
# Analysis of Transit Buses as Probe Vehicles for Arterial Performance Measurement

利用公共汽车数据评估交通干线运行状况的分析

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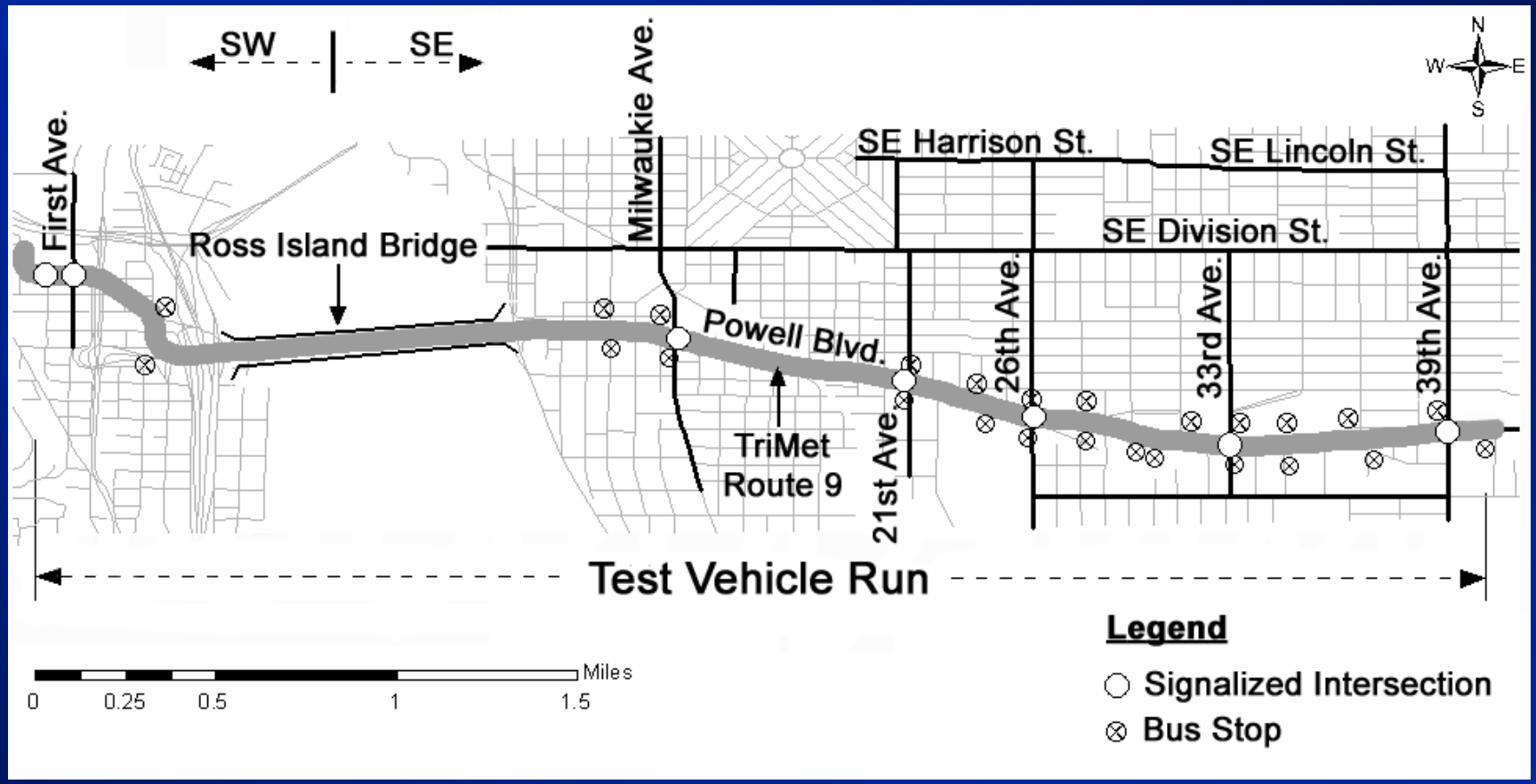
IEEE 6th International Conference on ITS
Shanghai, China
October 12, 2003

# Objectives 研究目的

- Introduce another use of AVL data
  介绍车辆自动定位(AVL)数据的另一种用途
- Examine possibility of using transit vehicles as probes
  验证利用公共汽车提取交通运行数据的可行性
- Demonstrate how AVL data can be used to characterize arterial performance
  论证利用AVL数据描述交通干线运行状况的方法
- Examine relationship between travel times and speeds of buses and automobiles
  求证干线上公共汽车与轿车在通行时间与速度上的关系
- Create application to predict/report arterial traffic conditions based on AVL data
  开发运用--利用AVL数据预测/记述交通干线运行状况

# Objectives 研究目的

# Study Corridor 课题研究中车辆行驶的线路




- Four-lane arterial 4车道干线
- 4 kilometers 4公里长
- East-West 东西向
- 50,000 ADT 日流量5万

