Data-Intensive Transportation Decision Making

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RICE Unconventional Wisdom

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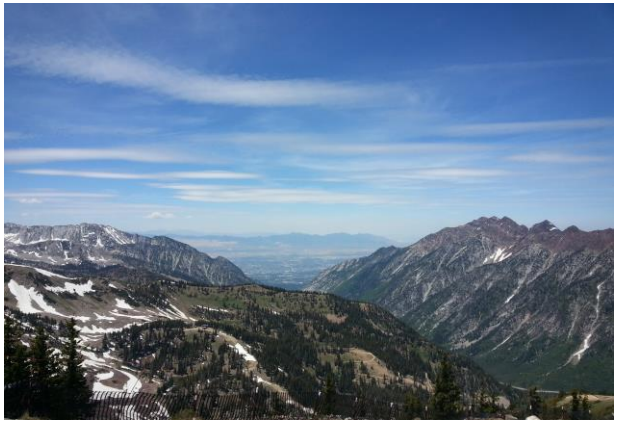
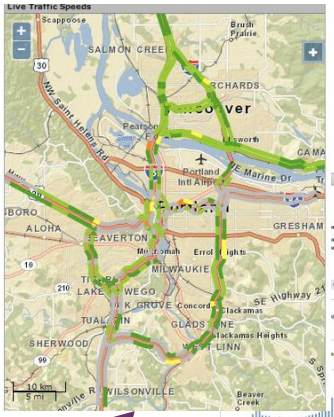
A bit about me...

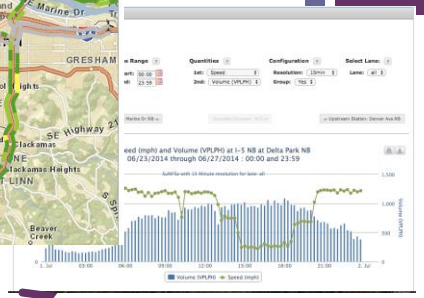
- PhD Database Management – Univ of Wisconsin Madison
- Data Management System Design and Implementation
  - Paradise (1990-1996) - sold to NCR/Teradata
  - NiagaraST Data Stream System (1996-2014)
  - S-Store – Streams + OLTP (2013-…)
- Transportation Data Management
  - Portal Transportation Data Archive (2004-…)
  - Portland Observatory (2013-…)
  - BikePed Portal (2014-…)



Portal Data Archive

- Portland-Vancouver Transportation Data Archive
  - Established in 2004 – Happy 10th Portal!
  - Policy of Open Data
  - Publicly-funded (Thanks to NSF, FHWA, Metro, RTC, OTREC)
  - Focus on open-source software (PostgreSQL, PostGIS, OpenLayers, HighCharts)
  - ~3 TB PostgreSQL Database





Portal Data Archive

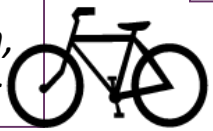
Speed, Count, Travel Time, Weigh-in-Motion, *Variable Speed*

Travel Time, Traffic Signal, Bicycle Count, Pedestrian Push-Button

Ons, Offs, On-Time Performance

Freeway
ODOT, WSDOT, Lane County

Arterial
City of Portland, Clark County, Clackamas County, *Washington County, Gresham, Tigard, Beaverton, Vancouver*

