LANE USE FACTOR ESTIMATION FOR INTERSECTIONS WITH LANE DROP

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OUTLINE

- Introduction
- Literature review
- Lane drop types
- Data collection
- Data analysis and proposed LUF
- Summary

INTRODUCTION

- What is LUF (Lane Use Factor)
  - The ratio of the highest lane volume over the total volume in a lane group
  - Used to determine the critical lane volume for signal phase or intersection analysis
- Currently used LUF (from HCM 2000)

Number of approach lanes	Lane use factor
1	1
2	0.55
3	0.4
4	0.3
5	0.24
Double left turns	0.6
Triple left turns	0.45

INTRODUCTION

- Lane drop intersection types

  - Merge
    - One of the lanes has to merge after the intersection

  - Form a Single lane (Alternative Merge)
    - The two lanes merge each other without indication of which lane yields the right-of-way.

- Are the LUFs for intersection without lane drop and intersection with lane drop be the same?
- If the LUFs are different from normal LUF, what will be the values?

LITERATURE REVIEW

- **Nanda Srinivasan** (2011) from NCHRP focused on auxiliary through lanes to estimated the volume. (TRB)
  - However, the estimated model used signal information; the lane use factor is still unknown for the many types of lane drop.
- **Jae-Joon Lee, Nagui M. Rouphail, and Joseph E. Hummer** (2005) from North Carolina University developed a set of field-verified estimates for the lane utilization factor. (NCDOT project)
  - However, the lane utilization factor was a different concept from the lane use factor focused in this research; the field data was collected in North Carolina state only, which may not be in Maryland.

LITERATURE REVIEW

- Difference between LUF and lane utilization factor

$$LUF = v_{gl} / v_g \quad (1)$$

where v_g =total lane flow rate (vph);
v_{gl} =highest lane flow rate in a lane group (vph).

$$\text{Lane utilization factor} = v_g / v_{gl} N \quad (2)$$

where v_g =total lane flow rate for the lane group (veh/h)
v_{gl} =highest lane flow rate in a lane group (vph)
N = number of lanes in lane group
(Jae-Joon Lee, Nagui M. Rouphail, and Joseph E. Hummer 2005)

- The LUF can be obtained by the lane utilization factor by:

$$LUF = 1/(N * \text{Lane utilization factor}) \quad (3)$$

Where N = number of lanes in lane group

- So this study will test whether the models from NC university can fit the field data from Maryland.

LANE DROP TYPES

- 5 lane drop types have been studied

(1). Two through lanes with one lane drop

(2). Three through lanes with one lane drop

(3). Double left turn lanes with one lane drop

(4). Two through lanes form a single lane

(5). Double left turn lanes form a single lane

DATA COLLECTION

- 29 different sites in Maryland
- Over 130 hours traffic data
- AM peak, PM peak and off-peak hours in weekdays

Types	No. of locations	No. of data group (# of 15 min)
3 through →2	6	71
2 through → 1 (exclusive)	10	251
2 left →1	8	148
2 through “form a single lane”	3	37
2 left “form a single lane”	2	44