# Test Vehicle Data 对照组轿车的数据

| TIME | LAT | LON | DIS |
|---|---|---|---|
| 6:25:30 | 45.50040167 | 122.6747567 | 0 |
| 6:25:33 | 45.50046 | 122.67402 | 0.035854 |
| 6:25:36 | 45.50051667 | 122.6732583 | 0.037043 |
| 6:25:39 | 45.50057667 | 122.6724783 | 0.037949 |
| 6:25:42 | 45.50063833 | 122.6716817 | 0.038763 |
| 6:25:45 | 45.50070167 | 122.670875 | 0.039256 |
| 6:25:48 | 45.50076333 | 122.670075 | 0.038923 |
| 6:25:51 | 45.50082667 | 122.6692783 | 0.038775 |
| 6:25:54 | 45.50088833 | 122.668485 | 0.038602 |
| 6:25:57 | 45.50094833 | 122.6676833 | 0.038991 |

GPS-- 全球卫星定位系统

GPS-Insturmented Passenger Vehicle
配备了GPS装置的轿车

- GPS Coordinates GPS坐标
- Time stamped every 3 sec
  每隔3秒提取数据

Availability 已有数据

- November 1, 2001: AM Peak
- November 3, 2001: Mid Day
- **November 7, 2001: AM Peak**
- November 10, 2001: Mid Day

**November 7, 2001 Data**

18 runs on both directions

2001年11月7日采集了双向共18个数据样本

# BDS Data 公共汽车运行调度系统的数据

| SERVICE DATE | Leave Time | Stop Time | Arrive Time | BADGE | DIRECTION | TRIP NO | LOC. ID | DWELL | DOOR | LIFT | ONS | OFFS | EST. LOAD | Max Speed | PATTERN DISTANCE | X Coor. | Y Coor. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01NOV2001 | 8:53:32 | 8:49:15 | 8:53:28 | 285 | 0 | 1120 | 4964 | 0 | 0 | 0 | 0 | 0 | 21 | 41 | 10558.58 | 7644468 | 676005 |
| 01NOV2001 | 8:55:00 | 8:51:41 | 8:54:46 | 285 | 0 | 1120 | 4701 | 4 | 0 | 0 | 0 | 1 | 20 | 50 | 15215.05 | 7649112 | 676328 |
| 01NOV2001 | 8:56:22 | 8:52:00 | 8:55:08 | 285 | 0 | 1120 | 4537 | 36 | 3 | 0 | 6 | 0 | 26 | 34 | 15792.35 | 7649674 | 676220 |
| 01NOV2001 | 8:57:44 | 8:53:44 | 8:57:08 | 285 | 0 | 1120 | 4622 | 5 | 2 | 0 | 0 | 1 | 25 | 47 | 18500.66 | 7652240 | 675442 |

