# Cellular Probe Feasibility Study

Eric Meyer, PhD, P.E.
Telvent Farradyne, Inc.


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# *Cellular Probe Feasibility Study*

Project Background


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The Kansas Department of Transportation (KDOT) and Cellint initiated a test of Cellint's Traffic Sense system, which derives travel time and speed data from cellular probes. Kansas City Scout is the freeway management system in Kansas City, and is jointly funded by the Kansas and Missouri Departments of Transportation. Scout's array of traffic sensors were used as the baseline against which the Cellint system was compared. Scout utilizes inductive loops and sidefire radar for traffic detection. Telvent Farradyne provides Scout with operational and technical support, including data analysis functions.


KDOT's goals were to determine the feasibility of using cellular probe data either in place of or to supplement data from conventional sources. Incident detection was the application of greatest interest, but other applications were also relevant, including the display of average speeds on a web site, providing travel times, and other performance measures.

# Project Timeline

- January 2006 – Discussions begin between KDOT and Cellint.
- February 2006 – Scout begins providing speed data to Cellint.
- March 2006 – Cellint creates a website with speed bands.
- April 6, 2006 – MOU is executed between KDOT and Cellint.
- April 2006 – Cellint agrees to also provide data along  a section of I-435 in Missouri.

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# Project Timeline (Cont.)

- May 2006 – Cellint completes their calibration work and begins to provide their initial slow down reports.
- June through August, 2006 – Cellint provides blind speed data along the I-435 study corridor.
- Winter 2006/2007 – Telvent analyzes the blind test data and produces a preliminary report.
- June 2007 – Final report completed.

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Data Analysis


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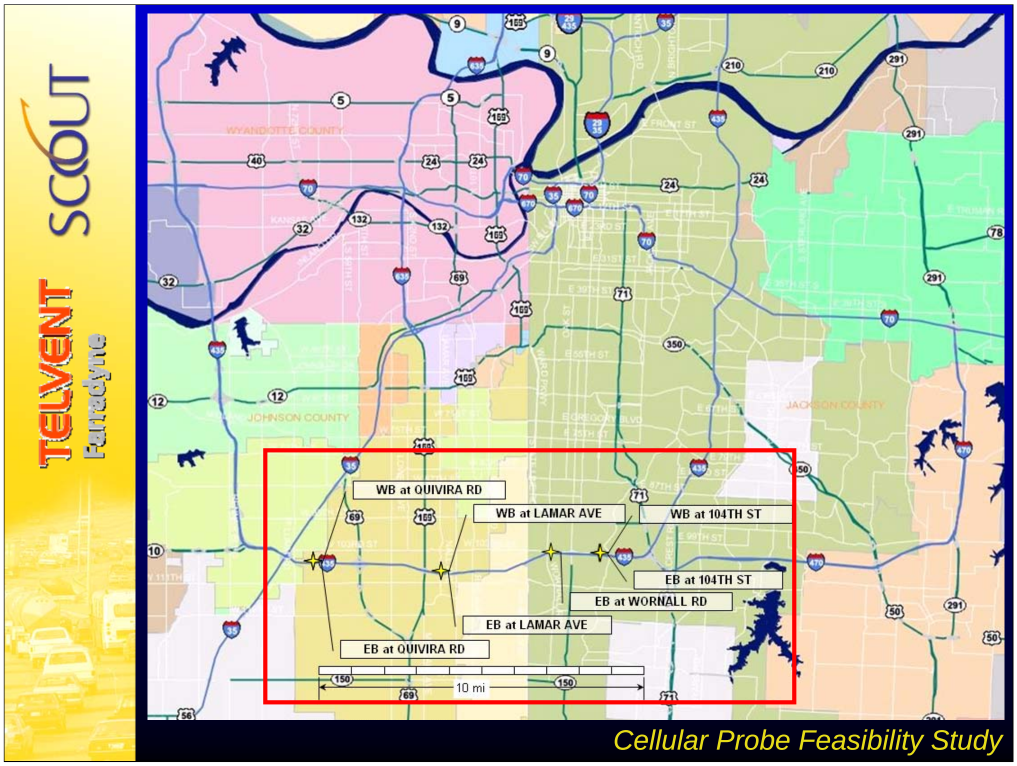
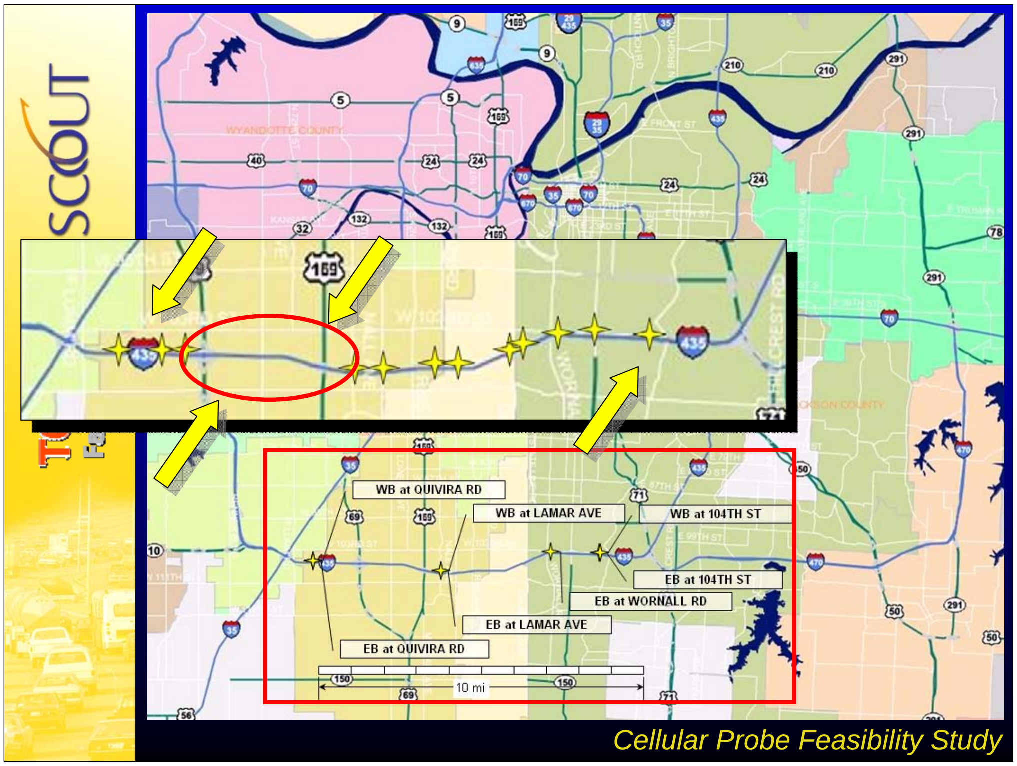
# Analysis Overview

