Real-Time Street-Level Positioning
of All Phones in the Network
Combined with State-Of-The-Art
Big Data Analytics Layers

Cellint

Best Mobility Data Solution for Smart City Management and Planning

Smart Mobility Data Solutions Since 2005

- Tracking the entire network population with street level accuracy (anonymously)

- Using state-of-the-art analytics layers on top of this data for a Smart City management system, including:
  - Real time speed/congestion information at **sensors' grade quality**
  - Origin Destination studies from a street level to a country-wide perspective
  - Breakthrough solutions for traffic management, transportation planning, safe city, crowd management, emergency evacuation, tourism management and congestion mitigation analysis

- Nation-wide coverage in US and Canada. Major projects & excellent references from agencies, municipalities and cellular companies world-wide

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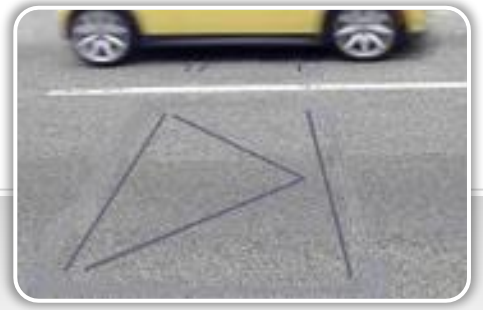
The Challenges of Real-time Traffic Systems

1st generation
Road sensors



- The gold standard for traffic management
- Ranges from inductive loops and side view radars to cameras
- High cost and low reliability results in less than 1% road coverage.

2nd generation
Cellular Triangulation

- Plenty of raw data from the mobile network but location accuracy within the cell tower coverage is vague
- A single antenna may cover 10-20 roads, making it impossible to pinpoint vehicle location/speed

3rd generation
GPS

- No live data for 90% of the road sections most of the time.
- Historical patterns are used to compensate for lack of data
- Studies show that these solution miss-detect 50% of the incidents on average

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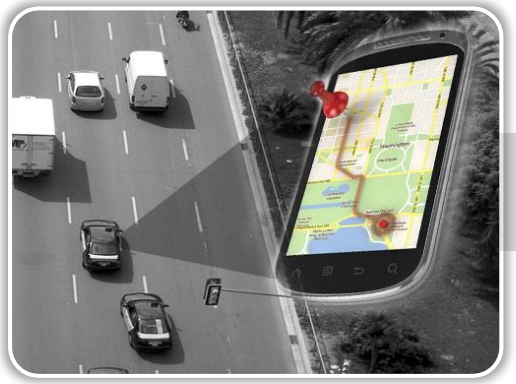
4th Generation: TrafficSense

Recording



Cellular network on the routes is mapped during physical trips. Cellular network messages are recorded with GPS tags.

Road Signature Database Creation

Recordings are analyzed to create signature of cellular message sequences for each road section

Real-Time Traffic Data Feed

Live data from the network is matched with the signature database and each phone (car/bus/train) is matched to a route and accurately located in short intervals

TrafficSense: Real-time Road Management

Speed/travel time

- Section speed: sensors' quality
- Travel time between junctions:

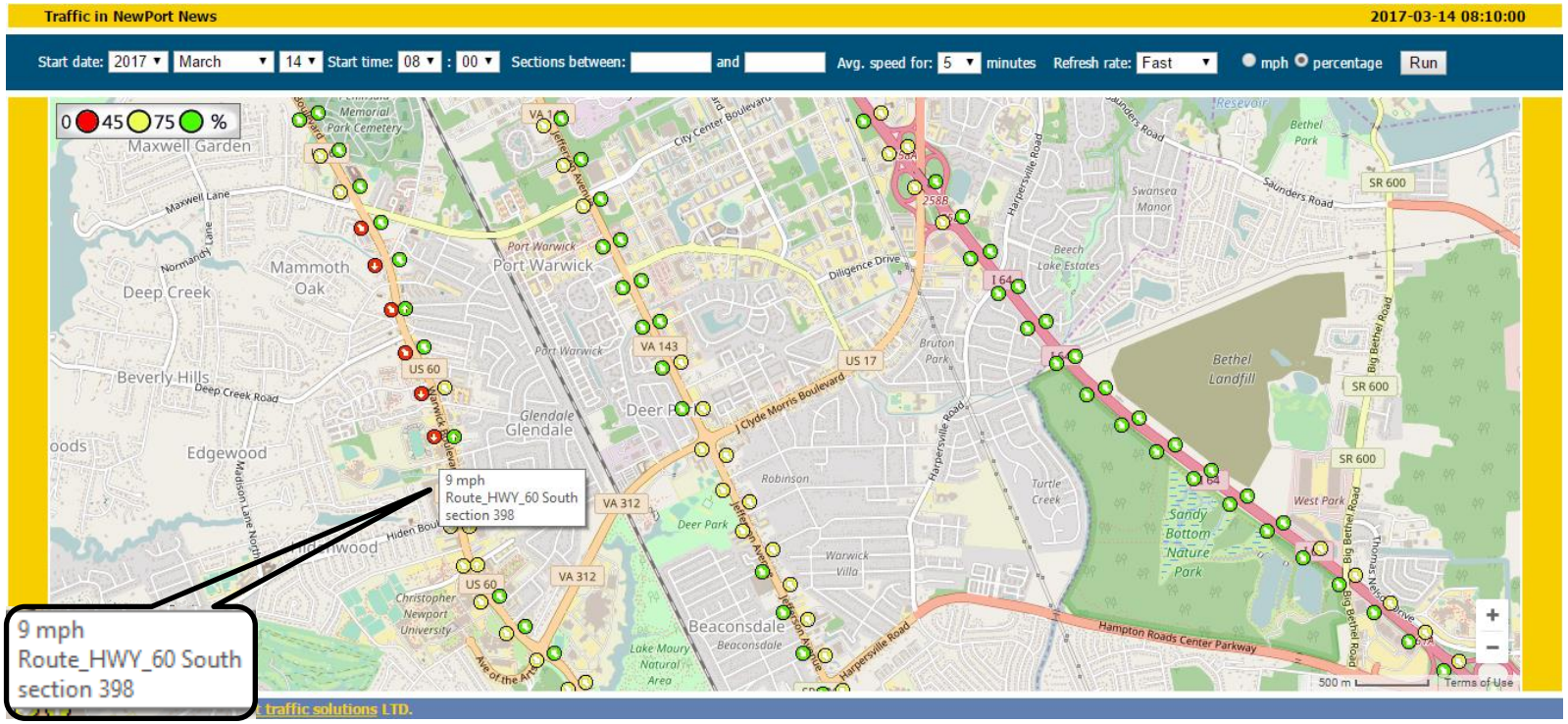
Slowdown/delay Detection

- Slowdown detection: similar to sensors
- Delay time in junctions relative to free-flow

