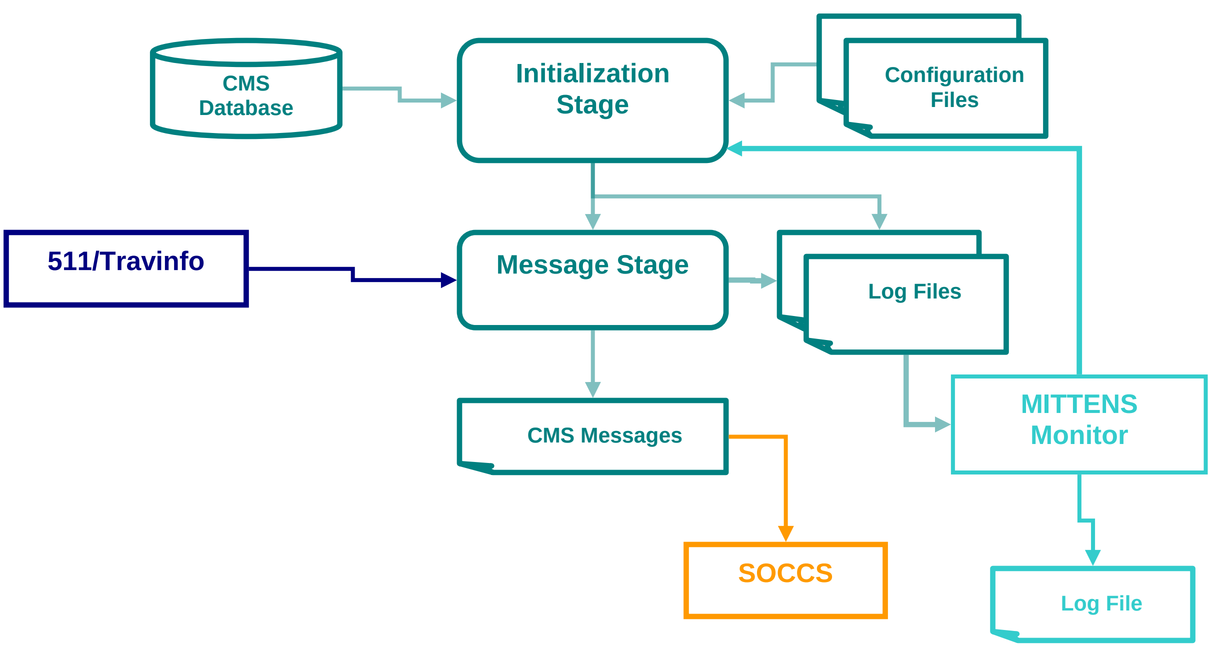


Figure 2 - Operational Overview: Showing the two operational stages and the inputs and output

Input and Output

There are three sources of input and two outputs. MITTENS receives the 511/Travinfo messages, accesses the CMS Database and reads the configurations files. The output is a file that includes all the CMS messages. As MITTENS produces the CMS messages, it periodically records its progress in log files.

Input - 511/Travinfo Messages

During the operational stage, MITTENS receives messages from 511/Travinfo via the Travinfo Open Messaging Service (TOMS). There are two types of messages: link travel times and link definitions. The link travel times report the current travel time along a given link definition and are used to calculate the route travel time.

Input – Static Data

The Static Data consists of the CMS locations, the route definitions, the CMS masks, the display schedule and the routes to be displayed. The static data is initially stored in a database, but during the initialization stage, the data is moved to memory where it is accessed during the message stage. Please see the System Architecture and Operating Rules document, section “Data Entities” for more information.

Input – Configuration Files

There are four configuration files: the Selection File, the TOMS Client Properties File, the CMSE Properties File, and the Logging Framework File. The Selection File is used to configure the CMS TT messages, while the TOMS Client Properties File and the CMSE Properties File define how MITTENS’ receives the input and in what file the output will be placed. The Logging Framework File defines what data is logged in the log files, and with what level of detail.

The Selection File

The Selection File is used to select a predefined configuration from the CMS database. The configuration governs which set of CMS’ will be used, which routes will be calculated, and how the messages will be formatted. The configuration also determines the schedule for the displays. In the future, the Selection File will select a schedule, which can transition between different configurations. Please see the System Architecture and Operating Rules document, section “Data Entities” for more information.

The TOMS Client Properties File

The TOMS Client Properties File defines the properties of the TOMS Client module. It defines the connection properties for the database that holds the static data: the database name, username and password. It also defines the connection to the TOMS server: IP addresses, username, password, and the blanking policy. The blanking policy specifies how long MITTENS will wait while not receiving any messages from the TOMS server. If this wait time is exhausted, blank

CMS TT messages are written in the CMS message file. The TOMS Client Properties File also defines the name of the output file.

The CMSE Properties File

The CMSE Properties File defines the properties of the CMSE module. It defines the database connection properties as well as the way in which it will record its progress. In a later section, this feature is described in more detail.

The Logging Framework File

The Logging Framework File defines to what level of detail MITTENS will record its activities in the log files. Examples of recorded activities are the initialization of certain modules and connecting to the 511/Travinfo system.

Output - CMS Travel Time Messages

The output is the CMS travel time messages which are placed in the CMS Message File. Each line in the CMS Message File is a travel time message that will be displayed by a given CMS. This file is read by SOCCS. Please see the System Architecture and Operating Rules document, section "Message Generation Module" for more information on the format of the messages.

Output - Log Files

MITTENS periodically writes to various log files as it performs its tasks. These files are described in more detail in the "MITTENS Administration" section.

Data Entities

A number of data entities are used to hold the 511/ Travinfo messages and the static data. This section describes what each data entity holds. The following section, "Subsystems" describes how the data entities are used.

CMS Database

The CMS Database holds the static data. In addition to this, the database is used to save the link definitions and the link travel times contained in the 511/Travinfo messages. Please see the "System Architecture and Operating Rules" document, section "Data Entites" for a full description of the CMS Database.

Memory

CMS Data

CMS Data holds the static data that has been read from the CMS Database.

m_msgsToProcessQueue

m_msgsToProcessQueue holds the unprocessed messages from 511/Travinfo.

link_Def

link_Def is used to hold the link definitions published by 511/Travinfo.

link_TT

link_TT is used to hold the link travel times published by 511/Travinfo.

recentTT

recentTT is used to hold the most recent route travel times.

Subsystems

Figure 3 provides more details regarding MITTENS' two operational stages. It shows MITTENS' subsystems, their interactions, and handling of the inputs and output. During the initialization stage, the Initializer reads in the Configuration Files and initializes the Information Source Monitor (ISM), the Message Processing Thread (MPT), the TOMS Client and the CMS Engine (CMSE).

During the message stage, a connection is made to the 511/Travinfo TOMS Server by the ISM. This connection is given to the MPT which receives the messages and passes them to the TOMS Client. The TOMS Client determines the content of the messages and, if necessary, invokes the CMSE to create the CMS Message File. When SOCCS requests this file from the Web Server, the Web Server passes it to SOCCS.

As in Figure 2, MITTENS is shown in green, 511/Travinfo in blue and SOCCS in orange. The solid lines indicate that data is being passed and the dashed lines indicate an initialization.

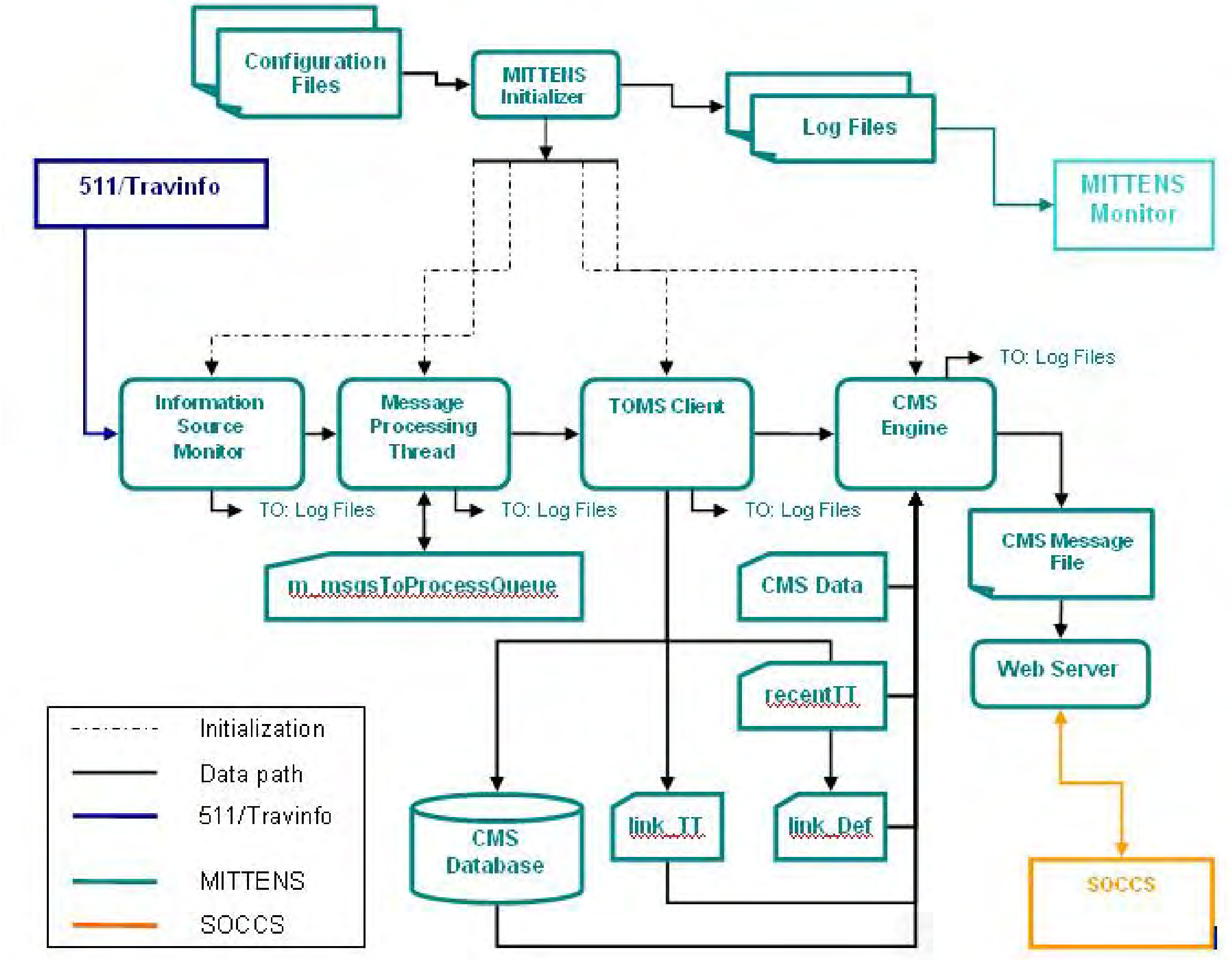


Figure 3 - MITTENS' Subsystems

Initializer

The Initializer is used during the Initialization Stage to initialize the subsystems used in the Message Stage. It performs the following:

1. Initializes the Information Source Monitor with the TOMS server connection properties
2. Initializes the Message Processing Thread
3. Initializes the TOMS Client with the blanking policy and CMS Database connection properties
4. Initializes the CMS Engine with the CMS Database connection properties and the selected configuration

The Initializer has no role during the Message Stage.

Information Source Monitor

The ISM is used to start and maintain a connection with the TOMS server. It is initialized with the TOMS server connection properties. Once the ISM is initialized, it attempts to form a connection with the TOMS server. If a connection is made, the connection is passed to the MPT. The ISM continues to monitor the TOMS server connection. If the connection is lost, the ISM attempts to reestablish the connection.

Message Processing Thread

The MPT handles the messages from the TOMS server and passes them to the TOMS Client. It uses the m_msgsToProcessQueue to store the messages waiting to be passed to the TOMS Client.

When the Message Processing Thread (MPT) is initialized, it creates the m_msgsToProcessQueue. During the message stage it performs two tasks in parallel:

1. Receives messages from the 511/Travinfo connection and places them in m_msgsToProcessQueue.
2. Checks the queue every minute and, if a message exists, passes the message to the TOMS Client.

TOMS Client

The TOMS Client processes the 511/Travinfo message that it receives from the MPT. When necessary, it invokes the CMSE to produce the CMS Message File.

The TOMS Client is initialized with the blanking policy and CMS Database properties and saves these into memory. It then creates link_Def and link_TT which will be used to store the information in the 511/Travinfo messages.

After the TOMS Client is initialized, it starts a timer and waits for a message from the MPT. Figure 4 shows graphically how the TOMS Client waits for a message, how it processes a message and how the TOMS Client invokes the CMSE.

While it is waiting for a message, if the timer's value exceeds the blanking policy, then the CMSE is invoked to produce blank CMS messages in the CMS Message File. If a message arrives from the MPT, then the timer is reset, the message is decoded and the memory and database are updated. If the message is a link definition, the contents of the message are stored in link_Def and in a link definition table in the CMS Database. If the message is a link travel time, the contents of the message are stored in link_TT and in a link travel time table in the CMS Database and the CMSE is invoked to produce CMS TT messages. A reference to link_TT is passed to the CMSE when it is invoked to produce the CMS TT messages.

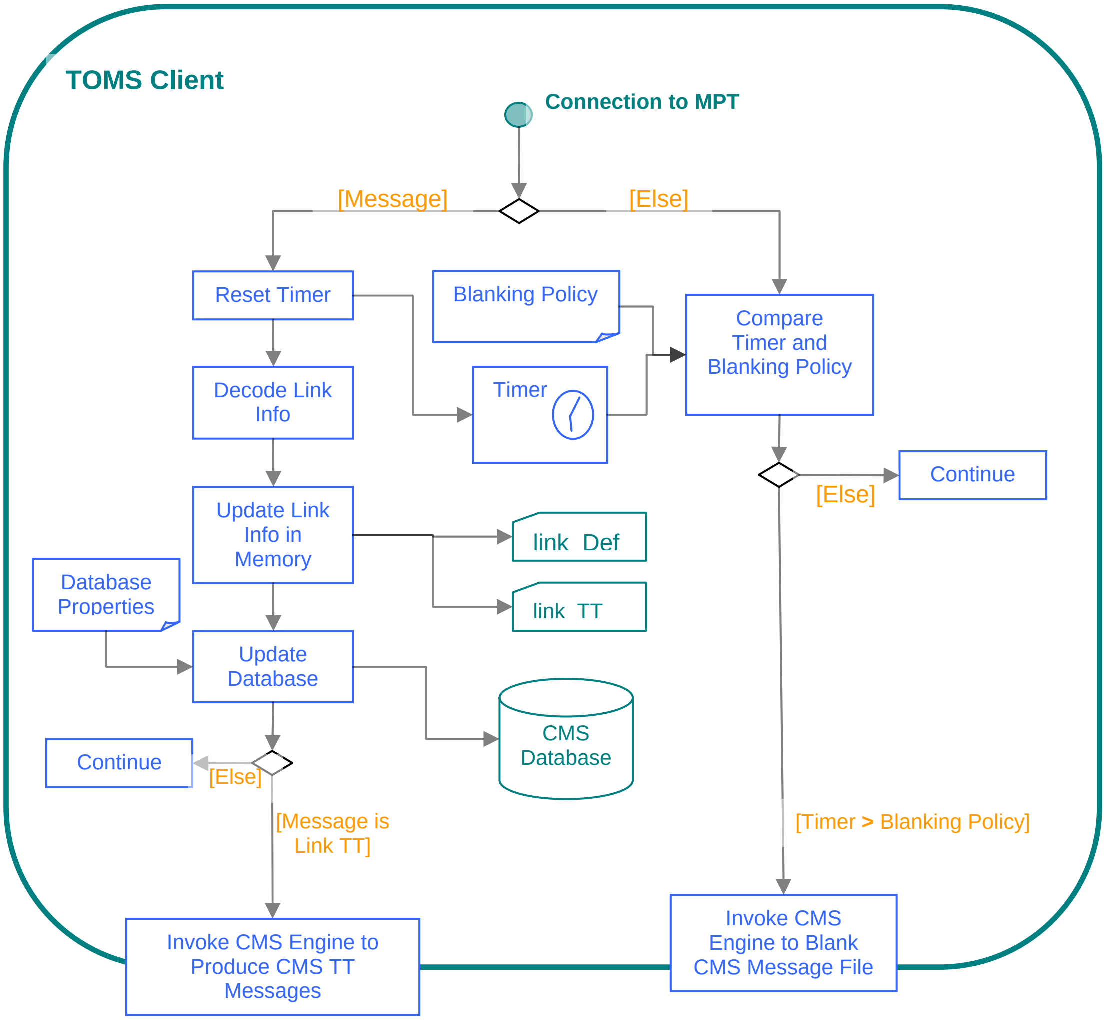


Figure 4 - TOMS Client During the Message Stage

CMS Engine

The CMSE is invoked by the TOMS Client to produce CMS messages and writes them to the CMS Message File. The CMS Message File either contains CMS TT messages or blank CMS messages. It produces the CMS Message File based on the CMS Database configuration that it retrieves in the Initialization Stage. This section describes CMSE's activity during the Initialization Stage and the Message Stage.

<u>Initialization Stage</u>

The CMSE is initialized with the CMS Database properties and the selected configuration. Using the selected configuration, the CMSE connects to the CMS Database and loads into CMS Data the schedule. The CMS Masks associated with the given configuration are then retrieved and loaded into CMS Data. For every CMS Mask, each route and its attributes, constraints and corresponding links are loaded into CMS Data. Figure 5 below shows how loops are used to retrieve each route in each CMS Mask.

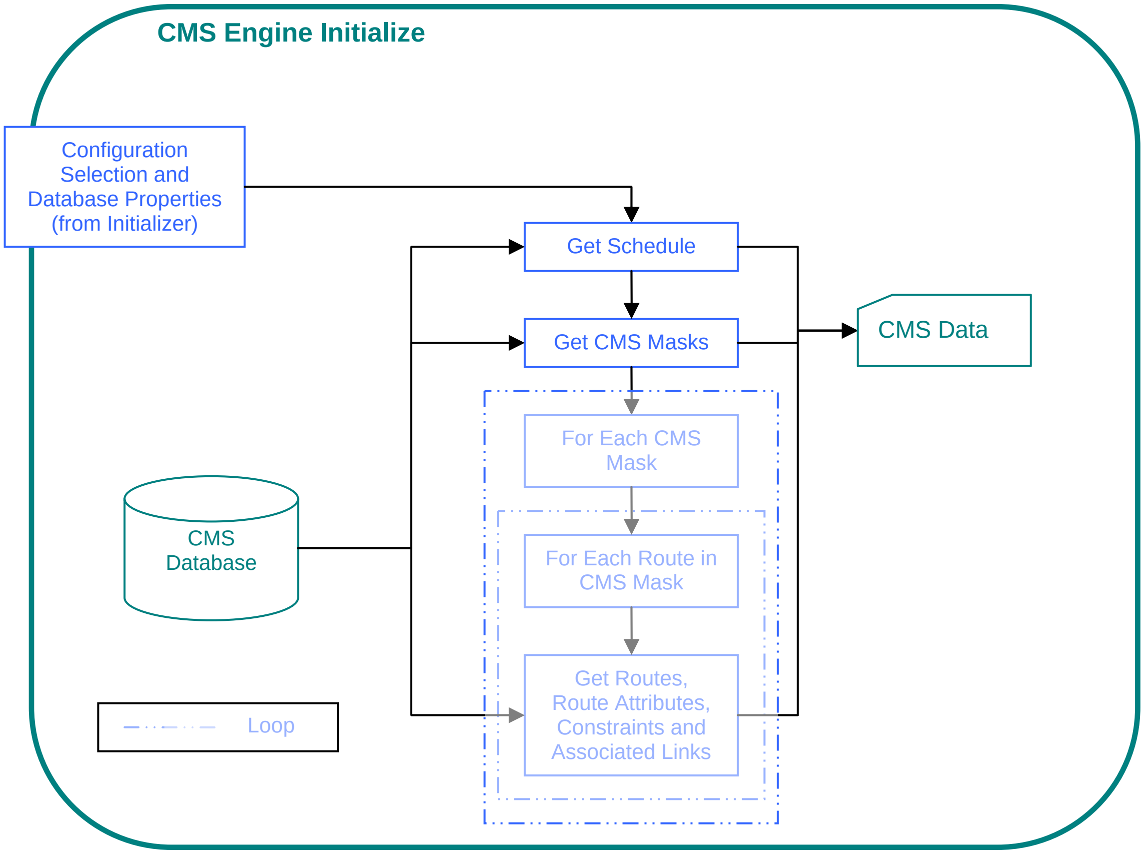


Figure 5 - Initializing the CMS Engine

Message Stage

After the CMSE has been initialized, the CMSE is ready to be invoked by the TOMS Client. Figure 6 shows how the CMSE responds to the TOMS Client's instruction. Either the instruction is to produce a blank CMS Message file, or it is to produce the CMS Message File with updated route travel times. When the CMSE is instructed to update the route travel times, the TOMS Client passes the CMSE the necessary reference to link_TT. In Figure 6, two diagnostic files are shown: CMS Message History Log and the Travel Time Constraint Log. The diagnostic files are described in the "Administration" section.