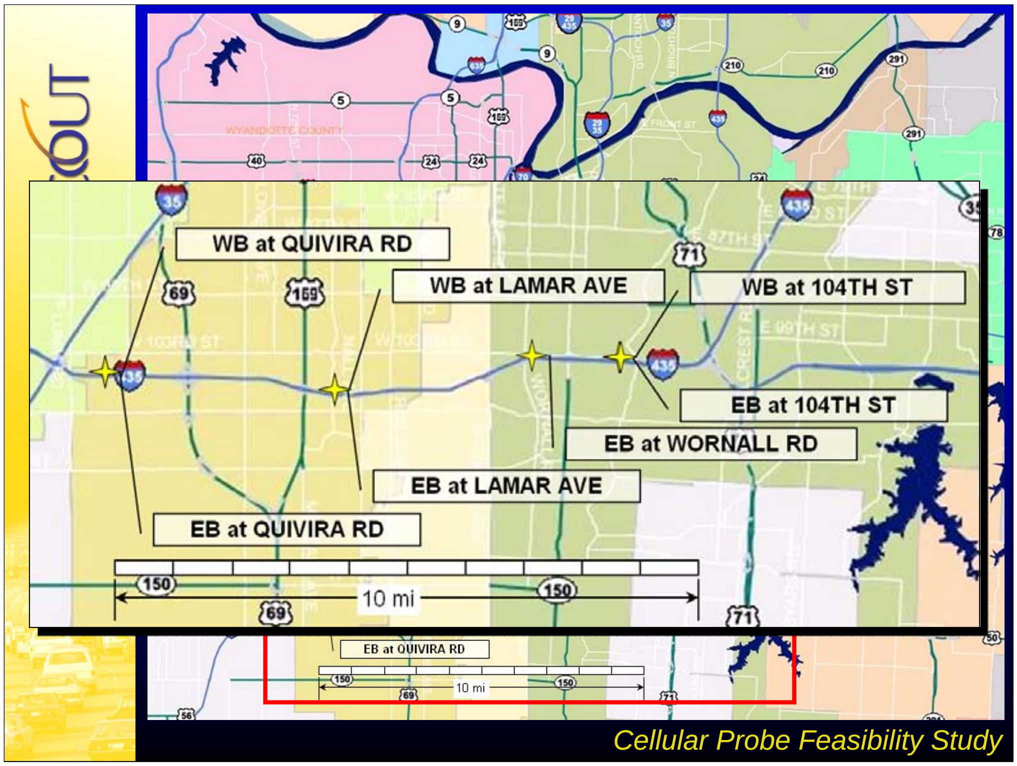
- General Reasonability
  - Compare the Cellint map to the Scout website map.
  - Observe how the Cellint speed bands change during accidents and construction lane closures.
- Speed Data Analysis
  - Scout provides detector speed data to Cellint for the calibration of the TrafficSense system.
  - Cellint provides blind cell probe speed data so Scout can perform an independent study.




The location of the evaluation was the southern corridor of I-435 in Kansas City. This corridor is approximately 10 miles long, approximately half of which is in Kansas and half in Missouri.  This is the second most traveled corridor in Kansas City with ADT's approaching 140,000 vpd.




Stars indicate locations of Scout traffic sensors. The red oval highlights a conspicuous gap in the sensor array caused by long term construction that necessitated the removal of all ITS devices. This construction persisted throughout the evaluation period. Cellint was able to provide data for this segment, but no Scout data was available for comparison, so it had to be omitted from the analysis. This highlights one of the significant advantages of using cell probes. The Traffic Sense system is not subject to construction-related outages the way that conventional loops and radar sensors are.




A subset of the Scout locations was identified for use in the evaluation.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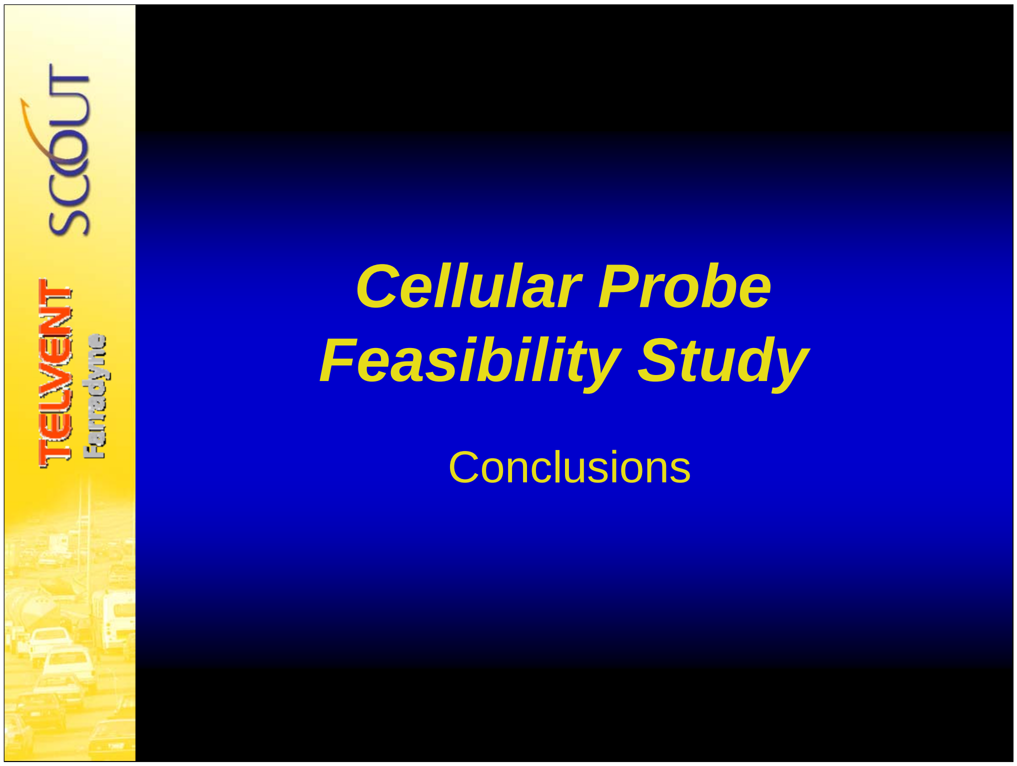


Because of the time limitations imposed on this presentation, the conclusions will be presented first. Then with whatever time remains, the approaches and some characteristics of the data will be discussed.


