Position Paper on DynaFlow™

Derivation of Real-time Flow Data for Principal Roadways and Arterials in Major U.S. Markets

Proprietary

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1. Background and Introduction

Determination of traffic flow, usually thought of as highway speeds but also including consideration of volume, vehicle classification, driver behavior and other traffic characteristics, is essential to advanced traffic information systems. From calculation of travel time forecasts to inform personal navigation devices to capacity analysis for highway network managers, traffic flow data is an increasingly critical resource for travelers, logistics suppliers and transportation planners.

Collecting real-time flow data has traditionally relied on a series of road sensors, such as embedded loops and/or above ground poles along rights of way. Loop detectors, first deployed in the 1980's and the most common sensor system, require pavement intrusion, power provision and communications costs. The life cycles of early deployments are coming to an end; malfunctions and road construction typically cause at least 25% and often over 40% of a system's loop detectors to be out of service at any one time.

Since they do not require digging up the roadbed, roadside sensors are less costly to maintain, but installation investment is nevertheless steep, with ongoing power and communications expense. Data processing for all sensor types may be delayed up to 20 minutes, particularly in times of high volume when the information would be most critical.

After more than a decade of evaluation, public sector agencies have determined that fixed sensors are expensive to deploy ($100 million or more per metropolitan area), expensive to maintain, afford limited geographic coverage, and offer mixed reliability. And so, in the US in 2006, barely half of urban expressways in only 25 markets had any type of public sensor in place and even then only in sections:

Mkt Rank	Market	# sensors	Mkt Rank	Market	# sensors
2	Los Angeles(LAX)	3578	18	San Diego(SDE)	440
3	Chicago(CHI)	1331	21	Denver(DEN)	89
4	Washington DC(WDC)	320	23	Portland (POR)	163
5	Baltimore(BAL)	83	24	Cincinnati(CIN)	34
6	San Francisco(SFO)	1254	25	Kansas City(KCY)	168
9	Detroit(DET)	218	26	Milwaukee(MKE)	568
10	Dallas (DAL)	98	27	Sacramento(SAC)	189
11	Houston(HOU)	303	28	Norfolk(NOR)	232
12	Atlanta(ATL)	100	30	San Antonio(SAT)	1908
14	Seattle(SEA)	966	35	Salt Lake City(SLC)	464
16	Minneapolis(MIN)	928	50	Louisville(LOU)	16
17	Phoenix(PHX)	349	57	Fresno(FRE)	14

Figure 1: Number of Road Sensors Providing Flow Data Available to Public in 2006

Newer, cost-effective sensor technology is recently available to public agencies, which offers flexible installation procedures with minimal infrastructure impact. As it overcomes the bureaucratic hurdles of system acceptance, it still faces the limit of only providing flow data where installed.

The most significant emerging technology in flow data collection is Traffic Probe. Compared to fixed-point sensors, which derive flow data from vehicles crossing the sensor, probes collect data based on the movement of the vehicles themselves. In concept, this method can dramatically expand roadway coverage to include both primary and secondary roadways. Meaningful road network flow data can be integrated and analyzed. Without reliance on infrastructure investment, both deployment and operation should be a fraction of the cost for traditional sensors. Significantly, processing delays for probes are typically less than five minutes.[1] Coverage is continuous, rather than limited to pre-determined fixed points.

There are three primary methods to obtain traffic probe data:

- Transponders - such as "tags" issued for Electronic Toll Collection
- Cellular probes
- GPS devices on commercial fleets

Transponders collect travel time, but only between fixed points where readers have been installed. By nature, transponders will best provide data for their related toll road.

Cellular Probes are in an earlier development stage than Transponders or GPS devices but show much greater long-term promise, primarily because proprietary technology need not be installed in vehicles. Cell phones are ubiquitous, and since speed data is derived from administration of cellular traffic, and not direct contact with the cellular device, communication costs are minimal. In practice, both operating and capital costs are low, although the wireless company typically expects payment for use of its data. The technique is fully scalable once technical arrangements are in place.

A considerable body of research on cell probes development and deployment already exists. Cell probes work by identifying multiple traffic patterns, which are then compared with corresponding historical patterns. The system derives travel times first, and then converts travel times to average segment speeds.