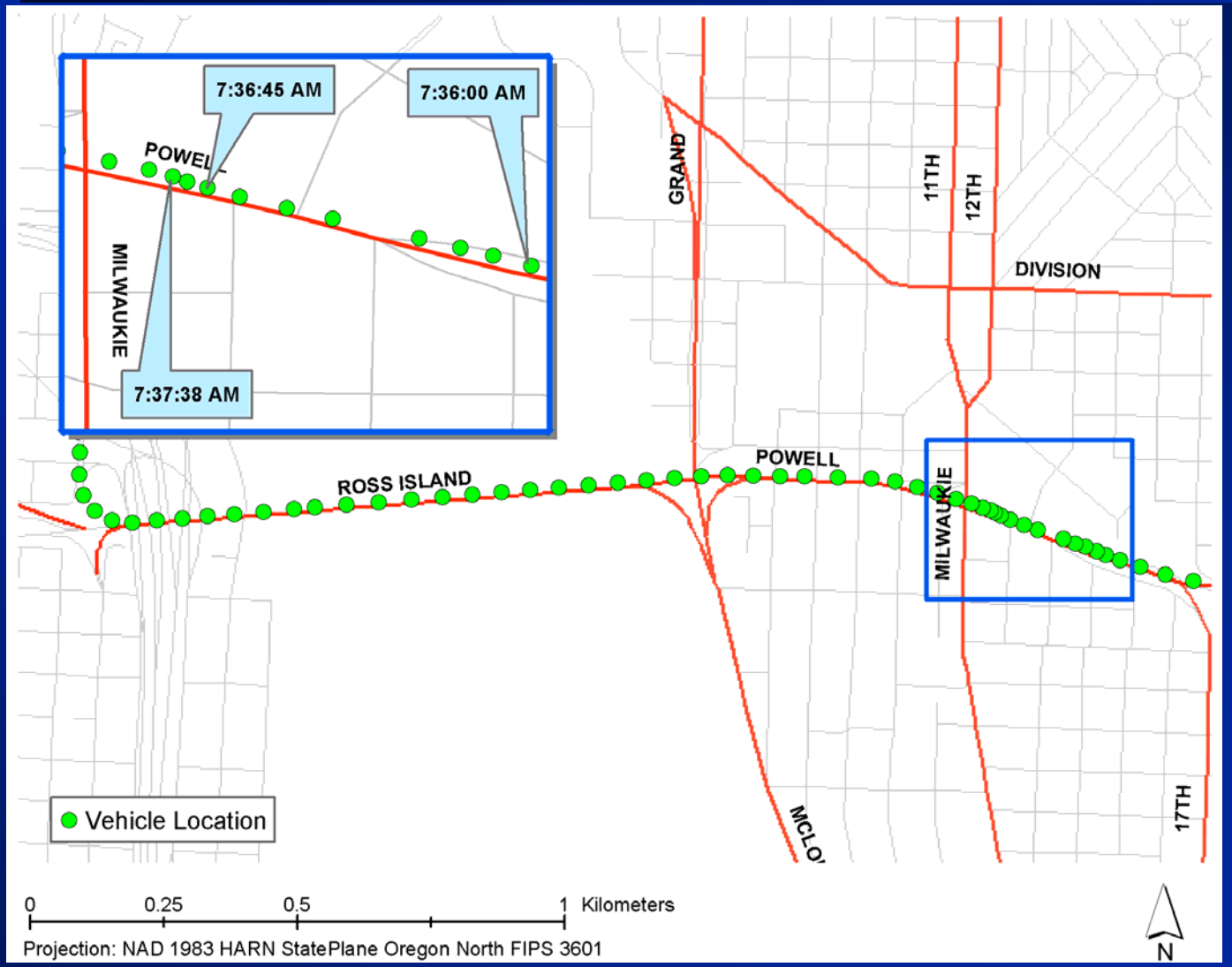
Bus Dispatch System 公共汽车运行调度系统

- AVL 车辆自动定位数据
- Differential GPS 差异GPS
- Automatic Passenger Counter
  自动乘客计数器
- Wireless Communication 无线通讯

**November 7, 2001 Data** 2001年11月7日的数据

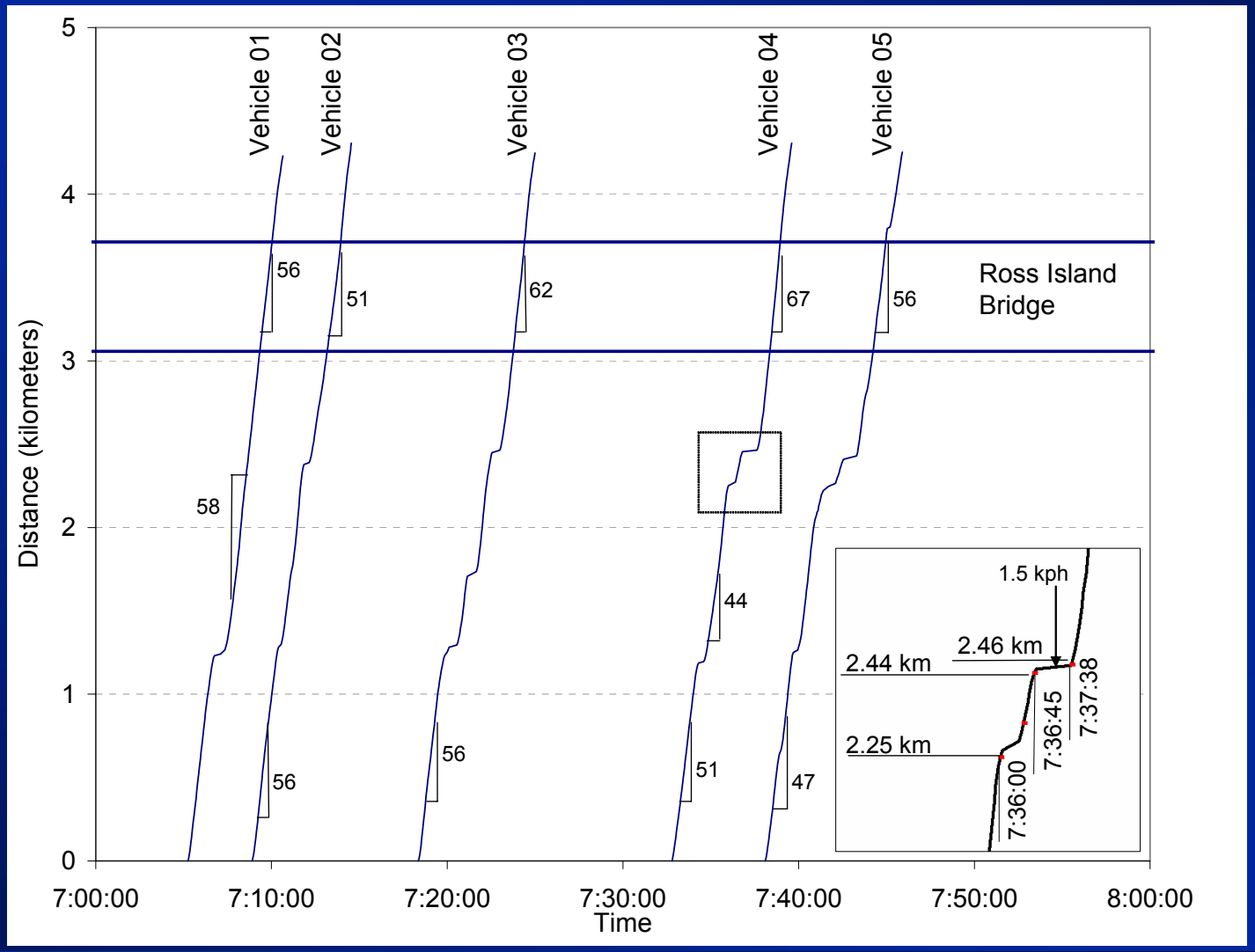
- 16 runs on westbound direction
  16个样本数据为西行公共汽车
- 15.7 sec dwell per served stop
  每次停靠站花费15.7秒钟
- 3 boarding & 3 alighting 上下乘客各3人