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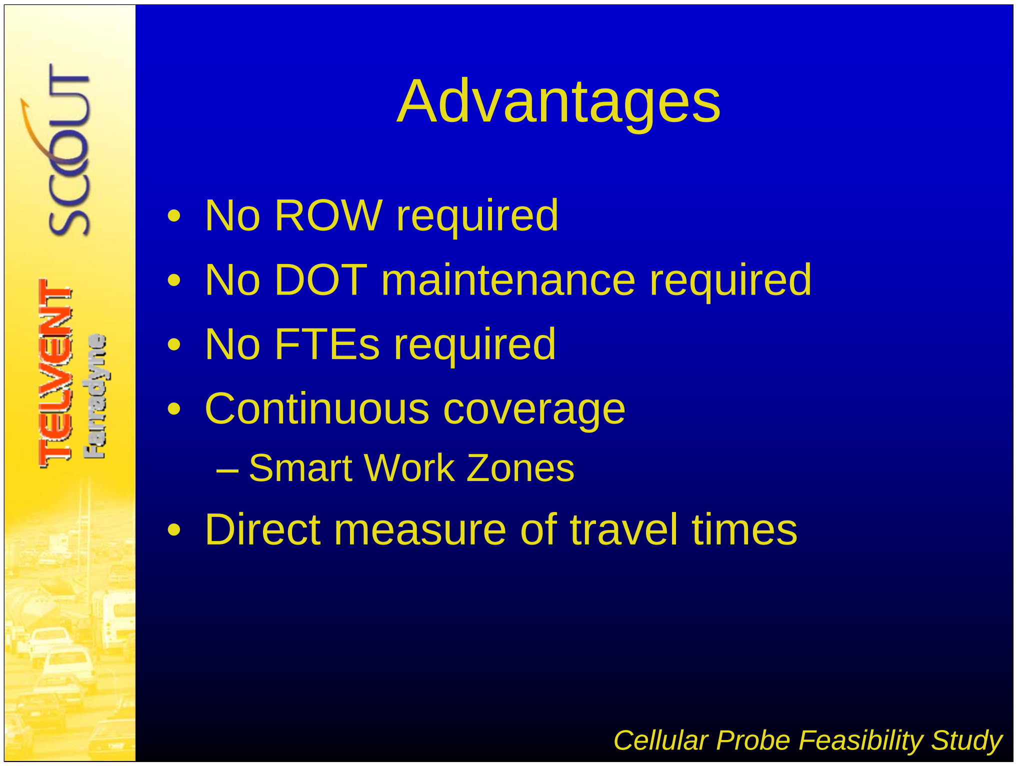
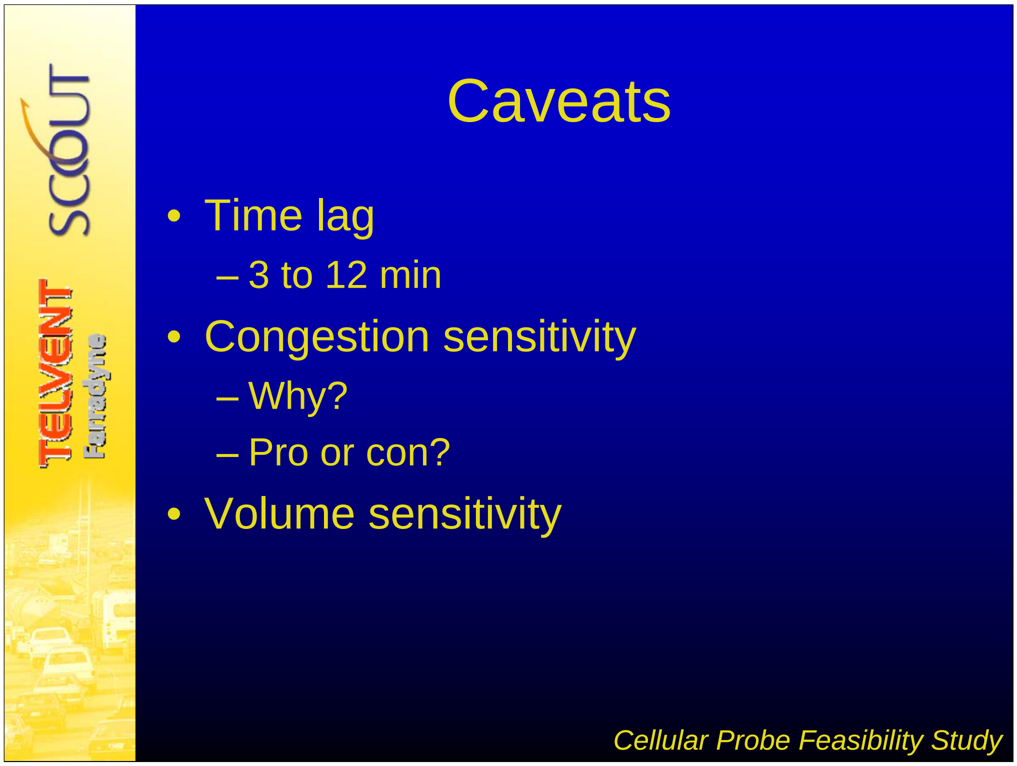



The Traffic Sense system does not require equipment located on the right of way. The system does not place additional burdens on DOT maintenance resources, and no DOT FTEs are required for operations. The system provides continuous coverage and is not susceptible to outages from construction, making it an excellent fit for Smart Work Zone applications. The system provides a direct measurement of travel times, rather than estimating travel times from spot speeds. Consequently, it may provide better data for certain performance measures.

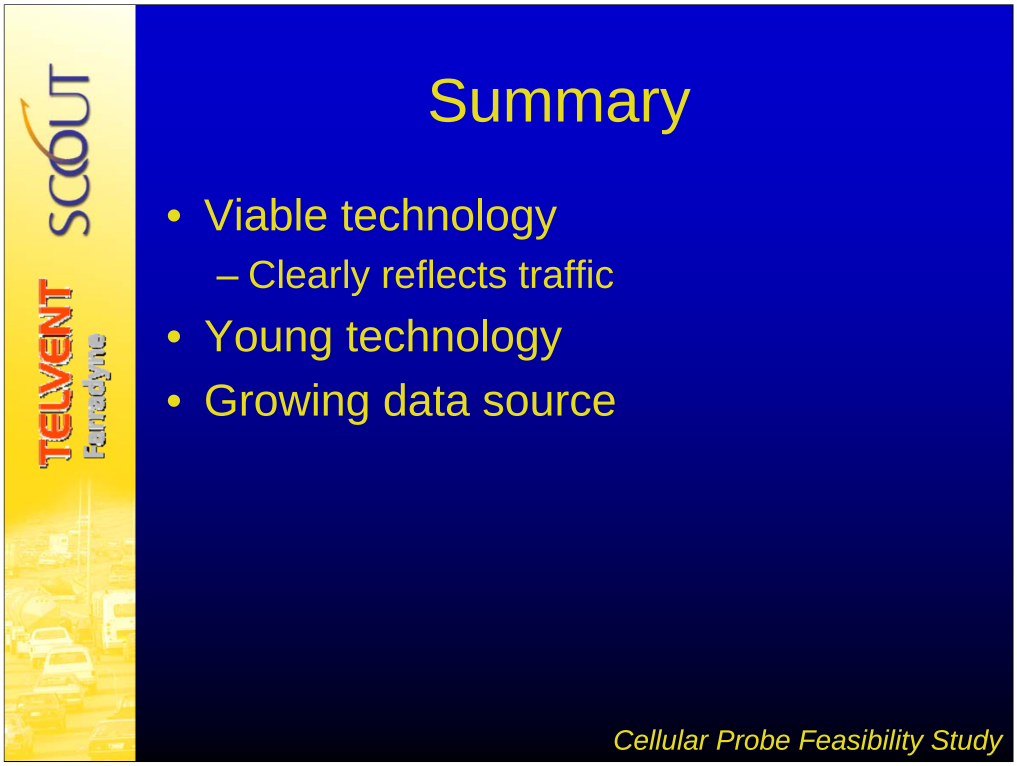



There is an obvious latency inherent in the Traffic Sense data. The magnitude of the latency seems to vary from site to site, and ranges from 3 minutes to about 12 minutes. The average value is probably around 6 minutes.

The system appears to be extra sensitive to low-level congestion. It is not clear why this occurs. This phenomenon may be an asset for some applications.

The system does not function well when volumes are extremely low. The operational threshold needs to be better defined.


Cellular probes have many great advantages, yet this is not the solution for all traffic data applications. For ATIS functions and providing travel times, Traffic Sense performs very well. For incident detection in an urban environment, the latency is probably too great for the system to be effective. In more rural areas, however, the latency may tolerable, and this may prove to be a useful solution. Valuable performance measure data could be collected with this technology, some of which would not be readily available by any other means.