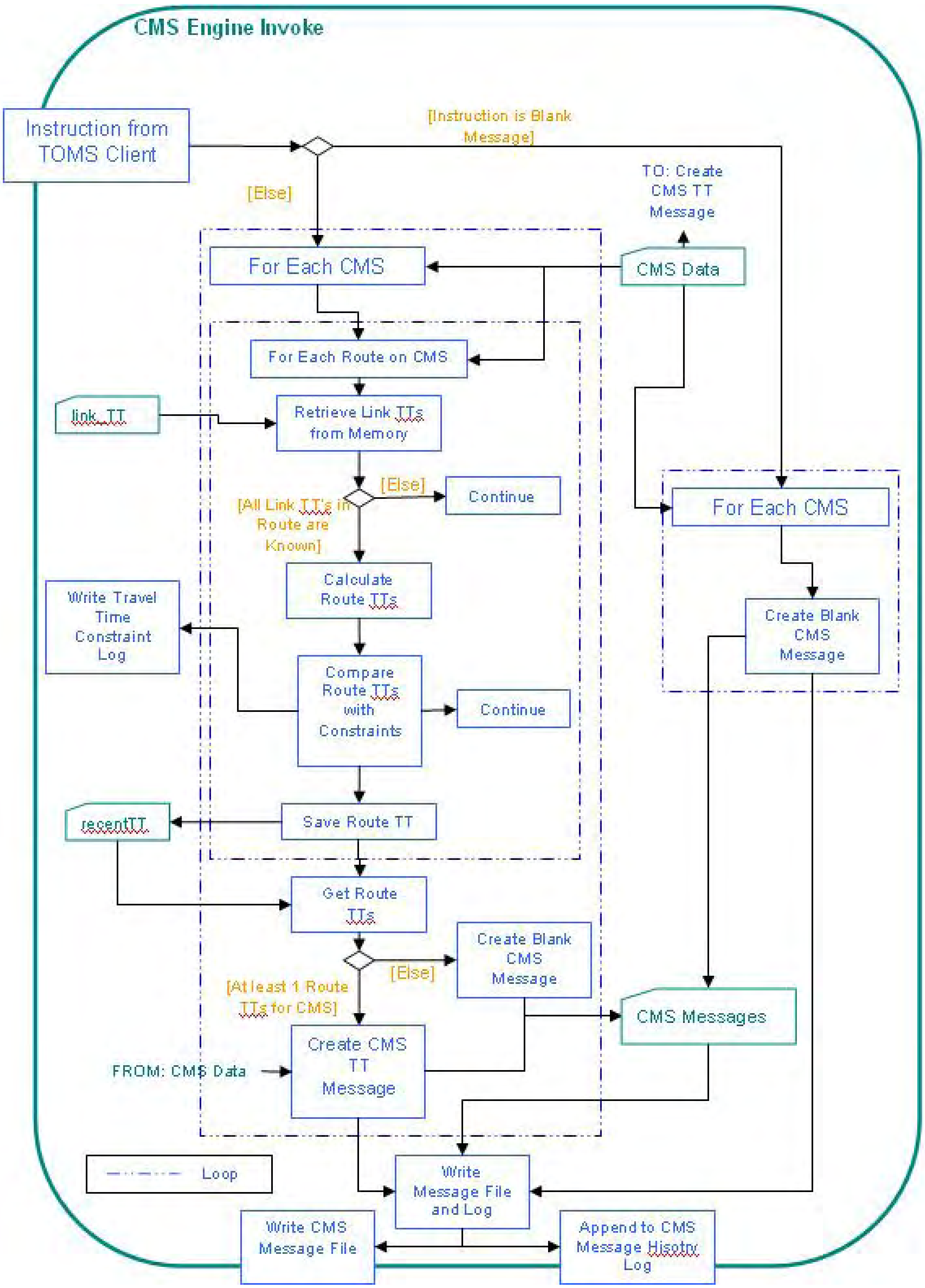


Figure 6 - Invoking the CMS Engine

If the CMSE receives the instruction to create a blank message, the CMSE creates a blank message for each CMS defined by the CMS Masks. Once all CMS’ have been processed, the CMS Message File is written.

If the CMSE receives the instruction to calculate the route travel times, the CMSE uses the reference to link_TT to calculate the route travel times for each CMS Mask stored in CMS Data. For each CMS Mask, the CMSE gets the associated routes and tries to calculate the travel times using link_TT. If not all the link travel times in a route are known, the route is ignored and the CMSE continues processing the other routes. Once a route has been computed, the CMSE compares the value to the constraints associated with each route. If the route travel time is not within the constraints, it is either ignored, set to a minimum travel time, or the previous route travel time is used (Please see the System Architecture and Operating Rules document, section “Routes”). Once the route travel times have been calculated, the formatting in the CMS Mask is used to create the CMS TT message and store it in memory. When all the CMS Masks have been processed, the CMS Message File is written.

MITTENS / SOCCS Interface

The CMS Message File written by the CMSE is accessed by SOCCS through a web server. SOCCS requests this file from the web server, and the web server returns the CMS Message File to SOCCS. Please see the System Architecture and Operating Rules document, section “SOCCS” for more information.

MITTENS Monitor Design

Operational Overview

MITTENS and MITTENS Monitor execute as separate processes on the same server. Figure 2 and Figure 7 show the interaction between MITTENS and MITTENS Monitor through the log files. Generally speaking, MITTENS Monitor is designed as an error recovery system. More specifically, if MITTENS encounters a critical error in which it is unable to produce travel time messages, it records the error in one of the log files called the SOS log. As presented on Figure 2, critical errors can be reported by each of MITTENS' subsystems. MITTENS Monitor periodically reads the SOS log, monitors MITTENS' running status and takes appropriate action according to predefined rules stored in the MITTENS Monitor's configuration files. There are three actions which MITTENS Monitor can perform: do nothing, restart MITTENS, and alert the administrator of a critical error. The rules may specify that for a given MITTENS status an alert message should be generated. In this case, the Alert Engine is used to generate the message. Figure 7 shows the subsystems in MITTENS Monitor.

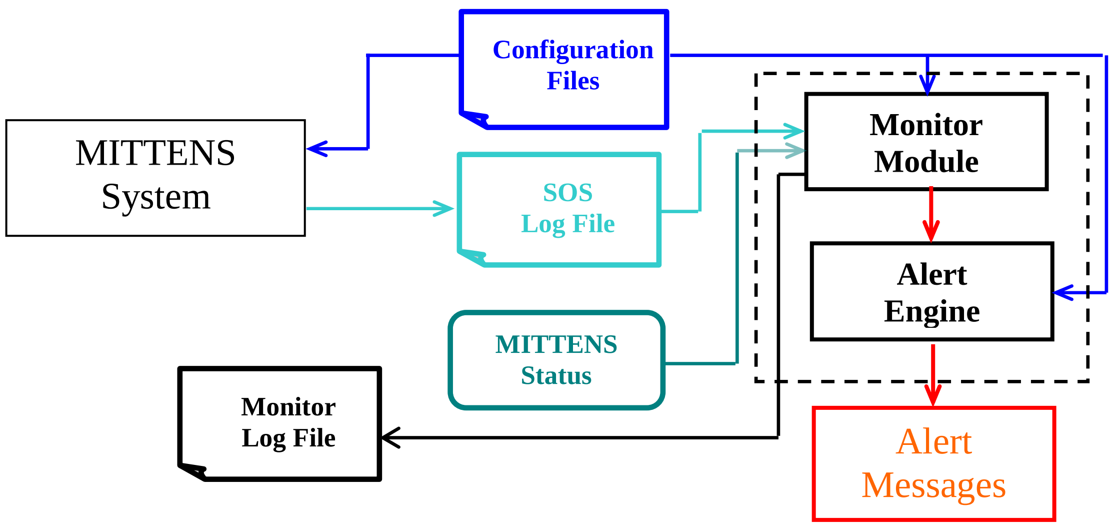


Figure 7 - Overview of MITTENS Monitor and its interaction with MITTENS

Input and Output

Inputs to MITTENS Monitor includce three configuration files, the running status of MITTENS, and the SOS log file. The outputs from Monitor are alert messages and a log file.

Input – Running Status of MITTENS

The running status of MITTENS, especially the current number of active processes of MITTENS in the system, is the input to MITTENS Monitor. The reason this number is crucial is due to the possibilities that MITTENS might be stopped for services or multiple instances of MITTENS might be running simultaneously in the system. In both cases, Monitor needs to respond appropriately. This input can be detected and collected automatically by MITTENS Monitor.

Input – SOS Log

The SOS log is generated by the running MITTENS process. Whenever some critical error conditions happen, e.g. database error, MITTENS will log the message in a log file based on which Monitor can respond gracefully.

Input - Configuration Files

The Monitor File

The Monitor File is used to define important properties of MITTENS Monitor, e.g., the time interval to repeatedly monitor MITTENS.

The Alert File

The Alert File contains configurations for the Alert Engine, including desired alert message generation alternatives and their options.

The Coordinator File

The Coordinator File defines the action rules of the MITTENS Monitor with respect to each possible entry in the log file. For each logged error condition, a corresponding action is defined and will be implemented by Monitor (e.g., to restart MITTENS).

Output – Alert Messages

MITTENS Monitor can generate alerting messages to notify the system administrator to be aware of error conditions of MITTENS. Messages can be disseminated using different means, ranging from pop-up windows, audible alerts, emails, short messages, and phone calls. All alternatives shall be specified and enabled (or disabled) in the Alert configuration file.

Output – Log File

For tracking purposes, a log file from Monitor, named monitor.log is created and records the actions taken by Monitor during the monitoring process.

Subsystems

As shown in Figure 7, MITTENS Monitor contains two major components: the Monitor Module and the Alert Engine. The Monitor Module checks the status and log file of MITTENS and takes action accordingly. The Alert Engine receives an alert generation request from Monitor Module and produce appropriate alert messages.

Monitor Module

The Monitor Module performs the bulk of MITTENS Monitor work. It checks the SOS log file generated by MITTENS and the current running status of MITTENS and decides which action MITTENS Monitor should take. Figure 8 provides a detailed flow chart of Monitor Module.

Table 1 shows the actions that Monitor Module takes in response to the number of running MITTENS processes and the SOS log. If the Monitor Module finds that no MITTENS processes are running and the SOS log does not report that MITTENS is 'In Service,' the Monitor Module starts MITTENS. If the Monitor Module finds that one MITTENS process is running and that there is a database error, it sends a request to the Alert Engine to generate an alert message to the administrator.

Table 1 - MITTENS Monitor Action Rules

MITTENS Monitor Action Rules			
MITTENS' SOS Log	Number of Running MITTENS Processes in the System		
	0	1	>=2
Working	Start MITTENS	Do nothing	Stop and Restart MITTENS, generate alert messages
In Service	Do nothing	Do nothing	
Database Error	Start MITTENS	Generate alert messages	
Restart Me	Start MITTENS	Stop and Restart MITTENS, generate alert messages	

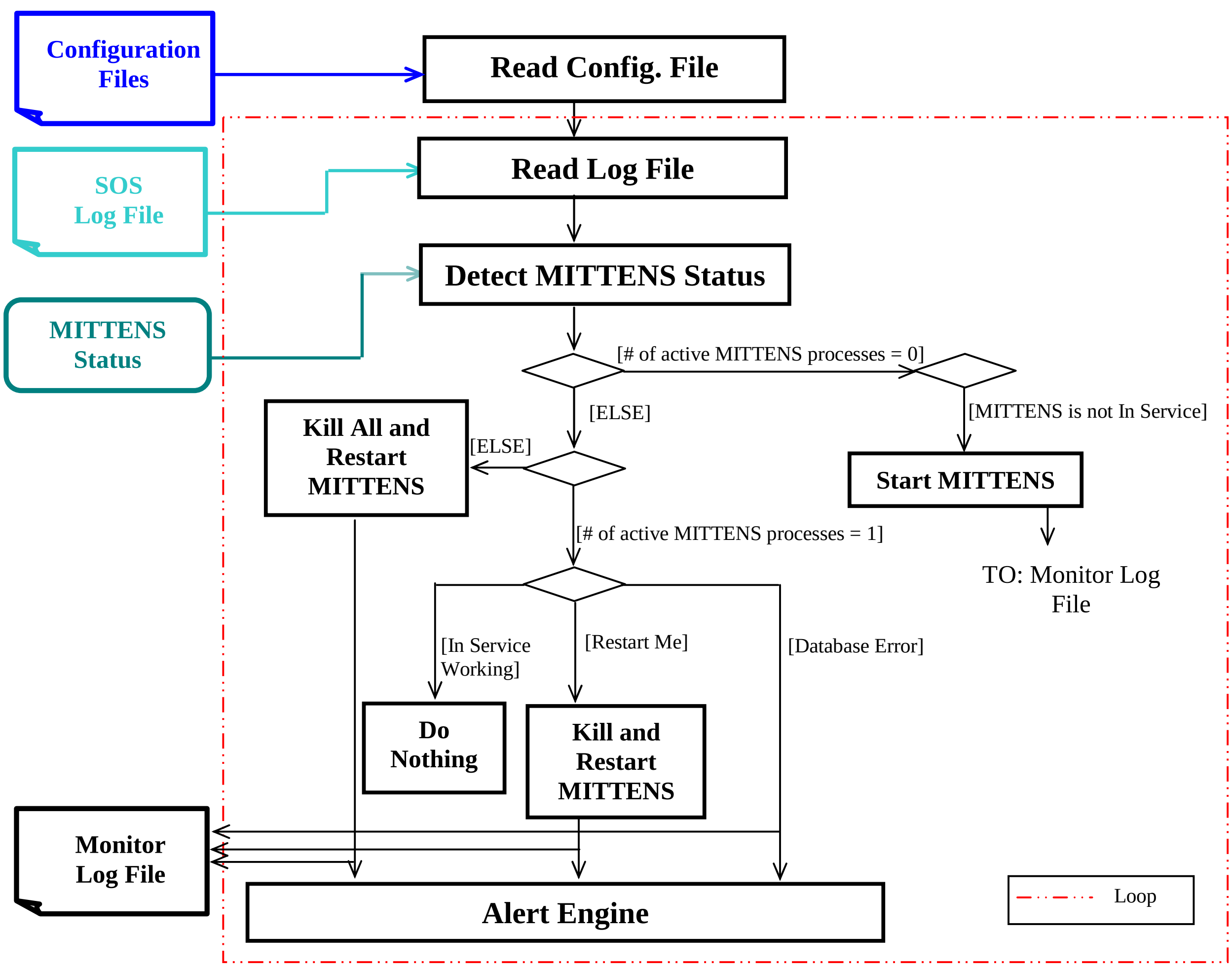


Figure 8 - Monitor Module Flow Chart

Alert Engine

The Alert Engine receives alert generation requests from Monitor Module and produce alert messages according to desired options defined in the configuration file, as shown in Figure 9. This figure depicts a framework for designing the Alert Engine. Note that the Alert Engine is implemented as a separate package from the Monitor Module. This way, the Alert Engine can be maintained relatively independently and its functionality expanded.

In the current implementation, a framework is developed to facilitate all five options shown in Figure 9: pop-up windows, audible messages, e-mails, short messages (SMS), and phone calls. However, due to the uncertainty regarding available resources under the real operation environment, only the pop-up window alert has been fully developed and tested. This means that whenever some critical condition happens, a pop-up window is generated to notify the system administrator. The audible messages and e-mail options have been implemented and tested as well. However, it is recommended that these options be disabled unless the system administrator is assured that Internet access is available. The SMS and Phone call options were not implemented in the current version of MITTENS Monitor.

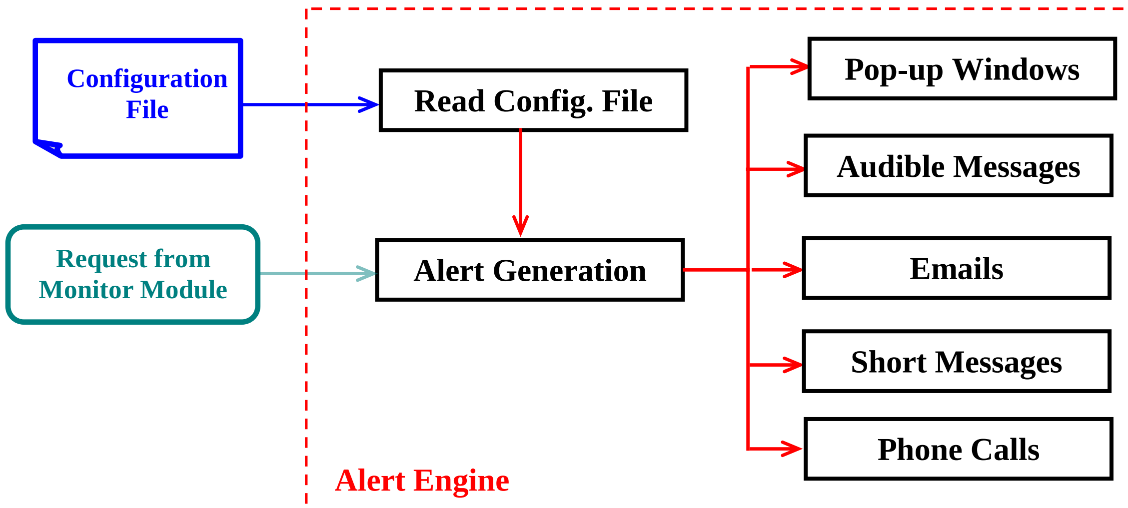


Figure 9 - Alert Engine Flow Chart

Administration of MITTENS and MITTENS Monitor

When MITTENS is started, it enters the Initialization Stage followed by the Message Stage. As mentioned earlier, during the Initialization Stage the configuration files are used to define the input and output properties. Once MITTENS is started, it relies on the configurations set during the Initialization Stage and on the messages received from 511/Travinfo. In a similar way, MITTENS Monitor uses options specified in configuration files to define its operating parameters.

From a user's standpoint, there is not much that can be done to manipulate MITTENS' and MITTENS Monitor's activity once they are running. What the user can do is configure the two systems before starting and to monitor the two while they are running. Configuring the systems involves editing the configuration files and changing the static data. Monitoring the systems involves checking the diagnostic files which are written at various points in their execution. This section describes the diagnostic files as well as the configuration files, how to edit the static data, how to monitor MITTENS' and MITTENS Monitor's actions and how to manage the two systems.

Currently, there is some redundancy in the properties that are specified in TOMS Client Properties File and the CMS Engine Properties File. Both the TOMS Client Properties File and the CMS Engine Properties File specify the connection parameters to the CMS database.

MITTENS Configuration Files

As noted earlier, there are four configuration files read during the Initialization Stage: the Selection File, the TOMS Client Properties File, the CMSE Properties File, and the Logging Framework File. The section below will discuss the format of these four files and how to use them to configure MITTENS. Please note that any changes to these files will only take effect when MITTENS is restarted.

The Selection File

The Selection File is a three-line file that is used to specify a predefined configuration within the CMS Database. The current name for the Selection File is "cms.states." Its format is the following:

```
#This file hold parameters changeable by admin or operator
#Current Schedule Id
CMS.CURRENT.SCHEDULE_ID=1
```

For more information on the SCHEDULE_ID please see the System Architecture and Operating Rules document, section "Data Entities" and "Figure 3."

Future versions will allow the system administrator to use a graphical-user-interface to select a schedule. In this case, the SCHEDULE_NAME will be displayed. The corresponding SCHEDULE_ID will be saved in "cms.states." In the event of a system crash, MITTENS can be restarted with the correct SCHEDULE_ID.

The TOMS Client Properties File

The TOMS Client Properties File (TCPF) is used to configure the input and output properties. This involves the properties related to the TOMS server connection, the CMS Database connection, the output file, and the diagnostic file.

Table 2 - The Properties File

List of Properties Defined in the Properties File		
Section	**Property Name**	**Description**
TOMS Server Connection	TOMS.ClientIdentity	Used by the TOMS server
	TOMS.jms.BrokerNames	IP addresses used by the Java Messsage Service (JMS)
	TOMS.jms.ConnectionUserName	JMS username
	TOMS.jms.ConnectionPassword	JMS password
	TOMS.jms.ConnectionRetries	Number of times to attempt to reconnect
	TOMS.jms.ConnectionInterval	Number of milliseconds between reconnects
	TOMS.jms.ConnectionPingInterval	Ping interval used for detecting dropped connection
	TOMS. jms.TopicTrafficEvents	Name of traffic events information
	TOMS. jms.TopicIncident	Name of traffic incident information
	TOMS. jms.TopicLinkInfo	Name of link information
	TOMS. jms.QueueTOMSRequests	Name of queue for sending requests
	TOMS. jms.ResponseTimeout	Time interval to wait for a response when requesting data
	TOMS.jms.UseDurableSubscription	Whether or not to use durable subscriptions
	TOMS.jms.TopicEventDurSubName	Durable subscription name for events topic
	TOMS.jms.TopicIncidentDurSubName	Durable sbscription name for incident topic
	TOMS.blanking.minutes	Blanking policy
Database Connection	TOMS.DbHost	Database host name
	TOMS.DbName	Database name
	TOMS.DbUsername	Database username
	TOMS.DbPassword	Database password
	TOMS.DbLinkDataTableName	Name of table for link travel times
	TOMS.DbLinkDefTableName	Name of table for link definitions
	TOMS.Link.Traffic.Save	Whether or not to save link traffic times in database
Diagnostics	TOMS.DiagnosticFile	Travel Time Constraint Log
	TOMS.CriticalLogFile	Critical Event Log
	TOMS.MessageLogFile	Message Log
	TOMS.SOSLogFile	Critical error recovery file created by MITTENS and used by MITTENS Monitor
Other	TOMS.run_milliseconds	Length of time for MITTENS to run – ‘0’ is indefinite
	CMS.SPEED.NOMINAL_MPH	Speed limit along the routes
	CMS.SOCCS.OUTPUT_TMC_FILE	Output file

The TCPF is divided into sections with each section pertaining to a particular set of properties. For example, the first section covers the TOMS server connection, which is followed by the CMS Database section. Table 1 shows the sections, the property names and descriptions covered in the Properties File.

The current name for the TCPF is "TOMSClient.props." Below is a description of the sections and how to change the property values. In general, before each property there is a comment that provides a brief description. In some cases, the property values should not be changed, and this is indicated in the comment description. Table 1 lists all the properties specified in the Properties File. In the following sections, however, only the major properties will be covered in more detail.

TOMS Server Connection

The TOMS server properties are under the the JMS section in the Properties File. The user is able to change the IP address, the username, the password, and a number of other connection variables. Shown below are the properties for the IP address and username.

```
# JMS: Comma-separated list of broker URLs  in a cluster to which the
#application might initially connect.
# If one connection attempts fails, other connections from the list will be
#tried until either a connection
# is made or the list is exhaused. Sequential access to the list is assumed,
#i.e. the first broker on the
# list will be tried first.
TOMS.jms.BrokerNames=67.114.203.202:2506,67.114.203.201:2506

…

#
# JMS: The JMS  topic/queue connection username.
#
TOMS.jms.ConnectionUsername=calccit
```

The blanking policy property defines the length of time for which MITTENS will wait for a message from the TOMS server. If MITTENS hasn't received any link travel time from TOMS server, MITTENS will blank the CMS message file. The property is defined in minutes:

```
TOMS.blanking.minutes = 11
```

Database

The Database section includes the connection properties for the CMS Database and two of the table names stored in the database. As mentioned earlier, the two tables are used to save the link travel times and the link defintions.

```
#
# Password and username for database
#
TOMS.DbHost=localhost
TOMS.DbName=cms
TOMS.DbUsername=cms

…

TOMS.DbLinkDataTableName=TOMS_LINK_TRAFFIC
```

```
TOMS.DbLinkDefTableName=TOMS_LINK_DEF
```

Diagnostic Files

MITTENS produces three diagnostic files. The names and locations of any of these files can be changed. The current entries are:

```
#
# For diagnostic
#
TOMS.DiagnosticFile=/home/bchiou/cms/diagnostic/diag
TOMS.CriticalLogFile=/home/bchiou/cms/diagnostic/critical_log
TOMS.MessageLogFile=/home/bchiou/cms/message/d4cms.log
```

The diagnostic files are described in detail in the “Diagnostics” section.