# Vehicle Location Over Time 一定时间段内车辆的所在位置图

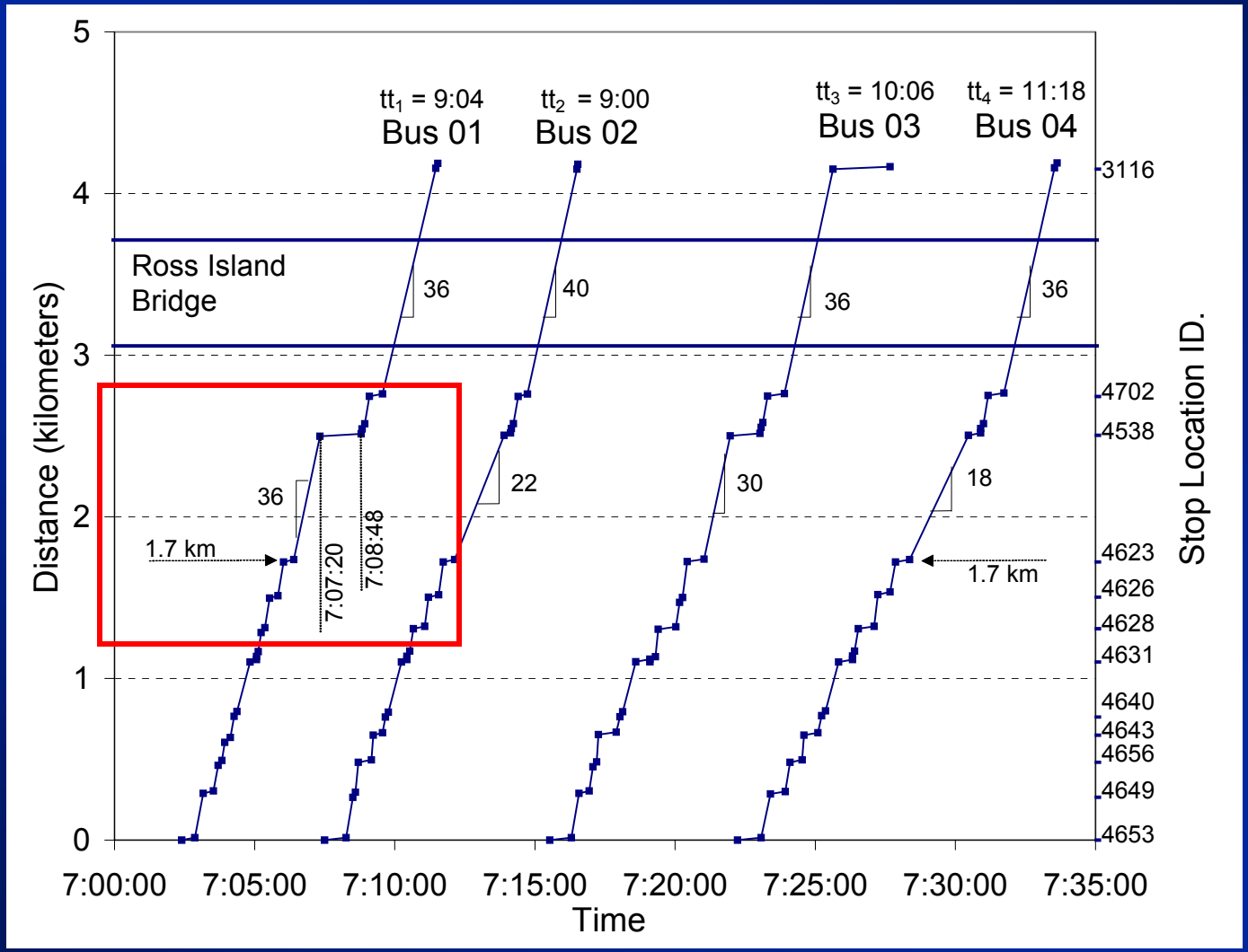


# Vehicle Location Over Time

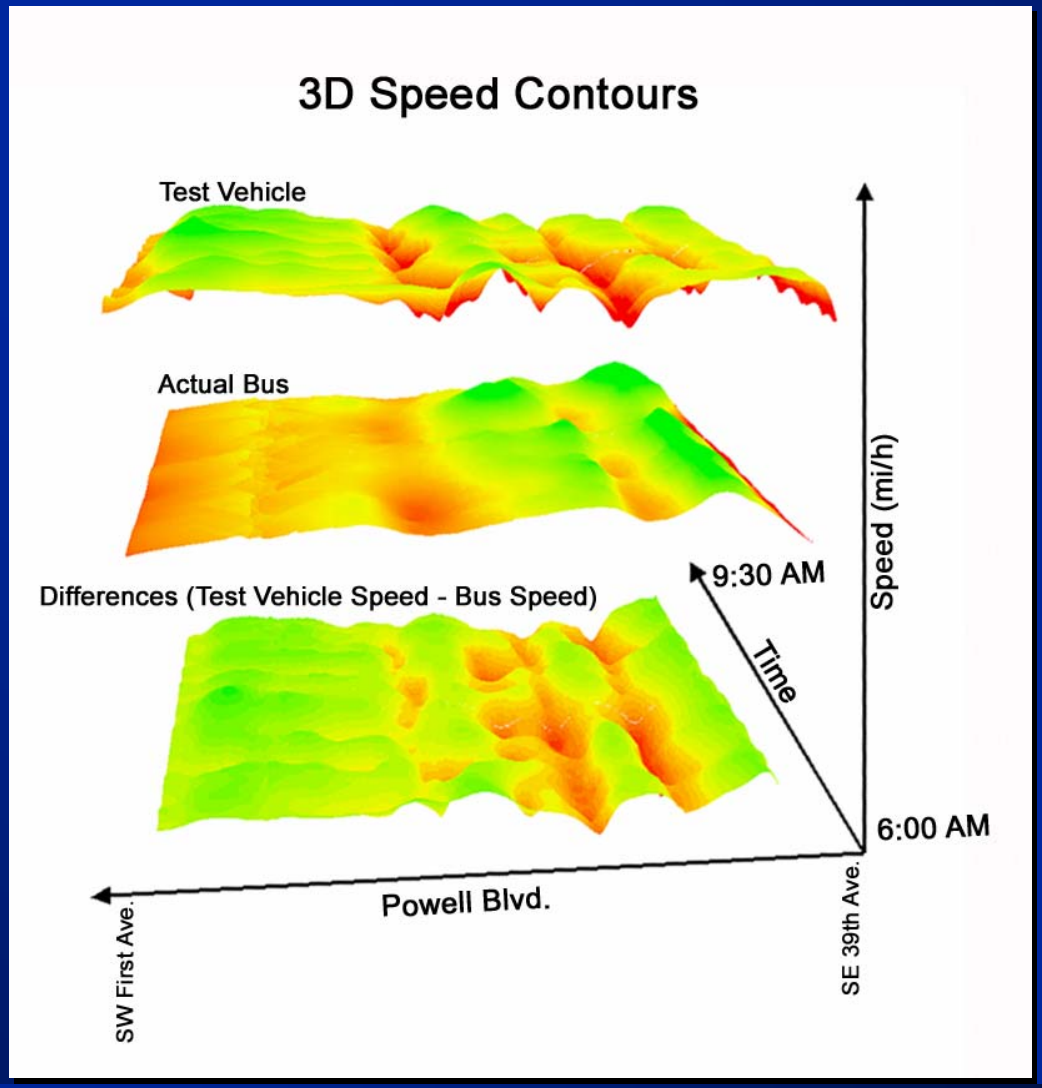
## 一定时间段内车辆所在位置的距离/时间过程图



# Bus