In summary, the TrafficSense system performed well, demonstrating that this is a viable solution for many traffic data needs.  Yet, it is a relatively young technology that has not yet gained widespread acceptance.  As the transportation community begins to recognize the value and the maturity of this technology, there will yet be many advances in the technology itself as well as its application to new problems.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Methodology


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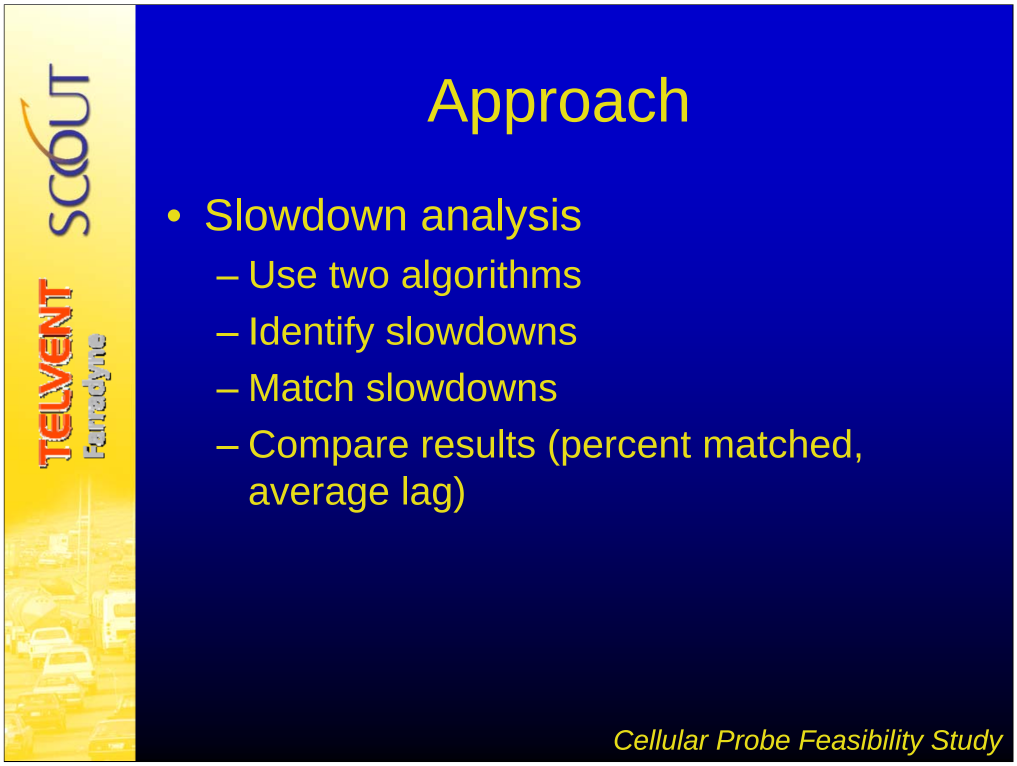
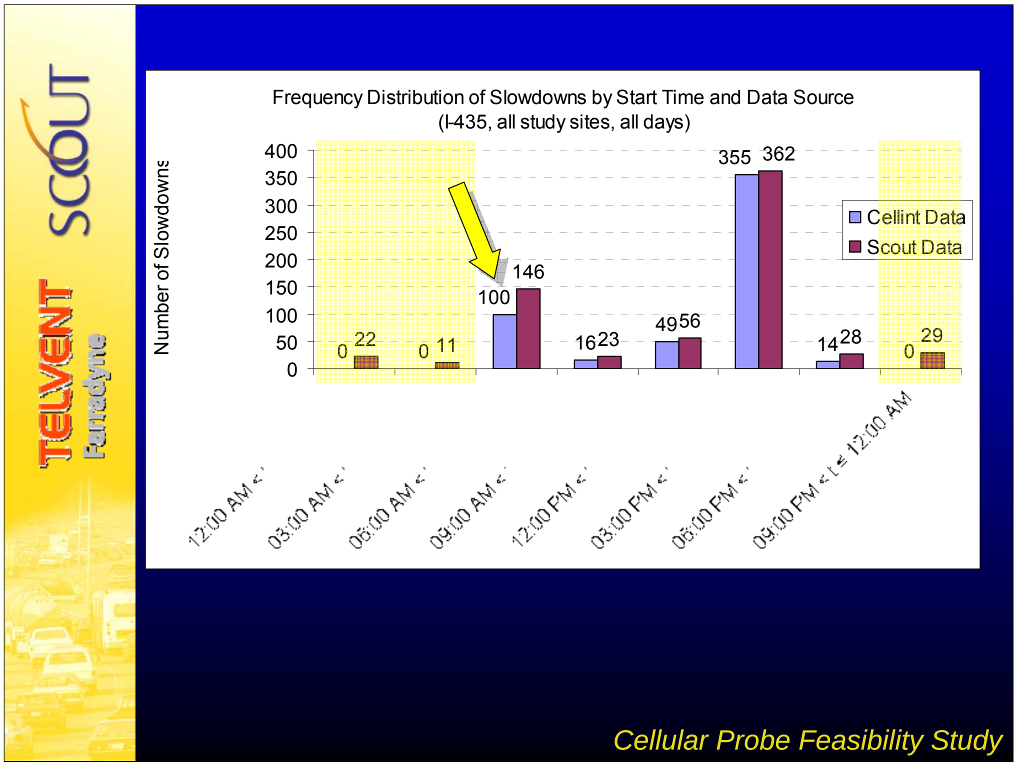
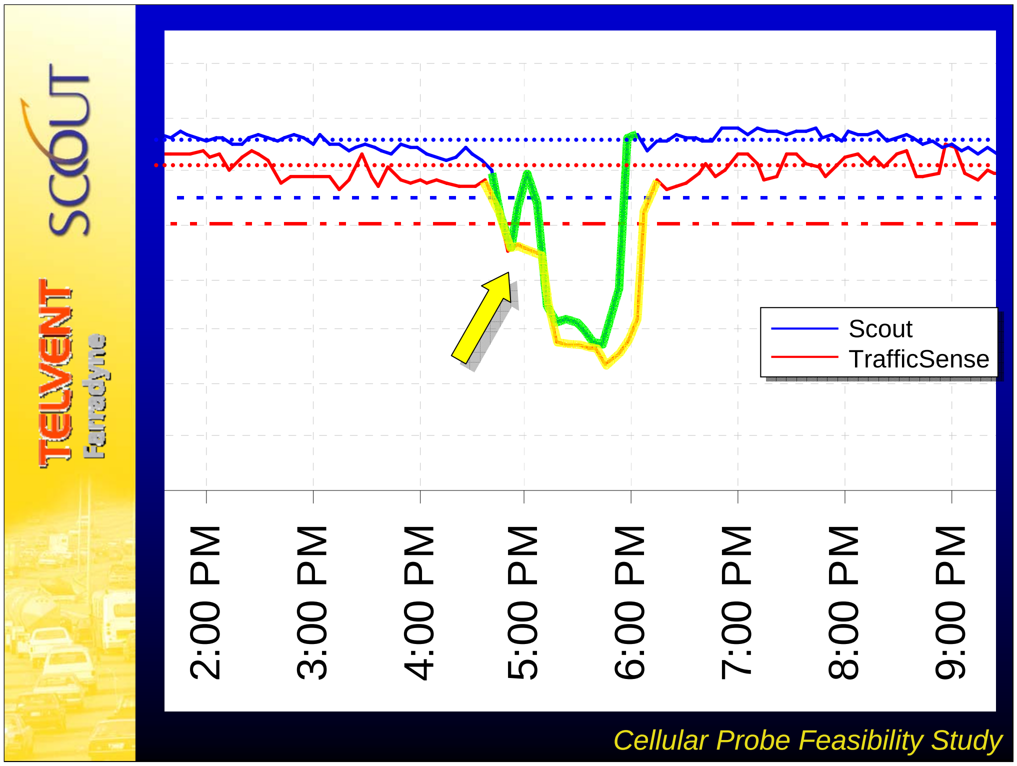



Incident detection was the application of greatest interest from KDOT's perspective. Since this evaluation used only speed data, incidents were represented by reductions in average speed, referred to here as slowdowns. Cellint had developed a definition of "slowdown" in their internal testing. A separate definition was also developed as part of this work. Both definitions were applied to the data, and they yielded very similar results.

The algorithm (or definition) for identifying slowdowns was applied to the data from TrafficSense and to the data from Scout. The slowdowns identified were matched between the two data sets, based primarily on the start time of the events. The results were examined and some adjustments made for instances where the slowdown definitions resulted in misrepresenting the relationship between the two data sets. For example, there often occurred a dual peak in the afternoons. In a dual peak, a small slowdown occurs at about 4:45, presumably representing workers who get off work at 4:30. This slowdown lasts about 15 minutes. Then another slowdown, more acute and longer lasting, begins at about 5:15, presumably from those workers whose workday ends at 5:00 or after. In some cases, the early peak in one data set would be mild enough that it would not register as a slowdown, while in the other dataset, the early and normal peaks are combined into one event. The beginning of the early peak in the second data set would get matched with the beginning of the normal peak in the first data set. This inaccurately represents the true latency, and would be manually corrected.