Data Analytics

- Insight, post processing analytics
- Both in real time and offline

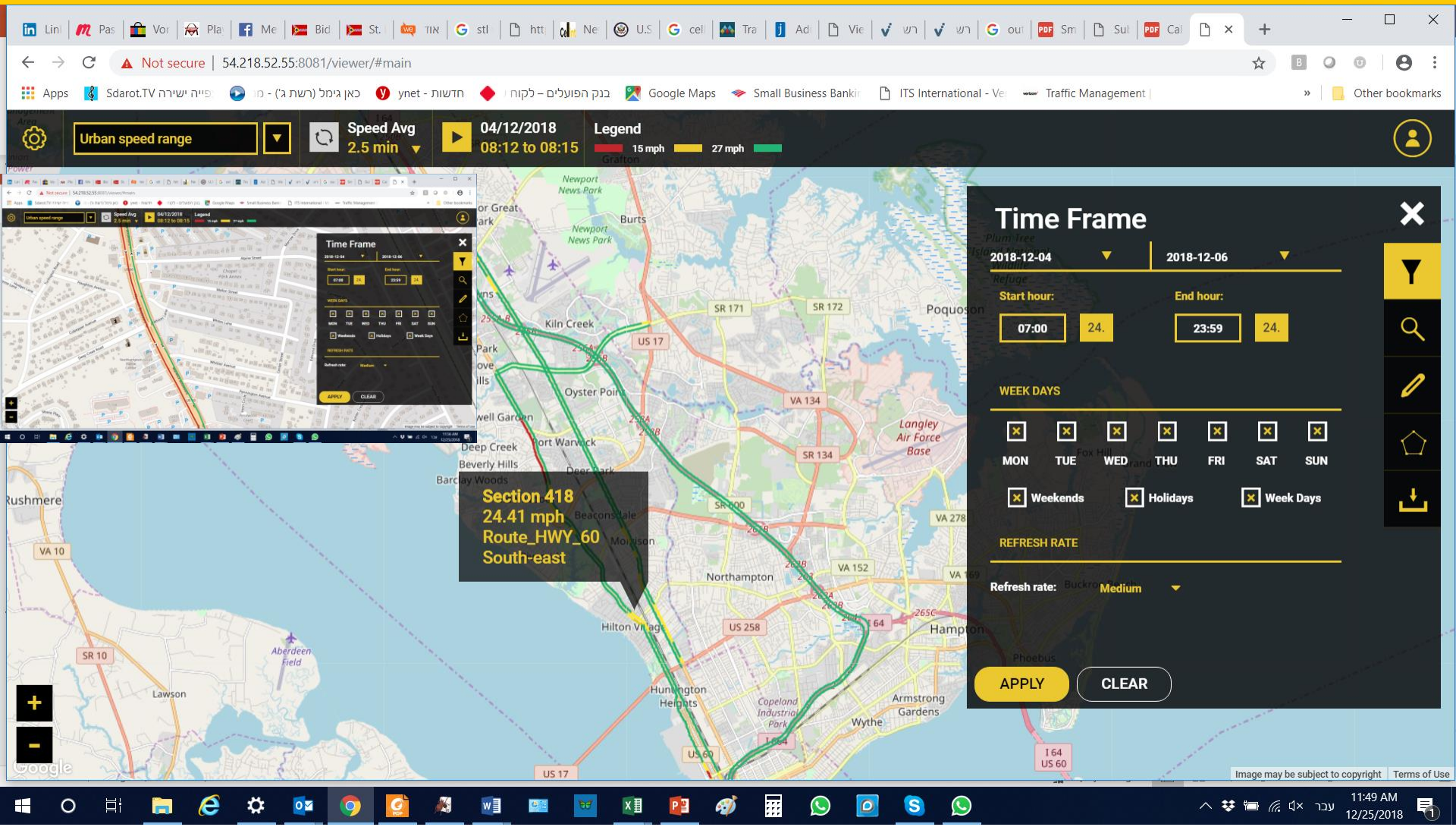
Live Traffic and Re-run Visualization



Start date: 2017 March 14 Start time: 08 : 00 Sections between: and

Avg. speed for: 5 minutes Refresh rate: Fast mph percentage Run

Live Traffic and Analytics



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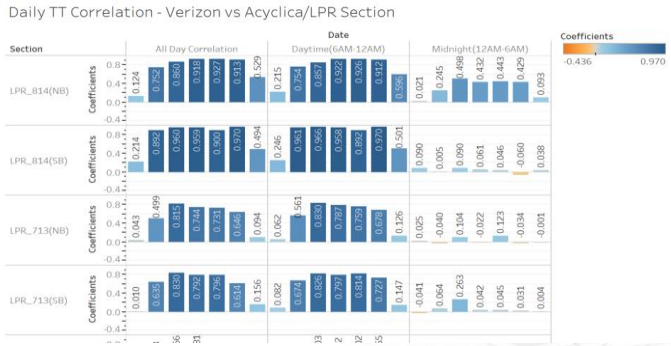
2018 Arterial Validation – Seattle DOT

Seattle DOT hired University of Washington to evaluate Cellint's real time data quality (provided by Verizon) against ANPR (also called LPR) and Bluetooth/WIFI solution (Acyclica) in short intervals on arterials & HW. Quoting the report:

- "During weekdays, the LPR data and the Verizon data match well from the perspective of travel time and travel time reliability…"
- "During weekends, the Verizon data can still capture morning peak and evening peak traffic patterns, which is slightly captured by the LPR data and is hardly reflected by the Acyclica data…"
- "During night time or on weekends, the travel time measured by the Verizon data is more stable than the other two data sources…"

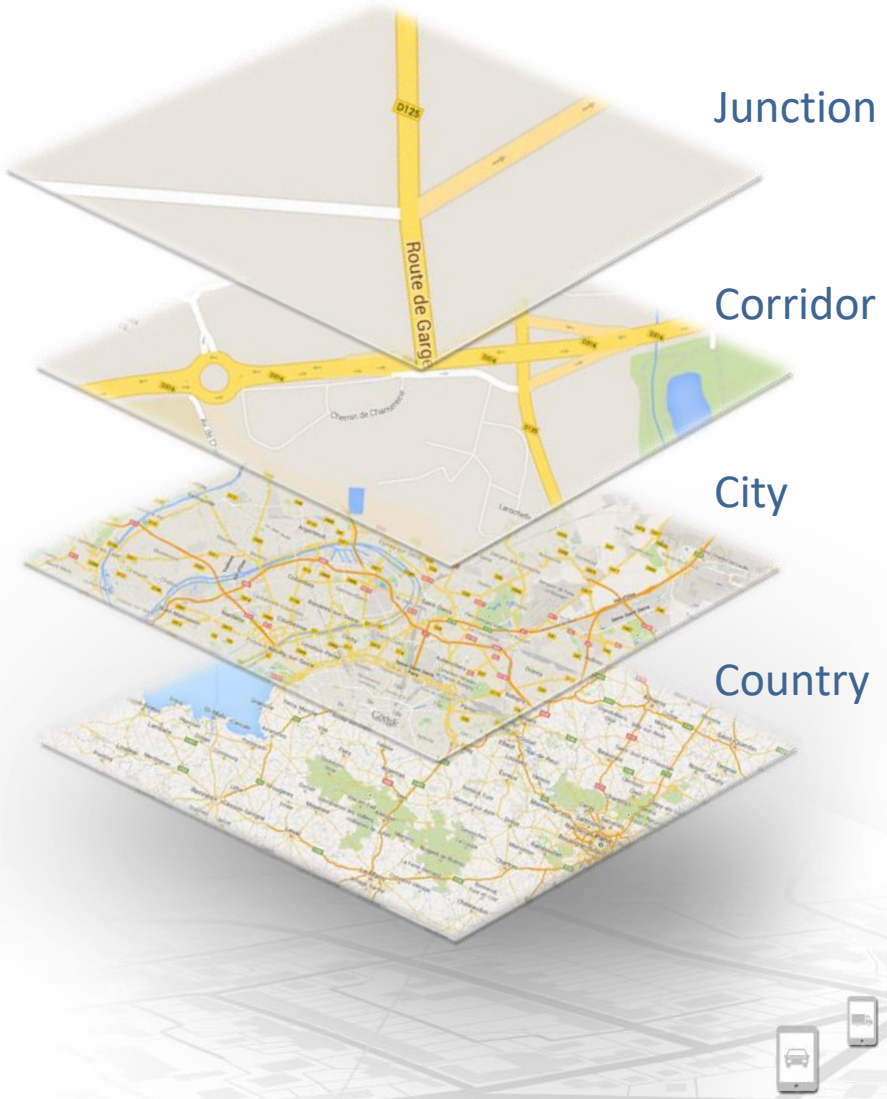


The Challenges of Origin Destination (OD) Studies

- **Field Surveys**: Labor intensive and expensive, small and sporadic sample size, safety issues if on the roadways
- **Sensor data (including cameras and Bluetooth)**: Very expensive for permanent deployments or not reliable due to short surveys, high cost field deployment and safety issues. Long term – MAC address is scrambled
- **GPS Data Aggregators**: Most commuters are not represented in the data, as well as other population segments, biased and sporadic data, can't extrapolate how many people are actually going from one point to another
- **Cellular network data at cell/sector accuracy**: Very good for zone survey but lack the ability to conduct OD analysis related to a specific street/road/railway, thus limited in use cases