Output File

The CMS message file’s name is defined as the OUTPUT_TMC_FILE. Its location and name can be changed. However, the web server through which SOCCS and MITTENS communicate is also configured to point to this file. If the output file’s name is changed, then the web server must also match this change. Below is an excerpt showing the property definition:

```
CMS.SOCCS.OUTPUT_TMC_FILE=/home/bchiou/cms/message/d4cms.txt
```

The CMSE Properties File

The CMSE Properties File (CPF) defines the properties of the CMSE, which include the database properties and the logging detail level while MITTENS is calculating the route travel times. The database properties are used to connect to the CMS database and the logging detail level is used to define the amount of information the CMSE records. The advantage of defining the logging detail level is to conserve processing time and disk space while still allowing the administrator or developer the ability to closely inspect MITTENS route travel time calculations. The CPF allows the user to log the calculations for a particular CMS, a particular route or particular decision points. Logging the decision points in the route travel time calculation allows the user to see which travel time constraints are being applied to a particular route. The decision points are points in the travel time calculations where the constraints are enforced. These decision points are shown in Figure 10.

The process loops through every active CMS Mask and processes the applicable routes. First, the process examines the link travel times to determine whether or not the route travel time (RTT) can be calculated. If all the link travel times are known along a given route, then the process applies the minimum and maximum travel times to the RTT. The RTT is then compared with the previous RTT. If the absolute difference between the two is greater than delta, then the RTT is saved, and the process continues. Otherwise, the RTT is set to the previous RTT. Once all the routes for a given Mask are processed, either a CMS travel time message or a blank message is produced. Diagnostic records are written to a file as MITTENS executes different branches in the decision tree. Each diagnostic record is appended to the file, so that all the records are saved. The circles, in the figure above, indicate that a new record is added to the file. The symbol, inside the circle, is a diagnostic ID, which is used to format the record. The diagnostic ID and the format of the records are explained in the next section. Please see the System Architecture and Operating Rules document for more information regarding the travel time calculations.

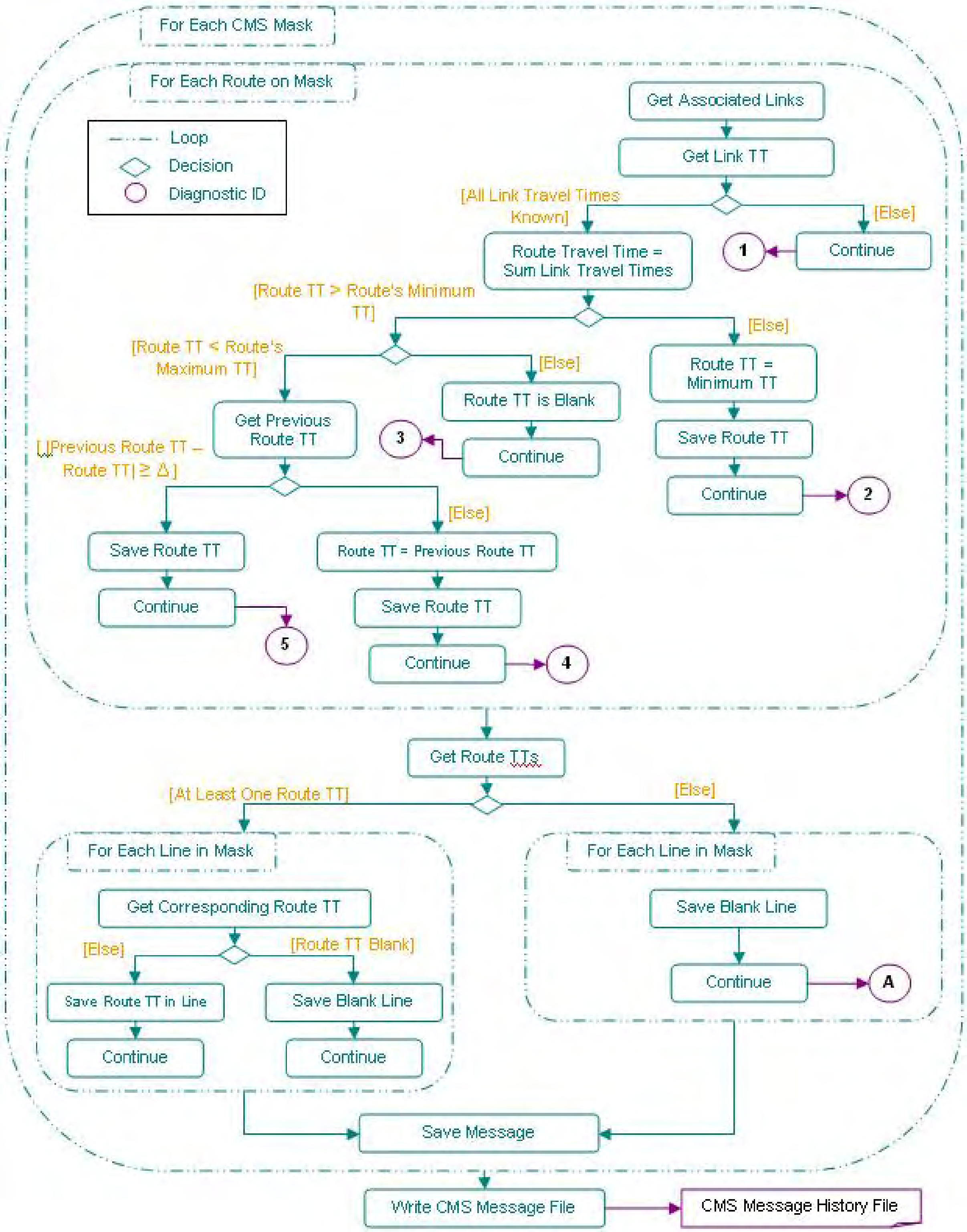


Figure 10 - Decision Tree in Creating CMS Messages

The decision points are as follows:

- **A.** Records whenever a blank CMS message is created. This record is currently not implemented.
- **1.** Records whenever the RTT is unable to be computed because not all of the link travel times are known.
  - a. Reports which links have unreported travel times.
  - b. Usefulness – Shows any recurring link whose travel time is not being reported by 511/Travinfo. Also shows if blank messages are caused by unknown link travel times.
- **2.** Records whenever the RTT is set to the minimum travel time.
  - a. Reports calculated RTT and the minimum travel time for that route
  - b. Usefulness – Shows how often the minimum travel time is enforced.
- **3.** Records whenever the RTT exceeds the maximum travel time.
  - a. Reports calculated RTT and the maximum travel time for that route.
  - b. Usefulness – Shows how often the maximum travel time is enforced. Shows if the blank messages are caused by route travel times which are too great.
- **4.** Records whenever the RTT is set to the previous travel time because the absolute difference is less than delta.
  - a. Reports the calculated RTT, the previous RTT and Delta
  - b. Usefulness – Shows how often the delta function prevents toggling
- **5.** Records the calculated RTT.
  - a. Reports the calculated RTT
  - b. Usefulness – Records what is eventually used to generate the messages

The calculations logs for a particular CMS may be turned on and off. Additionally, certain routes can also be turned on and off. The calculations log record decision points according to Figure 10. The following is an excerpt from the file, cms.properties. The CMS and route names used refer to the CMS ID's and route ID's in the CMS Database.

```
CMS_DIAGNOSTIC_ON_CMS_IDS=CMS070|CMS078

CMS_DIAGNOSTIC_ON_ROUTE_IDS=7001|7003|7802
CMS_DIAGNOSTIC_OFF_ROUTE_IDS=7702|7506

CMS_DIAGNOSTIC_DECISION_1=On
CMS_DIAGNOSTIC_DECISION_2=On
CMS_DIAGNOSTIC_DECISION_3=On
CMS_DIAGNOSTIC_DECISION_4=On
CMS_DIAGNOSTIC_DECISION_5=Off
```

Turns calculation log on for CMS070 and CMS078. Note - each CMS ID is separated by the pipe character (|)

Turns on routes 7001, 7003, and 7802 and turns off 7702 and 7506

Specifies which decisions to record

In future versions, if there are too many ID's listed in the CMS section and the route section, the ID's may be placed in another text file. For example, the CLFF may read:

```
CMS_DIAGNOSTIC_ON_CMS_IDS=file: onCMSs.txt
CMS_DIAGNOSTIC_ON_ROUTE_IDS=file: onRoutes.txt
CMS_DIAGNOSTIC_OFF_ROUTE_IDS=file: offRoutes.txt
```

The 'file' tag indicates that the list of ID's is stored in the subsequent file name

The Logging Framework File

MITTENS logs its status according to the level of detail defined in the Logging Framework File (LFF). There are five logging levels which range from detailed logging of every event in the system to only logging critical errors which have stopped MITTENS from performing its function. The advantage of such a framework is that it gives flexibility to the developer and the administrator. The more detailed the logging is, the easier it is to see what tasks MITTENS is performing. However, detailed logging slows down MITTENS and consumes disk space. As MITTENS is being developed it is useful to have detailed logging in order to investigate particular problems. However, once MITTENS is stable, it is only necessary to have MITTENS log the critical errors that it encounters. Table 3 outlines the logging framework in order from minimal logging to detailed logging. The LFF is different from the CPF in that the LFF specifies a logging level for all of MITTENS processes. The CPF, on the other hand, only specifies the logging level during the CMS message creation process.

Table 3 - Logging Framework

Logging Framework	
Log Level	**Description**
Fatal	Any event which inhibits MITTENS from producing travel time messages
Error	All events in the Fatal category plus events which inhibits MITTENS from performing non-critical tasks
Warning	All events in the Error category plus any other abnormal events
Information	All events in MITTENS
Debugging	All events in the Information category plus system information that is helpful in debugging

The logging detail level is specified in the Logging Framework File, log4j.properties, which defines the name of the log file, the log level, and the method to handle the growth of the log file. The current name of the log file is MITTENS.log. The log level can be specified according to the framework described in Table 3 with the commands in Table 4.

Table 4 - Logging Framework Commands

Logging Framework Commands	
Log Level	**Command in LFF (case sensitive)**
Fatal	fatal
Error	error
Warning	warn
Information	info
Debugging	debug

As MITTENS records its progress it is obvious that the log file will grow in size to a point beyond manageable. The way to deal with this is to set a size limit on the log file and use a rolling method to save the log files. The rolling method is that once the size of the log file reaches the size limit, it is copied to a new file named x.1 (x is the name of the log file) and a new log file is started. Once this new log file reaches the size limit, x.1 is copied to x.2 and the new log file becomes x.1. Again, a new log file is started. The number of files that are created is specified by the user.

An excerpt of the Logging Framework File is shown below with explanations:

```
log4j.rootLogger=debug, R                                  Logging Framework Command

log4j.appender.stdout=org.apache.log4j.ConsoleAppender
log4j.appender.stdout.layout=org.apache.log4j.PatternLayout

# Pattern to output the caller's file name and line number.
log4j.appender.stdout.layout.ConversionPattern=%5p [%t] (%F:%L) - %m%n

log4j.appender.R=org.apache.log4j.RollingFileAppender
log4j.appender.R.File=MITTENS.log                          Log file name

log4j.appender.R.MaxFileSize=500KB                         Size of log file
# Keep one backup file
log4j.appender.R.MaxBackupIndex=5                          Number of
                                                           files to be
log4j.appender.R.layout=org.apache.log4j.PatternLayout     created
log4j.appender.R.layout.ConversionPattern=%p %t %c - %m%n
```

MITTENS Monitor Configuration Files

The Monitor File

Table 5 - Description of the Monitor File

The Monitor File	
Property	**Description**
RUN_CYCLE	Frequency of monitoring
COORD_PROP_FILE_NAME	Coordinator file name
ALERT_PROP_FILE_NAME	Alert file name
SOS_LOG_FILE_NAME	SOS log file name
MONITOR_LOG_FILE_NAME	MITTENS Monitor log file name
FIELDS_SOS_LOG_RECORD	Number of fields for each SOS log record
LOCK_FILE_NAME	Name of file used so that MITTENS and MITTENS Monitor do not access the SOS log file at the same time
SCRIPT_FILE_NAME	Name of script used to run MITTENS
TOM_CLIENT_NAME	The name of the 511/Travinfo TOMS Client
DEFAULT_BUFFER_SIZE	Variable used in parsing the configuration files
TIME_ZONE	Time zone

There are eleven total entries in the Monitor File, monitor.prop. Table 5 lists the properties defined in the Monitor File along with a short description of each property. The RUN_CYCLE property indicates the time interval (in seconds) for the Monitor to periodically check the running status of MITTENS. The next two entries define the names of the configuration file for the coordinator and the alert engine, respectively. The SOS and Monitor log file names are provided next. FIELDS_SOS_LOG_RECORD defines the number of fields for each SOS log record. In the current implementation, this value should not be changed. LOCK_FILE_NAME is the name of a file used as an exclusive "lock" for accessing the SOS.log file. The purpose is to synchronize between MITTENS and the MITTENS Monitor to avoid the situation when both of them try to access the file simultaneously. The next two entries define the UNIX script file name for starting MITTENS and the name for the TOMS client. They are used for killing and restarting the MITTENS process. DEFAULT_BUFFER_SIZE is the default buffer size used for parsing the configuration files. Finally, the time zone string is given for providing correct timestamp information associated with each log record.

Except FIELDS_SOS_LOG_RECORD, all other ten entries must be correctly configured by the system administrator before running the MITTENS Monitor.

The Coordinator File

The following is an excerpt from the Coordinator File, coordinator.prop:

```
RESTART_ME=Restart Me
DB_ERROR=Database Error
IN_SERVICE=In Service
WORKING=Working
```

The Coordinator File defines four action items used by MITTENS and MITTENS Monitor, namely, Restart Me, Database Error, In Service, and Working. The meaning of each item is self-explanatory. This file is to maintain internal consistency between MITTENS and the Monitor and thus system administrators should not change it.

The Alert File

The Alert File, named alert.prop, defines various alterative methods to generate and disseminate alert messages, including pop-up windows, audible messages, emails, short messages, and phone calls. The system administrator can edit this file to enable/disable each option. Note that the current implementation supports only the first three options (Pop-up windows, Audible messages and emails). An example of the file is as follows.

Table 6 - Alert File Description

The Alert File	
Property	**Description**
POPUP_WIN_ENABLE	Enables pop-up window alerts
AUDIBLE_MSG_ENABLE	Enables audible message alerts

SOUND_FILE_NAME	Name of audible message
EMAIL_ENABLE	Enables email alerts
SENDER_HOST	Name of sending email server
SENDER_ADDRESS	Name of sending email address
EMAIL_SUBJECT	Email alert subject header
ADDRESSES	Receiving email addresses
SMS_ENABLE	Enables SMS alerts
PHONE_CALL_ENABLE	Enables phone call alerts

There are currently ten entries in the Alert File, alert.prop. The first entry, POPUP_WIN_ENABLE, is for enabling (1) or disabling (0) the pop-up window option. The next two entries are for the audible message option. Firstly, AUDIBLE_MSG_ENABLE can enable/disable this option and then SOUND_FILE_NAME indicates a file name containing the sound data to be played. The next five entries are for the email option. EMAIL_ENABLE is to enable/disable the email option. SENDER_HOST and SENDER_ADDRESS indicate the email sender' host and address, respectively. EMAIL_SUBJECT provides the subject of the email and ADDRESSES defines a list of email addresses to which the alert email will be sent. Individual email address is separated by "|" in this list. Finally, the last two entries, SMS_ENABLE and PHONE_CALL_ENABLE, are for enabling/disabling SMS and phone call options. Since both of them have not been implemented, they should be set as disabled (0).

MITTENS Diagnostics

Currently there are a number of diagnostics that report on MITTENS' status: the Critical Event Log, the SOS Log, the Message Log, the Calculation Log, the MITTENS Log, and the Console Log. Each diagnostic file is written at particular points in MITTENS' execution. Figure 4 shows the Message Log and the Calculation Log being written to at different points in the CMSE's execution. The Crticial Event Log, the MITTENS Log, the SOS Log, and the Console Log are written throughout MITTENS' execution. In addition to these six major log files, there is a minor log file called the Travel Time Constraint Log that can be used to supplement the information found in the Calculation Log.

Critical Event Log

When MITTENS encounters a critical error from which it cannot automatically recover, it records the problem in the Critical Event Log. These critical errors may include connection problems with the TOMS server, problems with accessing the CMS Database, or the property values in the configuration files are not in the correct format. Each critical error is appended to the existing Critical Event Log, thus, the Critical Event Log is a history of all the critical errors that MITTENS has encountered.

```
Sun May 15 02:46:21 EDT 2005TOMS hasn't sent any link traveltime for more than
   11 minutes
Tue May 17 20:10:12 EDT 2005TOMS hasn't sent any link traveltime for more than
   11 minutes
Tue May 17 20:51:30 EDT 2005TOMS hasn't sent any link traveltime for more than
   11 minutes
```

The Critical Event Log is currently named "critical_log" and is located in "/home/bchiou/cms/diagnostic/." The name is specified in TOMSClient.props as the CriticalLogFile.

SOS Log

The SOS Log records MTTENS status as it carries out its tasks. The records written to the SOS log are read by MITTENS Monitor. The records are in the following format: [SUGGESTED ACTION | ERROR MESSAGE | DATE/TIME], where "|" is used to separate different fields. The "suggested action" indicates what action needs to be taken to solve MITTENS' error. The "error message" explains why the "suggested action" is necessary. Finally, the "date/time" is a timestamp of when the record was created. The following is an excerpt from the SOS log file:

```
Working|Received JMS server published message|Wed Mar 01 09:16:06 EST 2006
```

Each time a record is written in the SOS log file, MITTENS overwrites any other previous content. This is to ensure that MITTENS Monitor reads the most updated log. Also, since MITTENS writes to the SOS log and MITTENS Monitor reads from it, there is a possibility that MITTENS Monitor will try to read the SOS log at the same time as MITTENS is writing to the file. To avoid this situation, before MITTENS or MITTENS Monitor can access the SOS log, the file is locked until it finishes the file I/O.

The SOS Log is currently named SOS.log and is located in "/home/bchiou/cms/TOMSClient/." The name is specified in MITTENS' Properties File, TOMSClient.props, as the SOSLogFile and in the MITTENS Monitor configuration file, monitor.prop, as the SOS_LOG_FILE_NAME.

Messages Log

The Message Log records every message that is written to the CMS Message File. When a new CMS Message File is created, the contents of the file are simply appended to the Message Log. In this way the contents of the Message Log record every CMS Message File. Figure 4 shows the Message Log being written to at the same time as the CMS Message File. Below is an excerpt of the file:

```
200504191504;70;Blank;Single Stroke;Single Stroke;;;;;;;0.0;
200504191506;78;1 Page (Normal);Single Stroke;Single Stroke;TRAVEL TIME
   TO;HERCULES  11 MIN;FAIRFIELD 28 MIN;;;;0.0;
200504191506;70;1 Page (Normal);Single Stroke;Single Stroke;TRAVEL TIME TO;
   SFO 22 MIN;SF 4TH ST 12 MIN;;;;0.0;
```

The current name for the file is "d4cms.log" and is located in "/home/bchiou/cms/message/." The name of the log is specified in TOMSClient.props as the MessageLogFile. Please see the System Architecture and Operating Rules document, section "Message Generation Module" for more information on the CMS message format.

Calculation Log

The Calculation Log records the calculation of the route travel times according to the settings specified in the Calculation Properties File. The format is: [DATE/TIME, MASK ID, CMS ID,

DECISION POINT, ROUTE ID, CALCULATION DECISION]. The Calculation Log records when a constraint for a given route is enforced. The following is an excerpt:

```
Wed Mar 01 09:43:08 EST 2006|MA07001|CM070|2|7002|  new_tt: 21 is less
    than min 22, set to min 22
Wed Mar 01 09:43:08 EST 2006|MA07001|CM070|4|7001|  new_tt: 11, org_tt=
    10. delta is less than 2. set it tt to org_tt
Wed Mar 01 09:43:08 EST 2006|MA09802|CM098|4|9801|  new_tt: 14, org_tt=
    14. delta is less than 2. set it tt to org_tt
Wed Mar 01 09:43:08 EST 2006|MA09802|CM098|2|9804|  new_tt: 19 is less
    than min 23, set to min 23
```

In the first line of the excerpt, the minimum travel time constraint is being enforced on route 7002. The second line shows that the minimum delta constraint is being enforced on route 7001. Please see the System Architecture and Operating Rules document for more information on the travel time constraints.

The Calculation Log's current name is "diag" and is located in "/home/bchiou/cms/diagnostic/diag." Its name is specified in TOMSClient.props as the DiagnosticFile. Please see the System Architecture and Operating Rules document, section "Message Guidelines" for more information on the constraints.

MITTENS Log

The MITTENS Log records the events that take place in the MITTENS process according to the level of detail defined in the Logging Framework File.

The MITTENS Log's current name is "MITTENS.log" and is located in "/home/bchiou/cms/TOMSClient."

Console Log

The Console Log informs the user of MITTENS' initialization. It reports the starting time of MITTENS, the connection to the database, the connection to the TOMS server, and the receiving of messages.

The following is an excerpt from the Console Log. It shows MITTENS creating the diagnostic files, the connection to the database and the connection to the TOMS server.

```
Starts at Thu Jun 02 13:22:10 EDT 2005
create diagOut for /home/bchiou/cms/diagnostic/diag
create msgLogOut for /home/bchiou/cms/message/d4cms.log
create criticalOut for /home/bchiou/cms/diagnostic/critical_log
…
getScheduleDef: new config=1
getCurrentMaskDef: mask_id=MA07801,route_id=null
…

Brokers URLs: 67.114.203.202:2506,67.114.203.201:2506
JMS Topic Connection Factory created successfully.
Attempt #1 to establish a JMS topic connection...
Successfully created topic connection on Broker '67.114.203.202:2506'...
Creating links topic subscriber. Topic name - 'tomsLinks'.
```

Creating the diagnostic files

Getting the static data from CMS Database

```
Starting topic connection to broker '67.114.203.202:2506'.
Brokers URLs: 67.114.203.202:2506,67.114.203.201:2506
JMS Queue Connection Factory created successfully.
Attempt #1 to establish a JMS queue connection...
Successfully created queue connection on Broker '67.114.203.202:2506'...
Received the requested links definitions data...
```

Making the connection to the TOMS Server

The console log is reported in “nohup.out.” For more information on “nohup.out” please see the following section, “Managing MITTENS.”