The first comparison performed was the number of slowdowns identified in each data set for a given time period. This graph shows the overall performance of the data sets was similar during the day with the exception of the morning peak period. At night, the TrafficSense system tended toward 60 mph, presumably because the data were too sparse to yield valid averages. Consequently, no slowdowns were observed in the TrafficSense data between 9 PM and 6 AM. This nighttime regime persisted past 6 AM, causing the disparity in the number of slowdowns observed in the 6AM to 9AM time period. As the morning rush began, the TrafficSense system would revert to normal operations and resume patterns consistent with the Scout data.



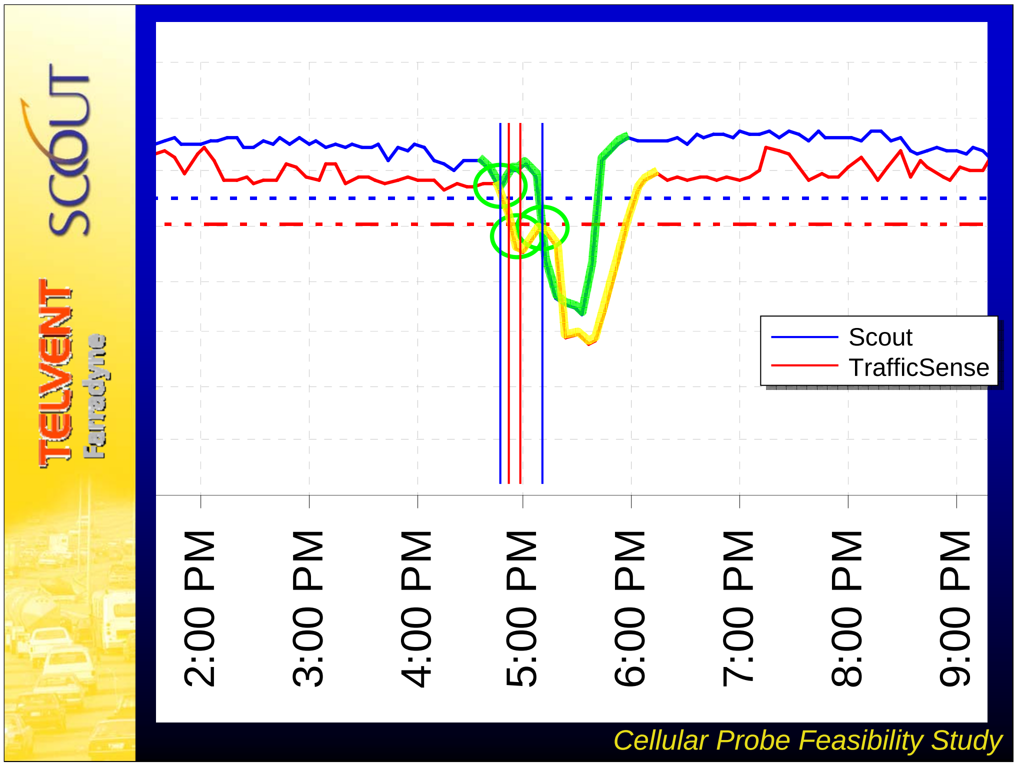

This plot shows several phenomena that occurred frequently in the data.

First, there is a latency in the TrafficSense data, particularly apparent in at the end of the slowdown.

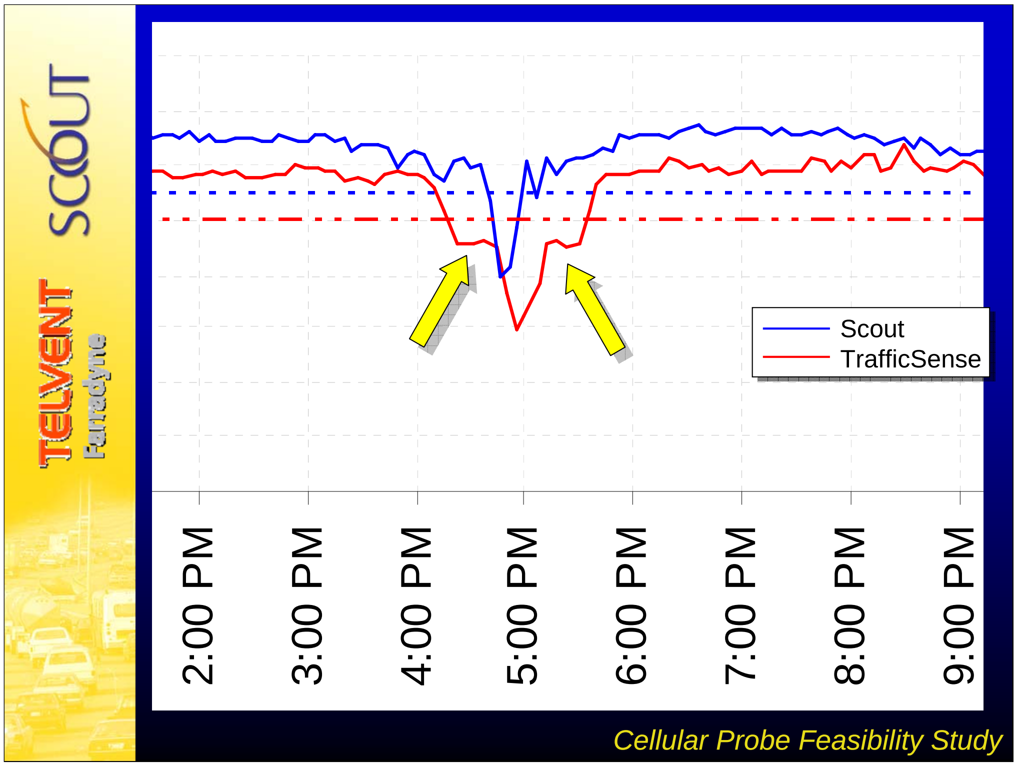
Second, the Scout data shows two distinct peaks, one beginning at about 4:45 and the other at 5:15. The TrafficSense data does not show the separation between the two peaks, combining them into one slowdown.

Third, during uncongested conditions, there is approximately a 5 mph difference between the average speeds observed in the two data sets. This is most likely an effect of systemic error in the Scout sensors' configuration.