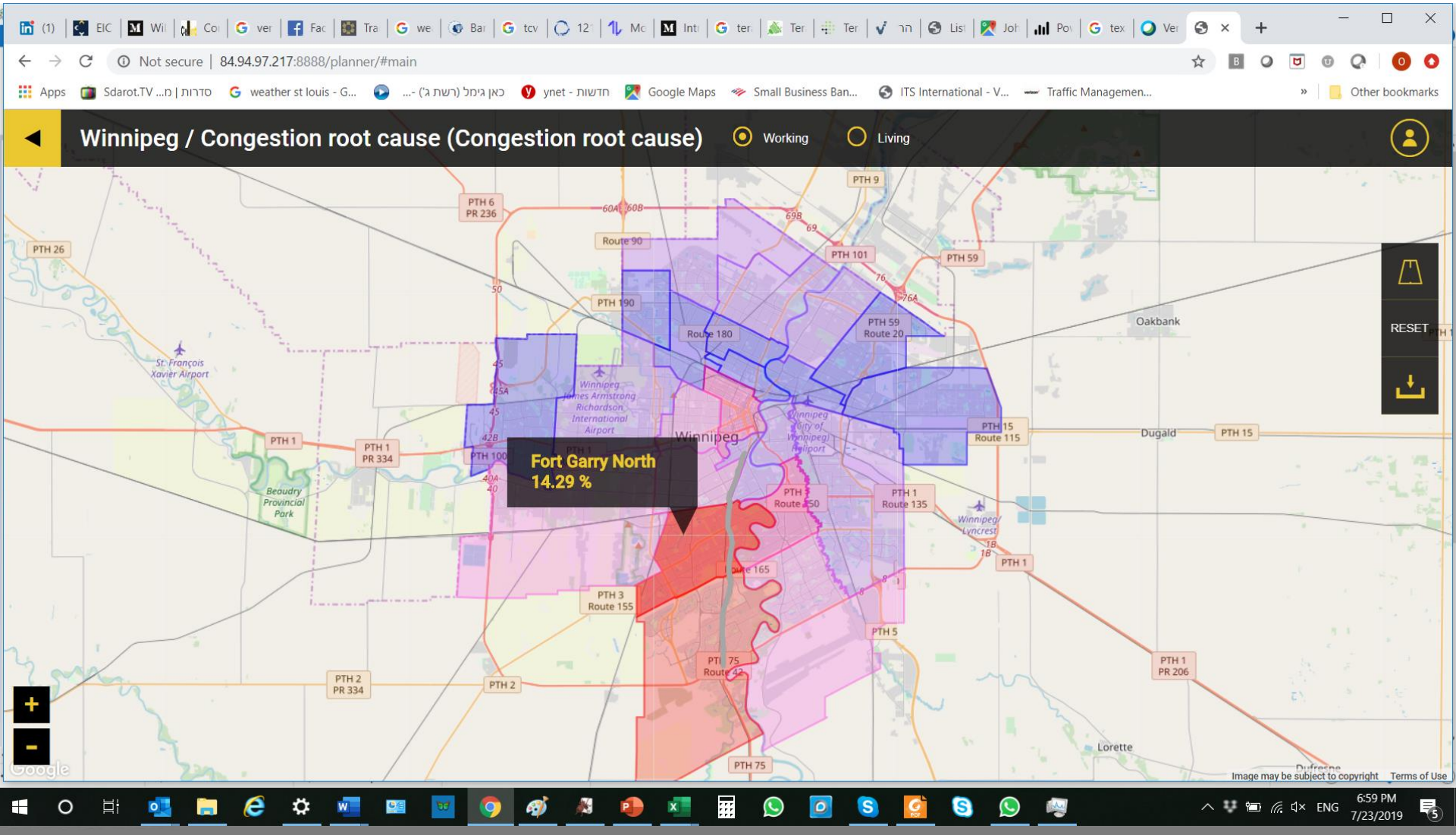
Origin Destination Analysis with Street Level Accuracy

- Origin destination analysis from junction level to country level
- Complex junctions/intersections OD analysis
- Enables corridor signal tuning/ validation by using turning percentage, origin destination matrix and delay time
- Enables state of the art traffic impact studies, traffic calming projects and travel surveys for planning new transportation line/station, infrastructure, etc.
- Metro wide data with multi mode analysis (cars, busses, subway, trains, etc.) Distribution of where all people live, work and visit



Advanced Population Movement Analytics Tool

- Insights including advanced visualization and data/reports export

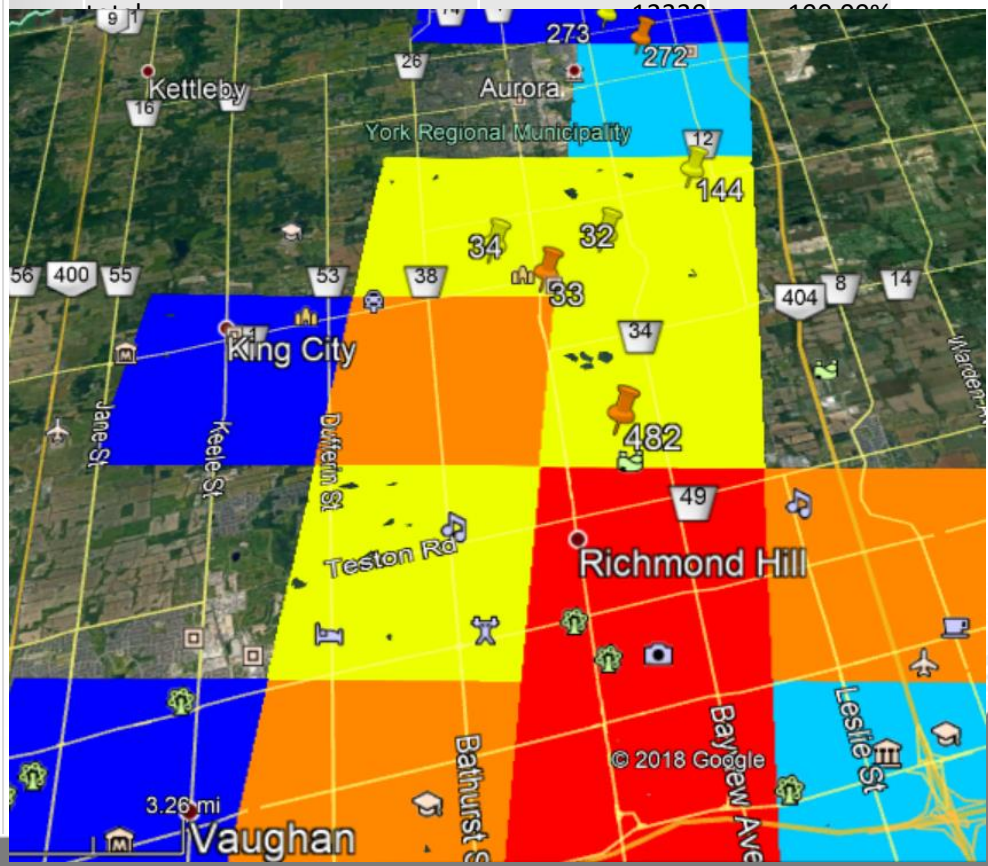


Project Example: Multimode Analysis

A new rail station was opened in Greater Toronto Area. Metrolinx, the regional transportation agency, needed to know its impact. Cellint created signatures and ran the data retroactively for the relevant months before and after the opening, while answering some substantial questions, such as:

- What percentage of the new station users used the train before, and from which line/station
- Distribution of where the new users live and travel to
- Distribution of where the diverted users live and travel to

line	station	pass. Per station	% per station
Barrie	Newmarket	2681	21.74%
Barrie	Aurora	1032	8.37%
Barrie	King City	57	0.46%
Richmond Hill	Richmond Hill	3993	32.38%
Richmond Hill	Langstaff	2430	19.71%
Stouffville	Stouffville	482	3.91%
none	none	1655	13.42%

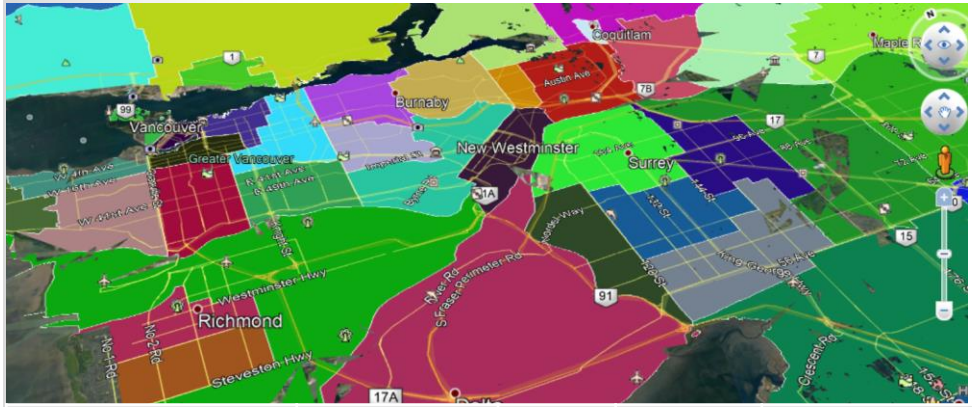


Project Example: Transportation Plan

Translink needed to create a long-term infrastructure plan for the North Shore, BC. Cellint created cellular signature for the main bottlenecks, such as bridges, and analyzed usage patterns for users from the entire metro area, answering questions such as:

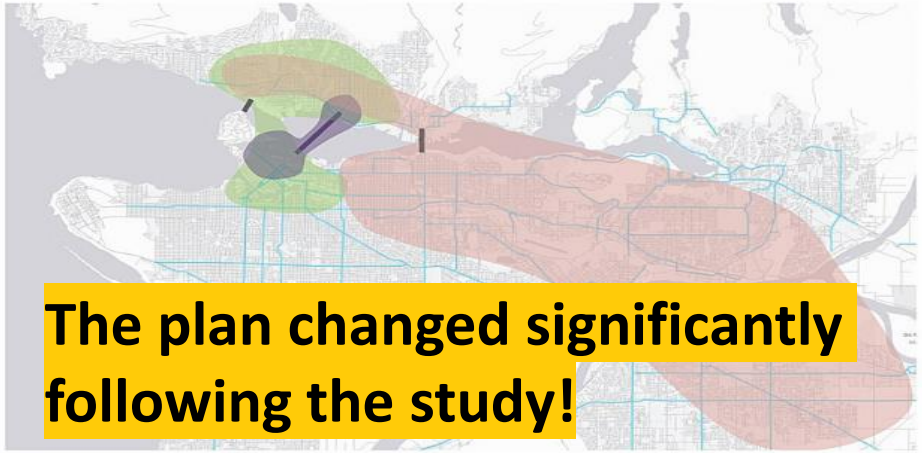
- Home distribution of people using each of them
- Where they came from and went before and after using them
- Extent of using them

The results showed that a planned new bridge is not required to handle the expected growth, settling the debate among all the stakeholders.