Trajectories 公共汽车运行的距离/时间过程图



# 3-D Speed Contour 3维空间行驶速度等值面图



# Conceptual Bus 引进两种概念上的公共汽车

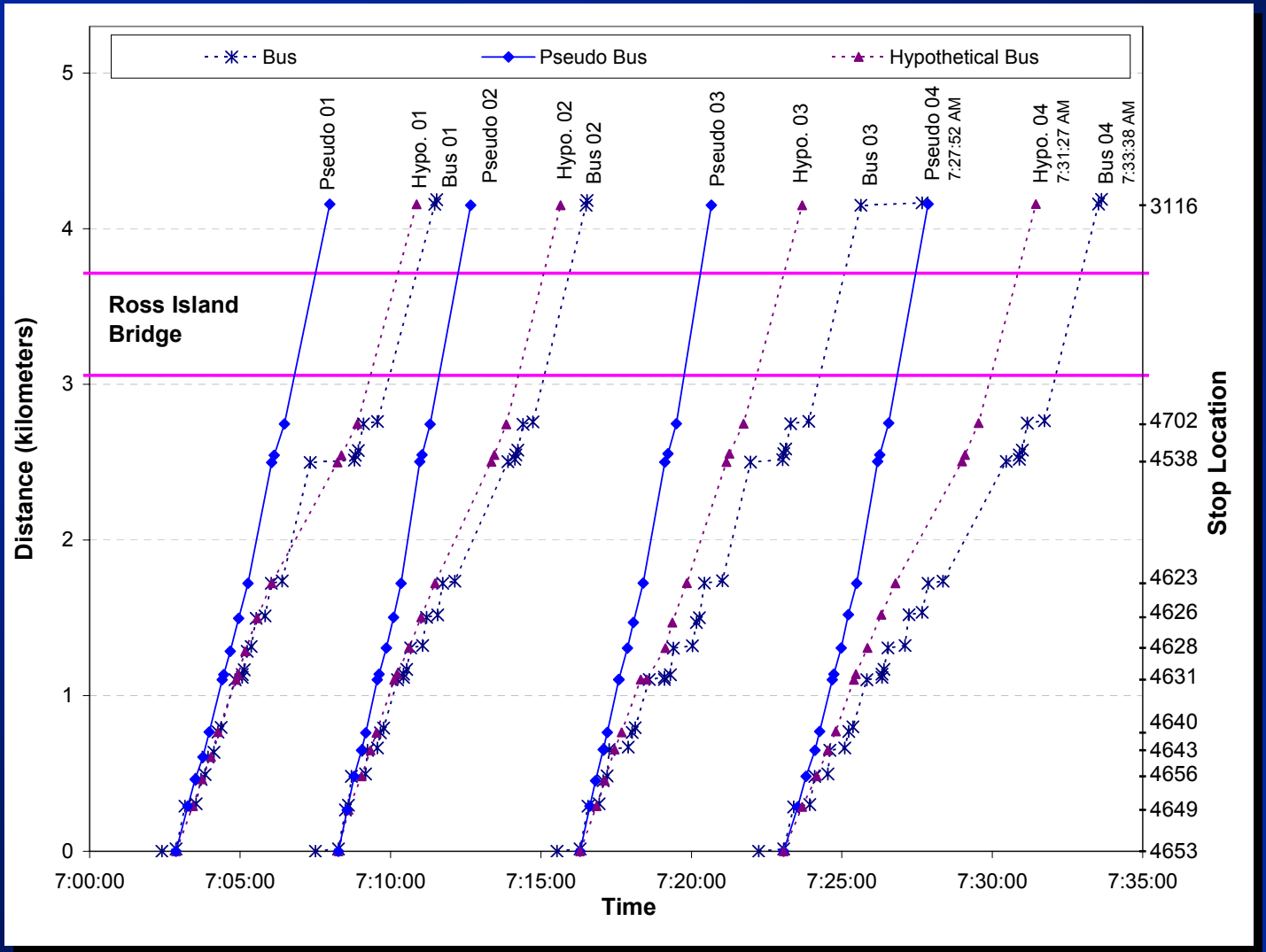
- Hypothetical Bus – run without stops or passenger activities