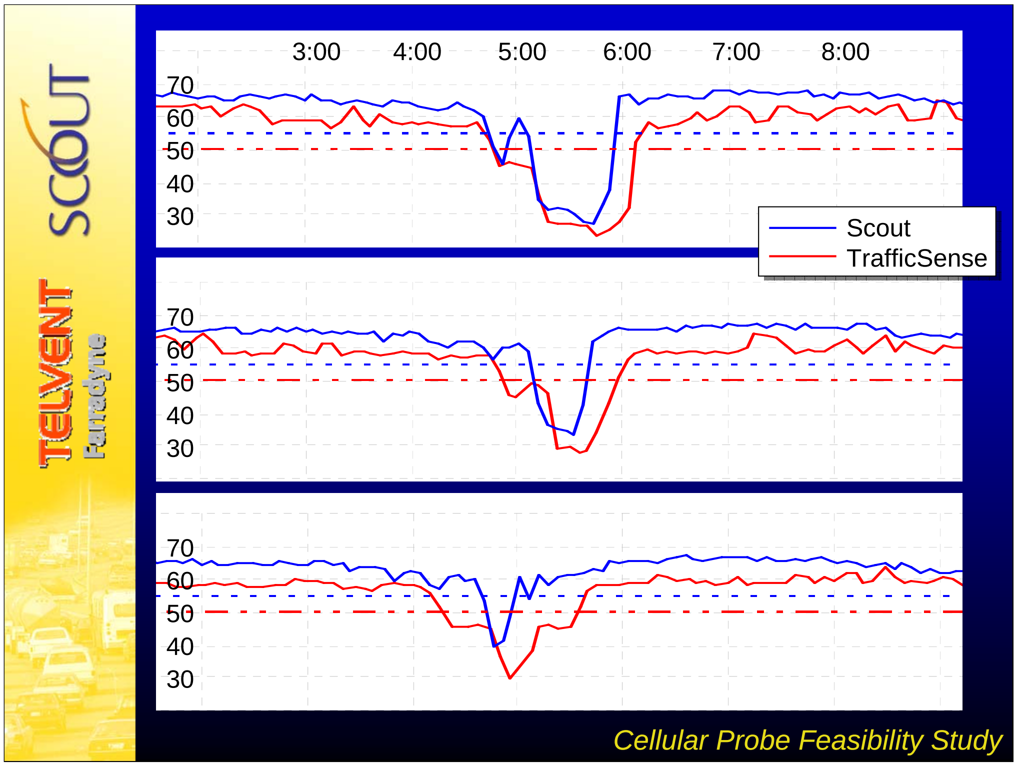
These issues notwithstanding, the TrafficSense data clearly approximates the Scout data well.



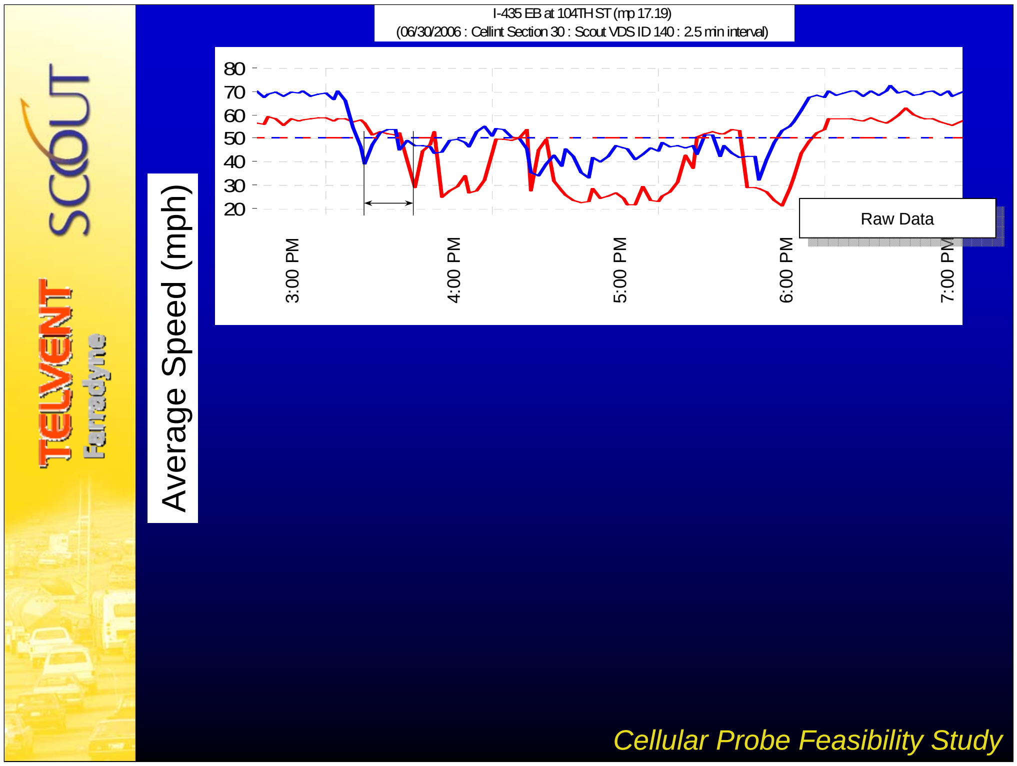

This plot shows the phenomenon described earlier in which the early peak does not qualify as a slowdown in the Scout data, and the separation between the early and normal peaks does not occur (strictly speaking) in the TrafficSense data. By observation it is clear that both data sets show both events, and that there is a latency in the TrafficSense data. However, blind application of the definitions of slowdown yielded a negative latency in the TrafficSense data (i.e., TrafficSense detected the slowdown *before* the Scout sensors). This type of anomaly was manually remove from the data. In some cases, the missing peaks were added, while in other cases the early peak was ignored, depending on the magnitude of the early peak.



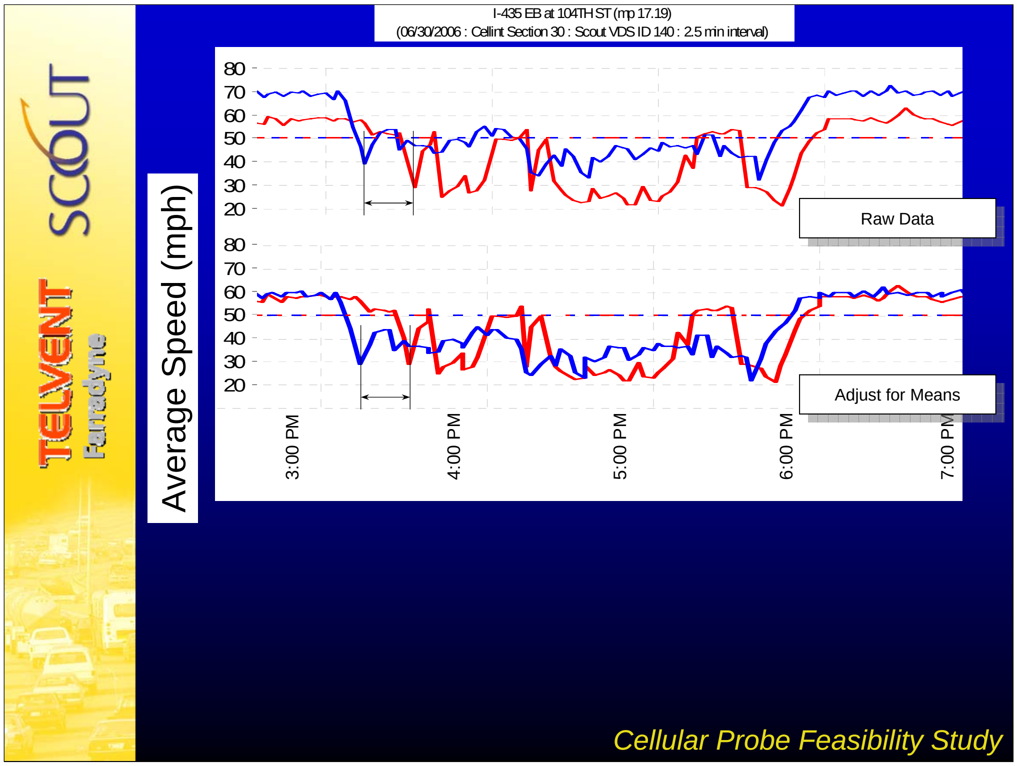

This plot shows the sensitivity of TrafficSense to light congestion. Where Scout data shows a reduction in average speed of approximately 5mph, TrafficSense shows a reduction of 10-15 mph. Otherwise, the data sets show similar characteristics here.