From area	Burnaby Metrotown	Burnaby NE	Burnaby North	Burnaby South Central
Area 11	1.30%	0.33%	1.12%	0.62%
Area 12	1.05%	0.24%	0.85%	0.57%
Area 14	1.43%	0.83%	1.87%	0.96%

Second Narrows traffic is regional whereas Lions Gate and SeaBus are more localized



The plan changed significantly following the study!

Source: Cellint Traffic Solutions & TransLink Compass

Corridor Origin-Destination Project & Validation

- For Hwy 2 corridor in Alberta,
- Point validation vs. Bluetooth where available
- Less than 10% difference

Leaves CGY + CI Mills to Everywhere (3A)	total %	relative %	Matching Bluetooth Percentage
Stays in CGY + CI Mills			
to Airdrie	4.66%	73.57%	
to Between Airdrie & Red Deer	0.54%	8.56%	
to Red Deer	0.33%	5.25%	5.8%
to Between Red Deer & Leduc	0.08%	1.30%	
to Leduc	0.07%	1.03%	
to Edmonton	0.65%	10.29%	10.1%
Total	6.34%	100.00%	

Leaves EDM to Everywhere (1A)	total %	Relative %	Matching Bluetooth Percentage
to CGY & CI Mills	0.86%	11.05%	10.5%
to Airdrie	0.15%	1.91%	
to Between Airdrie & Red Deer	0.30%	3.91%	
to Red Deer	0.27%	3.48%	3.7%
to Between Red Deer & Leduc	1.20%	15.39%	
to Leduc	5.00%	64.25%	
to Edmonton			
Total	7.79%	100.00%	

Table X-X: Origin-Destination Percentages: Weekday (06:00-09:00)

Origin-Destination Percentages: Weekday (06:00-09:00)		Destination District											
	District Name	Calgary External D	Calgary External C	Calgary External B	Calgary External A	Red Deer External S	Red Deer internal all	Red Deer External N	Edmonton-Leduc External S	Edmonton-Leduc internal Leduc	Edmonton-Leduc internal S. Edmonton	Edmonton-Leduc External N	Total
Origin District	District Name / Corresponding Approximate Area												
	Calgary External D (Calgary + Points S. E. & W.)		7.27%	2.16%	0.25%	0.13%	0.11%	0.02%	0.04%	0.09%	0.05%	0.11%	10.23%
	Calgary External C (Balzac + Cross Iron Mills)	7.03%		1.96%	0.12%	0.06%	0.05%	0.01%	0.01%	0.02%	0.02%	0.03%	9.32%
	Calgary External B (Airdrie)	2.54%	1.86%		0.78%	0.14%	0.10%	0.02%	0.03%	0.02%	0.03%	0.04%	5.56%
	Calgary External A (Crossfield + Carstairs + Didsbury)	0.33%	0.11%	1.08%		0.98%	0.21%	0.04%	0.05%	0.03%	0.05%	0.05%	2.93%
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.03%	0.04%	0.03%	2.77%
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.11%	0.19%	0.13%	2.85%
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.09%	0.11%	0.07%	2.44%
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.68%	0.48%	0.22%	4.09%
	Edmonton-Leduc internal Leduc (Edmonton S.)	0.08%	0.01%	0.02%	0.02%	0.03%	0.10%	0.10%	1.65%		5.59%	1.05%	8.67%
	Edmonton-Leduc internal S. Edmonton (Edmonton S.)	0.06%	0.01%	0.04%	0.05%	0.05%	0.15%	0.12%	0.46%	5.27%		21.11%	27.33%
	Edmonton-Leduc External N (Edmonton + Points N. E. & W.)	0.13%	0.02%	0.04%	0.04%	0.05%	0.11%	0.09%	0.23%	1.09%	22.03%		23.82%
	Total	10.55%	9.39%	5.65%	2.96%	2.58%	2.56%	2.35%	4.09%	8.42%	28.60%	22.86%	100.00%

Project Won Ministry Innovation Award!

Project Example: The Old City of Montreal

The City was trying to understand the level of congestion in the old city and the reasons for the congestion:

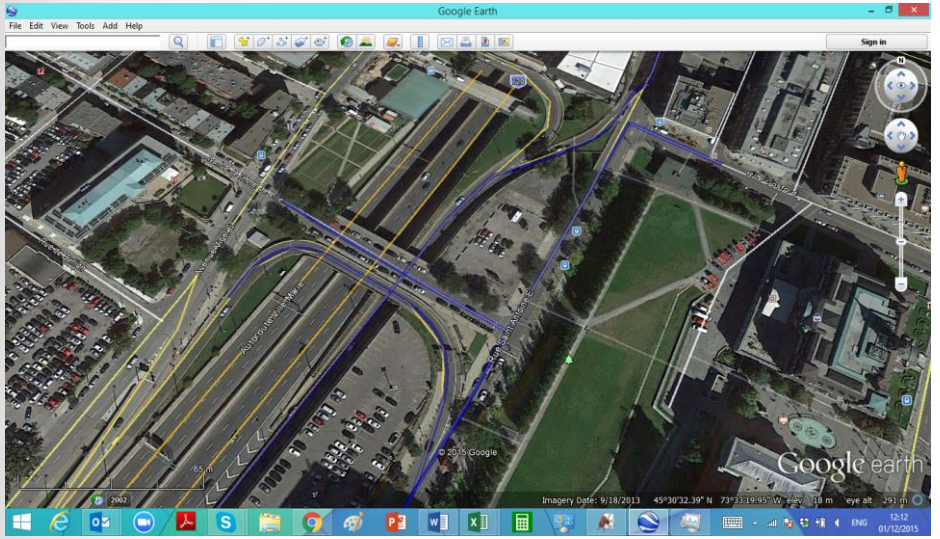
- Speed data for short road segments received in real time and aggregated to historical database to identify level and nature of congestion

Section number	10456	10457	10458	10459	10460	10461	Average
Hour	from South West				to North East		
0	37.6	25.2	33.3	32.0	25.8	26.4	30.1
1	31.2	22.3	28.0	31.1	29.8	28.8	28.6
2	35.2	36.3	22.8	25.0	25.5	15.3	27.5
3	31.7	27.7	24.0	24.9	26.7	23.7	27.0
4	32.9	28.9	26.4	28.2	27.2	27.2	27.2
5	36.2	36.2	33.3	29.2	31.4	34.1	34.8
6	16.2	12.7	18.8	26.1	33.6	27.1	19.6
7	8.4	8.9	14.1	20.8	27.3	28.0	14.2
8	14.3	13.7	27.3	24.3	25.1	28.6	17.2
9	16.1	15.3	33.1	25.5	21.0	25.4	17.1
10	16.6	15.5	18.9	21.8	21.8	15.3	18.0
11	16.4	14.8	19.9	21.5	22.6	21.8	17.5
12	18.4	15.4	23.3	21.2	22.6	28.4	19.0
13	15.2	14.2	26.3	25.4	26.5	20.1	17.4
14	19.3	15.4	15.1	18.2	24.4	25.6	18.8
15	13.8	13.9	11.6	15.1	20.6	15.9	14.9
16	15.5	12.7	12.7	17.9	20.0	17.8	15.3
17	17.5	14.0	16.1	14.2	22.5	36.7	17.1
18	18.2	19.3	16.1	18.8	31.3	40.3	22.8
19	19.8	16.5	22.5	25.8	25.3	16.6	20.9
20	21.1	15.8	27.1	24.0	23.2	35.1	21.5
21	16.0	16.0	26.5	27.8	27.7	25.2	22.5
22	27.2	24.1	31.5	31.4	34.0	37.2	30.7
23	30.8	27.1	27.7	27.0	27.0	38.3	27.9

The Old City of Montreal – Congestion Root Cause Analysis

Origin Destination analysis was used to understand the reasons for the congestion:

- Micro OD at a junction level (on the right)
- Through traffic: what percentage stayed in the old city and what percentage was just passing through
- Origin destination analysis: where do these people come from and where are they going