TrafficCast International technology is deployed in the largest commercial cell probe system to date in Shanghai in association with affiliate TrafficCast-China and China Mobile. The Company recognizes that this success reflects unique business, government and societal factors very distinct from those in the United States. The cellular partner is the dominant provider in China, this partner is closely aligned with government priorities, including their urgent need for traffic management systems, and privacy issues do not have the precedence they do in the U.S. While TrafficCast firmly believes in the promise of cell probe technology, it does not realistically anticipate widespread acceptance in the US until 2009.

[1] The constraint on the amount of roads where data can be collected relates to the fraction of vehicles equipped as probes. The time required to collect these data depends in part on the form of communication used and the density of data needed to assure statistical significance for any speed or travel time reports.

GPS Devices are increasingly installed on commercial and public-sector vehicles which require a regular means of communication to download and upload data. Several companies dominate installation of truck fleet monitoring systems. Usually communicating via satellite systems, they typically report the vehicle location and status every half hour or so. Through 2005, about 600,000 of these systems had been sold; a smaller number are actively used, which provide their location information in less than 15 minutes – a maximum threshold of time interval for real-time traffic reporting. Most are installed on long-haul trucks.

For the most part, truckers avoid driving during rush hour since they are typically paid by the mile, and cover fewer miles when stuck in traffic. Long-haul drivers especially prefer off-peak periods when they are less likely to encounter traffic delays or accidents. Consequently, at rush hour, when traffic flow data is needed most, the number of trucks operating with GPS monitoring devices is substantially diminished.

Another factor fleet monitoring systems pose for speed calculations is the significant latency between when data is captured and when it is reported. In non-urban areas, the number of trucks reporting on a given road segment is small, so data accuracy suffers.

General Motors addressed this critical balance between data accuracy and latency in a 2004-2005 evaluation of minimal data requirements for GPS-based traffic monitoring. GM has a particular interest in this area due to its OnStar™ product line. The study concluded[2] that:

- For US coverage, at least 3% of all vehicles must be available for GPS probe sampling to effectively support real-time traffic monitoring of freeways only. That would require approximately 5 million vehicles. To extend coverage to major arterials and surface streets would require sampling rate of 5% or nearly 10 million vehicles.

Furthermore, based on the US Census data, it can be concluded that:

- For top 10 metropolitan areas in the US, meaningful data sampling would require at least 2.3 million probe vehicles for freeways and at least 3.8 million for major surface streets.

- For top 30 metropolitan areas in the US, meaningful data sampling would require at least 3 million probe vehicles for freeways and at least 6 million for major surface streets.

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[2] Sources: Journal of Intelligent Transportation Systems, Volume 9, Number 1, January-March 2005 ; US Census 2000; US Bureau of Transportation Statistics

A study[3] by the University of California at Berkeley in 2000, reached a similar conclusion: support of a real-time traffic information system based on GPS-probes in the San Francisco Bay Area would require 5% samples or 300,000 probe vehicles to adequately cover just the Bay Area freeways.

There are various claims that GPS data collected from commercial fleets more efficiently delivers samples necessary for real-time traffic flow information, based on typical routing and more productive utilization of such fleets (although the contentions ignore that fleets are less active or even inactive outside of work hours and on weekends). These assertions of fleet data efficiency range from 3X to 5X in the US to as high as 30X for the more densely traveled roadways in the UK. Even after applying such efficiency factors against the sampling requirements determined by the studies above, the maximum number of US commercial vehicles equipped for GPS probes would not be adequate for large-scale real-time traffic flow data collection at this stage or in the near future (by 2010).