MITTENS Monitor Diagnostics

Monitor Log

The log of MITTENS Monitor, named monitor.log, is a history of MITTENS Monitor’s actions. An example record is shown below,

```
Current Time Stamp: Thu Aug 18 16:19:15 2005
Number of Running MITTENS Processes: 1
SOS Log record: Working | MITTENS is working properly | Wed Aug 18
    14:30:19 PDT 2005
Action Taken: Do nothing
```

Each record in the Monitor Log consists of four lines. In the example above, the first line is the time stamp when the record was taken. Lines two and three record the number of running MITTENS processes and the SOS log at that time. The fourth line records the action that was taken by MITTENS Monitor.

Alert Messages

Currently, only pop-up windows, audible messages, and emails are implemented for disseminating alert messages. Figure 11 depicts a pop-up window generated when Monitor restarts MITTENS since it detects the “Restart Me” log in the SOS log file.

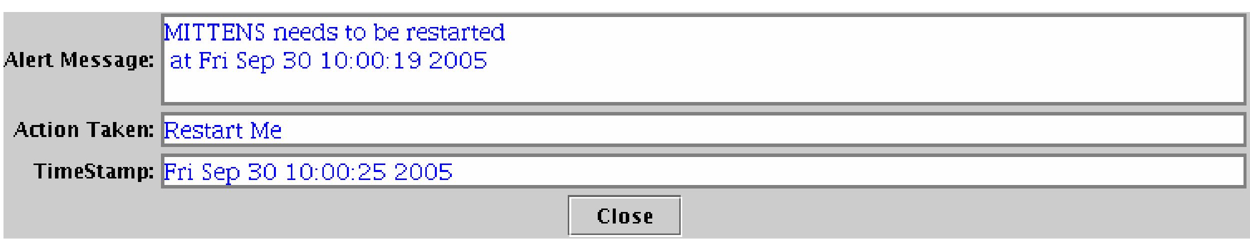


Figure 11 - Pop-Up Window Example

If enabled, an email as follows will be sent to all the addresses with a subject “Alert Message!”:

```
MITTENS needs to be restarted at Fri Sep 30 10:00:19 2005
Action Taken: Restart Me
Time: Fri Sep 30 10:00:25 2005
```

Changing MITTENS' Static Data

MITTENS' static data is held in a MySQL database. Queries into the database can change any of the static data held there. The current name of the database is "cms." Please see the System Architecture and Operating Rules document, section "Data Entities" for more information on static data held in the database.

Managing MITTENS and MITTENS Monitor

As briefly mentioned in the overview section, the preferable way to start MITTENS Monitor and MITTENS is to start the MITTENS Monitor first. The MITTENS Monitor checks any abnormal condition of MITTENS and take appropriate action, including starting MITTENS if it is not running.

Starting MITTENS Manually

In the event that MITTENS must be started without MITTENS Monitor, a shell script can be used to manually start MITTENS.

Shell Script

A shell script is used to start MITTENS. It contains links to the necessary JAVA files needed to start MITTENS. These include JAVA modules that connect to the CMS Database and the TOMS Server. Also, it contains a reference to the Properties File. This is located in the last line of the file:

```
$JAVA_CMD -classpath "${TOMS_CLIENT_CLASSPATH}" client.TOMSClient
   ${TOMS_HOME}/TOMSClient.props
```

In the example above, the Properties File is "TOMSClient.props." If the Properties File's name is changed, this line must match that change.

The current name for the shell script is "runit" and is located in "home/bchiou/cms/TOMSClient."

Running the Shell Script

To start running MITTENS, the present working directory must be: home/bchiou/cms/TOMSClient. type: "nohup runit & <enter>." "nohup" is a UNIX command that will continue to run MITTENS even after the user has logged out. nohup also catches the console log in "nohup.out."

Stopping MITTENS

The MITTENS process is stopped by using the "kill" function in UNIX. Enter the following commands

1. `ps –ef | grep runit <enter>`

A similar table will be reported:

```
bchiou   12234 12130  0 17:24 pts/4    00:00:00 /bin/sh ./runit
```

```
bchiou   12261 12130  0 17:48 pts/4    00:00:00 grep runit
```

```
2. kill -9 12234 <enter>
```
The number, ‘12234,’ is the process ID of the ‘runit’ script.

```
3. ps –ef | grep TOMS <enter>
```
A similar table will be reported:
```
bchiou 20753 12234 0 Jul08 ?      00:00:05 XXXXXX/TOMSClient.props
bchiou 30445 30171 0 13:11 pts1 00:00:00 grep TOMS
```
Where XXXXXX is a list of JAVA files.

```
4. kill -9 20753 <enter>
```

Starting MITTENS Monitor

Shell Script

Similarly as starting MITTENS, a shell script is used to start MITTENS Monitor. It contains links to the necessary JAVA files needed to start Monitor. The current name for the shell script is “runMonitor” and is located in “home/bchiou/cms/Monitor.”

Running the Shell Script

To start running MITTENS Monitor, the present working directory must be: home/bchiou/cms/Monitor. type: “nohup runMonitor & <enter>.” As the script for staring MITTENS, “nohup” sets the option to continue to run MITTENS Monitor even after the user has logged out.

Stopping MITTENS Monitor

Similarly as for stopping MITTENS, MITTENS Monitor processes can be stopped by using the “kill” function in UNIX. Enter the following commands

```
1. ps –ef | grep runMonitor <enter>
```
A similar table will be reported:
```
bchiou      4094  3935  0 11:15 pts0     00:00:00 /bin/sh ./runMonitor
bchiou      4003  3935  0 11:16 pts0     00:00:00 grep runMonitor
```

```
2. kill -9 4094 <enter>
```
The number, ‘4094,’ is the process ID of the ‘runMonitor’ script.

```
3. ps –ef | grep MITTENSMonitor <enter>
```
A similar table will be reported:
```
bchiou 4103  4094  0 11:15 pts0  00:00:00 XXXXXX/Monitor MITTENSMonitor monitor.prop
bchiou 4094  3935  0 11:20 pts0  00:00:00 grep MITTENSMonitor
```

Where XXXXXX is a list of JAVA files.

```
4. kill -9 4103 <enter>
```

Using the Diagnostics

The diagnostic files may be used to ensure that the system is running correctly or to diagnose a problem. For example, looking at the CMS Message History Log will show what destinations and their associated travel times are being displayed. The Travel Time Constraint Log provides an additional check on the travel times reported in the history log. As noted in the “Console Log” section, the console log reports if MITTENS has established a connection to the TOMS server and to the database and also if the route travel times are being created correctly. The MITTENS Monitor log can be used to check how many times MITTENS has been restarted and for what reason. Furthermore, the Alert Messages provide information regarding database errors such as the database being full.

If blank messages are being produced, one can consult the Console Log and the Critical Event Log to determine if MITTENS has lost its connection to the TOMS server. The Travel Time Constraint Log will also show if the route travel times are being calculated correctly. More information on blank messages is provided in the following section.

Blank Messages

If MITTENS produces blank messages, the diagnostic files can be used to determine the problem. The following steps describe a typical procedure when blank messages are produced. Please see the System Architecture and Operating Rules document, section “Blank Messages” for more information on why blank messages are produced.

1. Check the ‘`runit`’ process by typing: ‘`ps –ef | grep runit <enter>`’
    a. The fifth field of the first line will indicate when the process was started.
    b. Type ‘`date <enter>`’
    c. If the difference between the current time and the process start time is less than 10 minutes, then MITTENS may still be acquiring the link travel times from 511/Travinfo
    d. Wait until at least 10 minutes has elapsed and check the CMS Message History to see if MITTENS is producing CMS TT messages.
2. Check the traffic conditions
    a. If the travel times are above a maximum travel time, then blank messages will be produced.
    b. Check the Travel Time Constraint Log to see if the route travel times are greater than the maximum travel time.
3. Open the Critical Event log to determine if MITTENS encountered a critical problem.
    a. If the log shows that MITTENS has connection problems with the CMS Database or with the TOMS server, then MITTENS may need to be restarted.
    b. Using the directions above, stop MITTENS.
    c. Start MITTENS.
    d. If a connection with the TOMS server cannot be made even after restarting MITTENS, the problem may be with the TOMS server or with the CMS Database.
4. Open the CMS Message History log to see how long and how frequently blank messages are produced.

a. If blank messages are not produced by MITTENS, but bla
b. nk messages are still being displayed, SOCCS may be unable to retrieve the file from the web server.
c. If blank messages are being produced and the previous steps have not fixed the problem, try restarting MITTENS

Responding to Alert Messages

If the user receives an Alert Message, the correct response depends on the content of the message. If the Alert Message is that MITTENS has been restarted, no action needs to be taken. If the Alert Message is that there is a database error the user must use the MITTENS Monitor log to see what caused the database error and to respond accordingly.

Managing Disk Space

After MITTENS is running for a long period of time, the disk space used by MITTENS and MITTENS Monitor may overflow, and MITTENS Monitor and MITTENS have to be stopped to free disk space. The potential causes of running out disk space are as follows:

- Data base space for the link travel times. The link travel times received from the TOMS server can be saved to the database by setting the value of the tag id, TOMS.Link.Traffic.Save, in TOMSClient.props to "Yes". MITTENS will save all the link travel time it receives from the TOMS server in the CMS database, and it may run out of disk space over time. If this happens, MITTENS Monitor and MITTENS have to be stopped, the records in database table TOMS_LINK_TRAFFIC need to be removed before MITTENS Monitor can be started again. In future versions, an automated way of dumping the link travel times can free the administrator of this task. This can be implemented as either an internal method or external system that periodically checks the size of the TOMS_LINK_TRAFFIC table and takes action accordingly.

  If there is no needs to save the link travel time, MITTENS can be instructed not to save link travel times by setting the value of the tag to "No" in the TOMSClient.props file.

- Log files especially the following log files:
  - Message file d4cms.log in /home/bchiou/cms/message directory
  - Monitor.log in /home/bchiou/cms/TOMSClient directory
  - The log file diag in /home/bchiou/cms/diagnostic directory
  - Currently, only MITTENS.log's file size is automatically restricted. Future versions will automate the restriction of the file sizes possibly by using the same rolling method that is used for MITTENS.log.

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Slide Show

January 2006

Prepared by:

JD Margulici
Senior Development Engineer, CCIT

For:

California Department of Transportation
Division of Traffic Operations

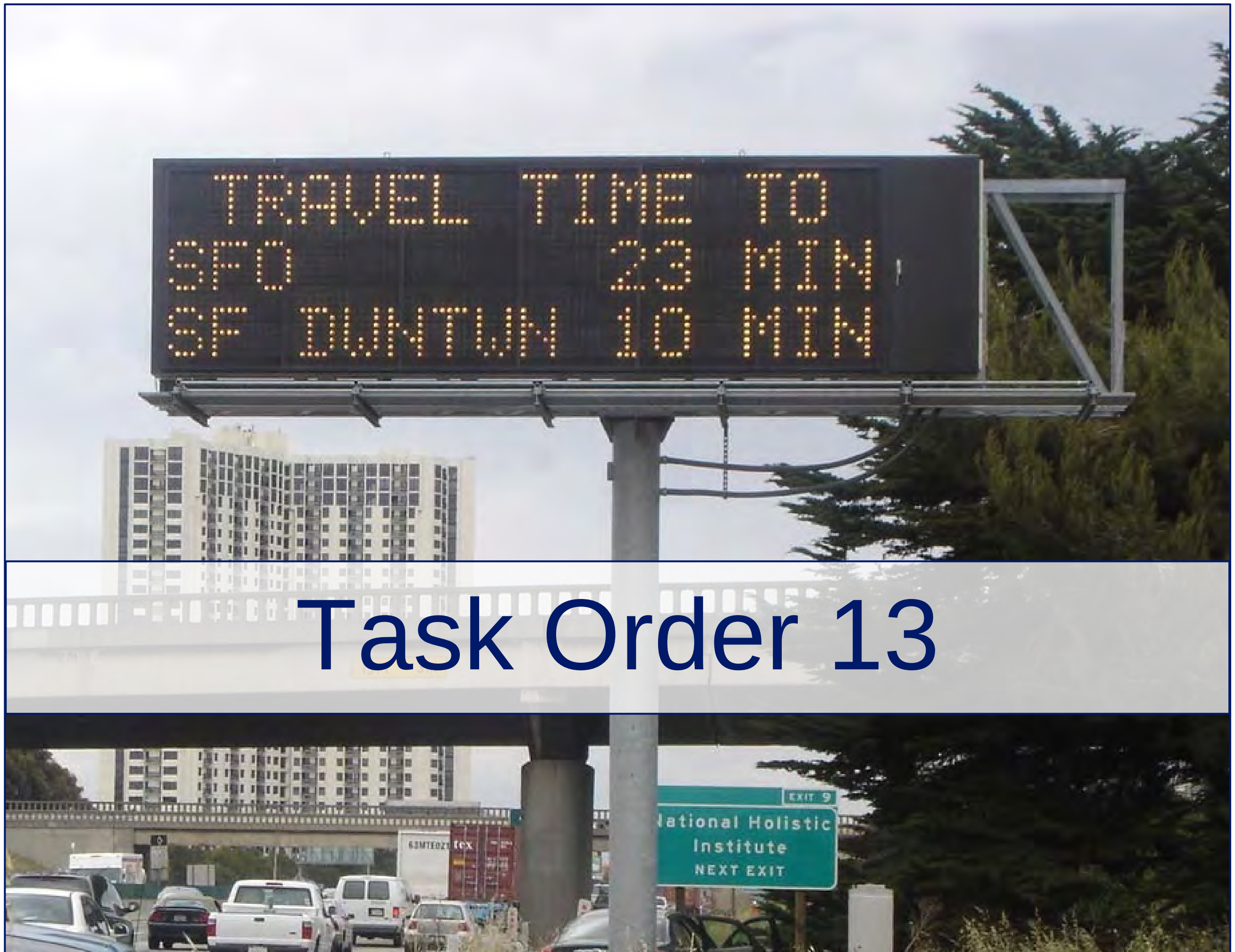
University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

California Center for Innovative Transportation

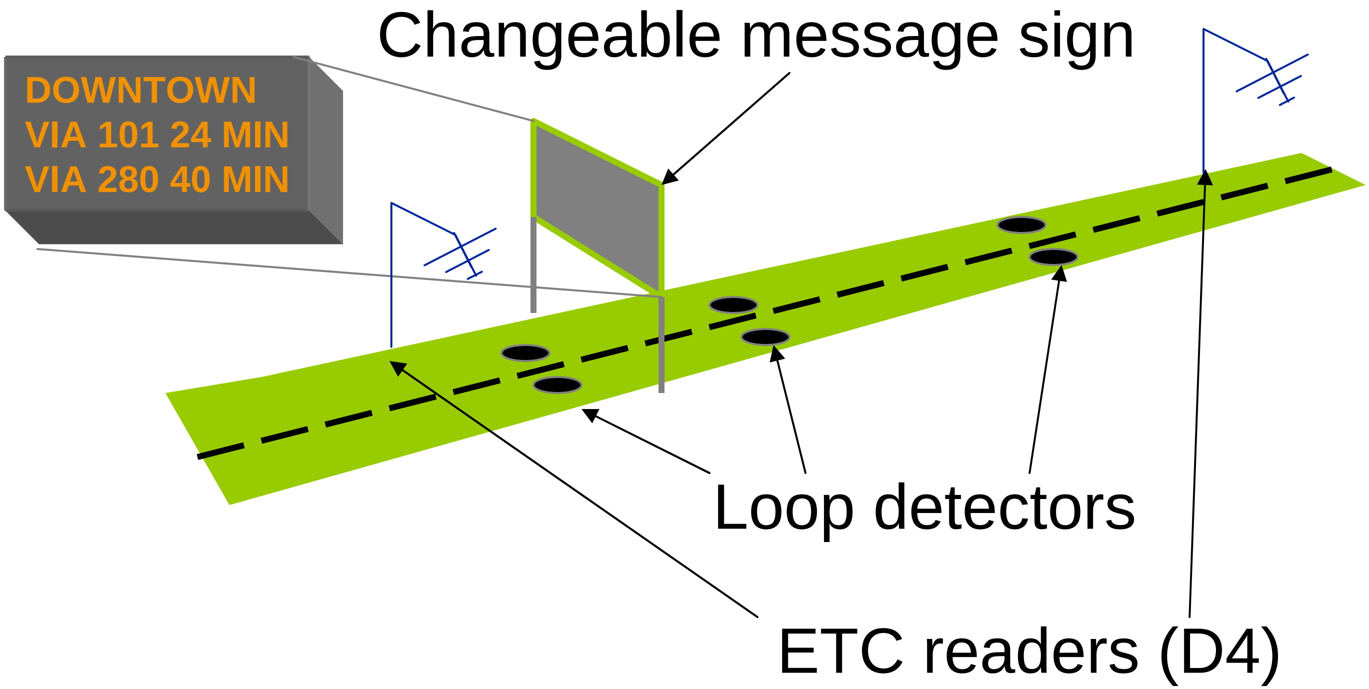
Task Order 13



Project overview

- Develop automated system for Caltrans
- 511/Travinfo is the initial data source
- CMS interface already exists (SOCCS or ATMS)

Project overview (2)



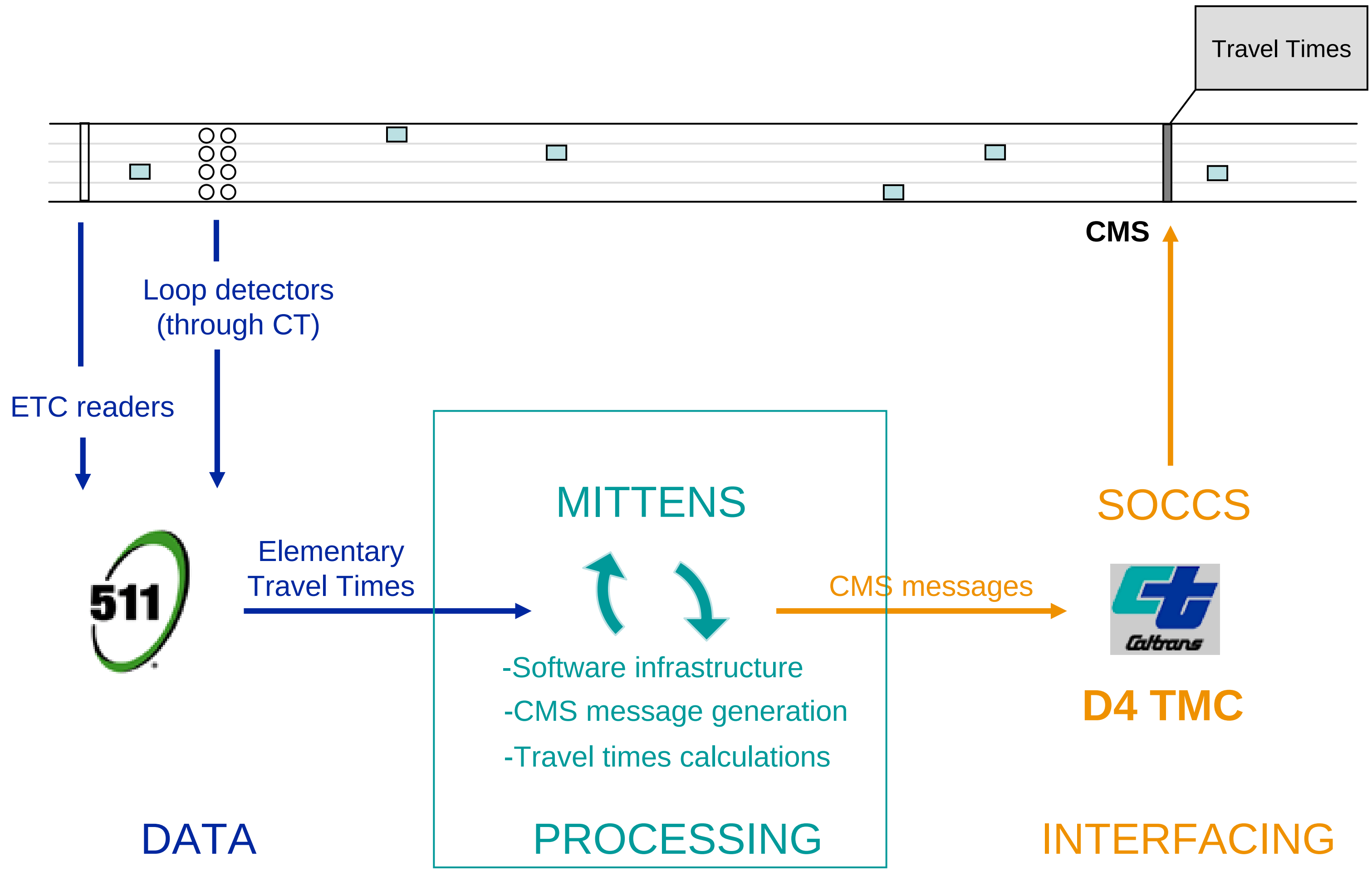
Specific project tasks

- Architect automated process
  - Build data structure for routes, display…
- Coordination between stakeholders
  - Caltrans D4, HDQ, MTC
- Implement and interface system
  - Retrieve data and generate messages
  - Messaging Infrastructure for Travel Times Estimates to a Network of Signs (MITTENS)
- Evaluate system
  - Commuter survey and traffic impact study
- Hand-off system to practitioners
  - Package, document, train

Full Deployment "Vision"

- 80-or so CMS active in the system
- Caltrans D4 fully autonomous
  - System administration and maintenance
  - Programming routes and schedules
- TMC operators 'in the loop'
  - Fully equipped GUI to control display
- Deployable in other districts
- And of course, HAPPY COMMUTERS