Analysis of those arrived at the junction from St. Antoine	All (including weekends and holidays)	work days	6:00-10:00	10:00-15:00	15:00-19:00	6:00-19:00
Which percentage exited St. Antoine in the junction	34.4%	52.0%	58.6%	34.3%	40.9%	44.2%
Which percentage stayed on St. Antoine through the junction	65.6%	48.0%	41.4%	65.7%	59.1%	55.8%

Analysis of those who traveled on St. Antoine after the junction	All (including weekends and holidays)	work days	6:00-10:00	10:00-15:00	15:00-19:00	6:00-19:00
Which percentage entered to St. Antoine in the junction	38.9%	55.1%	47.8%	51.1%	51.9%	50.5%
Which percentage arrived on St. Antoine before the junction	61.1%	44.9%	52.2%	48.9%	48.1%	49.5%

Hours ↓	Daily percent of travelers from each neighborhood out of total visitors who didn't stay in the old city more than 2 hours	Cote-Des-Neiges	Le Plateau-Mont-Royal	Le Sud-Ouest	Mercier–Hochelaga-Maisonneuve	Outremont	Rosemont–La Petite-Patrie
0-3		20%	19%	28%	17%	2%	15%
3-6		12%	20%	12%	36%	1%	20%
6-9		16%	18%	14%	26%	1%	24%
9-12		18%	21%	20%	20%	3%	19%
12-15		19%	21%	17%	18%	4%	21%
15-18		20%	22%	18%	17%	3%	20%
18-21		19%	22%	24%	16%	3%	17%
21-24		24%	17%	25%	15%	1%	17%
total		19%	20%	19%	19%	3%	20%

World Wide Breakthrough:
Automated Root Cause Analysis for **Congestion Mitigation**

- Analyzing mobility patterns of the specific people caught in the congestion
- Using the data to point out the main contributors for each congestion, (demand OD breakdown) and what mitigation measures can apply

From street and junction level accuracy

To the big picture: city and neighborhood levels

Eliminating the guess work out of the congestion mitigation analysis and turning it into a structured engineering process

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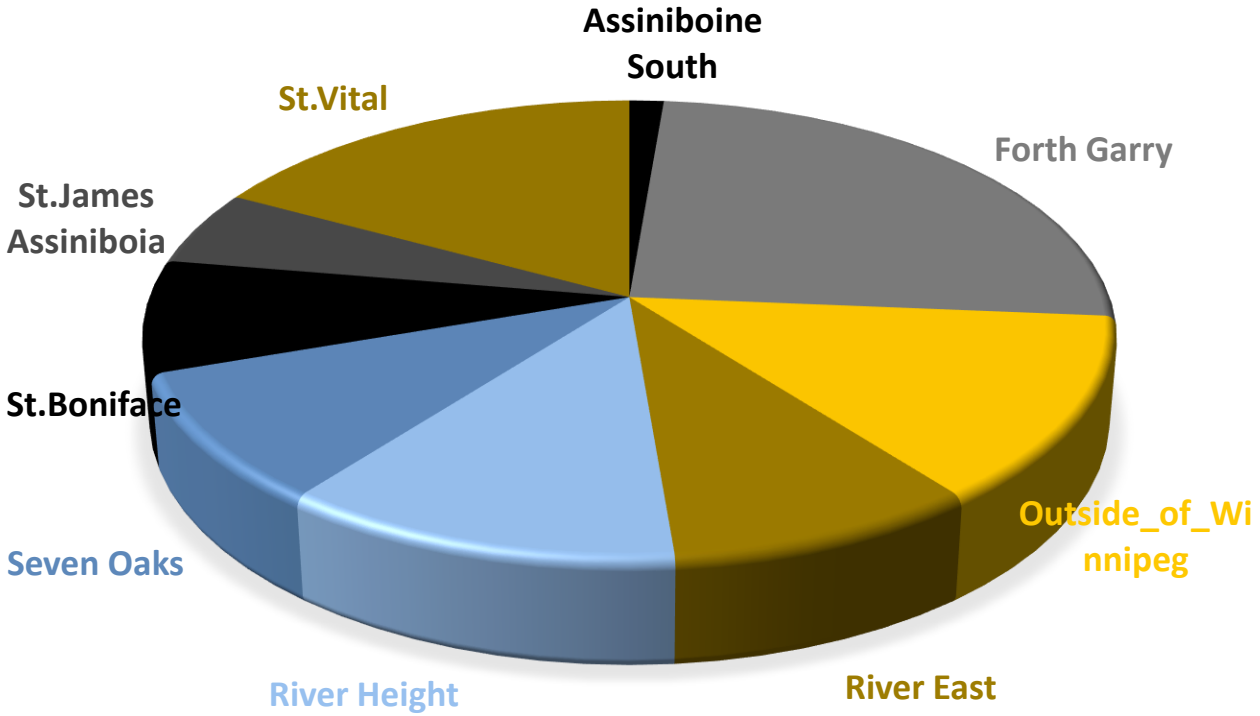
Congestion Mitigation Report for Pembina HW in Winnipeg

People who work in downtown, which traveled through Pembina HW: Where do they live?

Assiniboine South	1%
Forth Garry	25%
Outside_of_Winnipeg	13%
River East	9%
River Height	12%
Seven Oaks	9%
St.Boniface	8%
St.James Assiniboia	5%
St.Vital	17%



Conclusion: Habitant from Forth Garry who are working in Downtown are the largest single contributor to the Pembina HW congestion

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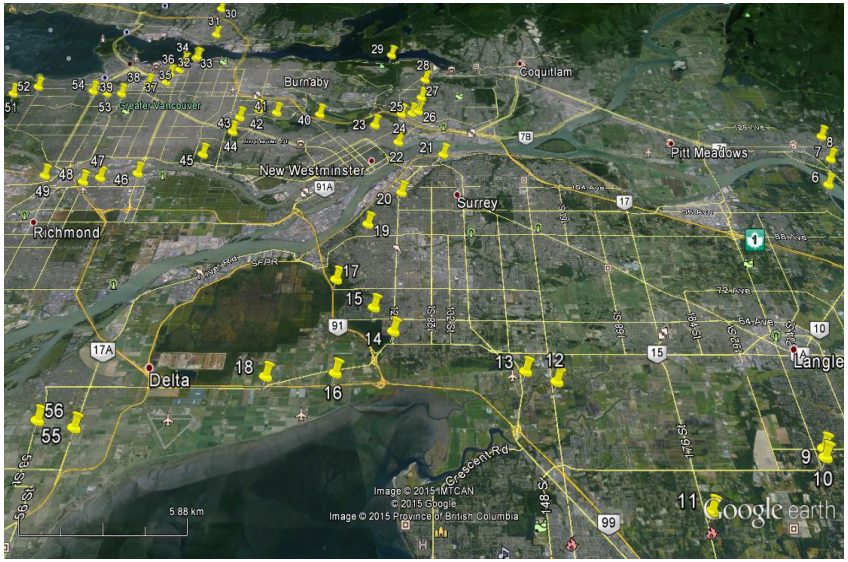
Cellular Counting Stations

- TrafficSense can provide cellular counting stations to measure Average Annual Daily Traffic (AADT) changes at each point on the road/railway, subject to initial reference calibration.



Cellular counting station in Vancouver metro area

Turns temporary counting projects into permanent counting stations, saving huge cost of routinely measure volumes every year, just to find there is no change

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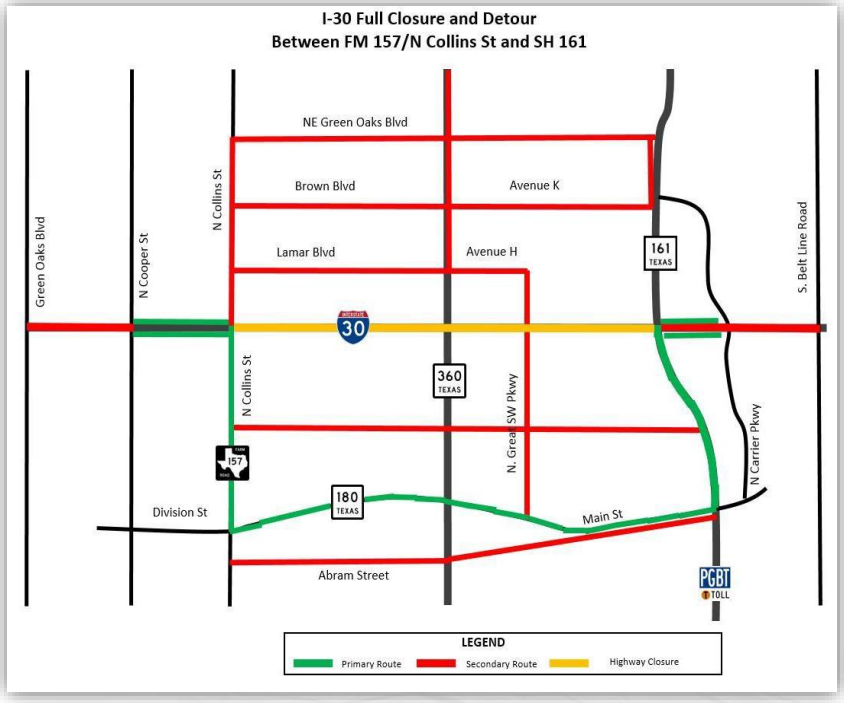
Counting and Micro Analysis for NCTCOG