		GM Evaluation of GPS Probe Required for Real-Time Traffic Minimum Vehicle Sampling Rates		Assume Commercial Fleet Efficiency for probe data sampling					
				Efficiency Factor = 3 Times Probe Vehicles Required		Efficiency Factor = 5 Times Probe Vehicles Required		Efficiency Factor = 30 Times Probe Vehicles Required	
US Metro Markets	Est. # Vehicles (US Census)	Freeway = 3%	Arterials = 5%	Freeway	Arterials	Freeway	Arterials	Freeway	Arterials
Top 10	3,069,733	92,092	153,487	30,697	51,162	18,418	30,697	3,070	5,116
Top 20	1,956,146	58,684	97,807	19,561	32,602	11,737	19,561	1,956	3,260
Top 30	1,330,011	39,900	66,501	13,300	22,167	7,980	13,300	1,330	2,217
Top 40	1,010,456	30,314	50,523	10,105	16,841	6,063	10,105	1,010	1,684
Top 50	820,860	24,626	41,043	8,209	13,681	4,925	8,209	821	1,368
Top 60	593,478	17,804	29,674	5,935	9,891	3,561	5,935	593	989
Top 70	509,462	15,284	25,473	5,095	8,491	3,057	5,095	509	849
Top 80	425,884	12,777	21,294	4,259	7,098	2,555	4,259	426	710
Top 90	386,638	11,599	19,332	3,866	6,444	2,320	3,866	387	644
Top 100	346,944	10,408	17,347	3,469	5,782	2,082	3,469	347	578
Total US	243,023,485	7,290,705	12,151,174	2,430,235	4,050,391	1,458,141	2,430,235	243,023	405,039

Figure 2: Evaluation of GPS-Equipped Vehicles Required for Derivation of Meaningful Real-Time Traffic Flow

2. DynaFlow: Baseline Aggregated Flow Data

In the face of these technology limitations, TrafficCast International (TCI) answers the demand for reliable, meaningful traffic flow data across the US with DynaFlow, traffic flow calculated in real-time using patented dynamic traffic models (US Patent No. 6,317,686).

DynaFlow is TCI's estimated travel speed for real-time application. For roadway segments with no sensors/detectors and no real-time coverage of probe vehicles, real-time traffic speeds (when clock time is zero – current) are estimated based on historical flow,

[3] PATH, University of California at Berkeley, Working Paper, PaperUCB-ITS-PWP-2000-18, 2000.

real-time flow (3 – 10 minutes latency), and traffic impact from incident, construction, special event, and weather condition.

Specifically, DynaFlow recognizes that traffic flow is impacted by five primary conditions, as defined in the US Department of Transportation analysis of traffic congestion and its impacts[4]. The analysis argues that, fundamentally, congestion (or restricted traffic flow) is caused by an imbalance between road network capacity and demand for access. In economic terms, any imbalance between supply and demand increases the price to use the system, measured in costs of delays and lost productivity. While the fundamental causes are structural, the secondary causes can be addressed through policy. Plans to alleviate congestion require reliable information which account for the interrelationship of these causes.