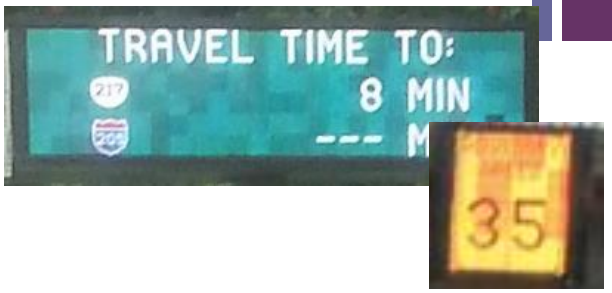


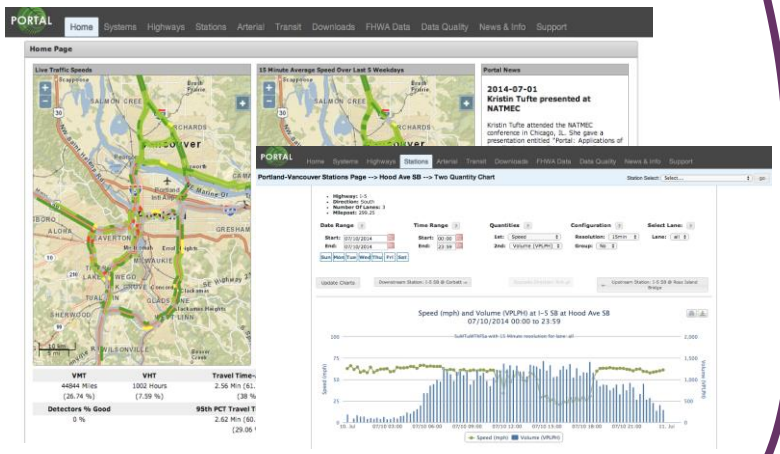
Transit
TriMet
C-TRAN

Other
Weather, Weigh-in-Motion, *Variable Speeds*

Uses of Portal

- Advanced Traffic and Incident Management Project Development
  - Research -> Planning -> Implementation -> Evaluation
- Education
  - Cloud Data Management
  - Civil & Environmental Engineering Curriculum
- Agency Performance Reporting
- Travel Model Usage
- ODOT Bottleneck Analysis
- Powell Blvd Signal Analysis
- Portland Arterial Concept of Operations





Portal Archive

Why Transportation Decision Making?

- **Increased Volume and Variety of Transportation Data**
  - Improved sensor and mobile device technology
  - Realization that data is too valuable to delete
    - ADUS - ITS Program Plan addendum 1998
  - Decreased storage costs

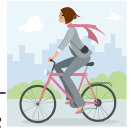
- **Increased Demand for Data-Driven Decision Making (MAP-21)**

Freeways
- Inductive Loops
- High-Definition Radar
- Third-Party

Transit
- AVL/APC
- GTFS

Safety
- Incident Reports
- Crash Reports

Arterial
- Measured Travel Time
- Traffic Signal Systems



Bicycle/Pedestrian
- Automated
- Manual

Ideas credit: David DeWitt, Microsoft/UW-Madison, SQL Server PASS Talk 2011

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    - ADUS
  - Decreased
- **Increased I**

- **Variety**
  - Occurs in many domains
    - Education, healthcare, …
  - Not lots of good existing solutions

Freeways
- Inductive Loops
- High-Definition Radar
- Third-Party

- AVL/APC
- GTFS

Safety
- Incident Reports
- Crash Reports

- Measured Travel Time
- Traffic Signal Systems

Bicycle/Pedestrian
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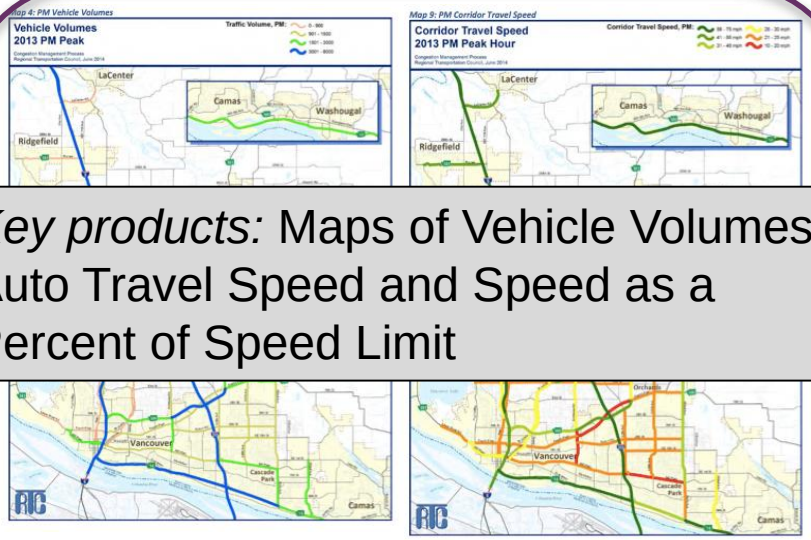
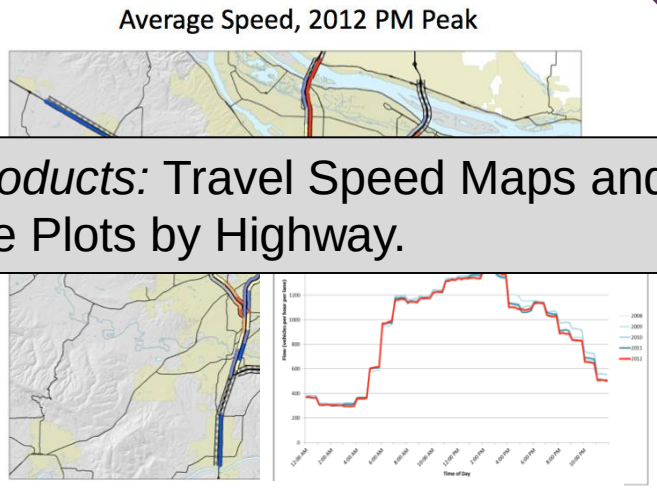
A Story of Three Reports…



Key products: Maps of Vehicle Volumes, Auto Travel Speed and Speed as a Percent of Speed Limit

RTC Congestion Management Process Monitoring Report (Vancouver, WA)



Key products: Travel Speed Maps and Volume Plots by Highway.