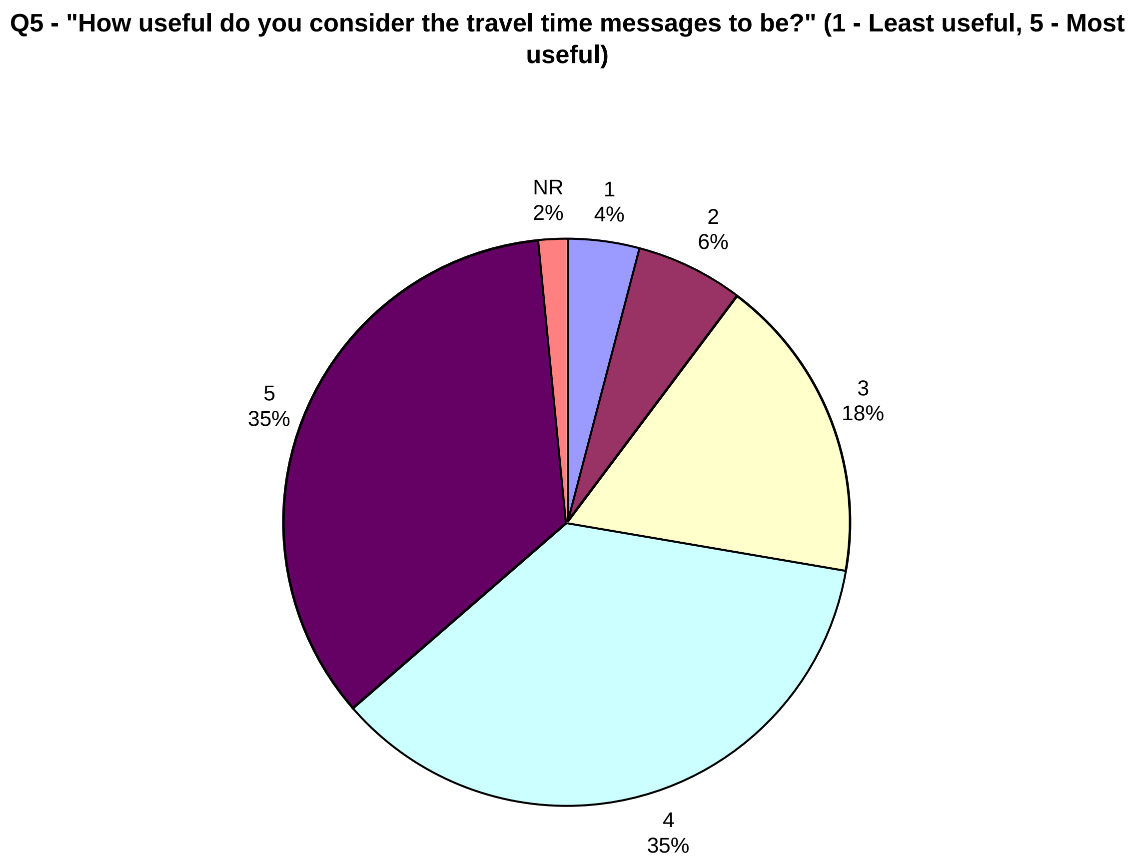
Project architecture (D4)



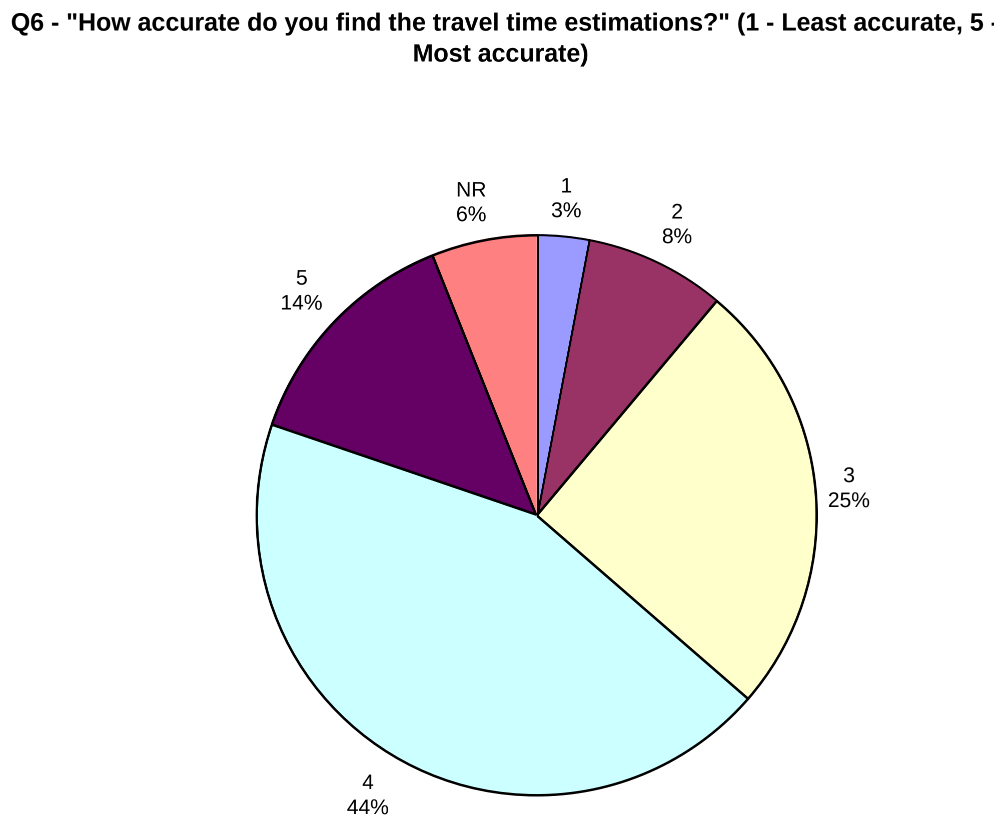
Project rollout

- Jan – Apr 05: Development & Testing
- May 05: Pilot roll-out (2 signs)
- Summer 05: Satisfaction survey
- Nov 05: System expansion (20 signs)
- Next steps:
  - GUI development (operator & administrator)
  - System handoff (Fall 06)
  - Complete expansion
  - Expand to other districts (D3, Sacramento…)

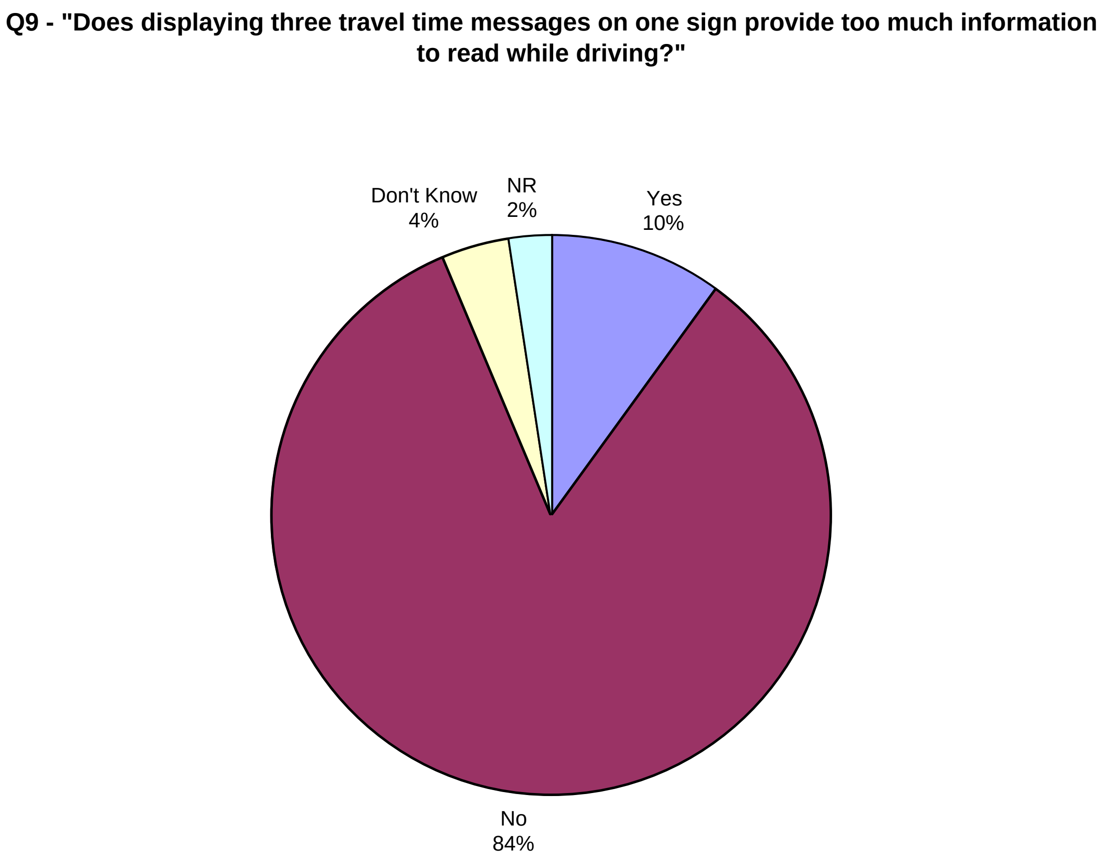
Survey results (1)



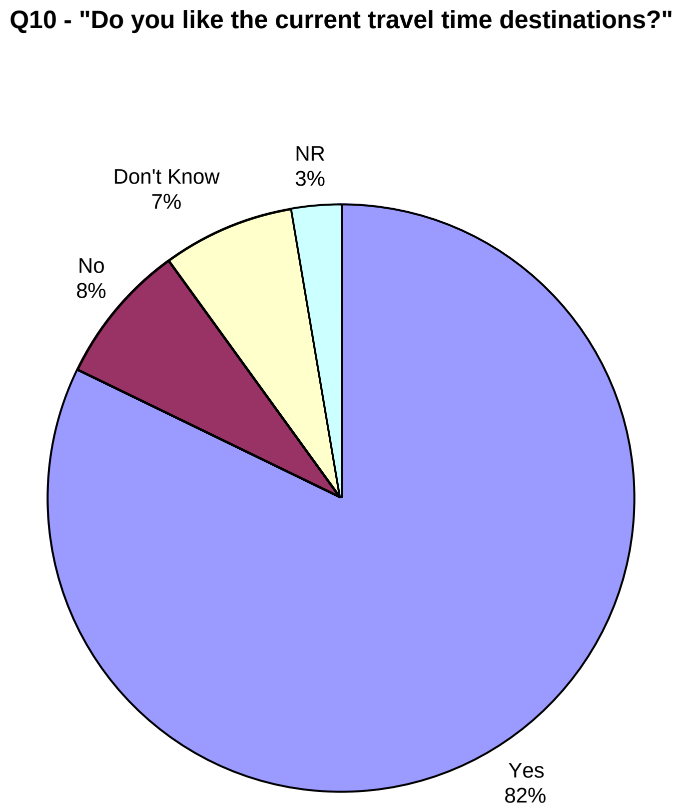
Survey results (2)



Survey results (3)



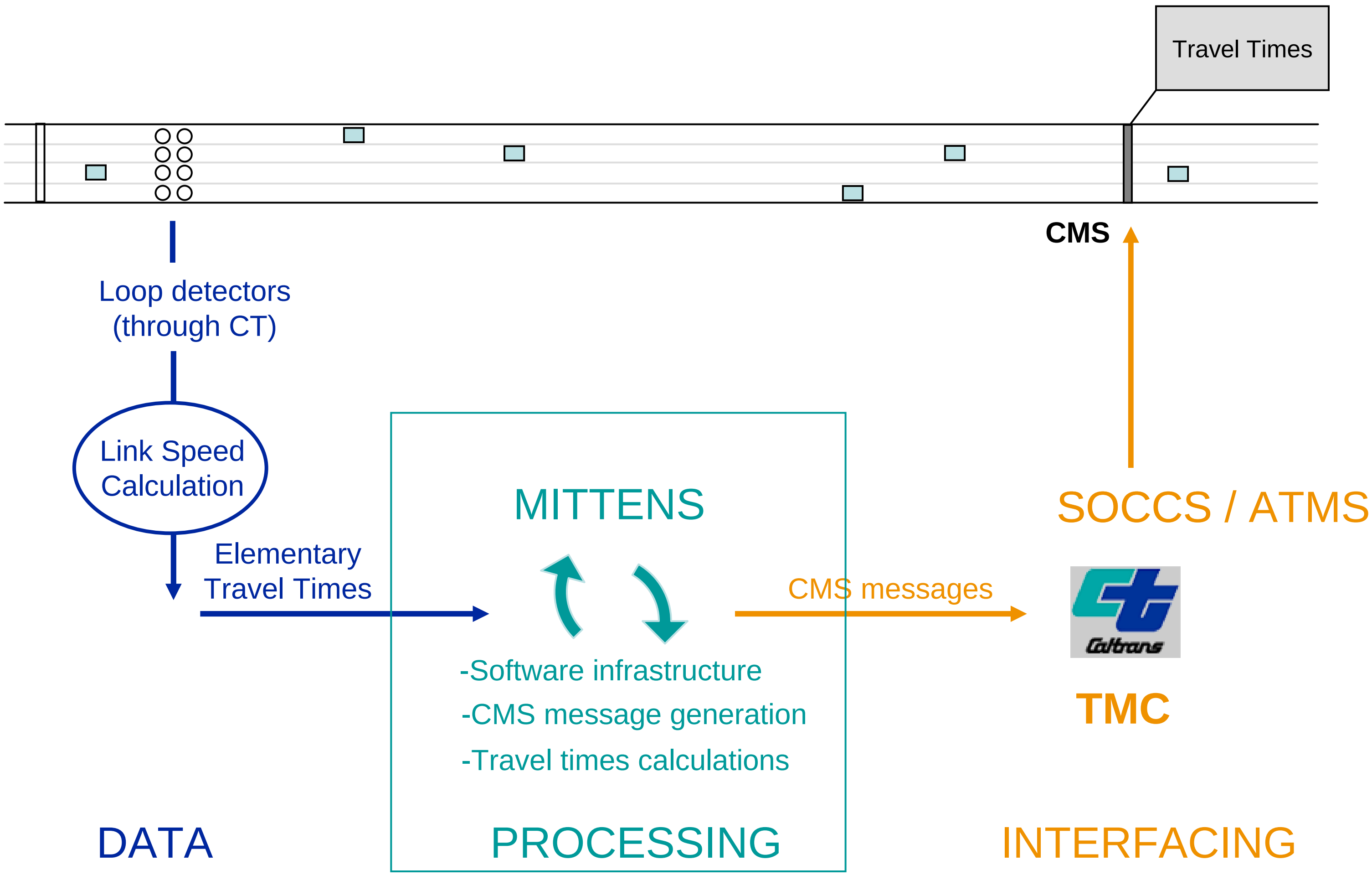
Survey results (4)



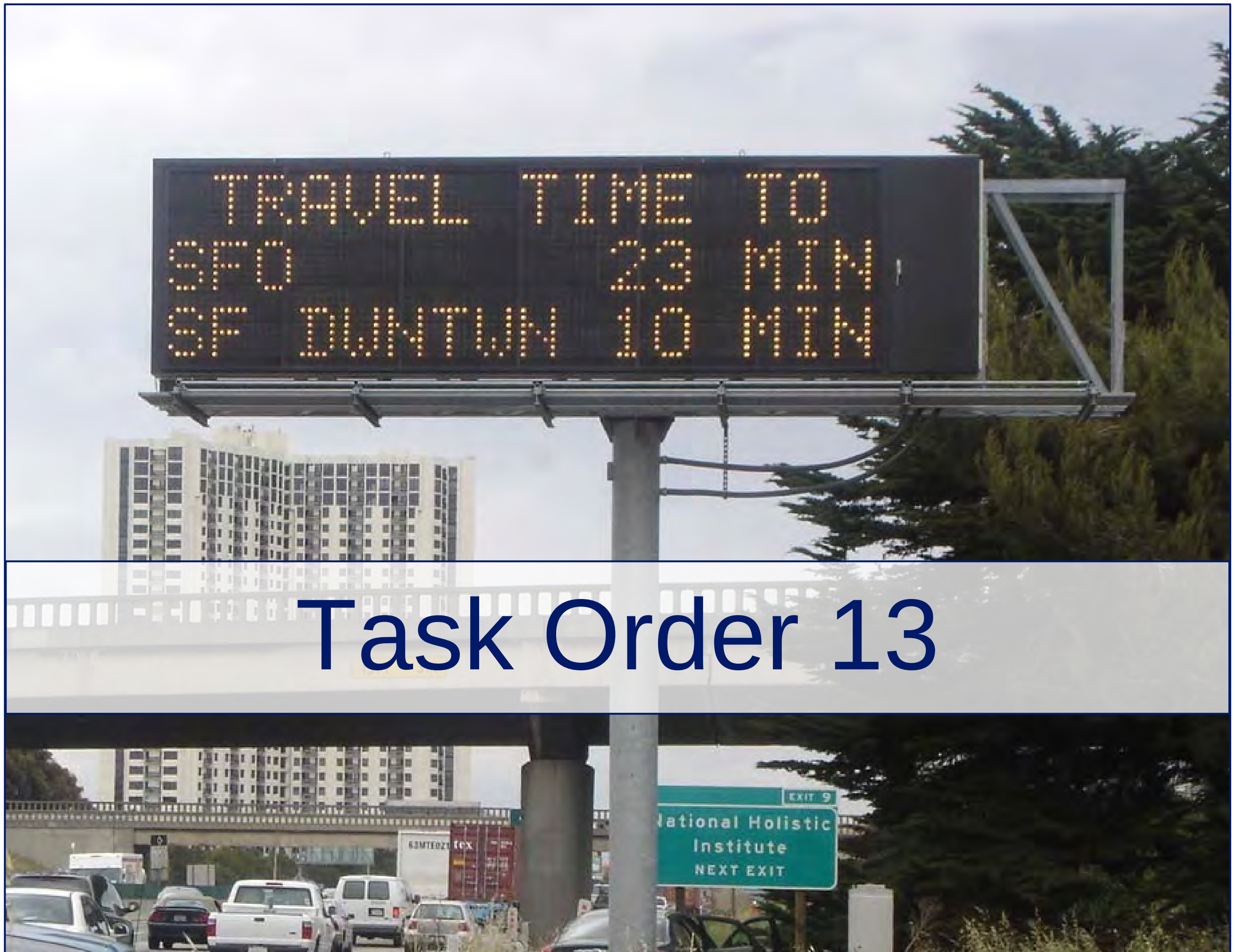
Product deployment

- D3 planned as part of CCIT TO 1009
- Other districts rollout: $50k-$100k
- Total cost of R&D: ~ $250k
- Added features: Transit / Parking info

Project architecture (Other Districts)



California Center for Innovative Transportation



Task Order 13

California Center for Innovative Transportation

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Project Narrative

January 2006

<u>Prepared by:</u>

JD Margulici
Senior Development Engineer, CCIT

<u>For:</u>

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

DISPLAYING TRAVEL TIMES ON CHANGEABLE MESSAGE SIGNS IN THE BAY AREA

Since May 2nd, 2005, motorists driving by Berkeley on Interstate 80 can read their estimated trip time to San Francisco on an overhead changeable message sign (CMS). This sign was one of the first in the San Francisco Bay Area to broadcast travel times on a continuous basis, with updates every minute. As of January, 2006, 20 signs are enabled, and further deployment is underway.

Several years ago, the Metropolitan Transportation Commission (MTC), which is the regional planning agency for the San Francisco Bay Area, embarked on a program to deliver 511 service to its constituents. This program has resulted in one of the most advanced and widely used regional traveler information system in the nation. One of its features is to provide travel time estimates between important nodes of the freeway network.

The California Department of Transportation (Caltrans) owns and operates about one hundred CMS in the San Francisco Region from its Traffic Management Center (TMC). Its local district, District 4, has long been willing to leverage this investment to provide more useful information to motorists. The solution came from a novel partnership piloted by the California Center for Innovative Transportation (CCIT), and involving Caltrans' Division of Research and Innovation (DRI), Caltrans District 4, and MTC.

A part of the Institute of Transportation Studies at the University of California, Berkeley, CCIT is a unique organization whose primary mission is to facilitate and implement the operational deployment of transportation research and innovation. The center is established as a bridge between the academic world, transportation public agencies and the transportation industry. Many projects are in the area of Intelligent Transportation Systems (ITS), for which CCIT maintains system design and development capabilities.

As a part of the University, CCIT has direct access to the academic and research communities. But what is more, as a non-profit, CCIT holds a distinctive position to break institutional barriers between public agencies and can fill a crucially needed role where the private sector sees too much risk and too little upside. This CMS project sets a good example of that role.

Essentially, the project consisted in developing the missing link between MTC's Travinfo system, which provides data for 511, and the District's TMC. In order to manually control the display on the signs, TMC operators use SOCCS, a piece of software developed by Caltrans' Division of Research and Innovation. CCIT integrated Travinfo and SOCCS by developing MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). MITTENS is a stand-alone software system designed to host a description of a freeway network, let operators configure commuter routes and sign displays, process link travel time information, and generate messages. DRI updated SOCCS in order to manage message priorities: while travel time messages from MITTENS are displayed by default, they are overridden by operator-input messages.

MITTENS relies on MTC's Travinfo for travel time predictions. These predictions are based on real-time traffic data collected by toll tag readers (FasTrak program) and by Caltrans' embedded loop traffic detectors. Predictions are updated every minute and are reported on the signs accordingly.

Real time traffic information on changeable message signs (CMS) has gained popularity in urban areas where congestion and incidents frequently affect the reliability of trip times. Signs have been used to broadcast information about downstream delays, incidents and travel times in a corridor. Under normal conditions, trip time is the most practical information that commuters can use to assess traffic, alleviate their stress, and ultimately make decisions on their route. Being aware of driving times to popular destinations, travelers may be able to choose an alternate route early if it appears that their intended route is too congested. In addition, this project takes advantage of the existing signs installed throughout the Bay Area and uses them for an innovative purpose that is widely understood by the driving public, improving the visibility of Caltrans' commitment to Intelligent Transportation Systems.

Changeable Message Sign on Interstate 80 in Berkeley, CA - May 2nd, 2005

Part of the project was devoted to evaluating the response from motorists. CCIT designed and distributed a survey that received close to 1,000 responses. This is another example where all the partners came together: CCIT distributed the survey at casual carpool pick-up locations, Caltrans used its Freeway Service Patrol as a distribution channel, and MTC provided amazing support by hosting an electronic version of the survey on its web site and advertising it. Throughout the survey, respondents showed steady support for the project. For instance, on a scale of 1 to 5 (5 being the highest), 70% of the respondents answered with 4 or 5 when asked "How useful do you consider the travel time messages to be?" Likewise, 82% of respondents replied that they like the destinations posted on the signs. When asked about any difficulty reading the signs, 75% responded with a 1 or 2 on a 1 to 5 scale, 1 being least difficult. In addition, motorists expressed their satisfaction by writing in comments on the survey. One respondent commented, "The signs are useful. The more info we have the better we can adjust our travel patterns." Another mentioned that, "knowing the estimated time even if it's a LONG time reduces driver anxiety dramatically."

One of the great achievements of the project team was the ability to deliver the first significant system expansion just in time for the 12th World Congress on Intelligent Transportation Systems in the San Francisco Bay Area. This required intense work from the District team, Caltrans Headquarters, MTC and CCIT alike. Despite many other pressing priorities imposed by the Congress, each organization devoted the time necessary to a successful implementation. As a result, the project was featured in the December 15th, 2005, edition of Inside ITS.

In the next phase of the project, which will take place in the second half of 2006, CCIT will deliver a complete package that lets TMC engineers and operators configure and control the system via Graphical User Interfaces (GUIs). The GUIs will be integrated with existing TMC tools to preserve harmony. Longer term, more integration and partnerships may be on the way as Caltrans District 4 is envisioning using the CMS to display transit parking information, based on the successful demonstration of Smart Parking in 2004-2005.