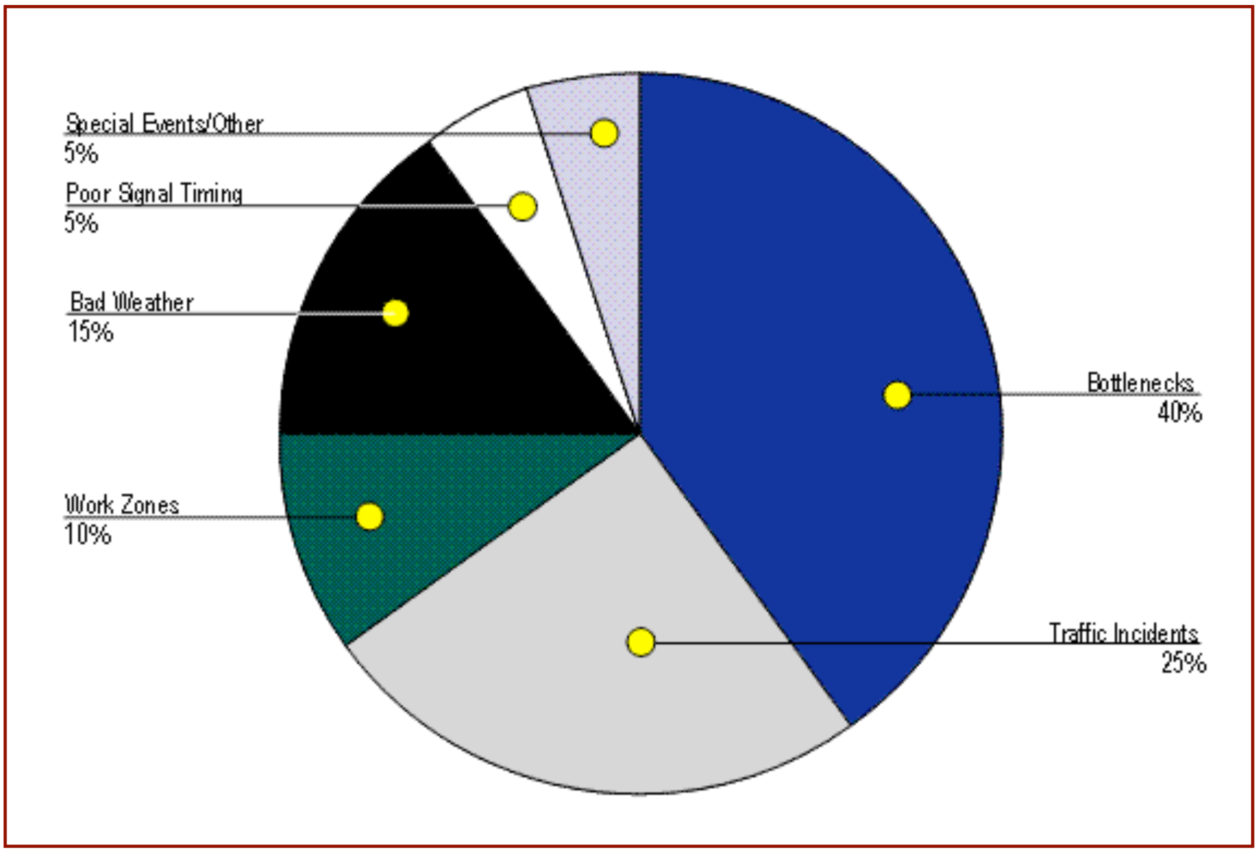

Figure 3: An Initial Assessment of Freight Bottlenecks on Highways, FHWA White Paper (Source), October 2005

By far the largest cause of congestion is "bottlenecks" – highly predictable constraints on traffic flow due to regular imbalances between capacity and demand. Even beyond peak

[4] National Strategy to Reduce Congestion on America's Transportation Network, US Department of Transportation, May 2006.

hours and bottleneck delays, traffic patterns have clear rhythms in the ebb and flow of daily and seasonal travel.

Up to 70% of normal traffic flow in all hours can be explained by these patterns. Dynamically modeling the impact of incidents, construction, weather, events and other factors against these patters can increase the accuracy of traffic flow prediction to over 90%. DynaFlow enables such modeling within markets and across inter-city routes for real-time and near-term forecasts of driving speeds and travel times.

The foundation of the model is reliable traffic pattern data. TrafficCast International archives road speeds reported from 14,000 public sensors deployed in more than 25 markets around the US. This archive is a precise record of speed trends, but market coverage is limited. TrafficCast International also aggregates and archives traffic volume data, congestion level data, travel patterns, temporal and spatial distributions, and granular road network utilization data from federal and state transportation agencies with a focus on 450,000 miles of major US roadway network. In addition, TrafficCast complements and enhances its internal archives integration of GPS tracking data, at this time collected primarily from movements of commercial fleets.

The integration exploits the accurate travel conditions GPS probes communicate, but avoids current sampling limitations of such data in real-time by aggregating the data points across time. After applying patented science and multifaceted algorithms to the integrated data, TrafficCast develops a baseline of typical travel speeds and traffic patterns for virtually all expressways and major arterials in the continental US, by hour of day, day of week and season of year.

Processing of the GPS tracking data begins with extrapolation of road speeds, latitude/longitude location and other information collected from vehicles. This data is positioned on digital map segments, the most granular building block of navigational analysis. Each segment typically represents between 250 and 1,400 feet of travel distance. Traffic patterns must be modeled at this highly granular level to be truly effective.

TrafficCast accounts for the idiosyncrasies of each data source as well as the relationships among the sources, and incorporates significant error detection and correction elements. Road speed data is then correlated to tertiary data and evaluated for patterns. Forecast speeds based on these patterns are then calculated through various predictive algorithms, which are verified against actual speeds reported in later data aggregations. "Artificial Intelligence" refines the predictions through this feedback process.