Metro Portal Annual Report

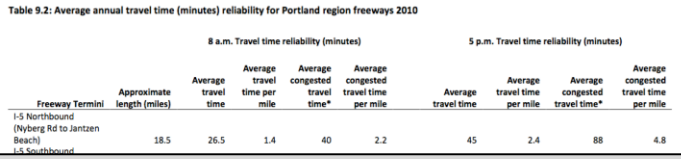


Table 9.2: Average annual travel time (minutes) reliability for Portland region freeways 2010

		8 a.m. Travel time reliability (minutes)				5 p.m. Travel time reliability (minutes)			
Freeway Termini	Approximate length (miles)	Average travel time	Average travel time per mile	Average congested travel time*	Average congested travel time per mile	Average travel time	Average travel time per mile	Average congested travel time*	Average congested travel time per mile
I-5 Northbound (Nyberg Rd to Jantzen Beach)	18.5	26.5	1.4	40	2.2	45	2.4	88	4.8
I-5 Southbound									

Key product: Table of travel time reliability

Metro Performance Measures Report (Portland, OR)

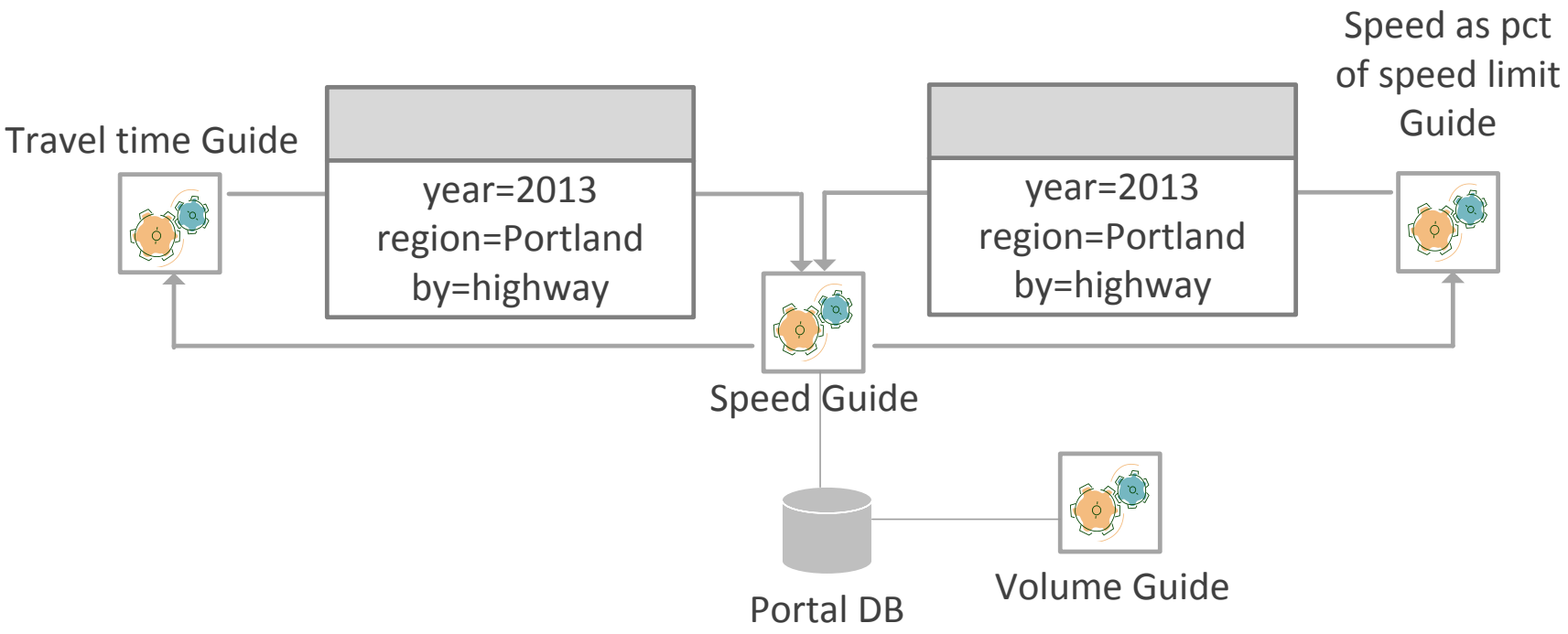
Comparisons & Observations

- Common Data Inputs to Key Products: Speed and Volume
  - Travel time is based on speed
- Similar types of Selections: Peak period; Mid-week days
  - Consistency across reports desirable in certain cases
- Recurrent Decision-Making Tasks
  - Similar decisions / reports for different locations and time periods
    - Annual Reports
    - Portland Reports, Vancouver Reports
  - Consistency across analysis and decisions is desirable in certain cases
- Currently require significant human time & effort to produce