Project Partners

Caltrans	UC Berkeley	511	MTC

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Meeting Minutes

January 2005 – December 2005

- January 27, 2005 (3 p.)
- February 4, 2005 (5 p.)
- February 25, 2005 (4 p.)
- March 18, 2005 (4 p.)
- August 24, 2005 (3 p.)
- October 12, 2005 (2 p.)
- October 28, 2005 (3 p.)
- December 7, 2005 (5 p.)

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – January, 27th 2005

Participants

Sean Campbell, Caltrans HDQ
Bensen Chiou, CCIT
Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
JD Margulci, CCIT
James Richardson, D4

Documents

CCIT-SOCCS interface v2
Sample output data from CCIT's program

Agenda

- Progress report from CCIT
  - Development

    CCIT's program near completion. Currently produces messages in the format defined in agreement with Sean Campbell. Last pieces include a validity check of the travel times to insure that no exuberant value can slip through.
  - Sample data

    Format agreed upon. CCIT to replace the CMS designation by an integer ('CMS065' becomes '65') in the text string. Default value for the flashing time should be '0.0'
- Data interface discussion
  - Data transfer protocol
  - Security

    Data transfer protocol and security were discussed at length. Constraints put forward by D4 are:

    - The message formatting and any static data that can be displayed on the signs need to be hosted on D4's own secured LAN. This will avoid malicious use of the program to display inappropriate content on the sign by university personnel or students.

- D4's LAN does not allow internet access.

Therefore the architecture of the project from a hardware and networking perspective needs to be changed to accommodate the constraints.

The proposed plan is to set up a server at D4's TMC to be operated by CCIT. The server will host the static data and the program. This server will be accessed by SOCCS over D4's intranet for retrieval of the messages' content.

The remaining questions are:

- How to feed the server with the travinfo data?
- How to provide CCIT remote access to the server?

Action item: Bensen Chiou to coordinate with Hector Garcia to assess options with a competent IT staff at D4.

CCIT also contacted BT-Systems, the host of the PeMS database, to inquire about their connection with TMC. It turns out the connection is a point to point line. However, PeMS server itself is connected to the internet and numerous students have privileged access to it. Moreover, BT-S seems reluctant to lend their line for additional data transfers such as the travel time application.

  - Data format

See above.

- Testing and validation
  - Technical testing
  - Functional validation
  - Schedules

Current schedule is to start displaying travel times on two CMS by May, 1. By April, 1, CCIT's program and SOCCS should be connected, which leaves one month for QA of the completed system.

CCIT intends to complete its developments by March, 1. From March, 1 through March, 31, CCIT will conduct a functional validation of the program by comparing the output travel times on the selected routes with other available data such as: individual tag reader data, PeMS data (loop detectors), and probe vehicles. An evaluation plan will be produced to that effect.

- Usability and Deployment
  - Roadmap

    The current plan is to display travel times on two selected CMS by May, 1, until June, 30. Further deployment will be part of a future proposal.

    The two selected CMS locations are on I-80 Westbound @ Ashby (CMS070) and on I-80 Eastbound @ University (CMS078). The destinations for which to display travel times still need to be determined.
  - Functional requirements

    Additionally, CCIT needs to know what range to impose to the travel times to be considered reasonable. A minimum and maximum percentage will be applied to the default travel time which is calculated using the posted speed on the route (for example, 90% and 1000%). Any travel time outside this range will be considered incorrect.

    Moreover, in the event where not all the data required to calculate the travel time on a route is available, the default time (as explained above) will be used on a portion of the route. A threshold should be set to determine what portion of the route needs to be fed with current data for the travel time to be considered accurate enough (example: 80% of the route (distance-wise) should be covered with current data, the remaining segments can be assigned the default value).

    Finally, what should the program do when no good data is available (either travel time out of range or not enough segment data to calculate)? It can either display nothing (meaning either leave a blank value in front of the destination on the sign or erase the destination from the sign all together) or display the default travel time value (not recommended).

    Action item: Alan Chow to give CCIT his inputs on this. Also, what destinations should CCIT display on the signs?

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting report – February, 11th 2005

Participants

Sean Campbell, Caltrans HDQ
Bensen Chiou, CCIT
Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
Ben McKeever, MTC
Carol Kuester, MTC
JD Margulci, CCIT
Charles Price, Caltrans D4
Kane Wong, Caltrans D4

Documents

Meeting Report 2005_01_27.doc
CMS TT - Architecture and Security.ppt

Agenda

- Brief presentation of the project to MTC guests

  The project uses Travinfo link travel times to calculate trip time estimates on a set of pre-determined routes originating from the CMS locations. The methodology is the same as the one used by 511 to calculate trip time estimates. Therefore everyone agreed that there should be little or no discrepancy between the trip time estimates read on the signs and trip estimates retrieved from 511 for closely matching routes. However, this will be verified during the validation period of the project.

  MTC reiterated their interest in the successful completion of the project and mentioned that travel times on CMS are regarded as an important feature in the Bay Area's transportation system by MTC director.

  Also, CCIT and MTC agreed that the data used by the application being developed is publicly available and doesn't pose privacy concerns.

- Architecture and security

- Updates from last meeting

  The two main security constraints are: (1) that the message generation module (the piece of software that generates the text strings that are actually displayed on the signs) is hosted by a machine that is part of the district's network; (2) no or limited connectivity to the internet is allowed from the district's network.

  In order to get data to the district, 3 communication channels are being considered: the PeMS private line from the district, the Caltrans reverse feed from Travinfo, and a limited internet connection to TOMS. In addition, a Virtual Private Network is likely to be needed between the application server and CCIT.

  CCIT also estimated the amount of data that needs to be transferred through the communication channels.

- Options assessment

  The three options presented seemed to receive the agreement from all parties. They need to be submitted to Caltrans' IT group so that a final path can be adopted.

  In the case of alternative 3, using the Caltrans reverse feed, MTC suggested that a customized client applet can be developed to suits the application's needs. Consequently, alternative 3 offers a lot of flexibility but is also the one that will require the most additional development since CCIT will have to modify the way it retrieves data too.

  Action item: Hector Garcia to coordinate with IT to obtain go ahead on one of the options. Also inquire about Oracle licensing agreement statewide.

  Action item: JD Margulici to pick up computer at the district for configuration by CCIT staff.

  Action item: CCIT to coordinate with MTC's contractor Tom Saul to obtain ampler information on the Caltrans reverse feed.

- Validation plan
  - Overview

Starting in March, CCIT will assess the quality and the consistency of the trip time estimates calculated for the selected routes to be displayed. Specifically, CCIT will study availability, validity and accuracy. Availability and validity will be checked systematically through a set of criteria throughout the study period. Accuracy will be studied through samples.

Action item: CCIT to prepare a validation plan by the next meeting.

- Coordination with Travinfo

  MTC runs an accuracy check program thanks to a float of GPS-equipped probe vehicles. The probe runs are automatically processed by computer software that allows straightforward comparisons between actual trip times and 511 estimates. MTC offered to make some of those runs available to CCIT for their validation efforts.

  Moreover, all parties agreed that a key requirement of the project is that information remains consistent between 511 and the signs. Therefore the validation plan should make provisions for systematic comparisons of the values from both systems on the selected routes. This implies that the 511 trip time estimates for the selected routes be recorded throughout the study period.

  Action item: JD Margulici to coordinate with Ben McKeever to set up some probe vehicle runs.

  Action item: CCIT to coordinate with MTC and MTC's contractor to investigate the possibility to receive logs of the 511 estimates for designated routes.

- Functional requirements and operational deployment

  Sean Campbell raised the issue of communication costs between the TMC and the signs. Because of those costs, message posting should be kept to the minimum necessary to satisfy the functional needs. In particular, even though travel times are computed every minute, it is not necessary to post a message unless a change has been recorded. Moreover, because the values are rounded to the closest integer in minutes, unnecessary ‘flip-flopping’ may occur (15 to 16 to 15 to 16 and so forth). Therefore a smoothing filter may be applied to avoid this.

Consequently, the message generation module will be modified so that only those messages that need to be posted are retrieved by SOCCS.

Action item: CCIT to coordinate with Sean Campbell to make the necessary modifications to the message generation module.

Action item: D4 to specify the rules for posting a new message.

⇒ CCIT’s proposal: a new message is sent to a sign when the travel time value of any one of the routes being displayed is off by 2 minutes compared to the calculated value, or is consistently off by 1 minute over 3 consecutive 1-minute rounds, or becomes unavailable during 10 1-minute rounds, or becomes available if it was previously unavailable. Additionally, a new message is sent to each sign every 15 minutes, no matter what the current message is.

Back to the last meeting, CCIT still needs to know what range to impose to the travel times to be considered reasonable. A minimum and maximum percentage will be applied to the default travel time which is calculated using the posted speed on the route (for example, 90% and 1000%). Any travel time outside this range will be considered invalid.

Moreover, in the event where not all the data required to calculate the travel time on a route is available, the default time (as explained above) will be used on a portion of the route. A threshold should be set to determine what portion of the route needs to be fed with current data for the travel time to be considered accurate enough (example: 80% of the route (distance-wise) should be covered with current data, the remaining segments can be assigned the default value).

Finally, what should the program do when no good data is available (either travel time out of range or not enough segment data to calculate)? It can either leave a blank value in front of the destination on the sign or erase the destination from the sign all together.

Action item: Alan Chow to give CCIT his inputs on this. Also, what destinations should CCIT display on the 2 signs selected for phase 1?

CCIT should also compare the way it treats link travel times with what is done by 511. When all links on a route have a current, valid estimate, the calculation is strictly the same. However, the criteria that invalidate link travel time values or the way missing data is corrected may vary. Moreover, 511 restricts the travel time values to what is achieved at the posted speed limit even if the measured trip times are faster. CCIT’s application should use similar if not identical rules.
Action item: CCIT to coordinate with MTC and its contractor to obtain 511’s algorithm.

Charles Price also brought up a usability question. In the case where numerous routes have potential interest for a given CMS, how does the system let the operator select which ones to display? Although this feature won’t be implemented in the first phase of the project ending 6/30/2005, provisions need to be made in the software infrastructure to allow its deployment in a later phase. CCIT’s design already has provisions for this feature. The specific design can be presented by CCIT in an upcoming meeting.

- Next meetings

  The next work meeting is scheduled for Feb. 25th, 10 am at District 4.
  Additionally, CCIT would like to participate in a higher level meeting involving Caltrans headquarters during the month of March. This will be an opportunity to give a progress report to our sponsors at headquarters. Also, such questions such as deployment and possible media coverage could be addressed.
  Currently, a videoconference internal to Caltrans is scheduled on March 2nd.
  Action item: Alan Chow to inform CCIT of the opportunity to either participate in the March 2nd videoconference, or call a separate meeting.

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – February, 25th 2005

Participants

Sean Campbell, Caltrans HDQ
Bensen Chiou, CCIT
Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
JD Margulci, CCIT
Kane Wong, Caltrans D4

Documents

Meeting Report 2005_02_11.doc
CMS TT - Architecture and Security.ppt
D4 CMS TRAVEL TIME – CCIT Comments.doc
Travel Times validation plan.doc

Agenda

- Architecture and security
    - Selection of the preferred architecture

      The preferred architecture builds upon the option 3 identified in the work document on security and architecture. The whole of the application developed by CCIT will be hosted on one server on the district's LAN. This server will receive data from the Travinfo system over a secure point to point line already in existence between the Travinfo LAN and the district's LAN. The only modification to the option 3 in the work document is that a replica of the TOMS messaging infrastructure will be used in place of the Caltrans Reverse Data Feed. This means that CCIT will be able to simply use a TOMS client on the application server, which is consistent with what has been developed so far. This solution requires MTC's contractor, PB Faradyne, to direct the TOMS feed to the secure line.

      Action item: CCIT to coordinate with PB Faradyne and Hector Garcia to set up the TOMS feed.

- Additional considerations

  CCIT is currently configuring the application server. The application server will be delivered to the district by March 15th. The district will provide an IP address and physical connection on its LAN for the application server. No back-up will be implemented for the application. In case of a hard failure, the travel time estimates will simply not be available to display. However, to protect against data loss, an image of the server should be saved. Since operational data is going to be stored on the server, a new image should be saved at regular intervals.

  Action item: CCIT to coordinate with Hector Garcia to determine most appropriate procedure and software utility.

- Functional requirements
  - Validation of the functional requirements

    Functional requirements are now almost complete for the first phase. A few points were discussed:

    - A-1: the format of the time stamp in the message records need to be specified.

    Action item: Bensen Chiou to coordinate with Sean Campbell to determine time stamp format.

    - A-3: the message server will refresh a unique master file that will contain the latest message for each CMS. The message server will restrict the posting of new messages based on the 'delta' rule specified in the work document. SOCCS will parse the file at regular time intervals. The refresh time has yet to be determined but could be as low as 1 minute for the first phase and will be configurable. Each time period, SOCCS will parse the master file and compare each message with what is already displayed on the corresponding sign. Only in the case where the two differ will it post the new message to the sign.
    - Sean Campbell issued a warning on the communication costs and the latency time involved in posting messages to multiple signs. Both can be addressed by switching from dial-up connections to GPRS modems.

This will be done in phase 1 for the two signs in the pilot project. Even with GPRS, some latency will remain, though well under a minute. With Dial-up connections, refreshing a 100 signs throughout the district will take several minutes during which SOCCS will place the CMS in a queue until they can access the modem. It is to be noticed that SOCCS will check the master file on the message server for the latest message before communicating to a CMS.

- Minimum travel time value, maximum travel time value and delta: these fields will be editable for each route. A default value will be calculated when a new route is created. The default minimum travel time value will be calculated by dividing the route length by an average posted speed of 60 mph. When the estimated travel time is less than the minimum travel time, the minimum will be posted on the sign. The default delta will be 2 min. The default maximum travel time value will be specified by the district at a later time. The district will also indicate what the program should do when the maximum travel time value for a route is exceeded.
- Display format: the display format is not definitive yet. The district will investigate several possibilities and get back to CCIT. CCIT commented that the proper display format could be determined by trying several formats and run user surveys to elect the best option. This could be done in the summer as part of a general evaluation of the pilot project.
- Graphical User Interfaces (GUI): no GUI will be developed during Phase 1. In the next phase, CCIT may develop two separate GUIs. These will be an operator GUI and an administrator GUI.

  The operator GUI will be an extension of the SOCCS GUI and will let the TMC operator select the proper travel time messages to display for individual signs or sets of signs. The messages will be selected from a library of pre-formatted messages. Some minor modifications to the SOCCS GUI will be required to provide a gateway to the operator travel time GUI. The transition will be transparent to the operator as the look and feel will be homogeneous.

The administrator GUI will let an administrator create and edit routes and their attributes, build and edit messages as part of the library of a given CMS, build system-wide configurations, and schedule messages and configurations.

Both GUIs will be browser-based and will be running in a client-server mode off the message server.

- Validation plan
  - Presentation

    JD Margulici presented the evaluation plan described in the corresponding work document. It was clarified that the travel time estimates for a given route from CCIT's application will be compared with 511 estimates for the closest matching route available in 511. The closest matching route is defined by applying the closest match between the beginning and end point of the route and the network of available nodes from 511.
  - Coordination with Travinfo

    Action item: JD Margulici to coordinate with MTC to organize probe vehicle runs.
- Miscellaneous follow-ups and future actions

CCIT staff will participate in the statewide conference on CMS travel times on March 2nd.

Action item: JD Margulici to prepare status report.

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – March, 18th 2005

Participants

Sean Campbell, Caltrans HDQ
Bensen Chiou, CCIT
Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
Ben McKeever, MTC
JD Margulci, CCIT
Kane Wong, Caltrans D4

Documents

Meeting Report 2005_02_25.doc
D4 CMS TRAVEL TIME – CCIT Comments.doc
Travel Times validation plan.doc
SIG Mtg #1 Final Agenda 3 2 05r2_CCIT.doc
CMS_TO_ROUTE.csv

Agenda

- General updates
  - Software development

    CCIT's application is about 90% complete, relative to the perimeter defined for the pilot project ending in June. On SOCCS'end, the development is also nearing completion: the last steps involve gluing the new objects together and tying to the GUI.

    Sean Campbell requests that the header field in the message format be suppressed for the time being, in order to conform with original specifications.

    Action item: Bensen Chiou to suppress header field in message format.
  - Server delivery

    The message server was delivered to the district in the morning (3/18). It was assigned a static IP address on the TMC network. One pending item to start running the application is to obtain the IP address where to fetch the TOMS feed from PBF.

Action item: Bensen Chiou / Hector Garcia to coordinate with Tom Saul to obtain an IP address for the TOMS feed.

- Functional requirements
    - o Discussion of the pending items

Ben McKeever reports on the national ITS conference on CMS travel times, where over a dozen DOTs were represented. Some of the key elements of interest are as follows:

- Some DOTs provide distance information along with travel times. This may help drivers less familiar with the area.
- Some DOTs provide a range rather than a single travel time value. However 511 predictions should be accurate enough to display one value.
- The two most common / preferred formats are as follows:

```
       SFO
18.7 MI     AHEAD
T.TIME 20-22 MIN
```

```
 TRAVEL TIME TO
SF DWNTWN 18 MIN
SFO          30 MIN
```

- Maximum travel time: usually, when the travel time exceeds a given value, the display will say: ‘OVER NN MIN’.
- The routes for which travel times are displayed have their distance usually comprised between 4 and 20 miles.
- A rule of thumb for displaying a given destination at a given location is that about 50% of the people who see the sign should be going to or beyond that destination.
- Airports are good destinations.
- Co-use of the signs with law enforcement authorities is perceived as an issue by other DOTs.
- Number of destinations displayed on a sign: 2 is effective, 3 tend to be a lot.

- Flash mode display is seen as too distracting and not recommended.
- Hours of operations are usually all day from early morning to late evening. Few DOTs display during peak hours only. Only one displays 24/7.
- A list of common abbreviations (airport, downtown etc..) was made available during the conference.

Action item: Ben McKeever to send a web link to access some of the conference material, including the list of abbreviations.

- No DOT currently uses predictive algorithms.
- Most DOTs use inductive loops as the primary source of data. A few use ID tags comparable to the FasTrak program.
- The transition period is crucial to the success of the program. It is a good idea to start advertising a week in advance ('travel times coming soon on this sign'). It is also good to get some press coverage.
- Free flow conditions: most DOTs still display travel time except in the nighttime or early morning periods. Most DOTs set a minimum travel time based on posted speed. The minimum is displayed even if real-time data indicates a lesser value.

Action item: D4 to hammer out functional requirements / display format.

- Verification and validation plan
  - Functional validation

    MTC started collecting data from probe vehicles on the routes targeted for the pilot. Comparison with 511 predictions proved very satisfactory, within 15% for all but one run. PBF is emailing daily 511 logs to CCIT for its validation. CCIT just started logging travel time estimates from its application. The functional validation plan will proceed as indicated in the document.
  - Verification plan

    Verification will start once the new version of SOCCS is installed in the district. We will set up a mock-up of the system within the district by hooking up a couple of spare 170 controllers. The connection will be either dial-up or GPRS depending on available equipment. SOCCS will be installed on the old D1 SOCCS server.

Action item: Hector Garcia to gather the necessary equipment to set up the mock-up.

The 170 acknowledges the message back to the CMS server. Therefore the complete verification can be performed by logging that feed. Sean Campbell will be in the district starting March 28th to coordinate the implementation.

- Planning
  - Technical testing and QA

  Technical testing is underway. There will be about two weeks of live action starting around April 1st to the go/no go decision on the 15th. If the decision on the 15th is positive, the switch date will be May 2nd. Advertising will start April 25th.

  Question: will we start displaying full-on on May 2nd, or will there be a warm-up period?

  - Evaluation and statewide perspective

  Evaluation will take place after June 30th. It may be a CT HDQ-directed effort. CCIT will also make provisions for the system evaluation in the continuation proposal.

  - Media coverage

  Press releases will be issued after April 15th to prepare for the launch. No ribbon-cutting ceremony will be organized.

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – April, 8th 2005

Participants

Sean Campbell, Caltrans HDQ
Bensen Chiou, CCIT
Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
JD Margulci, CCIT
Kane Wong, Caltrans D4

Documents

Meeting Report 2005_03_18.doc

Agenda

- Software development and testing
  - Report on tests started last week

    Testing in the previous week went well. The whole system was functional all the way to a 170 controller connected with an Ethernet cable. More testing will be conducted in the district with a GPRS modem to reproduce filed conditions.
  - Software development: SOCCS / CCIT updates

    SOCCS update almost complete. Essentially, some integration clean-up is still needed, as well as a few admin functionalities (e.g. restrict the application to one running window at a time, validating user inputs on Auto-CMS application…).

    The CCIT application was baptized MITTENS (Messaging Infrastructure for Travel Time Estimates to a Network of Signs). It is also nearing completion. A few additional features need to be implemented as part of the functional requirements.
  - Additional requirements

An automatic shutdown of the system will be added to SOCCS to handle disconnections between SOCCS and MITTENS. After N cycles without connecting, SOCCS will send blank messages to the signs. Likewise, MITTENS will start sending blank messages if it cannot connect to TOMS for a number of cycles. An additional provision should also be made to make sure that SOCCS blanks the signs if the message file doesn't get refreshed EVEN if it still accessible.

One correction that was made in the SOCCS-MITTENS protocol is that the text file placed by MITTENS on the travel time server should contain all the CMS at all times, even if those display blank messages. This will result in more predictable outcomes.

CCIT will also develop a documentation of MITTENS and provide a quick reference guide for the pilot. It is expected that District personnel will only perform very basic tasks on MITTENS during the pilot.

- Functional requirements
  - Finalize discussion if possible

The following format is adopted:

```
  TRAVEL TIME TO
SF DWNTWN 18 MIN
SFO       30 MIN
```

When the estimated travel time exceeds the max value for a route, then the signs stops displaying the whole line that contains that route. If there are no travel times to display, then the whole sign blanks.

  - TMC operators involvement & training

TMC operators will be trained on the new SOCCS GUI. This will be handled by TMC personnel.

- Validation plan
  - Updates

JD reported on the validation plan of the travel time estimates produced by MITTENS. The results are still preliminary but show that the difference between 511 and the signs would be 1 minute or less about 60% of the time, 3 minutes or less about 97% of the time. In some isolated occurrences, differences as high as 8 minutes out of a 34 minute-trip are observed. A more circumstanced report will be produced shortly by CCIT, that will show exact metrics by route and investigate the outliers.