3. Integration of Traffic Impacts within TrafficSuite™

TCI proprietary impact models dramatically augment the value of aggregated, historic traffic pattern data by calculating dynamic traffic flow in real time. The models are incorporated within the proprietary TCI system architecture, known as TrafficSuite™. This collection of software programs, reader files and monitoring systems enables the dynamic integration of real-time traffic impact data with historic traffic patterns and known bottleneck factors.

Through TrafficSuite, TCI gathers real-time traffic data from over 350 public and private sources:

- 181 - Incident and Construction Data Sources, including virtually all public agencies as well as elective sourcing from Westwood One's Metro Network, the leading producer of traffic incident data for the top 75 US media markets.
- 30 - Flow Data Sources, reporting traditional road sensors operated by public agencies. TCI also has a strategic alliance with SpeedInfo, a private venture deploying innovative sensor technology exploiting the flexibility of mobile communications and solar power.
- 3 - Weather Data sources, including site-specific precision weather forecasting models from MyWeather LLC, an affiliate company of Weather Central, Inc, the leading provider of weather graphics to media.
- 90 - Event data sources.
- 50 - Archival Traffic Data sources, including public sensor data as well as the processed GPS tracking data noted above.

The DynaFlow process calculates roadway link speed for both real-time and near-term "forecasts" up to 48 hours in the future. Longer-term forecasts based solely on weather and scheduled construction will be derived in a similar manner. The process involves four major steps:

1. Integrate sensor-based and GPS-based spped/flow data sources.

2. Apply weather impact to archived flow every 6 hours
   a. Future versions of DynaFlow will further integrate real-time weather data, including tracks of severe weather storm cells.
   b. Longer-term DynaFlow forecasts, also integrating planned construction, will further support trip planning tools.

3. Apply incident and construction impacts to step 2 output every 5 minutes.
   a. Heuristic statistical analysis will increase accuracy of incident and construction impacts over time.
   b. Future versions of DynaFlow will also integrate updated timing of traffic-impacting events, such as ball games and street fairs.

4. Produce DynaFlow data feed, updated incrementally every five minutes
   a. DynaFlow output will be fused with delayed DOT real-time data (where available) to further refine accuracy.

The DynaFlow data process diagram on the following page graphically details these steps. The diagram includes the following acronyms:

- Tci_hspd = TrafficCast archived speed data
- Lps_hsdp = Archived speed data from GPS sources
- ntid_wgrid = Weather data matched against digital map coordiates
- weather_info = Precision weather forecast data (MyWeather)
- weather_impact = TrafficCast weather impact modeling
- dynaspd_w = Dynaflow data; based on weather impacts only
- ntid/ntdir = Digital map coordinates/digital map direction
- tc_inci_constru = TrafficCast real-time incident/construction data
- impact_table = TrafficCast incident impact modeling
- dynaspd_w_inc = Dynaflow, including weather/incident/construction
- rtlinkspeed = Real-time flow data (where available)
- pspeed = Dynaflow data refined by sensor-based flow data (where available)
- ArcIMS = Graphic interface for mapping (ESRI ArcIMS™) for display