HW 30 corridor construction management: micro origin destination analysis, typical speeds and counting stations

Route	counters	TDS_prediction	difference
I30 Duncan Perry to Great Southwest Pkwy - WB	87317	87562	0.28%
I30 Great Southwest Pkwy to Duncan Perry -EB	87295	89713	2.77%
SH360.Brown Blvd-W-link1 – SB	77532	77737	0.26%
SH360.Brown Blvd-W-link2 – NB	79189	80344	1.46%

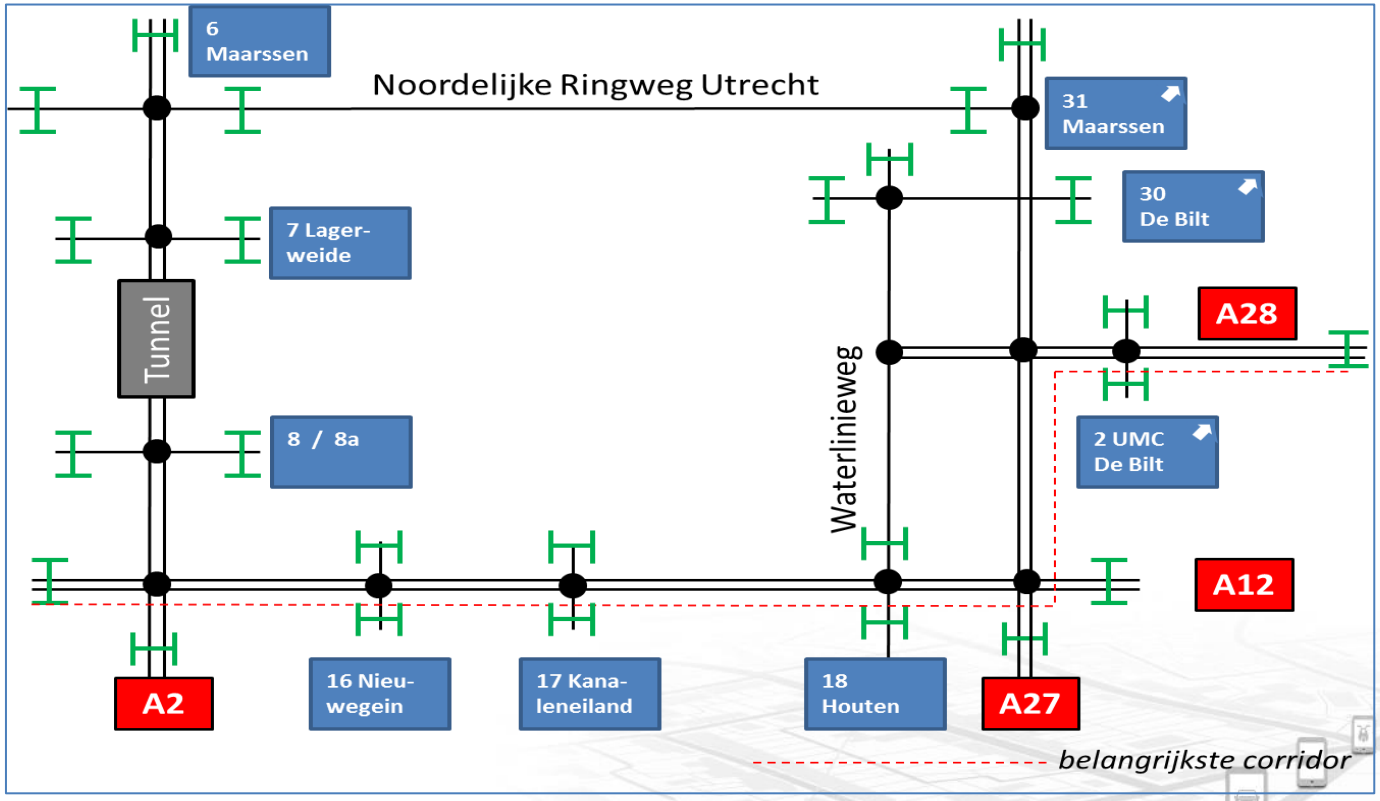
Quarterly reports as well as specific closure reports



Near Real Time Traffic Management In Utrecht

In collaboration with Vodafone for NDW and Utrecht DOT:

- Routing distribution of people during construction between roads
- Speeds, volumes and turning percentages



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Economic Development

Data can be used for Economic Development analysis:

- **Revenue generation:**
  - Which areas in your city/regions are attracting the most visitors, how long are they staying in each location and which hotels area are they staying in.
  - Where are these visitors coming from and their demographic characteristics
  - Which event they visited, where are they going before and after an event and how long it takes them to travel by each mode of transportation
  - What other locations/events are competing with yours when attracting your target audience, which audience prefer them, as well as potential reasons (e.g. lack of proper transportation, etc.)?
- **Under-served areas:**
  - Where do residents from under-served areas work and how does the public transit system match their needs?
  - What areas are not accessible to them?
  - What are the impacts of gentrification and where are people re-locating to?

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Transportation Plan and Economic Development Analysis for Bellville, Ontario

Who is arriving to the main shopping centers from each direction, local vs. visitors, what routes they are using, levels of congestion they generate and experience, how long they stay per time of day.

Project Saved The Ministry 30M$!

time range	6_10			
Junction	East	West	North	South
R 401 East-->Walbridge loyalist	92.20%		1.99%	5.80%
R 401 East-->R 62	88.95%		2.48%	8.57%
R 401 East-->R37-Cannifton	90.95%		5.14%	3.90%
R 401 West-->Walbridge loyalist		92.40%	1.96%	5.64%
R 401 West-->R 62		90.47%	2.17%	7.36%
R 401 West-->R37-Cannifton		94.21%	3.58%	2.21%
Walbridge loyalist North-->R 401	45.45%	31.82%	22.73%	
lbridge loyalist North-->Bell Blvd.	14.29%		85.71%	
lbridge loyalist South-->R 401	43.48%	20.87%		35.65%
lbridge loyalist South-->Bell Blvd.	29.91%			70.09%
0 North-->Bell Blvd.	12.70%	22.22%	65.08%	
0 South-->Bell Blvd.	8.33%	16.67%		75.00%
2 North-->R 401	61.04%	22.94%	16.02%	
2 North-->Bell Blvd.	0.00%	5.26%	94.74%	
2 South-->R 401	13.89%	28.70%		57.41%
-->Bell Blvd.	0.00%	4.62%		95.38%
ton North-->R 401	29.87%	37.66%	32.47%	
ton North-->Bell Blvd.		0.00%	100.00%	
-Cannifton South-->R 401	14.02%	54.21%		31.78%
-Cannifton South-->Bell Blvd.		17.00%		83.00%
Bell Blvd. East-->R 30	79.63%		9.26%	11.11%
Bell Blvd. East-->R 62	88.57%		2.86%	8.57%
Bell Blvd. East-->R37-Cannifton			100.00%	0.00%
Bell Blvd. West-->Walbridge loyalist			54.69%	45.31%
Bell Blvd. West-->R 30		96.43%	3.57%	0.00%
Bell Blvd. West-->R 62		100.00%	0.00%	0.00%

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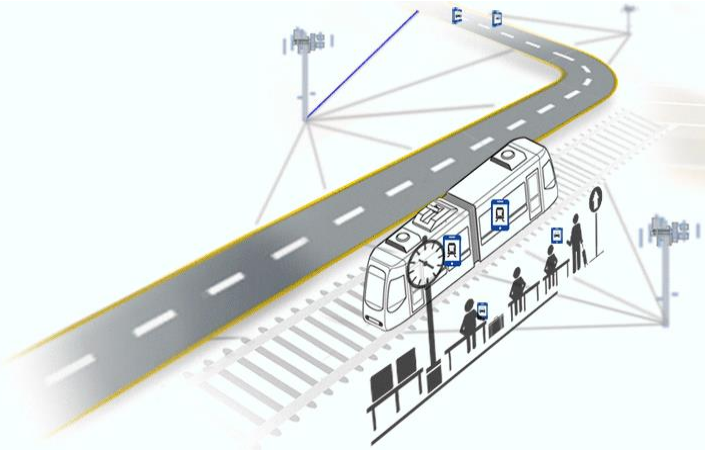
Crowd Management and Emergency Evacuations