- Planning and scheduling
    - Roadmap to switch date

    The decision to go live May 2nd was acted. The system will go into production 1 week before but will be disabled for the most part. During that time, the signs will advertise the upcoming messages. There will be a short trial on Wed, 27th around lunch time. A meeting will follow on Fri, 29th at 10am.

    - Media coverage

    Alan and JD to coordinate for press release through Caltrans / UC channels.

    - Operating system May-June

    During the first two months of the pilot, the system will be operating 24/7, and the signs will be displaying from 5am to 9pm by default. CCIT will be available for interventions on MITTENS. The District personnel will receive enough training to be able to switch the system on and off.

- New operator GUI demo

Sean demonstrated the new SOCCS GUI.

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – August 24^{th} 2005

Participants

Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
JD Margulici, CCIT
Xander Mitman, CCIT
Kane Wong, D4

Agenda

- Progress report from CCIT
  - System documentation

    CCIT delivered system documentation in early August.
  - Utility for definition of route(s)

    Sam has been working on the core software for the route definition. Xander will be driving the user interface, including gathering requirements and following through on the implementation. In terms of determining what information is displayed on the CMS, it must be robust enough to correctly handle the case where traffic info is not available for 100% of the links on the given route. It was suggested that in that case, the CMS should then display the travel time for a complete route of lower priority, if available. If no complete route is available, the CMS should be blanked.
  - User survey

    The survey questions have been completed and will be sent to D4 for review. See below for more detail on distribution.
  - Traffic impact study

    CCIT's analysis showed a statistically negligible slowdown in the areas surrounding the CMS displaying travel times. The full report will be delivered to D4.
  - Sys admin tools

The question remains as to whether the system will be connected to the Internet. This would serve two purposes: the system monitoring process could automatically alert administrators (via email or SMS) in the event of a critical error, and the system could use an API to retrieve maps from Yahoo! to graphically display the selected route. There may be security concerns about opening the system to the Internet.

- ITS World Congress (November 6, 2005)
  - Requirements

    Alan Chow would like to see approximately 20 signs added in key areas (Peninsula, SBC Park, 101 corridor) that would be seen by World Congress participants. A substantial limiting factor will be sparse 511 coverage. CCIT will evaluate the available resources and cooperate with D4 to determine which CMS will be good candidates for this expansion.
  - Impact on SOW

    Expanding the CMS coverage will add some manhours to this project but is not expected to delay the final delivery date. The development of the other modules will continue in parallel while CCIT manually defines the new routes and adds them to the system. This will become clearer as the new routes are selected.
  - Schedule

    CCIT anticipates they can complete the project by the current deadline of July 2006, including the manual CMS expansion for the World Congress,
- CMS survey
  - Resolve any open issues

    The survey may be distributed in a variety of ways. The following methods have been suggested:
    - Post on www.511.org
    - Distribute survey flyers at toll booths
    - Mail campaign to FasTrak customers
    - Poll individuals at commuter-heavy locations (i.e. PSEG office)
    - Poll individuals at Park & Ride lots around the Bay Area

        - Generate an email blast to target audience
- System deployment
    - User interfaces required for system handoff to Caltrans

      Xander will be gathering requirements for the UI components from the primary user groups. A Gantt chart clarifying the specific milestones and deliverables will be delivered to D4.
- Future work
    - Scope

      In addition to the above, JD suggested that CCIT empirically verify the accuracy of the 511 travel time predictions by hiring drivers to repeatedly drive certain routes while logging their actual travel times. The results could then be compared to the predicted travel times for a give time period.
    - Overview and clarification

      Detailed in the above minutes.

CCIT Task Order 13 – Travel Times on District 4 CMS

Work Meeting Agenda – October 12th 2005

Participants

Alan Chow, Caltrans D4
Charles Price, Caltrans D4
Hector Garcia, Caltrans D4
Kane Wong, Caltrans D4
JD Margulici, CCIT
Xander Mitman, CCIT

Agenda

- Discussion of Deployment of Travel Times
    - Finalize routes
        - Completed. See document "CMS Travel Times For World Congress- Final.xls"
    - Finalize masks
        - Completed. See document "CMS Travel Times For World Congress- Final.xls"
    - Testing and acceptable performance measures
        - CCIT will begin collecting travel time data for the intended routes and will perform statistical analysis to determine if routes appear to be giving reasonable travel times. We have little influence on 511's data so our best option is to check that our routes and calculations are being performed correctly.
    - Deployment schedule
        - Oct 10-14: Dedicated modems are being programmed at Caltrans
        - Oct 13-21: Begin full MITTENS travel time calculations and internal system testing at CCIT
        - Oct 13-21: Finalize MITTENS software development at CCIT

    - Monday, Oct 24, 10am: CCIT will install new MITTENS version at Caltrans TMC and integrate with SOCCS
    - Oct 24: Test partial system by sending travel times to approx. ten 170 controllers at Caltrans
    - Oct 25-Oct 31: Test full messaging infrastructure by sending travel time messages to the actual CMSs but cut power to the signs so that the messages are not displayed to the public
    - Tuesday, Nov 1: Travel times live on CMSs. Final testing before World Congress begins Nov 6.
- Survey
  - Survey has been on 511 website since late September: http://traffic.511.org/survey.asp?SID=14
  - Postage-paid paper surveys will be ready approx. Oct 14 and will be distributed at local "casual carpool" sites
  - An advertisement on this month's FasTrak bill will direct users to the survey
  - Potential initiatives:
    - Email employees of large companies using email lists from MTC
    - Put a link to the 511 survey on Caltrans D4 website

CCIT Task Order 13 – Travel Times on District 4 CMS

Meeting Report – October 28th 2005

Participants

Alan Chow, Caltrans D4
Hector Garcia, Caltrans D4
Kane Wong, Caltrans D4
Sean Campbell, Caltrans (arrived after the meeting)
Ben McKeever, 511 (via telephone)
JD Margulici, CCIT
Bensen Chiou, CCIT
Xander Mitman, CCIT

Agenda

- Discussion of Deployment of Travel Times
    - Route testing and statistics
        - US-101 South is now available from 511. Ben McKeever said that CA-24 will probably go live this weekend.
        - For today's initial test, we will use a configuration that does not include CM017 and CM015, both on US-101 S/B. These can be added to the configuration next week.
        - CM006, CM026, and CM096, all on CA-24 W/B, may also be added to the World Congress configuration next week if there are enough GPRS modems available that can be installed at CMS locations in time for the event.
    - Update of MITTENS software and database
    - Results of initial system testing with controllers
        - As of 10/27, not all travel times were received by the controllers. What caused the error?
        - Today after the meeting Sean restarted SOCCS' multi-CMS application so that it refreshed the IPs for the new GPRS modems. This fixed the problem and then all test CMSs were working

correctly. In the future, this should be restarted any time there is a change to static data such as IPs.

    - In the future, Sean warned that some issues may arise due to latency between when the message is sent and when the message is received by the controller. This has not been observed yet but it could become a source of problems when SOCCS is handling more signs. Sean suggests that all the GPRS modems and 170 controllers be switched from baud rate 1200 to baud rate 9600. This should decrease the latency from about 4 seconds to about 0.5 seconds. 9600 is the standard baud rate for most Caltrans utilities, according to Sean's experience. There is no drawback to using a faster baud rate.
    - Hector said District 4 has not experienced latency issues with 1200 but for World Congress and beyond they can upgrade to 9600 to be safe. The modem and controller must be set to the same baud rate. Hector will work with the field team to establish a schedule. Estimate was that all World Congress modems and controllers could be changed to 9600 by Monday, October 31.
- Full deployment on Tuesday, Nov. 1.
    - Decision was made to have an initial test on Friday, October 28, since all the pieces were already in place. District 4 staff will run a full live test and observe the behavior from TMC and the field. If everything appears to be stable the system will "permanently" go live on Monday, October 31.
- Field tests
    - Field observations will be required for test period on Friday, October 28 and from Monday, October 31 on.
- Press releases
    - JD has written a press release that will be distributed as part of UC Berkeley's World Congress press release.
    - Alan may create a press release from Caltrans.

- Survey
  - Ben reports that 511 has received hundreds of responses from the online survey so far. Results have been generally very positive.
  - JD has received some mail-in surveys which have not been analyzed yet.

CCIT Task Order 13 – Travel Times on District 4 CMS

Work Meeting Agenda – December 7, 2005

Participants

Alan Chow, Caltrans D4
~~Charles Price, Caltrans D4~~
Hector Garcia, Caltrans D4
Kane Wong, Caltrans D4
Ben McKeever, MTC
JD Margulici, CCIT
Bensen Chiou, CCIT
Xander Mitman, CCIT

Agenda

- Discussion of CMS Behavior in World Congress Deployment
  - General feedback
    - Overall positive reaction to travel times
    - Met deadlines
    - Some technical problems
      - After installing new modems, it was not clear that SOCCS had to be restarted to recognize the new IP addresses
      - One faulty modem (CM042) never updated so the same travel times were continuously displayed, giving the impression of incorrect travel times
    - Displayed travel times are not always reliable, based on anecdotal feedback. More details included below.
  - Lessons learned
    - Processes that generate travel times need to be analyzed in detail to verify that we are posting accurate information. MITTENS may need to be changed to address faulty travel times.

        - SOCCS has scalability issues due to limited processing power of its current server. When all 18 signs were activated, the other applications slowed down to the point that operators complained about it. Consequently, the system was modified to display fewer signs. Sean Campbell is working on a band-aid fix but ultimately SOCCS needs to be ported to a more robust server capable of distributing travel times to approximately 100 CMS without system degradation.
    - Suspicious travel times, in particular:
        - CM070 (Berkeley to SFO and SF DWNTWN)
        - CM028 (101SB in San Francisco)
        - CM014 (Belmont to SF DWNTWN)

        - Travel times on most CMS are now turned off due to both faulty travel times and limitations of SOCCS processing power.
        - Seven remaining CMS are CM015, CM017, CM078, CM029, CM050, CM069, and CM097.
        - There is a general discrepancy between travel times from 511 and CCIT. See below for more details.
        - JD suggested not displaying any travel times until completion of thorough testing and quality assurance.
        - It was decided to leave these seven signs active while testing continues.
    - 511 sensors
        - 511 FasTrak sensors in San Francisco are scheduled to be restored on Thursday, December 15. This should improve travel times on I-80 through downtown.
        - Bensen noted that the link travel times from TOMS appear to be published more than once per minute, approximately every 20 seconds. Ben thought this might be misinterpretation due to geographical link overlap (i.e. I-80 and I-580) but Bensen

confirmed that he's seeing the same link name being published. No definite ideas on how or why this is happening. Might require further research.

  - Ben remarked that data has been available on CA-24 since early November. This data may be utilized once the overall system performance has been stabilized.
  - Ben commented that 511 has a mix of live, historical, and predicted travel times. Live travel times can be a mix of loop and ETC data but there's no way to determine the ratio from the log files.

- CCIT's travel times analysis
  - Last week CCIT identified five routes for detailed testing that have been anecdotally noted for displaying inaccurate travel times. By comparing several days of travel times data generated by both 511 and MITTENS they identified differences between the expected travel time (511) and the actual displayed travel time (CCIT). The results were plotted to show trends in the differences. See figure below.
  - In general, MITTENS' travel times correctly tracked the trends of the 511 travel times, but the magnitude was typically lower by approximately 2 to 10 minutes. The cause of this discrepancy is unknown at this time and will be the focus of the next phase of testing.

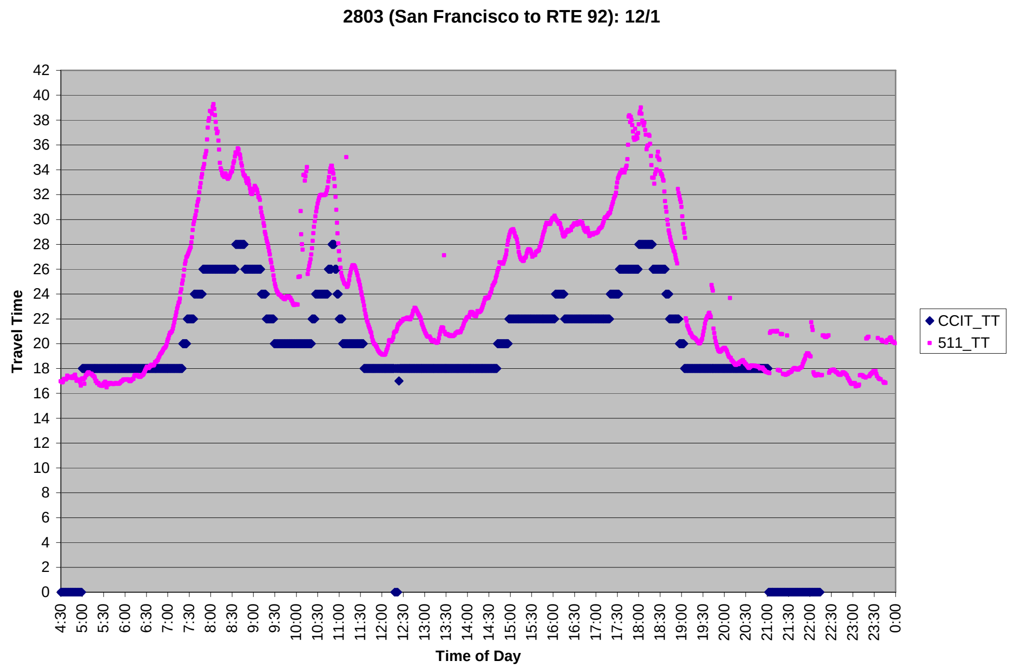


Figure 1: Example of 511 and MITTENS travel times comparison.

- Rigorous testing will be the core focus now, with the seven current signs being analyzed first. CCIT hopes to identify and fix any bugs in the system so that improvements will be seen system wide.

- CMS User Survey
    - Survey response was excellent with nearly 1000 user surveys submitted. About 2/3 responded online with the remainder replying by mail.
    - Overall, reaction to the travel times on CMS was very good. Most people felt they were useful (75%) and accurate, and the current destinations were appropriate.
    - One notable response was that many people felt they would not have any problem reading three different lines of travel times on one CMS.
    - Additional work will be done to cross-reference survey responses to age and household income level.
- Next Steps
    - CCIT will focus on testing and quality assurance as described above.

- Funding for the first phase has been exhausted. New funding has been approved but not received. JD and Alan will coordinate.
- Bensen will deliver an updated system manual including new debugging options and information on starting the services required after a computer reboot.
- A comprehensive report will summarize all the activities and results from the pilot phase. Two versions may be created: one for Caltrans and one for publication. Delivery date is approximately end of January.
- The user interface prototype will be presented to Caltrans after quality assurance has been adequately addressed.

California Center for Innovative Transportation

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Field Elements and System Configuration

- List of CMS and their locations (3 p.)
- Map of the CMS locations (2 p.)
- Map of the toll tag reader locations, December 2005 (1 p.)
- List of nominal Travel Time Messages on each CMS (4 p.)

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

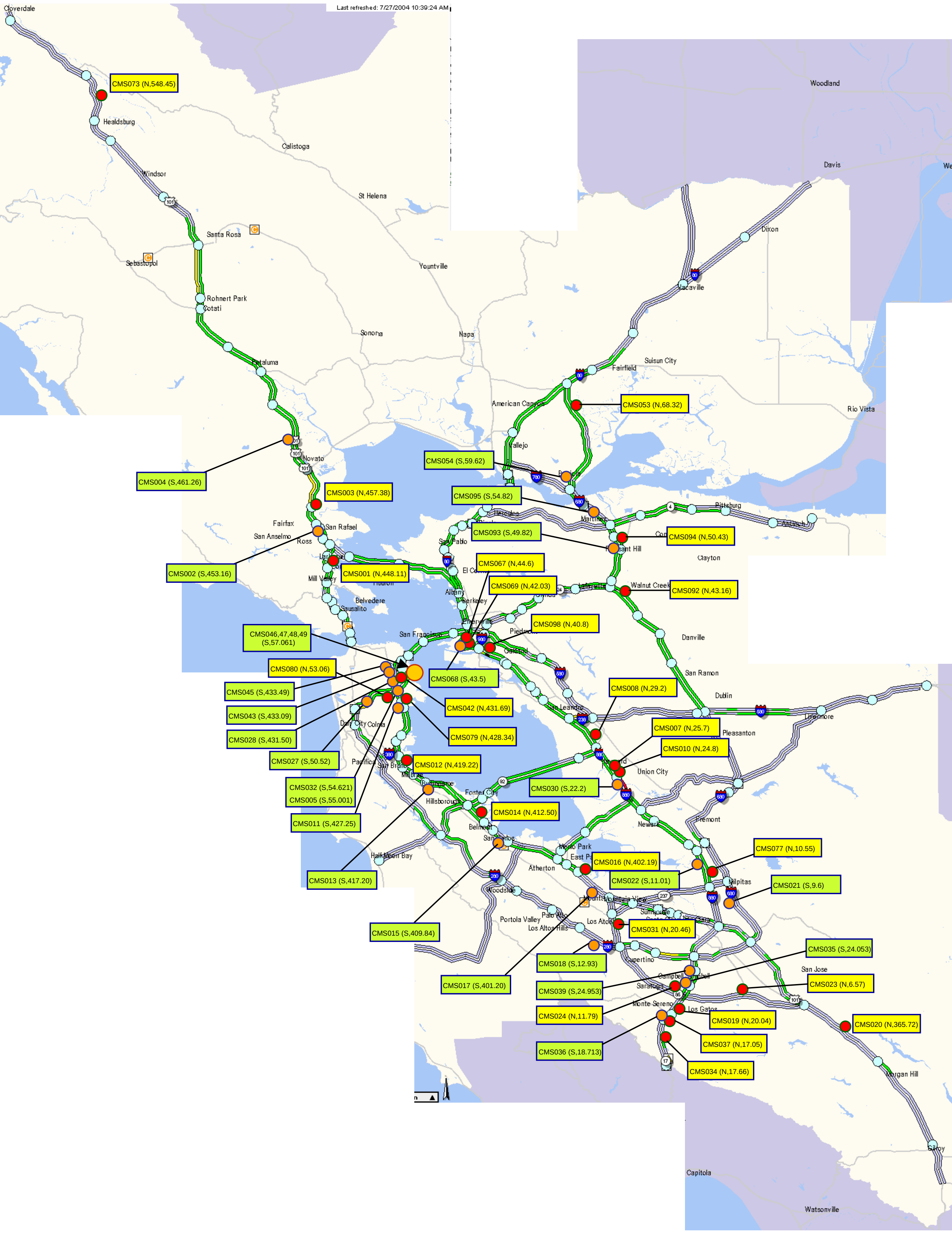
Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

List of CMS and their locations in District 4 (December 2004)

County	City	CMS_ID	Freeway	Direction	AbsPM	Prefix (post mile)	CalPM	Type
Marin	Sausalito	CM001	101	N	448.114		7.59	500
Marin	San Rafael	CM002	101	S	453.164		12.64	500
Marin	Novato	CM003	101	N	457.384		16.86	500
Marin	Novato	CM004	101	S	461.264		20.74	500
San Francisco	San Francisco	CM005	280	S	55.001		5.04	500
Contra Costa	Lafayette	CM006	24	W	10.388		6.04	55
Alameda	San Leandro	CM007	880	N	25.734		15.7	500
Alameda	Hayward	CM008	880	N	29.204		19.17	500
Alameda	Hayward	CM009	92	E	24.887	R	5.36	500
Alameda	Hayward	CM010	880	N	24.814		14.78	500
San Mateo	Brisbane	CM011	101	S	427.247		25.06	500
San Mateo	Burlingame	CM012	101	N	419.227		17.04	500
San Mateo	Burlingame	CM013	101	S	417.197		15.01	500
San Mateo	Belmont	CM014	101	N	412.497		10.32	500
San Mateo	San Mateo	CM015	101	S	409.837		7.65	500
San Mateo	East Palo Alto	CM016	101	N	402.187		0.03	500
Santa Clara	Palo Alto	CM017	101	S	401.197		51.52	500
Santa Clara	Cupertino	CM018	280	S	12.93		12.93	500
Santa Clara	Los Gatos	CM019	17	N	20.043		7.49	500
Santa Clara	Gilroy	CM020	101	N	365.721		16.45	500
Santa Clara	Milpitas	CM021	680	S	9.6		9.6	500
Alameda	Fremont	CM022	880	S	11.014		0.98	500
Santa Clara	San Jose	CM023	85	N	6.57		6.57	500
Santa Clara	Saratoga	CM024	85	S	11.79		11.79	500
Alameda	Oakland	CM025	24	E	7.273		9.12	500X
Contra Costa	Lafayette	CM026	24	W	9.948		5.6	500X

San Francisco	San Francisco	CM027	280	S	50.521		0.56	500
San Francisco	San Francisco	CM028	101	S	431.494		3.2	500X
Solano	Fairfield	CM029	80	W	41.496		14	500X
Alameda	Fremont	CM030	880	S	22.194		12.16	500
Santa Clara	Cupertino	CM031	85	N	20.46		20.46	500X
Santa Clara	San Jose	CM032	280	S	54.621	L	4.66	500X
Santa Clara	Los Gatos	CM034	17	N	12.663		0.11	500X
Santa Clara	Campbell	CM035	17	S	24.053		11.5	500X
Santa Clara	Los Gatos	CM036	17	S	18.713		6.16	500X
Santa Clara	Los Gatos	CM037	17	N	17.053		4.5	500
Santa Clara	Campbell	CM039	17	S	24.953		12.4	500
San Mateo	San Mateo	CM040	92	E	10.606		9.88	500
San Francisco	San Francisco	CM041	80	W	1.212		4.7	500
San Francisco	San Francisco	CM042	101	N	431.694		3.4	500
San Francisco	San Francisco	CM043	101	S	433.094		4.8	510
San Francisco	San Francisco	CM045	101	S	433.494		5.2	510
San Francisco	San Francisco	CM046	280	S	57.061		7.1	510
San Francisco	San Francisco	CM047	280	S	57.061		7.1	510
San Francisco	San Francisco	CM048	280	S	57.061		7.1	510
San Francisco	San Francisco	CM049	280	S	57.261		7.3	510
Contra Costa	Hercules	CM050	80	E	24.996		11.2	500
Solano	Vallejo	CM051	80	W	31.685		4.2	500
Solano	Vallejo	CM052	80	E	31.685		4.2	500
Solano	Fairfield	CM053	680	N	68.32		10.2	500
Solano	Benicia	CM054	680	S	59.62		1.5	500
Solano	Benicia	CM055	780	E	0.468		1.5	500
Alameda	Newark	CM059	84	E	34.07	R	4	500
San Mateo	Menlo Park	CM060	84	E	28.7	R	28.7	500
Alameda	Fremont	CM061	84	E	31.77	R	1.7	500
San Francisco	San Francisco	CM062	80	E	1.012		4.5	500