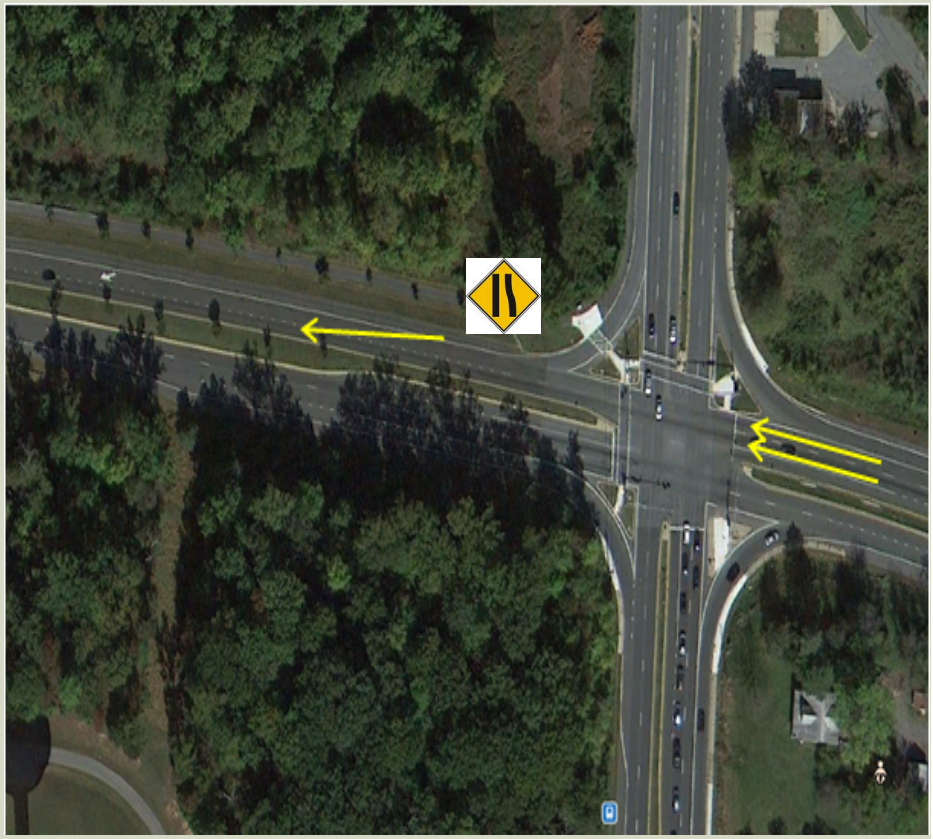
DATA ANALYSIS AND PROPOSED LUF

- Data analysis methods
  - 1. Boxplot
    - Examine the outliers;
  - 2.Statistical test
    - Compared with the normal LUF;
    - Compared with the estimation of models from NC university(if exist);
  - 3. Scatter plot
    - Observe patterns with possible factors;
  - 4. Categorize data based on the identified factors if necessary
  - 5. Provide suggested LUF

DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- Example:
- MD 650 @ Spenceville Road
- Right most lane merge into left lane after 850 feet from the intersection



DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 10 Locations
  - Spenceville Rd(MD 28) & Norbeck Rd (MD 650) @ Montgomery
    - North bound and west bound
  - Norback Rd (MD 28) & Georgia Ave (MD 97) @ Montgomery
  - Enterprise Rd (MD 193) & Annapolis Rd (MD 450) @ Prince George
  - Bel Air Rd (US 1) & Mountain Rd (MD 152) @ Harford
  - Greenbelt Rd (MD 193) & Lanham Severn Rd (MD 564) @ Prince George
    - East bound and west bound
  - Queens Chapel Rd (MD 500) & Hamilton St (MD 208) @ Prince George
  - Hamilton St (MD 208) & Ager Rd @ Prince George
  - Watkins Park Dr (MD 193) & Central Ave (MD 214)

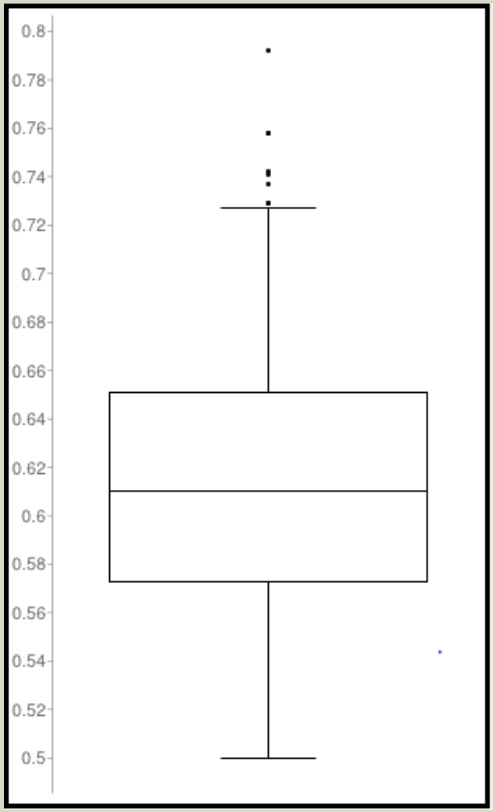
DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 1. Boxplot

Sample size	227
Median	0.610
Minimum	0.500
Maximum	0.792
First quartile	0.573
Third quartile	0.651
Outliers (8)	0.792 0.758 0.758 0.742 0.741 0.737 0.729 0.729

- LUFs are mainly located between 0.57 and 0.65.



DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 2. Compared with normal LUF
  - Descriptive statistics

Descriptive statistics	*LUF from field survey*
Mean	0.613
Standard Error	0.0035
Median	0.60
Standard Deviation	0.052
Sample Variance	0.0027
Range	0.23
Minimum	0.50
Maximum	0.73
Count	219
Confidence Level(95.0%)	0.0069

- Test the difference:
  - H0: The mean of LUF from field survey is the same as normal LUF for two lanes (0.55);
  - H1: The mean of LUF from field survey is not the same as normal LUF for two lanes (0.55);
- Result:
  - T-test: 17.075
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Normal LUF is not suitable for this type of lane drop intersection

DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 3. Test the model from NC University

$$LUF = 1/2 * 0.5435 * e^{\uparrow}(0.1782 ShortK + 0.6273 Avg{\downarrow}InvolK - 0.1047 N{\downarrow}sign)$$

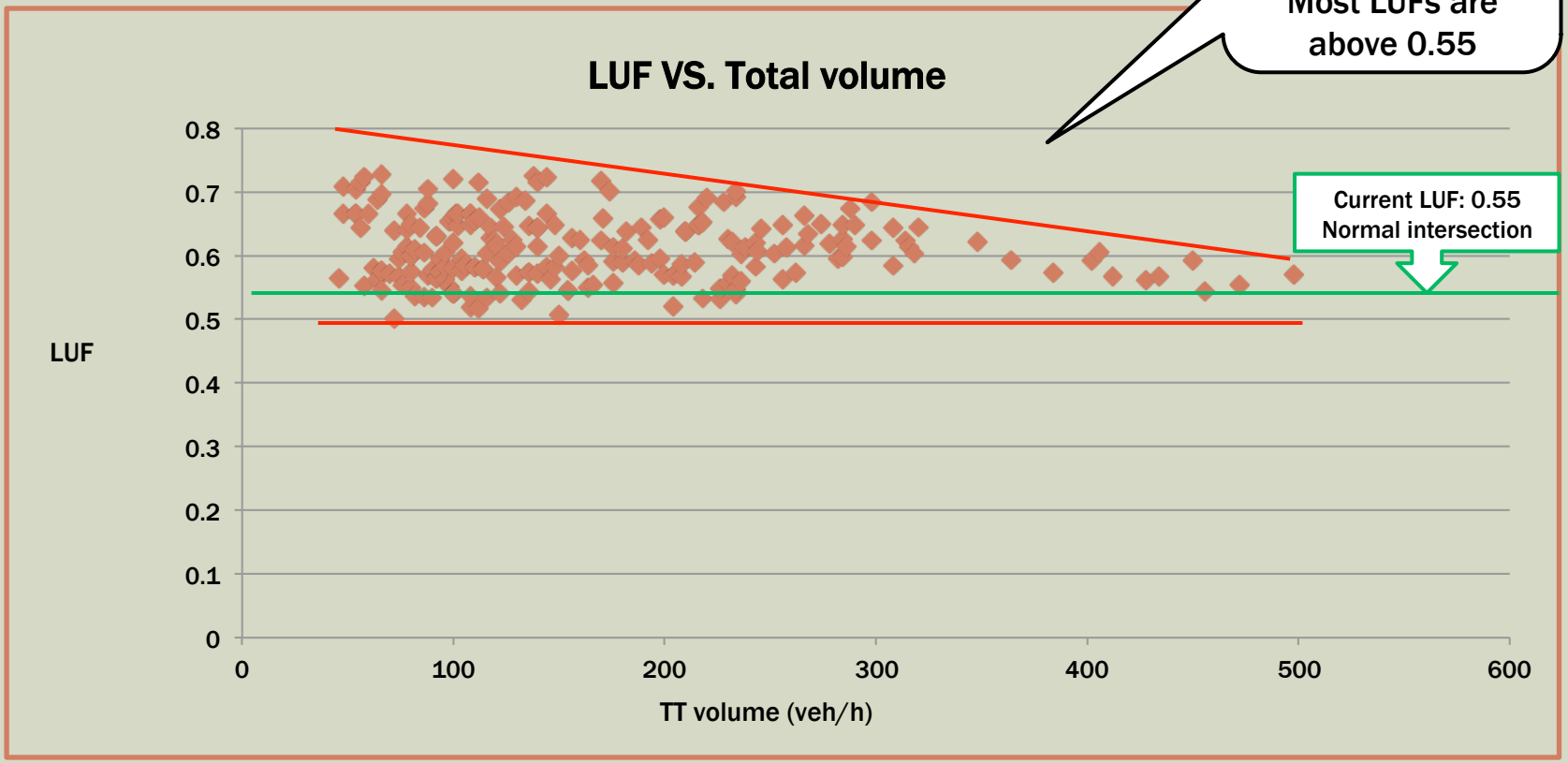
Descriptive statistics	*Lane use factor from field survey*	*Lane use factor from the model*
Mean	0.613	0.782
Standard Error	0.0035	0.004
Median	0.60	0.768
Standard Deviation	0.052	0.058
Sample Variance	0.0027	0.003
Range	0.23	0.237
Minimum	0.50	0.659
Maximum	0.73	0.897
Count	219	219
Confidence Level(95.0%)	0.0069	0.008