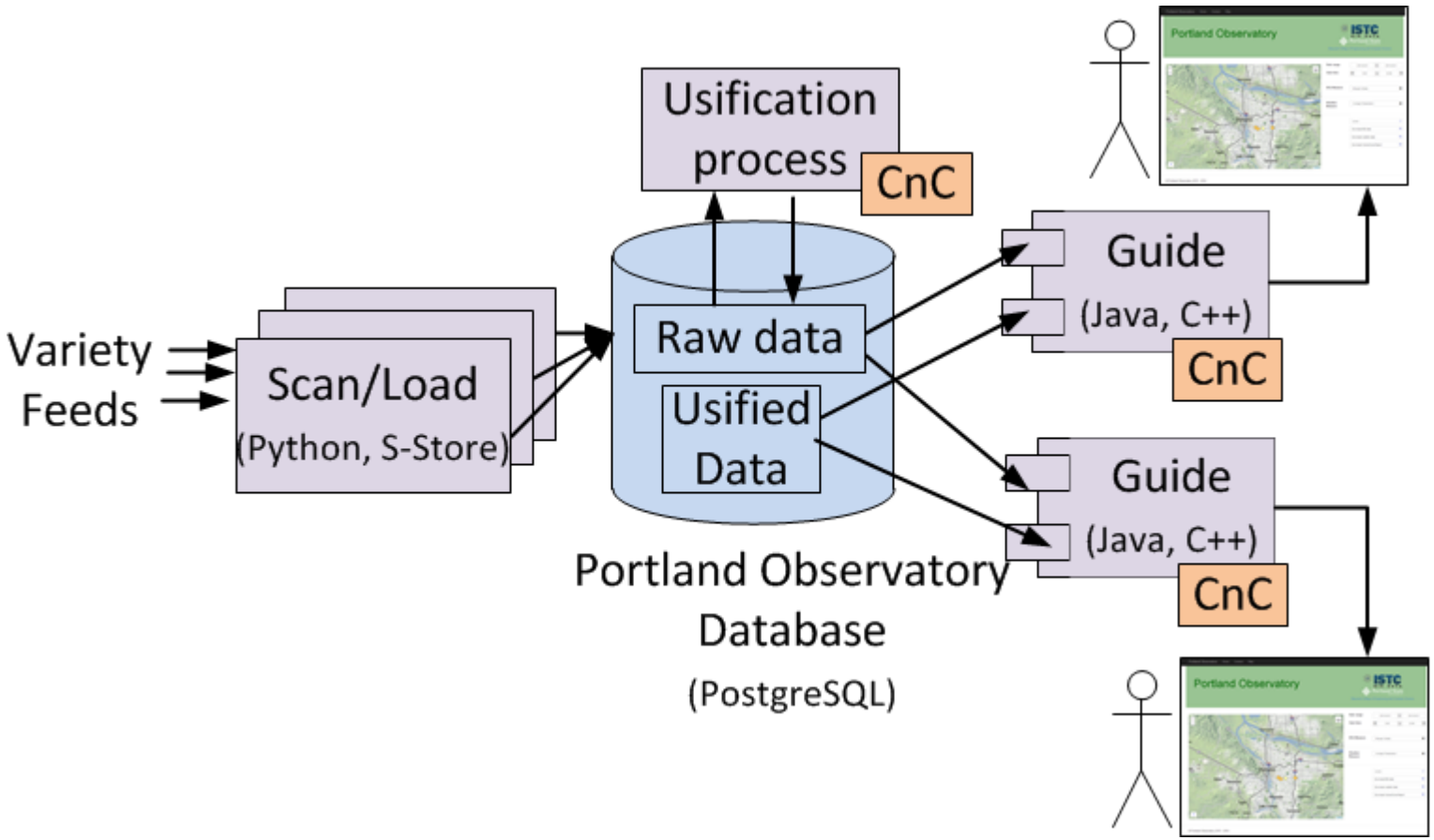
From Data to Decisions…

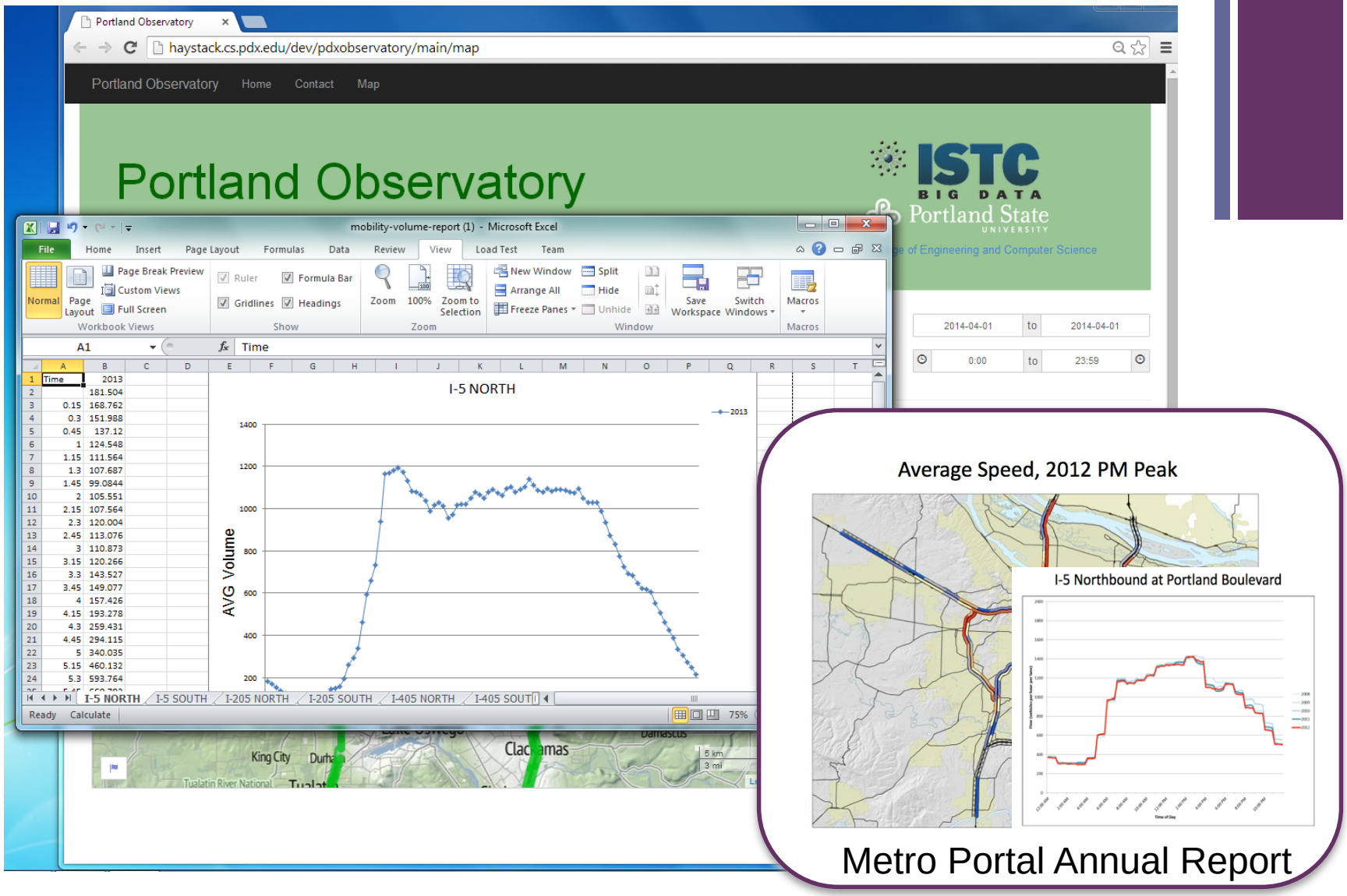
- Data stored across disparate locations and systems
  - Getting the data is sometimes the hardest part
- Decisions and analysis are difficult to document
  - Capturing human judgment and manual manipulation of data
- Can we apply existing technologies?
  - Data Integration – Traditional options are heavy-grade; not effective for reports generated annually
  - Database + SQL queries – Useful; but don't record judgments or reasoning behind judgments
  - Traditional data management techniques may be overkill (Data Integration) or may not capture the required information (SQL Queries)