San Francisco	San Francisco	CM063	80	W	2.212		5.7	500
Alameda	Albany	CM064	80	W	6.91		1.6	500
Alameda	Oakland	CM065	80	E	6.91		1.6	500
Alameda	Albany	CM066	80	W	8.31		3	510
Alameda	Oakland	CM067	880	N	44.634		34.6	500
Alameda	Oakland	CM068	880	S	43.534		33.5	510X
Alameda	Oakland	CM069	880	N	42.034		32	500
Alameda	Albany	CM070	80	W	9.89		4.58	500X
San Mateo	San Mateo	CM072	92	W	9.326	R	8.6	500X
Sonoma	Santa Rosa	CM073	101	N	548.453	R	80.5	500
Alameda	Fremont	CM077	880	N	10.554		0.52	500X
Alameda	Berkeley	CM078	80	E	11.5		6.19	500X
San Francisco	San Francisco	CM079	101	N	428.394		0.1	500X
San Francisco	San Francisco	CM080	280	N	53.061		3.1	500X
Alameda	Hayward	CM083	92	W	22.027		2.5	500X
San Mateo	Foster City	CM084	92	W	14.726		14	500X
San Mateo	Foster City	CM085	92	E	14.726		14	500X
Contra Costa	Lafayette	CM089	24	E	11.188		6.84	500X
Contra Costa	Pinole	CM090	80	W	21.446		7.65	5000X
Contra Costa	Danville	CM092	680	N	43.161		11.76	500X
Contra Costa	Pleasant Hill	CM093	680	S	49.081		17.68	500X
Contra Costa	Pleasant Hill	CM094	680	N	50.431		19.03	500X
Contra Costa	Pleasant Hill	CM095	680	S	54.821		23.42	500X
Alameda	Oakland	CM097	580	W	60.185		44.1	500X
Alameda	Oakland	CM098	880	N	40.834		30.8	500X



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Cloverdale
CMS073 (N,548.45)
Healdsburg
Calistoga
Windsor
St Helena
Santa Rosa
Sebastopol
Yountville
Rohnert Park
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Sonoma
Napa
Petaluma
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Dixon
Vacaville
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Oakland
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Colma
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Burlingame
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Foster City
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Hillsborough
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Fremont
San Carlos
Half Moon Bay
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Los Gatos
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CMS037 (N,17.05)
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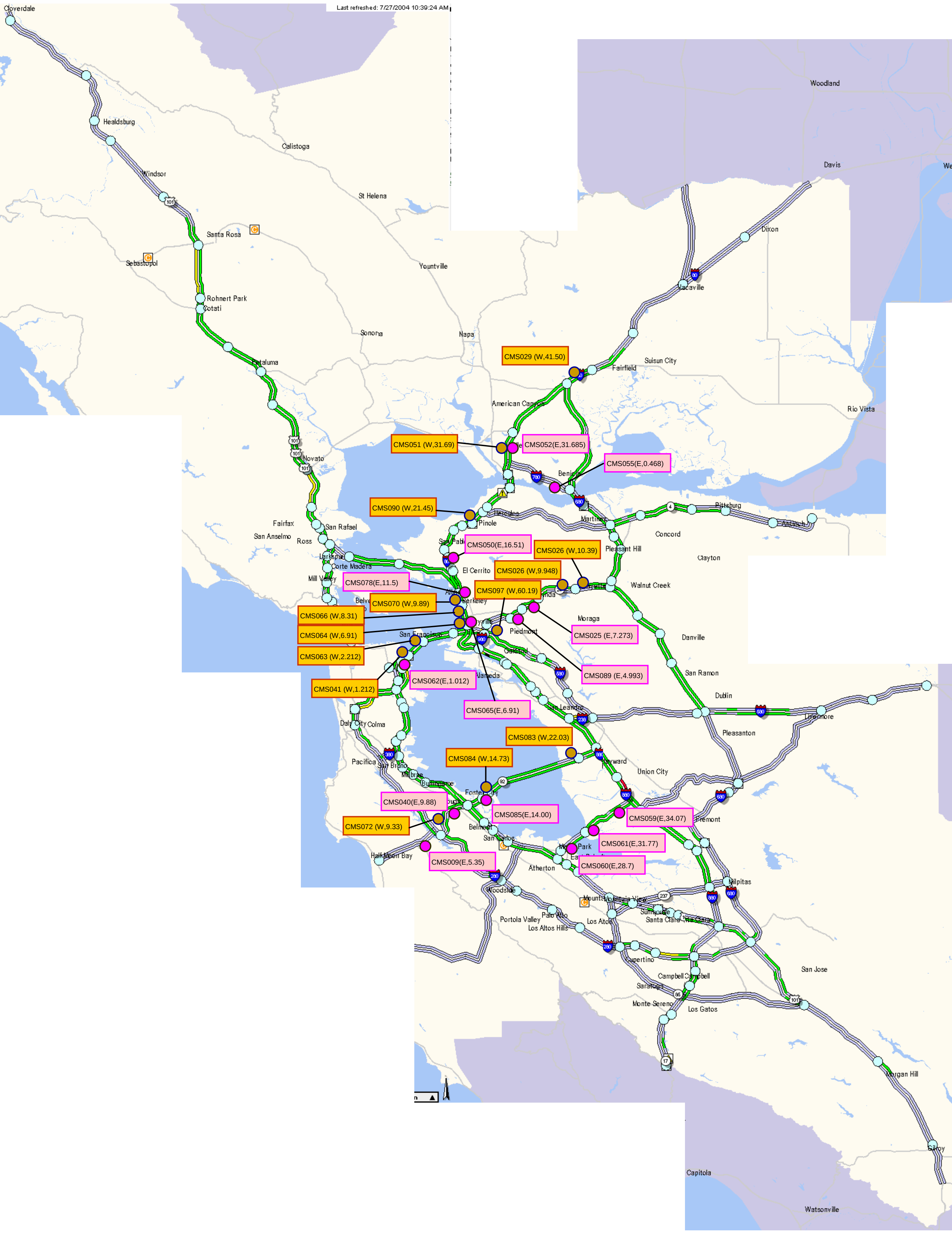
Morgan Hill
Gilroy
Capitola
Watsonville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Belmont
San Carlos
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Half Moon Bay
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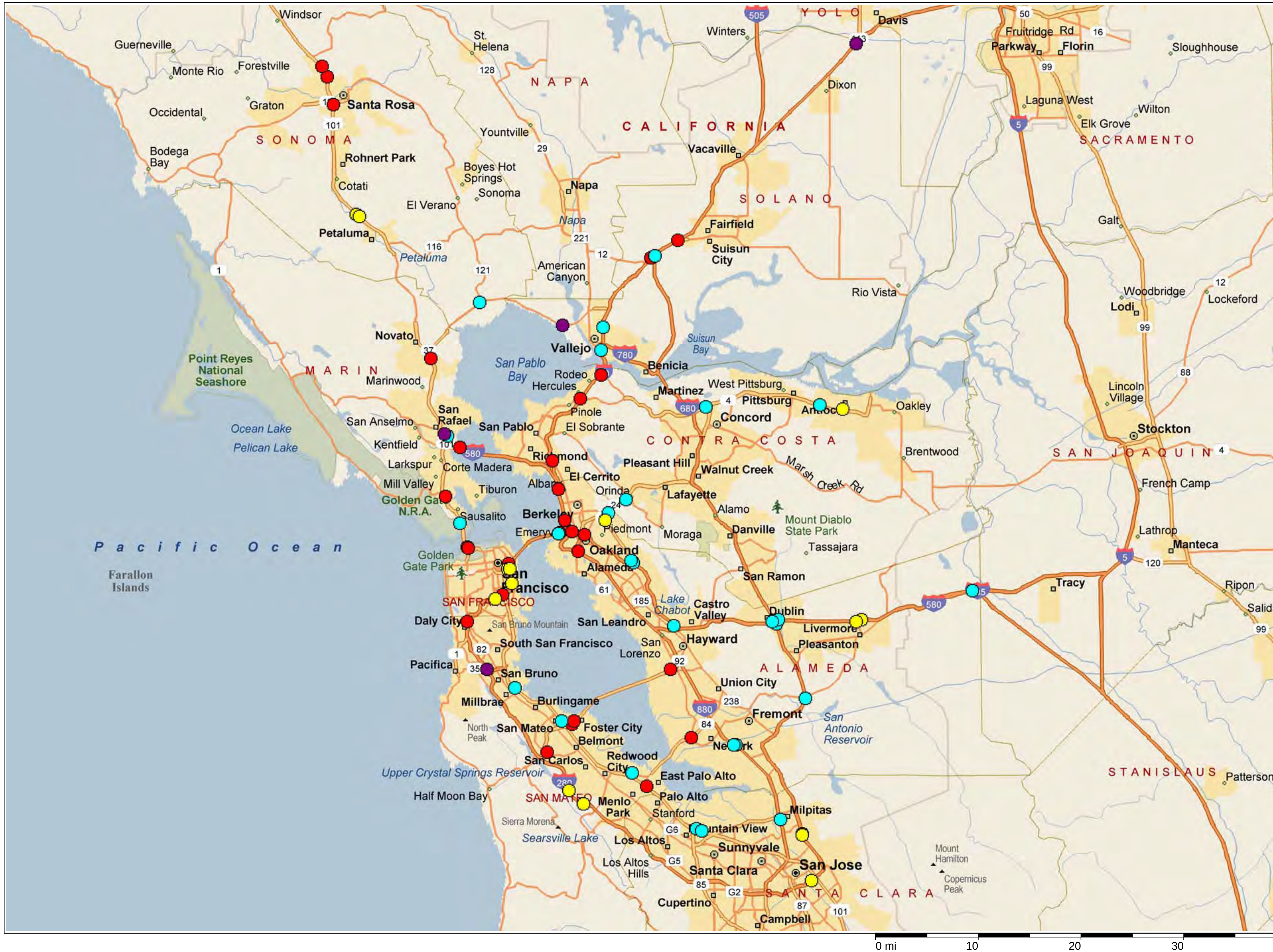
Atherton
Milpitas
Woodside
Mountain View
Sunnyvale
Santa Clara
Portola Valley
Palo Alto
Los Altos Hills
Los Altos
Cupertino
San Jose
Campbell
Saratoga
Monte Sereno
Los Gatos
Morgan Hill
Gilroy
Capitola
Watsonville

Traffic Gauge

Pushpins
- Phase I - Installed
- Phase IIB Installed
- To Be Installed
- Phase IIA Installed



Travel Time Messages in District 4 as of June, 2006

	SIGN #	COUNTY	CITY	DIR	ROUTE	LOCATION	P.M.	CMS MESSAGE
1	CM012	San Mateo	Burlingame	North	101	North of Broadway	17.04	TRAVEL TIME TO SF DWNTWN XX MIN OAKLAND XX MIN
2	CM014	San Mateo	San Mateo	North	101	South of E. Hillsdale Ave	10.32	TRAVEL TIME TO SFO ARPT XX MIN SF DWNTWN XX MIN
3	CM016	San Mateo	East Palo Alto	North	101	North of Embarcadero Rd	0.03	TRAVEL TIME TO RTE 92 XX MIN SFO ARPT XX MIN
4	CM042	San Francisco	San Francisco	North	101	North of 23rd St	3.4	TRAVEL TIME TO TRSR ISL XX MIN OAKLAND XX MIN
5	CM079	San Francisco	San Francisco	North	101	North of Candlestick Park Offramp	0.1	TRAVEL TIME TO SF DWNTWN XX MIN OAKLAND XX MIN
6	CM011	San Mateo	Brisbane	South	101	North of Sierra Point	25.06	TRAVEL TIME TO SFO ARPT XX MIN RTE 92 XX MIN
7	CM013	San Mateo	Burlingame	South	101	North of Peninsula Ave	15.01	TRAVEL TIME TO RDWD CITY XX MIN PALO ALTO XX MIN
8	CM015	San Mateo	San Carlos	South	101	South of Brittan Ave.	7.65	TRAVEL TIME TO PALO ALTO XX MIN RTE 237 XX MIN

Travel Time Messages in District 4 as of June, 2006

	SIGN #	COUNTY	CITY	DIR	ROUTE	LOCATION	P.M.	CMS MESSAGE
9	CM017	Santa Clara	Palo Alto	South	101	South of Embarcardero Rd	51.52	TRAVEL TIME TO RTE 237 XX MIN I-880 XX MIN
10	CM028	San Francisco	San Francisco	South	101	North of Cesar Chavez	3.2	TRAVEL TIME TO SFO ARPT XX MIN RTE 92 XX MIN
11	CM029	Solano	Fairfield	West	80	East of Suisan Valley Rd	14	TRAVEL TIME TO CARQ BRDG XX MIN BERKELEY XX MIN
12	CM051	Solano	Vallejo	West	80	West of Redwood Pkwy	4.2	TRAVEL TIME TO RTE 4 XX MIN BERKELEY XX MIN
13	CM070	Alameda	Albany	West	80	Ashby Ave	4.1	SF DWNTWN XX MIN SFO ARPT XX MIN OAK ARPT XX MIN
14	CM090	Contra Costa	Pinole	West	80	Appian Way	7.65	TRAVEL TIME TO BERKELEY XX MIN SF DWNTWN XX MIN
15	CM091	Contra Costa	Crockett	West	80	West of Carquinez Bridge	13.41	TRAVEL TIME TO BERKELEY XX MIN SF DWNTWN XX MIN
16	CM050	Contra Costa	Hercules	East	80	East of Willow Ave	11.2	TRAVEL TIME TO RTE 37 XX MIN FAIRFIELD XX MIN

Travel Time Messages in District 4 as of June, 2006

	SIGN #	COUNTY	CITY	DIR	ROUTE	LOCATION	P.M.	CMS MESSAGE
17	CM078	Alameda	Berkeley	East	80	East of University Ave	6.19	CARQ BRDG XX MIN FAIRFIELD XX MIN NOVATO XX MIN
18	CM006	Contra Costa	Lafayette	West	24	East of Happy Valley Rd	6.04	TRAVEL TIME TO HWY 13 XX MIN SF DWNTWN XX MIN
20	CM096	Alameda	Oakland	West	24	Shattuck Ave	2.9	TRAVEL TIME TO SF DWNTWN XX MIN OAK ARPT XX MIN
21	CM069	Alameda	Oakland	North	880	5th St	32	TRAVEL TIME TO SF DWNTWN XX MIN CARQ BRDG XX MIN
22	CM098	Alameda	Oakland	North	880	South of Oak St	30.8	TRAVEL TIME TO SF DWNTWN XX MIN CARQ BRDG XX MIN
23	CM097	Alameda	Oakland	West	580	Chetwood St	44.1	TRAVEL TIME TO SF DWNTWN XX MIN CARQ BRDG XX MIN
24	CM801	San Mateo	Montara	South	1	10th Street	36.05	TIME TO RTE 92 XXX MIN TIME TO RTE 280 XXX MIN

Travel Time Messages in District 4 as of June, 2006

	SIGN #	COUNTY	CITY	DIR	ROUTE	LOCATION	P.M.	CMS MESSAGE
25	CM802	San Mateo	El Granada	South	1	Capistrano Road	32.47	TIME TO RTE 92 XXX MIN TIME TO RTE 280 XXX MIN
26	CM803	San Mateo	Half Moon Bay	East	92	92 at Main St.	0.33	TIME TO RTE 280 XXX MIN
27	CM804	San Mateo	San Mateo	South	280	280 at Crystal Springs	R13.29	TIME TO RTE 92/1 XXX MIN
28	CM805	San Mateo	San Mateo	W	92	92 at Ralston	R8.09	TIME TO RTE 92/1 XXX MIN
29	CM806	San Mateo	San Carlos	North	280	280 at Edgewood	7	TIME TO RTE 92/1 XXX MIN

CCIT Task Order 13

Travel Times on Changeable Message Signs in District 4

Bibliography

December 2005

Prepared by:

Brian Huey
Graduate Student Researcher, CCIT

Yvonne Leung
Junior Development Engineer, CCIT

For:

California Department of Transportation
Division of Traffic Operations

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone: (510) 642-4522
Fax: (510) 642-0910
http://www.calccit.org

CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

DATA COLLECTION AND TRAVEL TIME ESTIMATIONS

Eisele, W.L., L.R. Rilett, K.B. Mhoon and C. Spielgelman. Using Intelligent Transportation Systems Travel-Time Data for Multimodal Analyses and System Monitoring. In *Transportation Research Record 1768*, Washington, 2001, pp.148-156.

This Travel Time Data Collection Handbook provides guidance to transportation professionals and practitioners for the collection, reduction, and presentation of travel time data. The handbook should be a useful reference for designing travel time data collection efforts and systems, performing travel time studies, and reducing and presenting travel time data. Initial chapters of the handbook describe how to design data collection activities, including the determination of parameters such as study size and scope, data collection technique, and other critical study elements. 7, Data Reduction, Summary, and Presentation.

Faghri, A., K. Hamad, D. Kerr, C. Magdefrau, J.R. Stokes and W. Yeung. *Application of Global Positioning System (GPS) to Travel Time and Delay Measurements – 2000 Phase.* Delaware Center for Transportation, University of Delaware, Newark, DE, September 2001.

This report updates the 1998 research that collected delay and travel time data, using a global positioning system, for roads in Delaware. In the 2000 research the global positioning system continued to operate beautifully. The report notes that the data collection for the year 2000 was successfully completed. Currently, data exists for the four years from 1997 - 2000. This will be valuable data for comparing travel time trends.

Treayford, R.S. and J. van Leersum. Accurate Predictive Urban Point-to-Point Peak Hour Travel Times: Trial Results. ITS America, 9th World Congress on Intelligent Transport Systems, 2002.

This paper reports the results of a predictive point-to-point travel time information service trial carried out in peak periods over six weeks in urban Melbourne where processed data from a historical and real time traffic database was pre-delivered by cell phone to commuting drivers. The data set of results was examined for the causes and trends of the errors encountered. The low mean signed error of the prediction travel times showed insignificant bias. The important result of the trial predictive travel times was the mean absolute error of 3 minutes 45 seconds for the trips that averaged around 40 minutes.

DRIVER'S RESPONSE

Enoki, S., M. Kawasaki and O. Jumpei. Variations in Behavior of Vehicles Traveling on Roads by Providing Travel Time Information. 7th World Congress, ITS Congress Association, Brussels, 2000.

> As road traffic networks have been constructed, expanded and arranged for a long time there are many opportunities for drivers to select routes to their destinations using car-mounted devices. Therefore, information on travel times has been attracting attention and interest among other information details provided by a traffic control center. The authors carried out a demonstration experiment to verify the validity of this information to user drivers, using branch routes whose travel time information could be presented, and variations in the behavior of vehicles traveling were analyzed. This paper describes the results

Kraan, M. Evaluating network wide effects of VMS's in the Netherlands. National Research Council (U.S.). 78th Transportation Research Board Meeting, Transportation Research Board, Washington, DC, Jan.1999.

> This paper summarizes an extensive evaluation study carried out at installing 14 new VMS's at the Amsterdam orbital motorway. The study involves a number of issues. First, the relation between the messages displayed at the VMS and the travel times experienced by drivers is analyzed. Second, a survey on how drivers perceive reliability and usefulness of the messages and a stimulus response analysis to find out how drivers respond in reality to the messages is described. Finally, a network-wide analysis of aggregate performance indicators, like queue length, distance traveled, and time spent on the network is included. The study showed that the use of VMS's has a positive impact on network performance in the Amsterdam freeway system. Total congestion has slightly decreased, while traffic performance has slightly increased.

Parentela, E and N. Eskander. Effectiveness of Changeable Message Signs CMS) On Los Angeles Freeways. Institute of Transportation Engineers, 2001 Spring Conference and Exhibit, Washington, DC, 2001.

> A survey was conducted to evaluate the effectiveness of changeable message signs (CMS) along Southern California freeways in terms of driver's response to displayed messages. The survey participants are regular commuters who spend an average of less than one to three hours daily on the freeway and are familiar with the operation of CMS. The usefulness of CMS and its ability to convey clear, accurate and reliable messages are some of the questions included in the survey. The paper also addresses the drivers' perception on trip safety and travel time. The results indicate a general agreement that CMS are helpful and reliable. Yet, while most motorists pay attention to the displayed messages

and follow the diversion messages such as a detour, 28 percent consider them to b a distraction and 17 percent do not want to see additional CMS.

Uchida, T., Y. Iida and M. Nakahara. Panel Survey on Drivers' Route Choice Behaviour Under Travel Time Information. 5th Vehicle Navigation and Information Systems Conference proceedings, IEEE Service Center, Piscataway, NJ, 1994, pp.383-388.

This study examines the way dynamic traffic information should be provided by observing driver response to a travel time information system actually in operation. The paper highlights the basic thinking behind and implementation of the surveys and outlines the results of preliminary data analysis. Route choice models based on individual response to traffic information are also estimated.

ASSESSMENT OF SYSTEM-WIDE BENEFITS

Cost-Effective Measures and Planning Procedures for Travel Time, Delay, and Reliability. National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2003.

> The objective of this project is to develop a guidebook that presents a framework and cost-effective methods to predict, measure, and report travel time, delay, and reliability data from a customer-oriented perspective. The framework will address time of day, transit and highway, passenger and freight, vehicle and user types, and levels of aggregation (such as facility type, functional classification, and system/corridor/segment). The framework will also present and assess various data collection methods, analysis approaches, and applications that most effectively support transportation planning and decision making for capital and operational investments and for quality-of-service monitoring and evaluation. The methods should be presented in a useful manner for application in a range of settings and complexity.

Lam, William H. K.; Chan, K. S. A Stochastic Traffic Assignment Model for Road Network with Travel Time Information via Variable Message Signs. Hong Kong Polytechnic University. Dept. of Civil and Structural Engineering, Proceedings of the 1996 IEEE Intelligent Vehicles Symposium, IEEE Service Center, Piscataway, NJ, 1996. pp.99-104.

> In view of the serious traffic congestion during peak hours in most metropolitan areas around the world and recent improvement of information technology, there is a growing aspiration to alleviate road congestion by applications of electronic information and communication technology. Providing drivers with dynamic travel time information such as estimated journey times on major routes should help drivers to select better routes and guide them to utilise existing expressway network. This can be regarded as one possible strategy for effective traffic management. This paper aims to investigate the effects and benefits of providing dynamic travel time information to drivers via variable message signs at the expressway network. In order to assess the effects of the dynamic driver information system with making use of the variable message signs, a time-dependent traffic assignment model is proposed. A numerical example is used to illustrate the effects of the dynamic travel time information via variable message signs.