- Test the difference:
  - H0: The means of two data groups are the same;
  - H1: The means of two data groups are not the same;
- Result:
  - T-test: 32.296
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - The model is not suitable for the data from field survey

DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

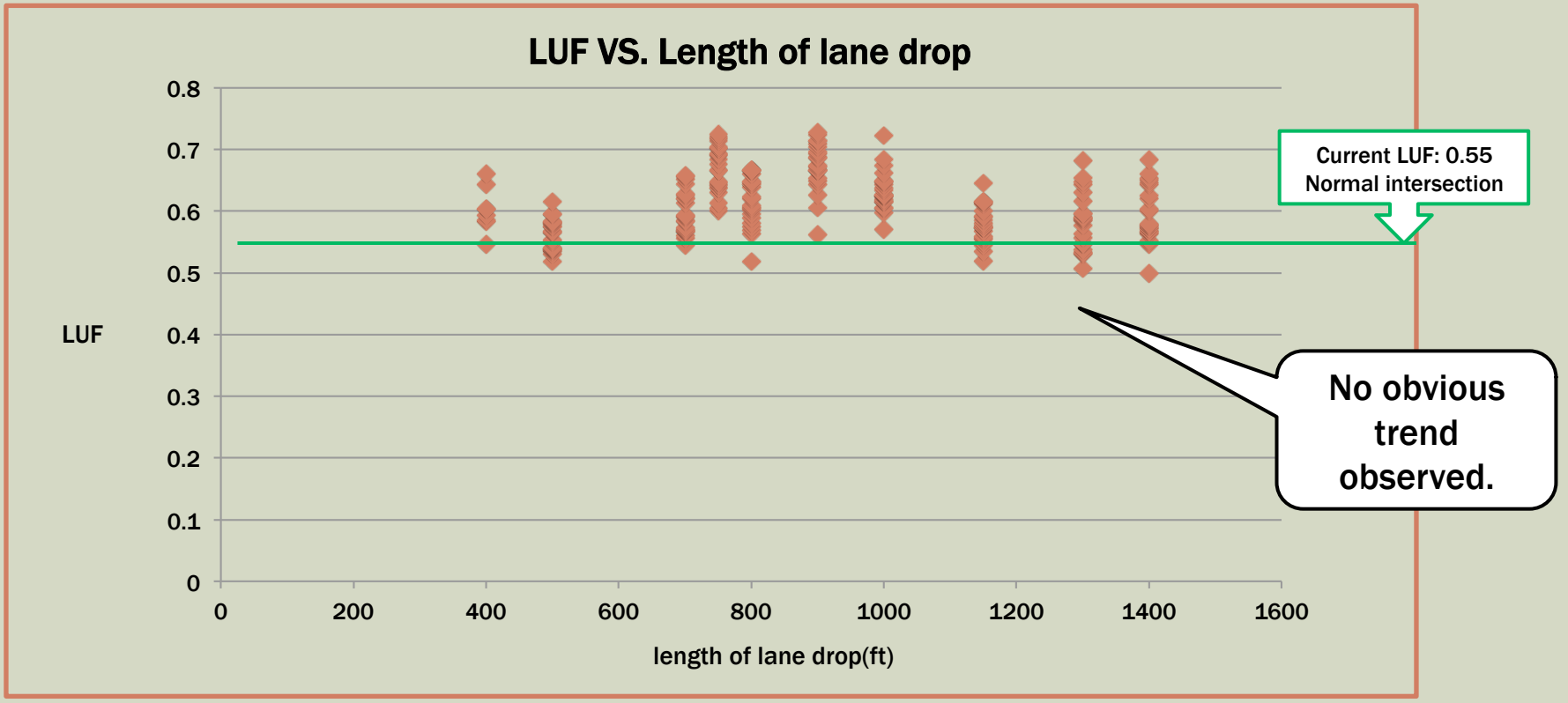
- 4. Scatter plot
  - (LUF vs. total volume):



DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

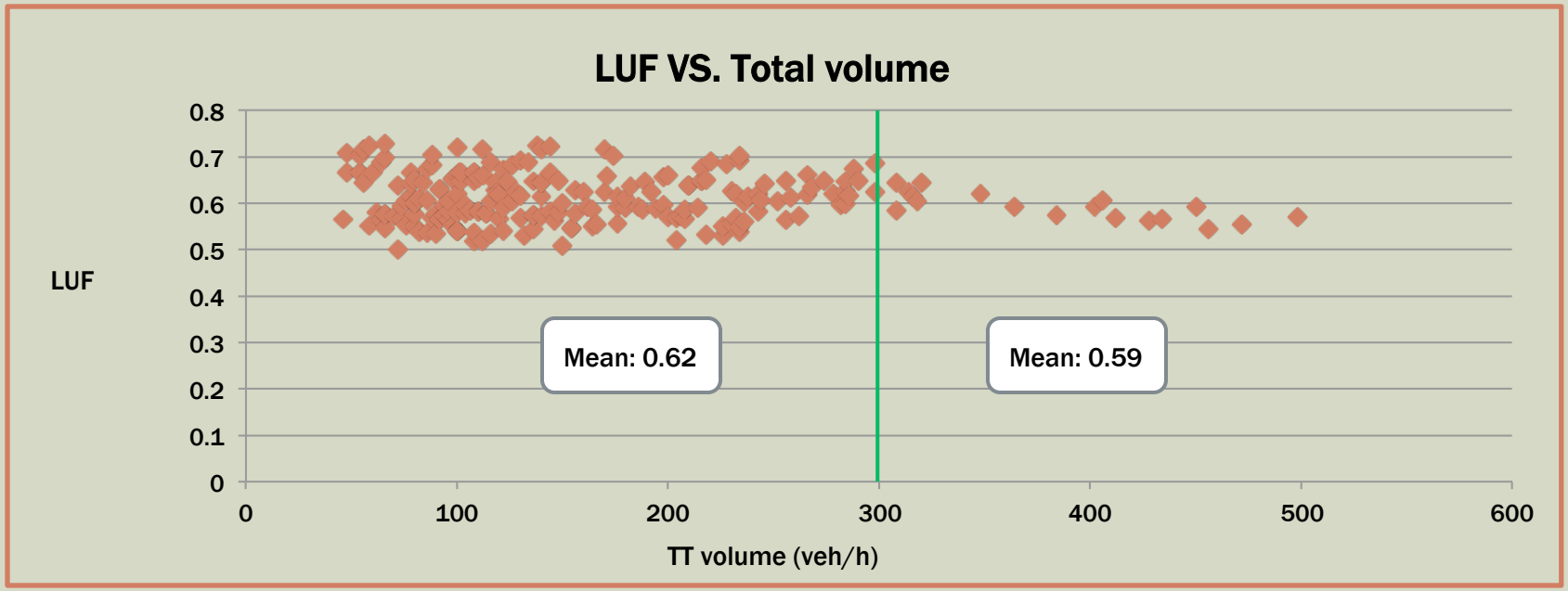
- 4. Scatter plot
  - (LUF vs. length of lane drop):



DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 5. Divide the data according to different volume range
  - Most LUF<0.65, when volume>600;
  - Ranges: less than 600vph; more than 600vph.



DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

- 5. Divide the data according to different volume range
  - Compare LUFs between ranges

Descriptive statistics	*Total volume: 0-600vph*	*Total volume: over 600vph*
Mean	**0.620**	**0.592**
Standard Error	0.004	0.007
Median	0.610	0.591
Standard Deviation	0.053	0.029
Sample Variance	0.003	0.001
Range	0.227	0.100
Minimum	0.500	0.544
Maximum	0.727	0.644
Count	201	18
Confidence Level(95.0%)	0.007	0.015
Confident interval for mean	(0.613,0.627)	(0.577,0.607)

- Test the difference:
  - H0: The means of LUFs in two volume ranges are the same;
  - H1: The means of LUFs in two volume ranges are not the same;
- Result:
  - T-test: 2.209
  - P value=0.028<0.05
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Based on approach volume, two LUFs are suggested

DATA ANALYSIS AND PROPOSED LUF

Type 1: 2 through – 1

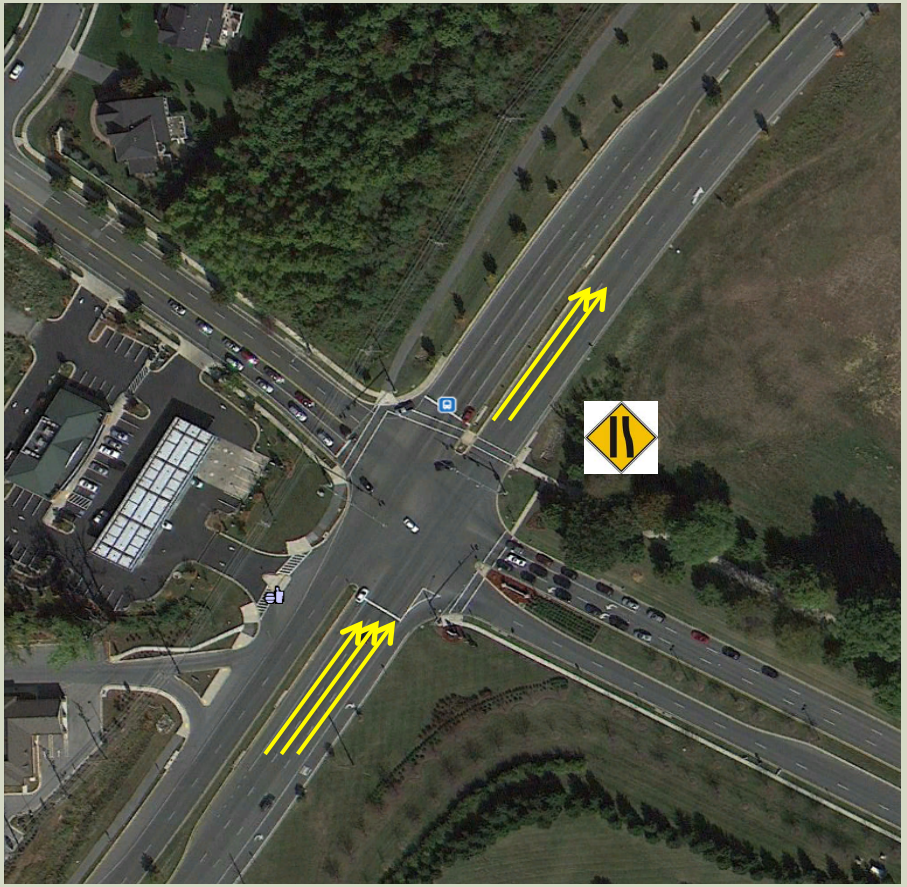
- 6. Conclusion
  - Suggested lane use factor for two lanes with one lane drop:

Total volume	Less than 600 vph	More than 600 vph
Lane use factor	0.62	0.59
Normal lane use factor for two lanes	0.55	

DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- Example:
- MD 450 @ Fairwood Parkway
- Right most lane merge to center lane after 900 ft from the intersection



DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- 6 Locations
  - Annapolis Rd (MD 450) & Fairwood Pkwy @ Prince George
  - Baltimore Ave (US 1) & South Dr @ Prince George
  - Campus Way S (MD 977H) & Largo Rd (MD 202) @ Prince George
  - Campus Way S & Central Ave (MD 214) @ Prince George
  - Iverson St (MD 458)& Branch Ave (MD 5) @ Prince George
  - Adelphi Rd & University Blvd (MD 193) @ Prince George

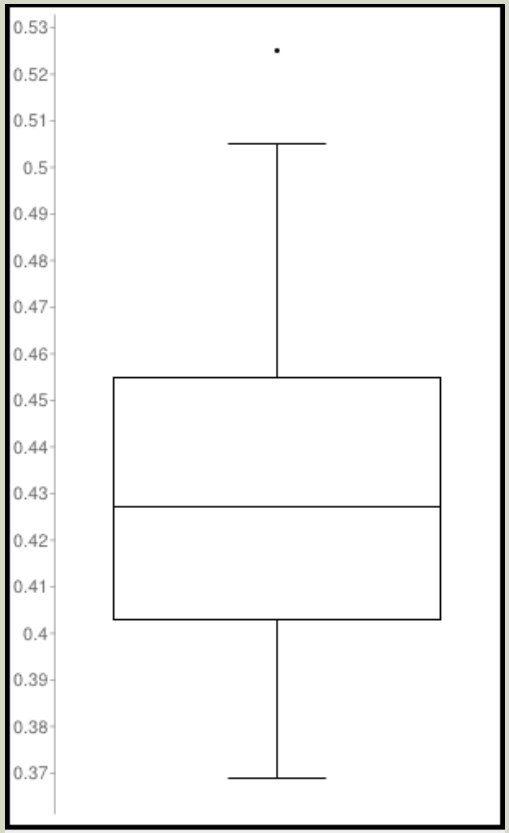
DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- 1. Boxplot

Sample size	71
Median	0.427
Minimum	0.369
Maximum	0.525
First quartile	0.403
Third quartile	0.455
Outliers(1)	0.525

- Most LUFs are located between 0.4 and o. 45



DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- 2. Compared with normal LUF
  - Descriptive statistics

Descriptive statistics	*LUF from field survey*
Mean	0.430
Standard Error	0.004
Median	0.427
Standard Deviation	0.031
Sample Variance	0.001
Range	0.136
Minimum	0.369
Maximum	0.505
Count	70
Confidence Level(95.0%)	0.008

- Test the difference:
  - H0: The mean of LUF from field survey is the same as normal LUF for three lanes (0.4);
  - H1: The mean of LUF from field survey is not the same as normal LUF for three lanes (0.4);
- Result:
  - T-test: 8.097
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Normal LUF is not suitable for this type of lane drop intersection

DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- 3. Test the model from NC University

$$LUF = 1/3 * (0.4033 + 0.2814 ShortK + 0.0576 * Avg\downarrow InvloK)$$

Where $ShortK$: Short lane length (ft)