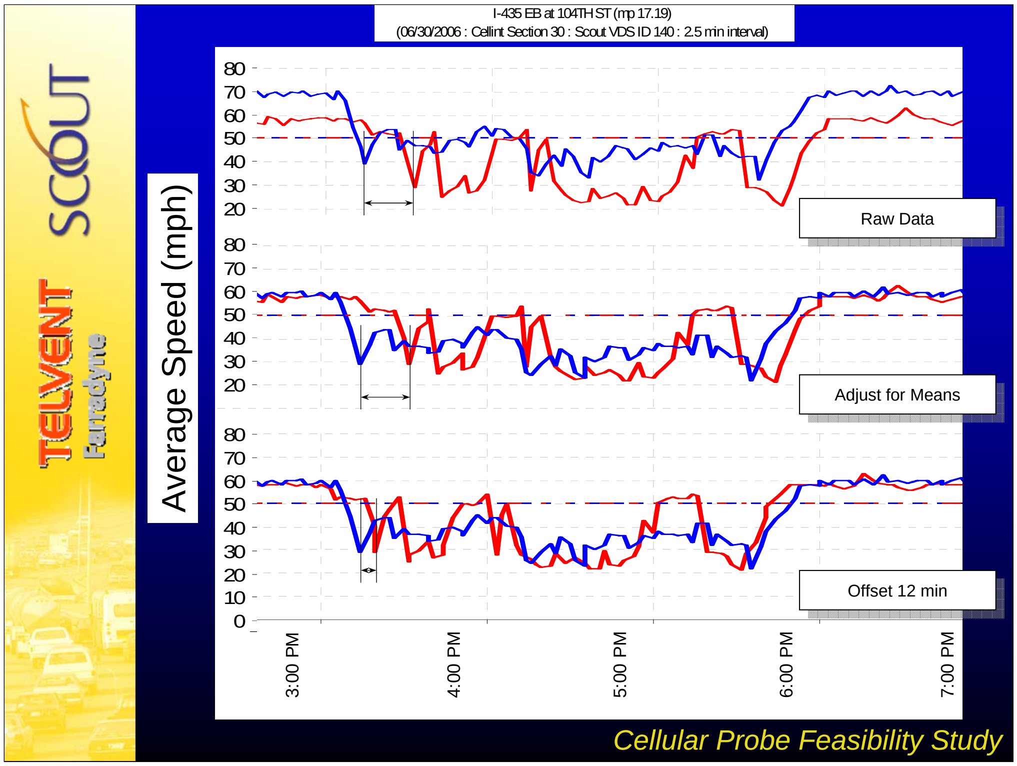

These are the three plots shown on the previous three slides. They show data from the same location and day of week on three different weeks. No incidents occurred during this time period on any of the three days represented, yet the patterns are quite disparate. This was characteristic at all sites. The changes in speeds from recurring congestion change dramatically from day to day.




This is data from the afternoon peak at one site, used here to illustrate some of the processing done to compare the data sets. Shown here is the raw data, with the latency of the TrafficSense data indicated using the initial slowdown event during this time period.

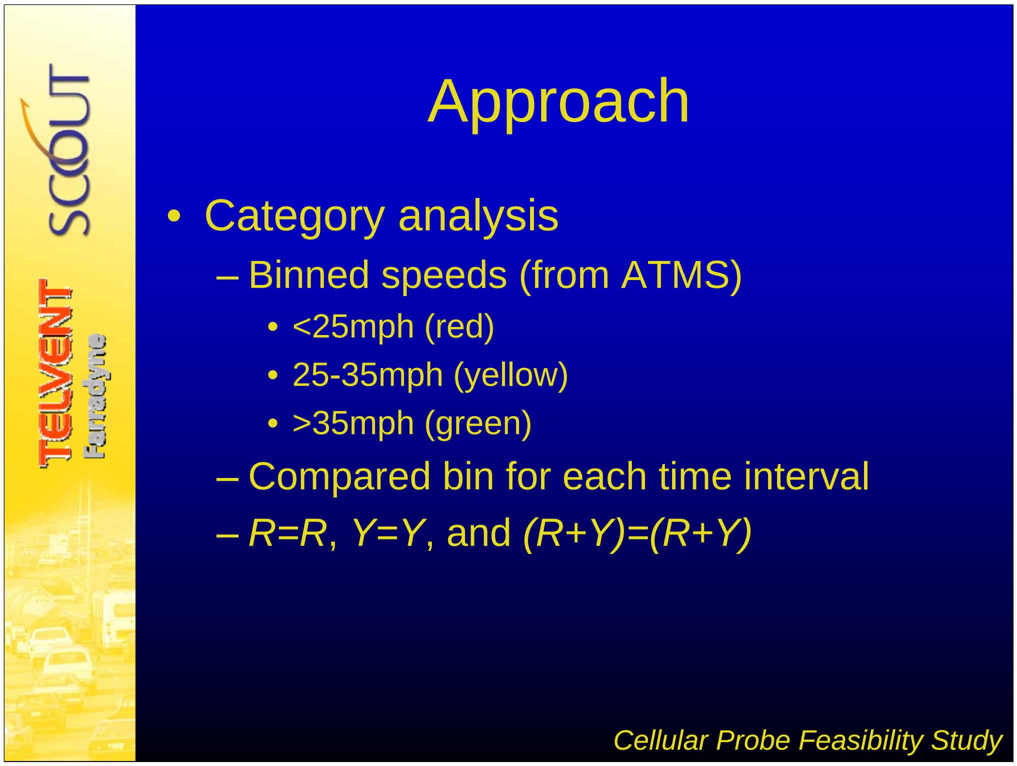



Note that in the upper graph (also shown on the previous slide), the uncongested speeds are approximately 10 mph greater in the Scout data than in the TrafficSense data. The reason for this disparity is unknown (one likely source is inadequately calibrated Scout sensors). However, since this evaluation is concerned only with the relationship between these two data sets, it is reasonable to compensate for this difference without compromising the validity of the comparison. An adjustment to the Scout data was applied, reducing all speeds by the difference between the average uncongested speed. This adjustment does not change the apparent latency. In some cases, however, it does change the nominal start time of slowdowns in the Scout data.



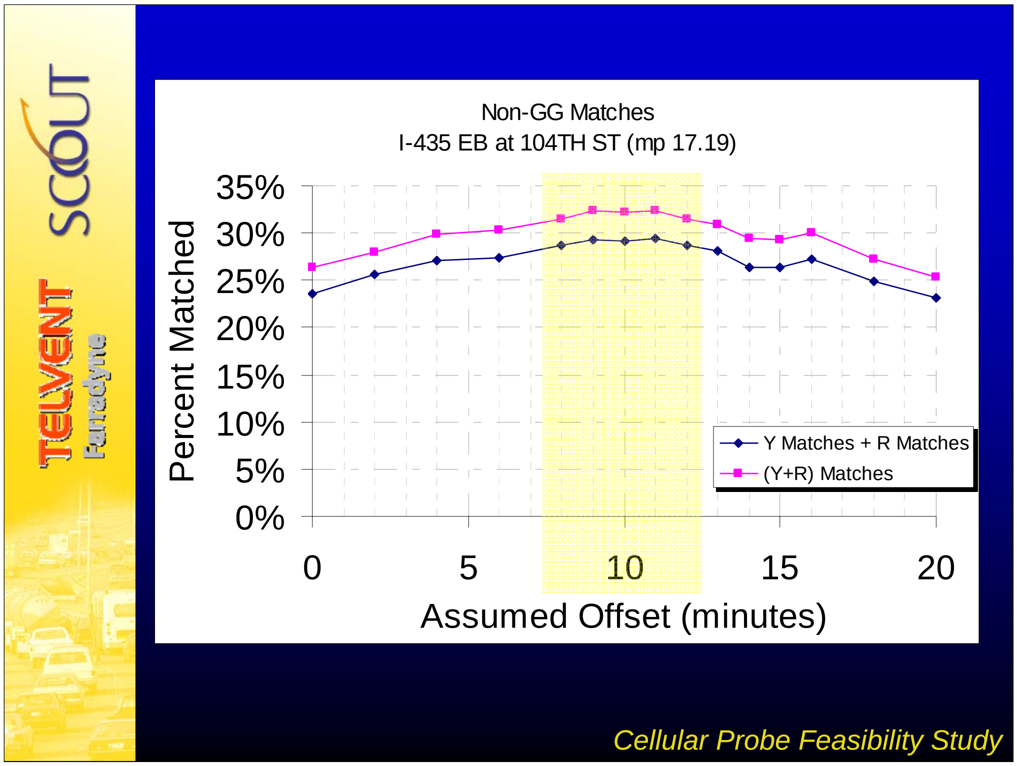

The third plot shown here illustrates how the data fit together after an offset is artificially applied to compensate for the alleged latency of the TrafficSense data. This shows a 12-min offset. This was an arbitrary value chosen simply by subjectively matching up the data shown. Based on all of the data examined, the actual latency of the system is probably about half that value.