  模拟直达公共汽车 –模拟的可不靠站和没有上下乘客的公共汽车

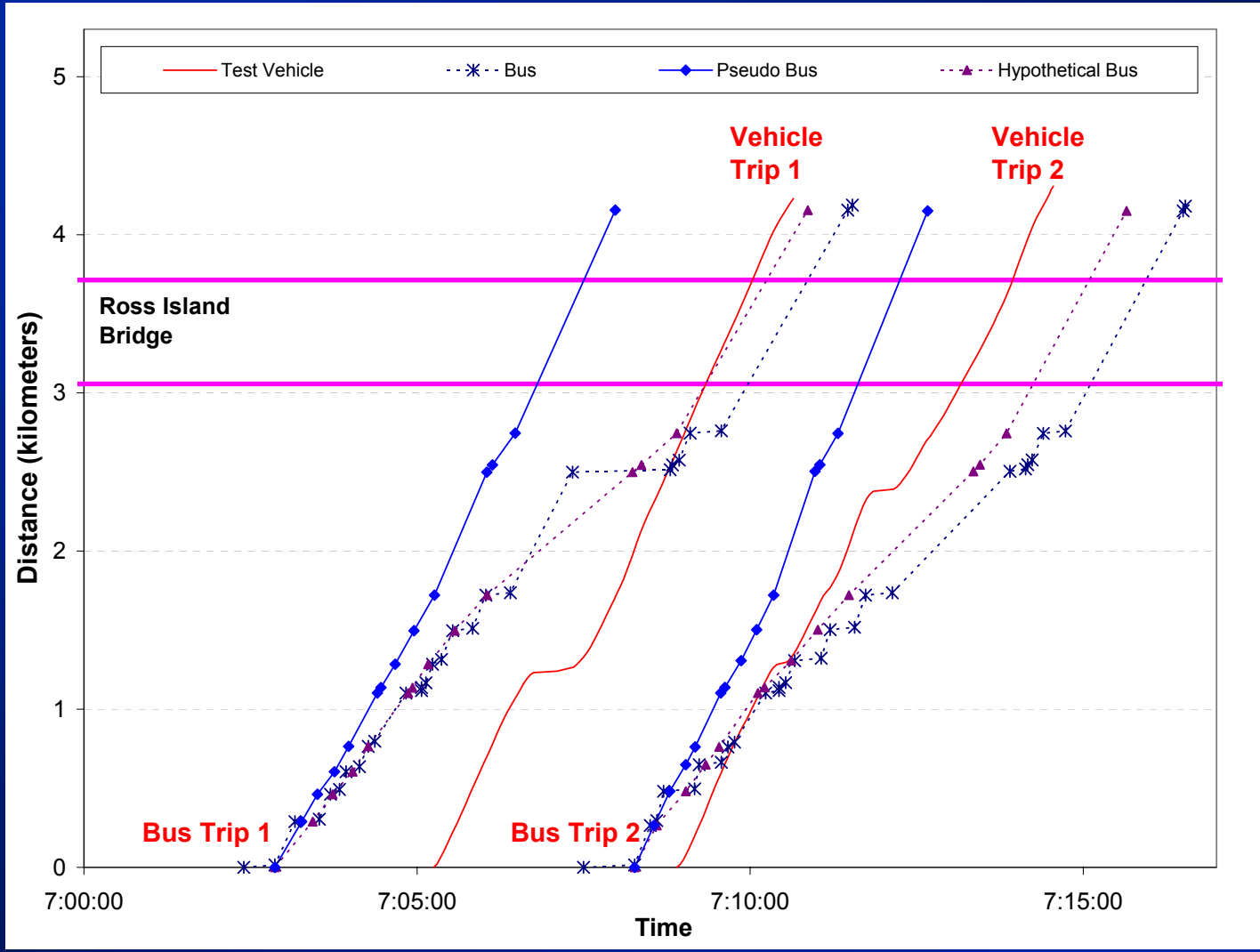
- Pseudo Bus – travel at maximum achieved speed record within link