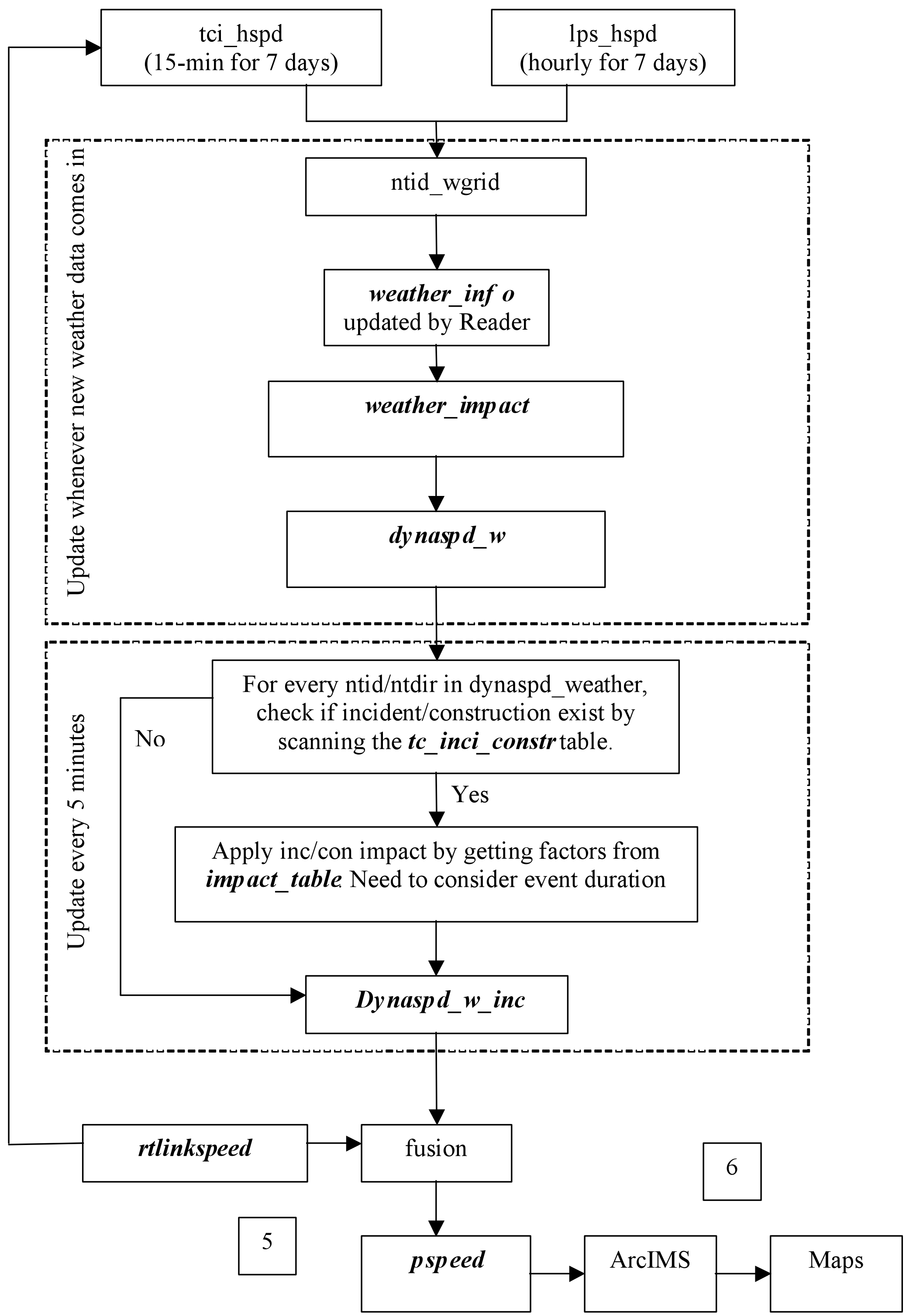

Figure 5: Dynaflow Data Process Diagram

4. Verification: DynaFlow Modeling Accuracy

Due to reporting latency, processing technologies and malfunctioning sensors, all "real-time" traffic flow data are at basis predictions. Their value is measured by (1) the confidence level in the forecast, and (2) more importantly, their correlation with actual conditions.

This correlation, perhaps better described as forecast accuracy, can be validated by a number of methods:

- Driving routes: the most expensive and least replicate-able option. Hiring drivers can seemingly provide "road truth" for speed and travel time predictions, but it is subject to the driving characteristics of the participants and requires multiple route passages to overcome sampling errors.

- Sensor data: where available, road sensors report link speeds that cost-effectively validate forecast speeds. However, sensor data is itself a real-time "forecast" subject to processing and algorithm errors. For the most part, sensors are limited to freeways and provide limited guidance for arterials. Sensor technology is also more prevalent in the western US.

- Sensor spot checks: sensors can be temporarily installed for validation of particular road segments, but this approach is not practical for national forecasts.

- GPS data probes: while GPS probe does not provide data samples sufficient for real-time traffic flow forecasts as outlined in the introduction, the raw GPS data can be used to validate forecasts "after the fact".

TCI will validate DynaFlow primarily through analysis of raw GPS data captured "live" but reported in the week(s) following the actual production of the forecast. This raw data, such as the data archived to develop typical speed patterns, has the advantages of replication, driver neutrality and "road truth" conditions. As digital data, it can also integrate into heuristic models and provide "artificial intelligence" to refine the accuracy of future forecasts.