1. Crowd management in real time for emergency\ event management
   - Volume of people in each zone in real time
   - In case of emergency - required destinations and mode of transportation for these people, potential evacuation routes and real time delays on these routes
   - Same data for event management

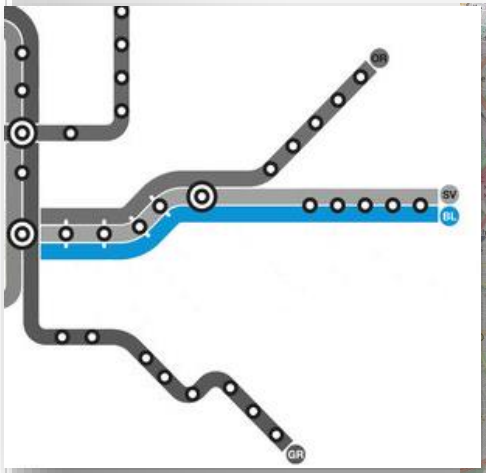
2. Best possible resilience
   - Will continue working when all other systems shut down due to power outage, and even when data transmission on the cellular network is stopped due to over load and all other data sources are lost

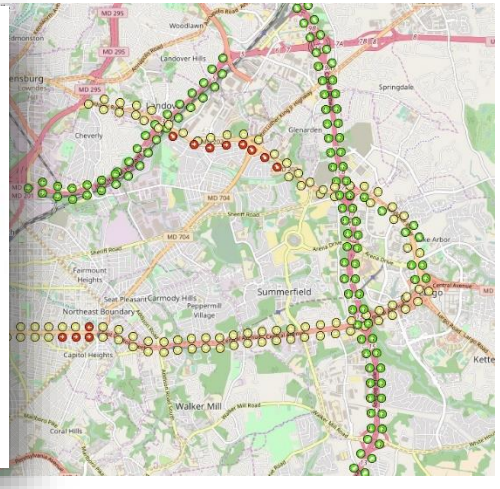


Events Management – Redskins in Washington

Real time traffic, volume of fans coming from each neighborhood and their route choices and origin destination analysis

- Both public and private transportation
- Comparing different events, impact on fans attendance due to different days/hours of the games
- Home distribution of fans, after games destinations
- Tailgating locations, volumes and length





	time	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	15:15
5	Audience time of reaching field area																		
6	Audience numbers:	5697	5192	6020	6150	6219	5984	4173	2608	1370	618	420	274	226	165	113	36		
7	Percent of total attenders:	7.3%	6.6%	7.7%	7.9%	8.0%	7.7%	5.3%	3.3%	1.8%	0.8%	0.5%	0.4%	0.3%	0.2%	0.1%	0.0%		
8	Audience time of leaving field area																		
9	Audience numbers:									299	161	145	133	145	169	444	497	529	1508
10	Percent of total attenders:									0.4%	0.2%	0.2%	0.2%	0.2%	0.2%	0.6%	0.6%	0.7%	1.9%
11	Fedex Field Attendents																		
12	Accumulated audience numbers:	38640	43832	49853	56004	62223	68208	72381	74989	76060	76517	76792	76934	77015	77010	76679	76218	75688	74180
13	Accumulated Percent of total attendents:	49.4%	56.0%	63.7%	71.6%	79.6%	87.2%	92.5%	95.9%	97.2%	97.8%	98.2%	98.4%	98.5%	98.5%	98.0%	97.4%	96.8%	94.8%

	road	direction	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	19:30
traffic volume distribution per road	Route_50_West	Out	6.6%	5.9%	4.6%	5.7%	5.3%	6.2%	9.3%	9.8%	12.3%	10.3%	7.5%	6.7%	4.1%	5.8%
	Route_202_East	Out	6.9%	3.1%	5.6%	5.0%	6.9%	1.9%	11.3%	13.1%	13.8%	13.8%	7.5%	5.0%	5.0%	1.3%
	Route_202_West	Out	7.4%	6.5%	4.2%	5.6%	3.3%	6.5%	11.2%	12.6%	13.0%	10.2%	6.0%	7.9%	2.3%	3.3%
	Route_214_East	Out	8.7%	5.5%	5.8%	6.1%	5.8%	6.7%	7.5%	11.3%	16.2%	6.1%	5.8%	4.1%	5.8%	4.6%
	Route_214_West	Out	6.9%	2.8%	5.1%	4.8%	4.3%	5.8%	10.4%	15.0%	17.0%	9.9%	6.1%	5.1%	4.3%	2.5%
	Route_495_North	Out	6.1%	7.2%	5.8%	6.1%	6.4%	7.2%	10.3%	10.4%	9.3%	8.5%	7.0%	5.9%	4.5%	5.1%
	Route_495_South	Out	5.7%	5.3%	5.8%	5.7%	6.0%	8.2%	10.0%	10.2%	9.8%	10.0%	7.8%	6.3%	5.0%	4.2%
	All outgoing roads	Out	6.1%	6.0%	5.6%	5.8%	6.0%	7.4%	10.0%	10.5%	10.4%	9.4%	7.3%	6.1%	4.7%	4.6%

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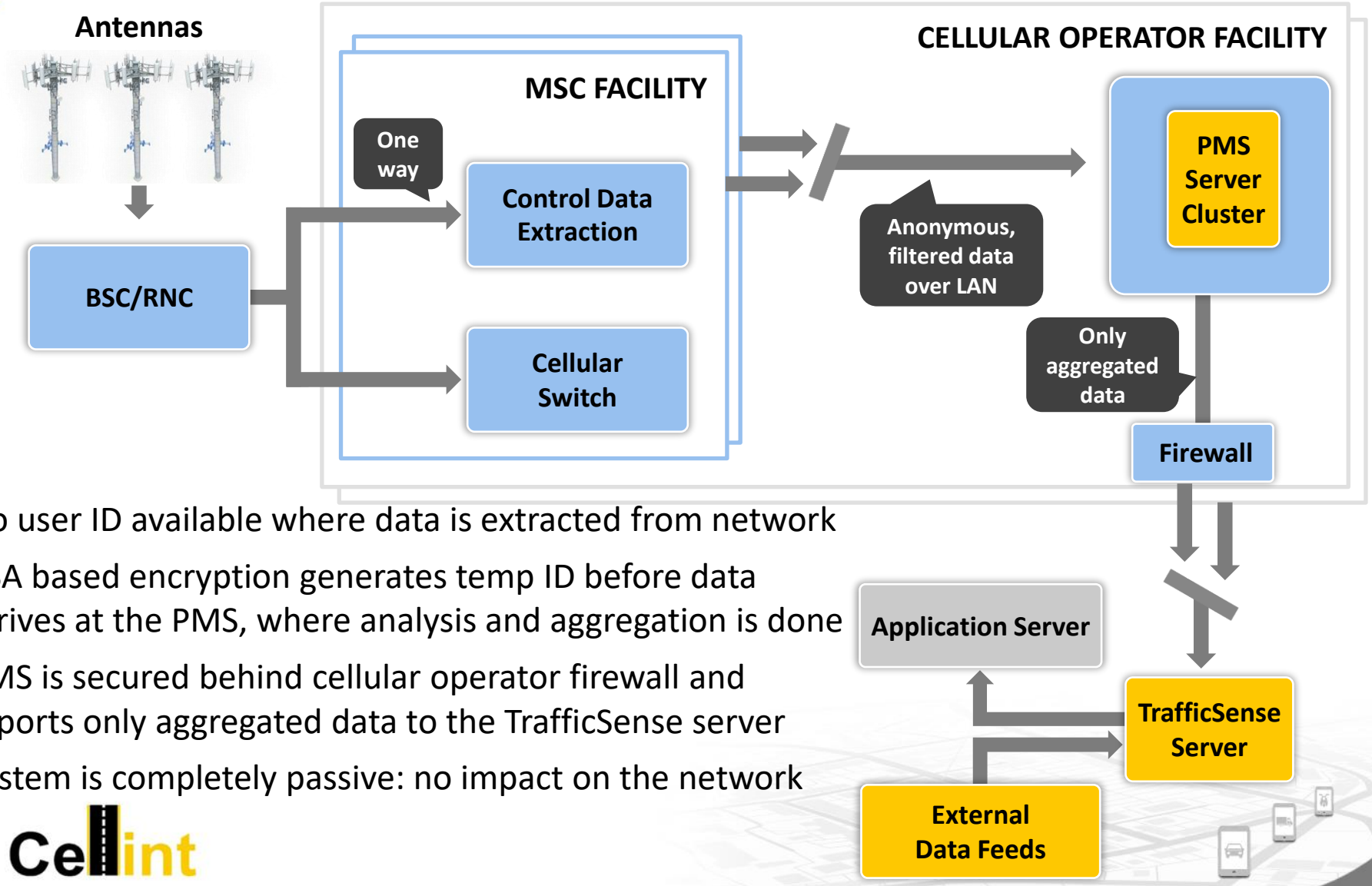
Privacy Protected Architecture – GDPR Compliance