The goodness of fit of the two data sets tended to be fairly consistent over time, but differed significantly from site to site. A generalized characterization was subjectively assigned to each site. These results are tabulated in the final report.

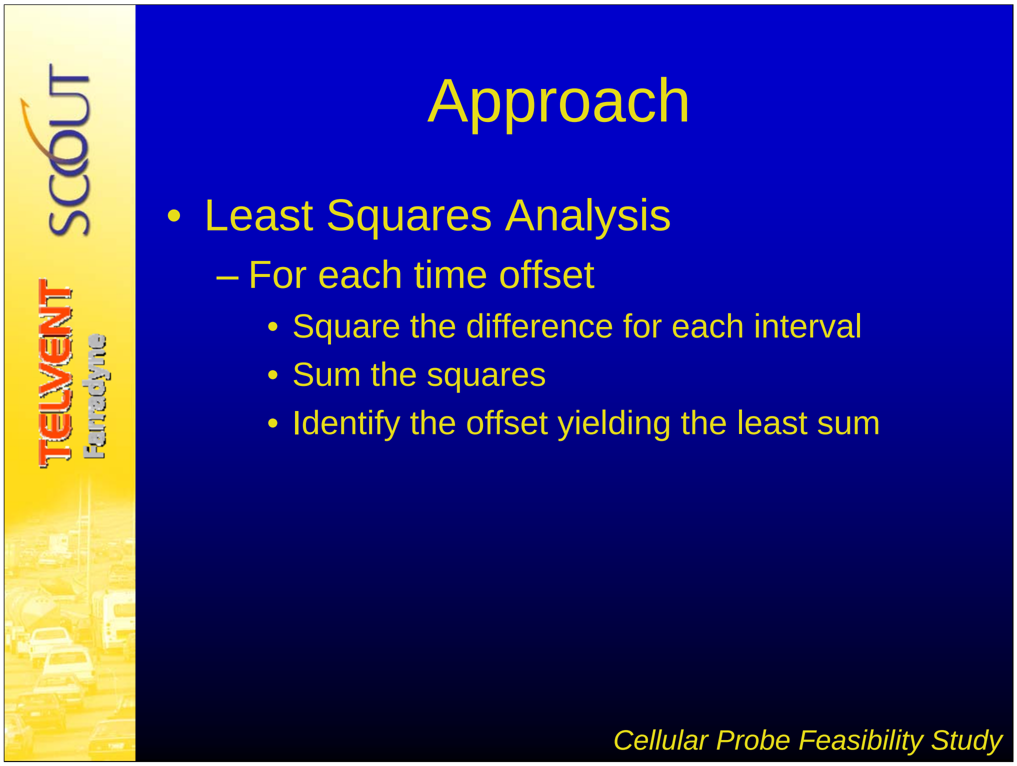



The goodness of fit of the TrafficSense data to the Scout data was objectively evaluated by two separate approaches. The first was a category analysis in which average speeds were aggregated into one of three bins, or categories, based on the speed ranges used for the color coded map at the Scout operator workstations. The categories were determined for each data set for each time period, and then each time period was compared to see if the two data sets showed the same category value. This would yield a percent of time periods matched. The time periods in which both data sets were in the green category were omitted from the calculation of match percentage, as their inclusion would mask the differences between the data sets.

Conceptually, if the TrafficSense were shifted along the time line to artificially reduce the latency, the match percentage should increase, the maximum indicating the value of the latency. This analysis was repeated as a two category analysis, combining the Red and Yellow categories.




This plot shows the results of the category analysis for one site. The maximum match percentage occurred around the 10-minute mark, but the maximum was not clearly defined. The changes in match percentage were not as high as expected. Some sites followed this pattern, while other sites did not.




A second analysis was performed to test the goodness of fit of the TrafficSense data to the Scout data in which the difference between the averages observed in the data sets was calculated for each time interval. Those values were squared and the squares summed. As with the category analysis, the TrafficSense data was shifted along the timeline in order to identify the shift interval that produces the best fit between the data sets. The results were very similar to those of the category analysis. The final report details the results.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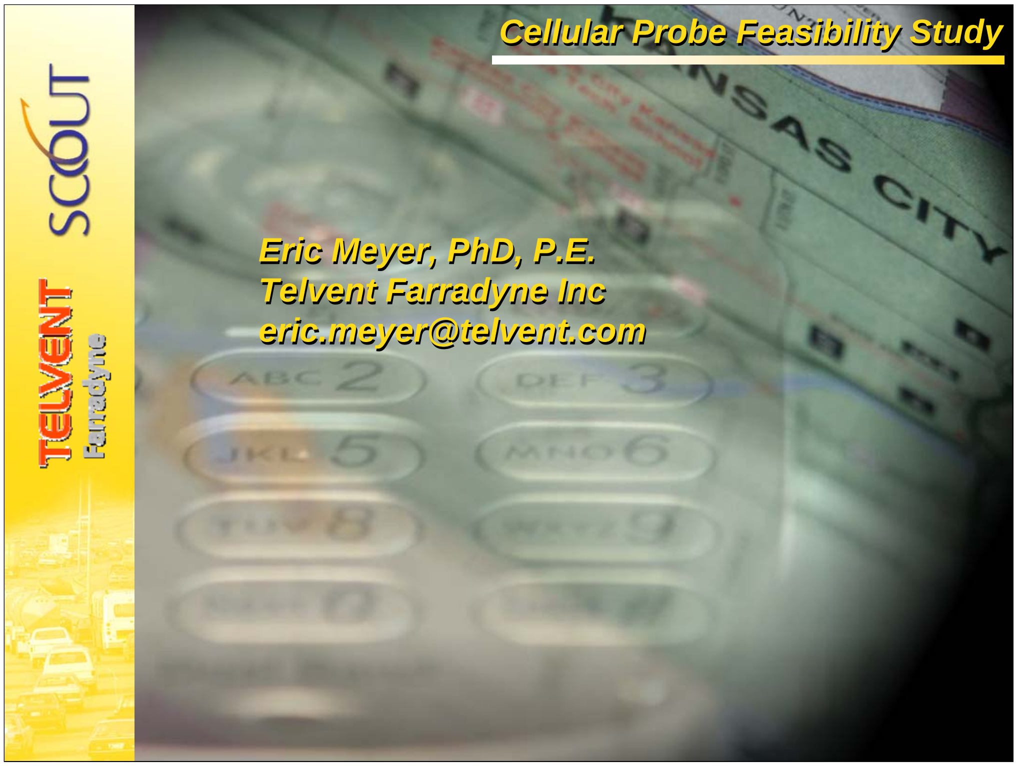


Contact Dr. Meyer with questions or if you would like to see the final report.