  假设高速公共汽车 --假设的可按照线路的最高速度行驶的公共汽车

# Three Bus Trajectories 3种公共汽车的距离/时间运行过程图

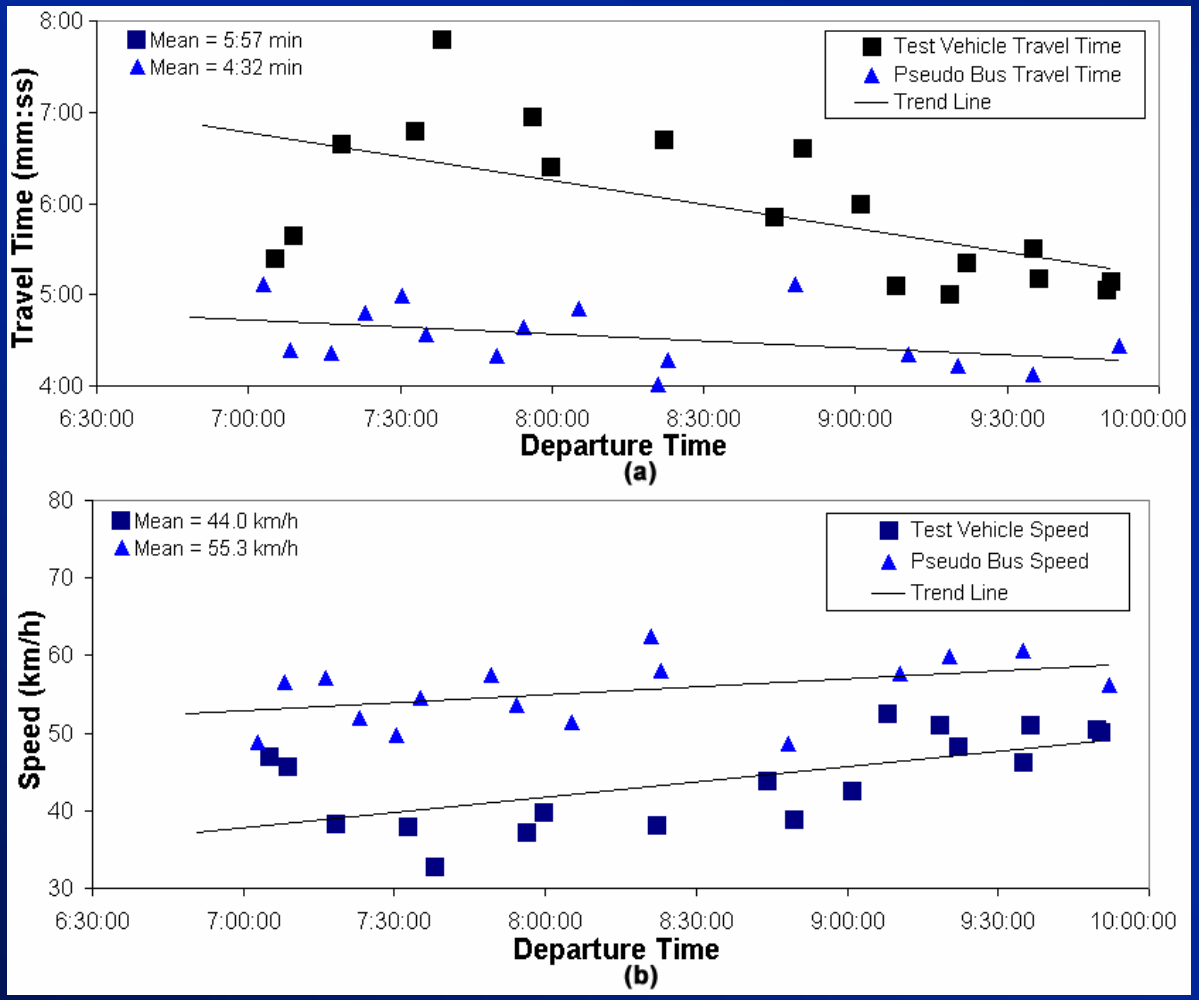


# Test Vehicles vs. Buses 对照组车辆和公共汽车的运行对比



# Pseudo Bus vs. Test Vehicle

## 假设高速公共汽车和对照组轿车的运行对比

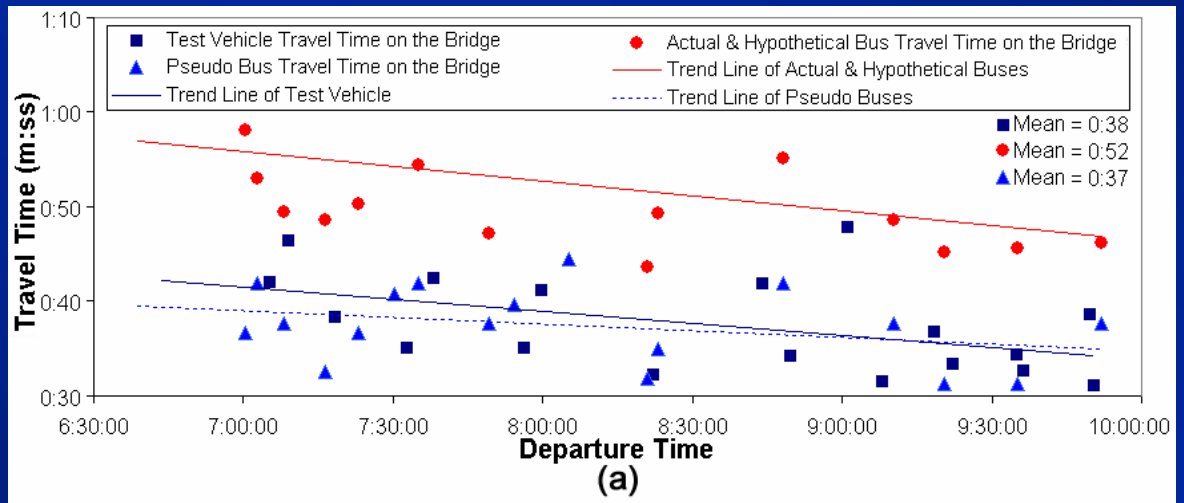



$tt_{veh} = 1.33\ tt_{pseudo}$

$V_{veh} = 0.79\ V_{pseudo}$

# Bridge Relationship

## 在ROSE ISLAND桥上各种车辆在通行时间与速度上的关系




$tt_{B\text{-}veh} = 1.03\ tt_{B\text{-}pseudo}$

$V_{B\text{-}veh} = 1.01\ V_{B\text{-}pseudo}$

# Statistical Analysis 统计分析

## Ensure minimum number of runs 确保最小样本数

$$n = \left[ \frac{t_\alpha \cdot s}{E} \right]^2$$

Where

- $s$ = estimate standard deviation of random samples 估计随机样本的标准方差
- $t_\alpha$ = t distribution statistic (used instead of *Za/2* when dealing with random samples or small sample size) t检验
- $E$ = maximum error of the estimation 最大误差

**Minimum number of runs最小样本数**

- Bus = 12 runs 公共汽车=12
- Vehicle = 7 runs 轿车=7

**Data availability 已有数据**

- Bus = 16 runs 公共汽车=16
- Vehicle = 18 runs 轿车=18

# Statistical Analysis 统计分析

## Verify relationship between test vehicle & pseudo bus

验证对照组轿车与假设高速公共汽车在运行上的关系在统计学上是相关的

- Alternative hypothesis: $\beta \neq 0$
- Level of significance: $\alpha = 0.05$
- Number of samples: $n = 18$
- T-critical: $t_{0.025}$ for 17 degree of freedom = $\pm 2.11$
- $t$ value is 10.27 > $t$-critical

# Statistical Analysis 统计分析

$$Y_{pseudo} = \alpha + \beta_{veh} X_{veh} + \varepsilon$$

$$Y_{veh} = \alpha + \beta_{pseudo} X_{pseudo} + \varepsilon$$

Using reverse regression 利用逆回归模型

- to test relative effects of measurement error