Hierarchical Report Structure

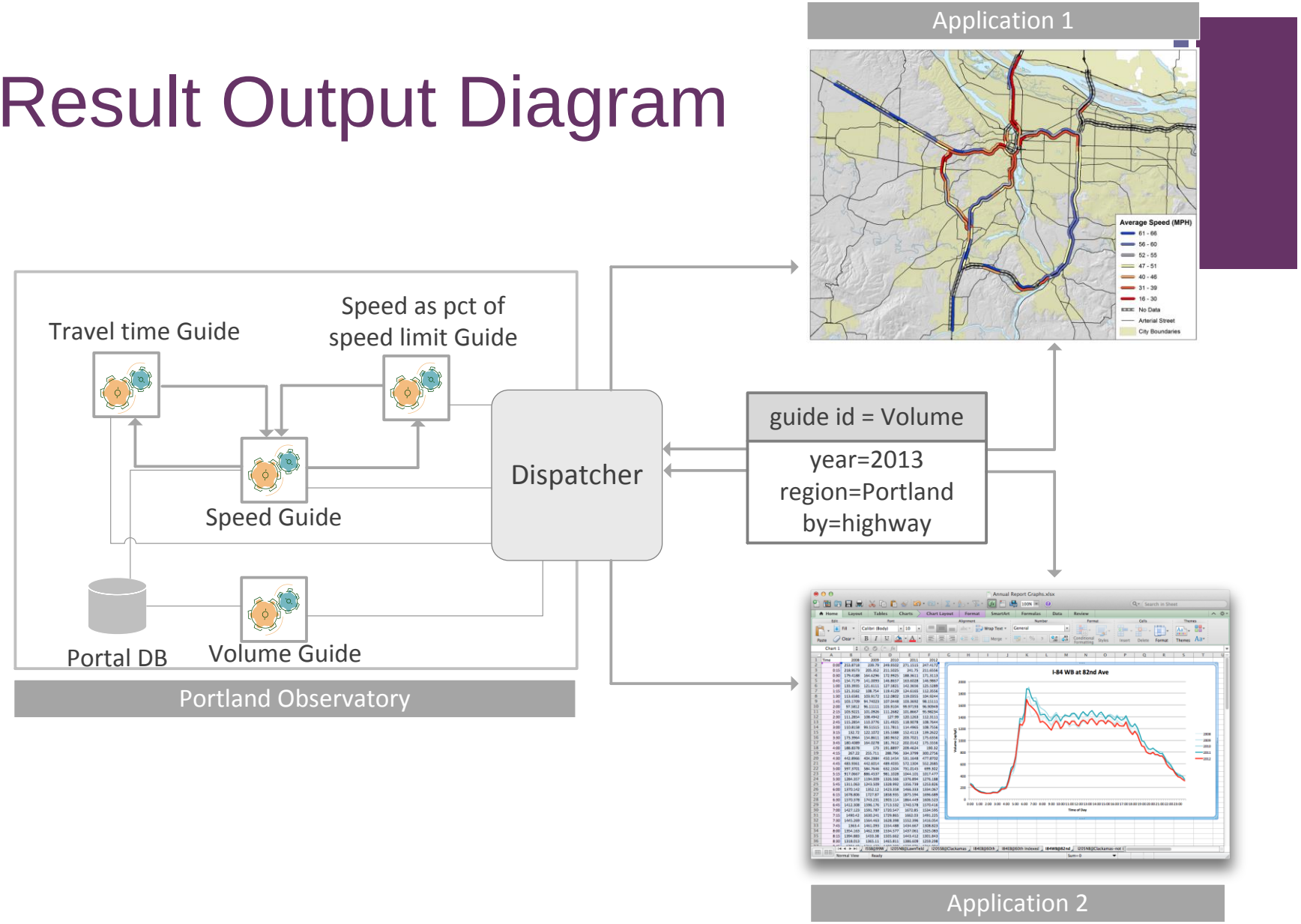


System Architecture




Portland Observatory
haystack.cs.pdx.edu/dev/pdxobservatory/main/map
Portland Observatory
Home
Contact
Map
Portland Observatory
ISTC
BIG DATA
Portland State
UNIVERSITY
mobility-volume-report (1) - Microsoft Excel
I-5 NORTH
AVG Volume
2013
2014-04-01
to
2014-04-01
0:00
to
23:59
Average Speed, 2012 PM Peak
I-5 Northbound at Portland Boulevard
Metro Portal Annual Report

Result Output Diagram



Summary

- Data-Driven Decision Making is the Future
- Opportunities found through examination of three performance reports
  - Shared Data Access
  - Capturing Recurrent Decision-Making and Report-Generation Processes
- Implemented a Guide Prototype
  - Front end Guide Capture using a web interface and
  - Back end Guide Instantiation using CnC and the PostgreSQL relational database.