Calibration and validation of DynaFlow data is a continuous working process. Efficient validation processing is itself a large development task, as the objective is to measure both confidence and accuracy for both individual markets and the national road network. Preliminary validation in selected markets, however, offer an indication of this validation/feedback process will evolve and could deliver the traffic flow data required by emerging travel information markets and advanced road network management.

Figure 6 charts variance between DynaFlow speed forecasts and actual road speed captured by GPS probes over time for a particular road segment. As the model processes impacts and "learns" the characteristics of resulting forecast errors, forecasts begin to resolve within commercially acceptable error discrepancies. The time to traverse this "learning curve" is contingent on available data sources, density of vehicle population and road link length. TCI estimates error rate normalization may take from 2 weeks in metropolitan areas to as long as 3 months for rural routes.

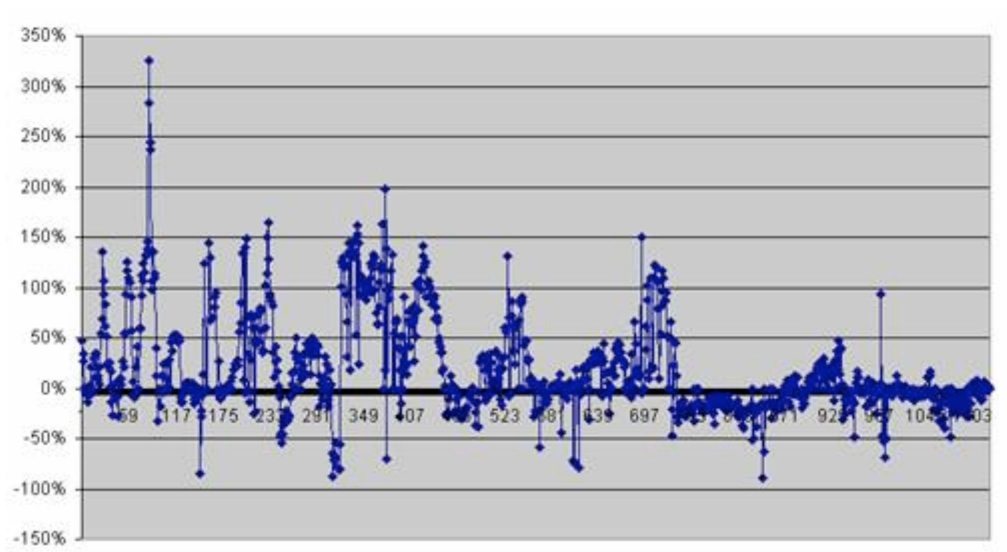

Figure 6: DynaFlow Data - Improving Accuracy Over Time Through Automated Feedback

5. Anticipated Applications

The potential of TCI DynaFlow to enhance a range of travel information applications is evident:

- Trip Planning Tools
  - Enhance travel scheduling with forecast impacts of weather, construction and (near-term) incidents against "typical" travel time for selected route(s).

- Real-Time Alerts
  - With a trip plan in hand, accounting for weather and construction impacts, incidents (accidents, crashes, etc.) have the strongest influence on travel times. While on the road, however, incident alerts are only meaningful if they include in affect on travel times on current route and possible alternates. DynaFlow will enable actionable traffic information.

- Dynamic Routing
  - Ultimately, evaluation of alternate routes will occur automatically. Integration with next-generation routing engines, which can include dynamic traffic impacts in calculating "best route" will require comprehensive and reliable flow data for freeways and principal arterials.

- Logistics Planning
  - DynaFlow will support productivity and scheduling tools for market-based routing applications (multi-stop delivery routes, A to B package express, etc.). It will also "connect the dots" for inter-city routing, supporting enterprises ranging from long-haul trucking to homeland security.

- Personal Navigation Devices (PND)
  - In this context, PND's range from hand-held mobile devices to factory-installed dashboard displays. DynaFlow will support an array of applications for these devices, from 'Red-Yellow-Green' representations of road speeds to contextual calculation of travel times to eventual dynamic routing solutions.

- Road Network Management
  - Local, regional and federal departments of transportation have moved beyond management of individual roadways and are increasingly focused on the performance of road networks and related corridors. DynaFlow supports these priorities with comprehensive flow modeling tools that provide travel time and speed forecasts for nearly all significant roads, which may or may not currently have sensors deployed.