  测试评估误差的相对效应
- Obtain bounds on the true $\beta$
  计算相关系数的界值
- $\beta_{veh}$ = 1.27
- $\beta_{pseudo}$ = 0.77

$$V_{veh} = 0.78 V_{pseudo} + \varepsilon$$

# Conclusion 结论

- **Possible to explain actual arterial traffic conditions using transit vehicle AVL information.**

  利用公共汽车的AVL数据可以解释/评估交通干线的真实运行状况

- **Bus movement created from maximum instantaneous speed achieved between each stop pair most reliably depicted traffic movement of non-transit vehicles.**

  公共汽车在两停靠站之间所达到的最高即时速度能最可靠地反映非公交车辆在交通干线上的运行状况

- **Test vehicle travel time was 1.25 times the pseudo bus travel time.**

  对照组轿车在交通干线上的通行时间是假设高速公共汽车的1.25倍

- **In reverse, test vehicle speed was 0.78 the pseudo bus speed.**

  反过来, 对照组轿车在交通干线上的行驶速度是假设高速公共汽车的0.78

- **Time-space diagrams and 3D visualizations were helpful for exploring the data before beginning detailed analysis.**

  在进行深入严谨的分析之前,建立时间/空间图形和3维空间直观图能有助于对数据的理解

- **Further analysis on both traffic directions on more numbers of days is ongoing**

  我们正在利用不同日期的更多数据进一步研究双向交通运行状况

# Acknowledgments
感谢下列单位和个人对本课题研究的帮助和贡献


The Tri-County Metropolitan Transit District (TriMet)

Steve Callas

Oregon Department of Transportation

Jack Marchant

City of Portland

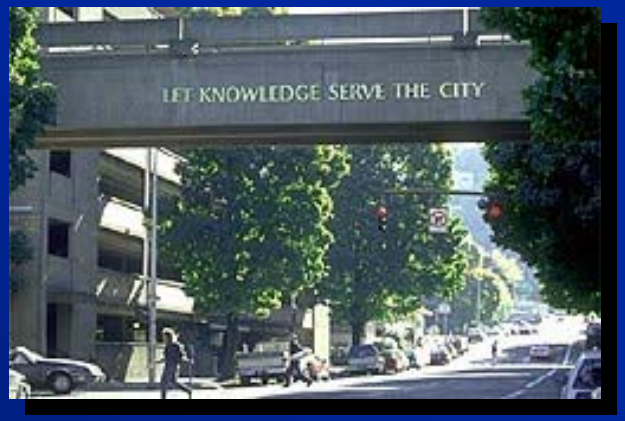
Bill Kloos

Department of Civil and Environmental Engineering, PSU

Chie Taniguchi, Tung Ly, John Fasana, Lara Downs, Tu Ho, Huy-Thac Tran, Ahmad Qayoumi, Michael Kehano, Renee Summers, Monica Leal and Shazia Malik

Center of Urban Studies

Ahmed El-Geneidy,James Strathman and Thomas Kimpel


**Thank You!!**