CnC + Databases

- Database Strengths
  - Schema
  - Transactions
  - Recovery
  - Very efficient on filters, joins, grouping
- Database Weaknesses
  - Limited expressiveness of SQL
  - Scaling can be limited by transactions and recovery
- CnC Strengths
  - Expressiveness and declarative nature

CnC + Databases: Just dump it all to files…

2013 Mid-weekday Volume by Station for selected stations

```
SELECT  s.name,  extract(year from l.starttime) as year,
        extract(hour from l.starttime) as hour,
        (extract(minute from l.starttime)%4)*15 as min15,
        round(avg(volume)*180) as volume,
        count(*) as numreadings
FROM loopdata_2013 l, detectors d, stations s
WHERE l.detectorid = d.detectorid  AND
        d.stationid = s.stationid AND
        extract(dow from l.starttime) in (2,3,4) AND
        d.stationid in (1059, 1031, 1021, 1092, 1090, 1064, 1079, 1010,
                        1105, 1044, 1100, 1127) AND
       volume > 0
GROUP BY stationid, year, hour, min15
```

Or maybe not…

CnC + Databases - Opportunities

- Language-level - CnC + SQL
  - Give visibility into parts of the decision making process that were previously obscured by “lines of code”
  - Transparency (justification), documentation of data used (privacy issues)
- Systems-level
  - CnC: Declarativeness at a higher level
  - Database: Efficient and pre-programmed filter, join, aggregation
- Current thought: SQL Query inside CnC step

Portland Observatory: Goals

- Find a domain that challenges the third “V” of Big Data: variety
- Align with PDX’s interest in Sustainability
  - Air quality data, Intelligent Transportation Systems
- Help people we work with
  - Planners, researchers, managers, public
- Reach out to other Intel centers and labs
  - ExaCloud, S-Store, Intel-UXR/ISTC-Social

Portland State UNIVERSITY

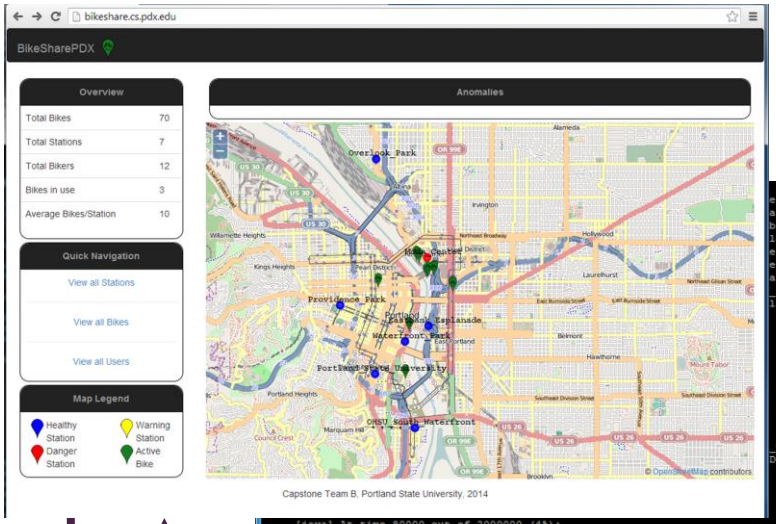
ISTC BIG DATA

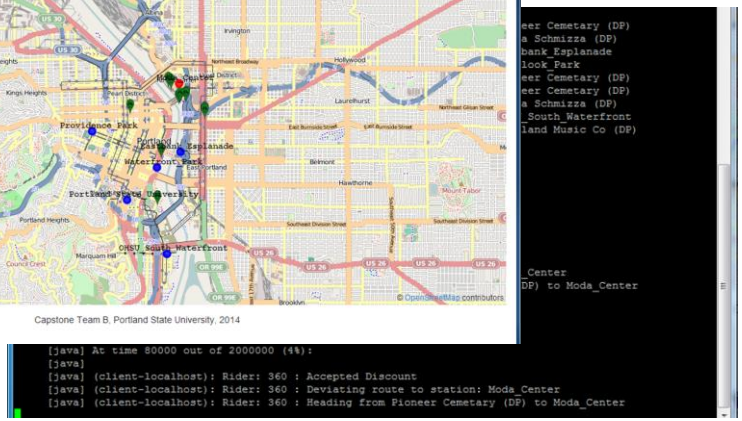
S-Store: Bike Share Demo

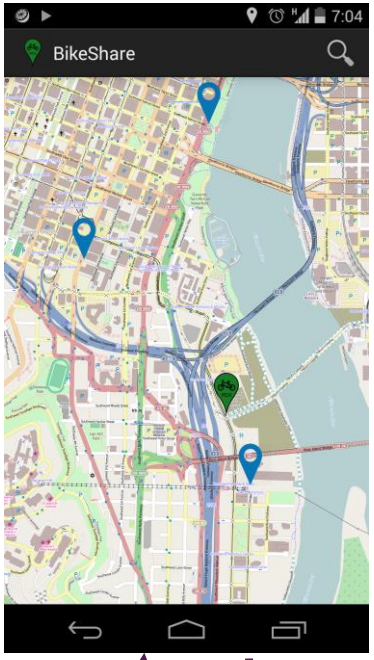
- S-Store: State of the art system for big-velocity applications
  - Combines stream processing and transactional guarantees
  - Built on the H-Store Database System
- Demo implementation of BikeShare system on S-Store
  - Web site and mobile app based on a bike sharing scenario
  - Customers check-out, ride & check-in bikes **(OLTP)**
  - Bike locations arrive as a stream
  - Discounts used to encourage riders to return bikes to stations needing bikes
    - Discounts calculated dynamically based on streaming bike positions **(Stream Processing)**