- No user ID available where data is extracted from network
- RSA based encryption generates temp ID before data arrives at the PMS, where analysis and aggregation is done
- PMS is secured behind cellular operator firewall and reports only aggregated data to the TrafficSense server
- System is completely passive: no impact on the network

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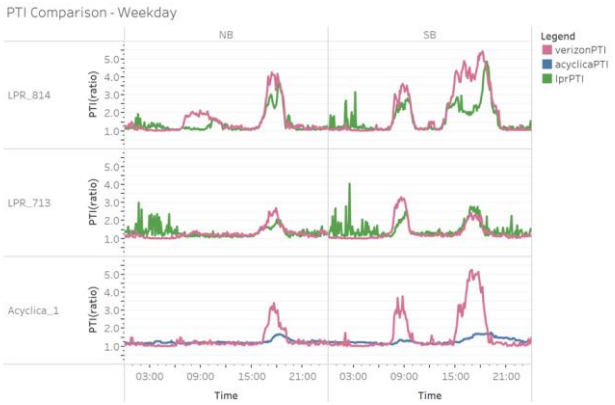
TrafficSense: Validated to Match Sensor Accuracy

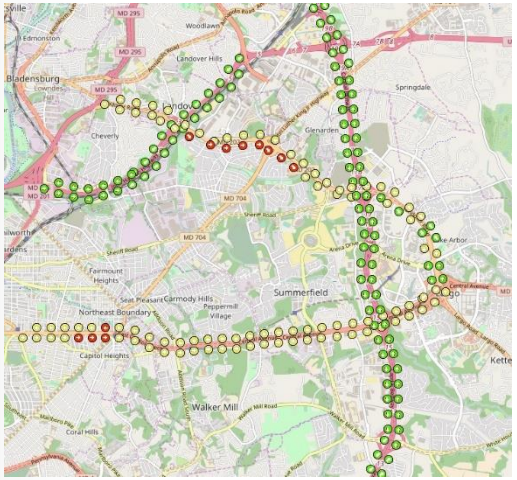
TrafficSense has been validated by transportation agencies, cities and DOTs to match real-time sensors' data quality. These reports are available upon request

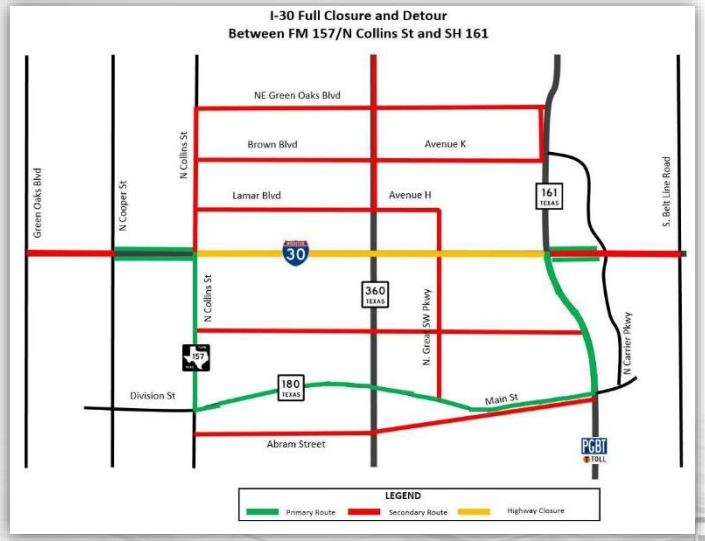
US – Partnership with Verizon: Nation-Wide Service

- Partnership with Verizon which sells the joint solutions under Verizon TDS brand name (Traffic Data Services)
- Projects and validations across the country: Seattle DOT, NCTCOG, Southlake TX, Illinois Tollway, Sedona AZ, Sacramento CA, Atlanta GA, etc.



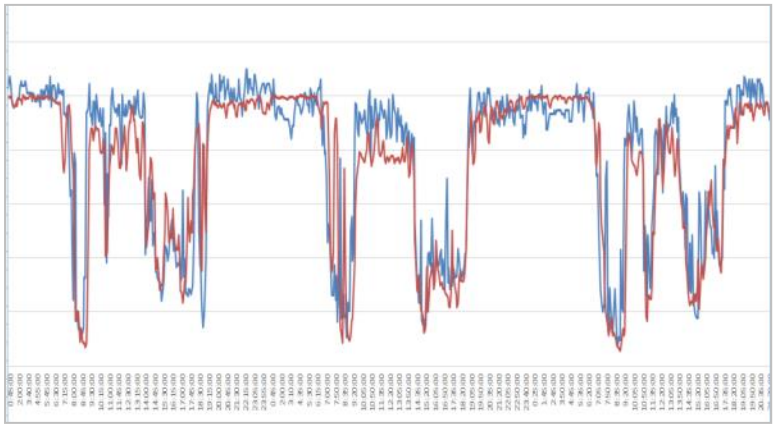
TrafficSense comparison to LPR



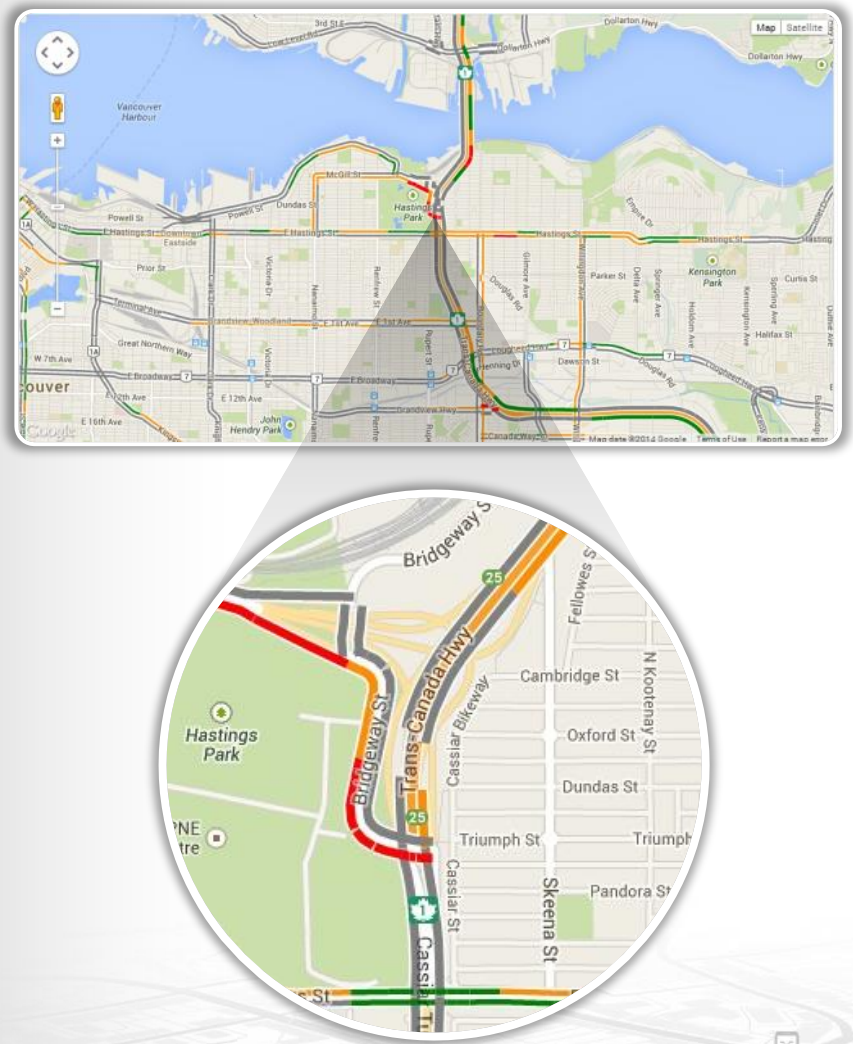


Canada – Partnership with Rogers: Country-Wide Service

- Projects and services for many cities and transportation agencies: Ontario, Toronto, Quebec, Montreal, BC, Vancouver, Calgary, Winnipeg, Halifax, Translink, Metrolinx, etc.
- Partnership with Rogers Wireless



TrafficSense validation in Vancouver



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Summary

- The next generation solution of mobility data for smart cities/regions management:
  - Real time traffic and travel monitoring validated to match sensors' grade quality
  - Analytics tools to generate insights from a junction level to a country-wide perspective, based on the entire network population with street level accuracy
  - The only solution, world-wide, enabling near real time origin destination analysis
- Nation-wide service in the US (Verizon) and Canada (Rogers), collaboration with Vodafone in the Europe
- Major projects & excellent references from tier one customers and partners across the globe