Portland State UNIVERSITY ISTC BIG DATA BROWN MIT CSAIL

BikeShare Architecture







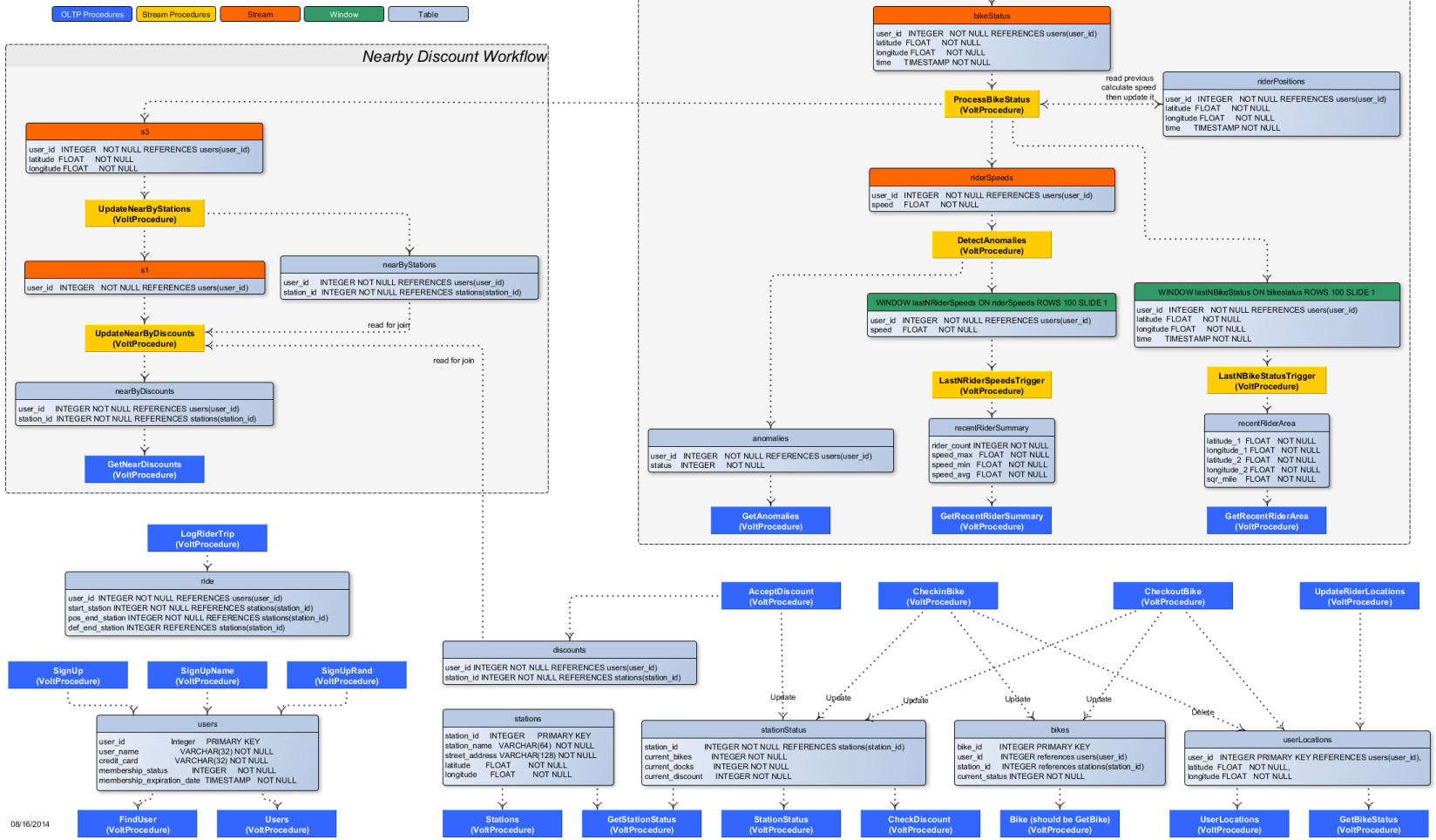
REST API (Flask)

Custom S-Store Client

S-Store

BikeShare Workflow (complete)

S-Store - BikeShare Benchmark
OLTP & Streams Workflows



THANK YOU!!

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