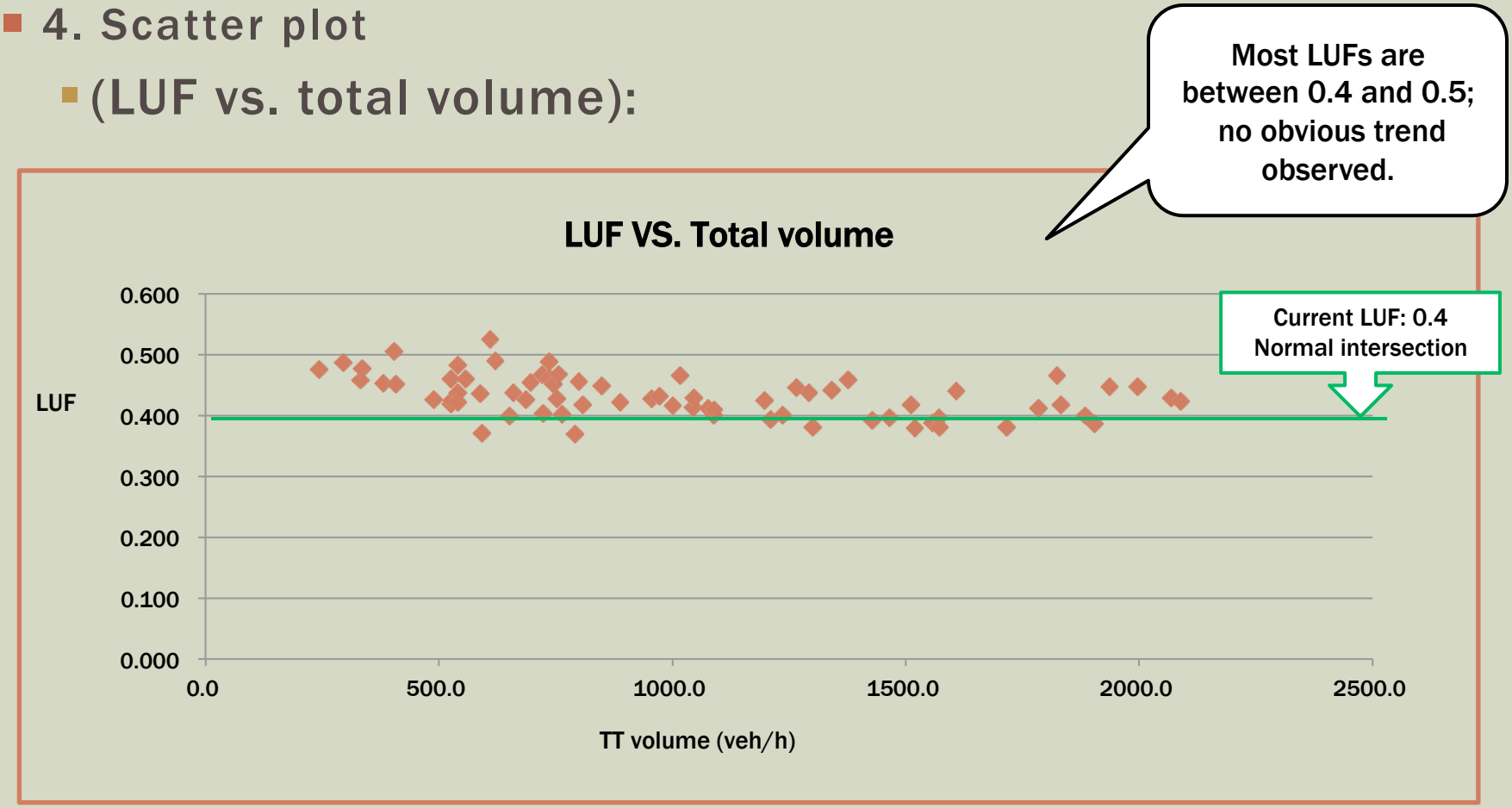
Descriptive statistics	Lane use factor from field survey	Lane use factor from the model
Mean	0.430	0.471
Standard Error	0.004	0.004
Median	0.427	0.470
Standard Deviation	0.031	0.033
Sample Variance	0.001	0.001
Range	0.136	0.118
Minimum	0.369	0.402
Maximum	0.505	0.520
Count	70	70
Confidence Level(95.0%)	0.008	0.008

- Test the difference:
  - H0: The means of two data groups are the same;
  - H1: The means of two data groups are not the same;
- Result:
  - T-test: 7.576
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - The model is not suitable for the LUF from field survey

DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

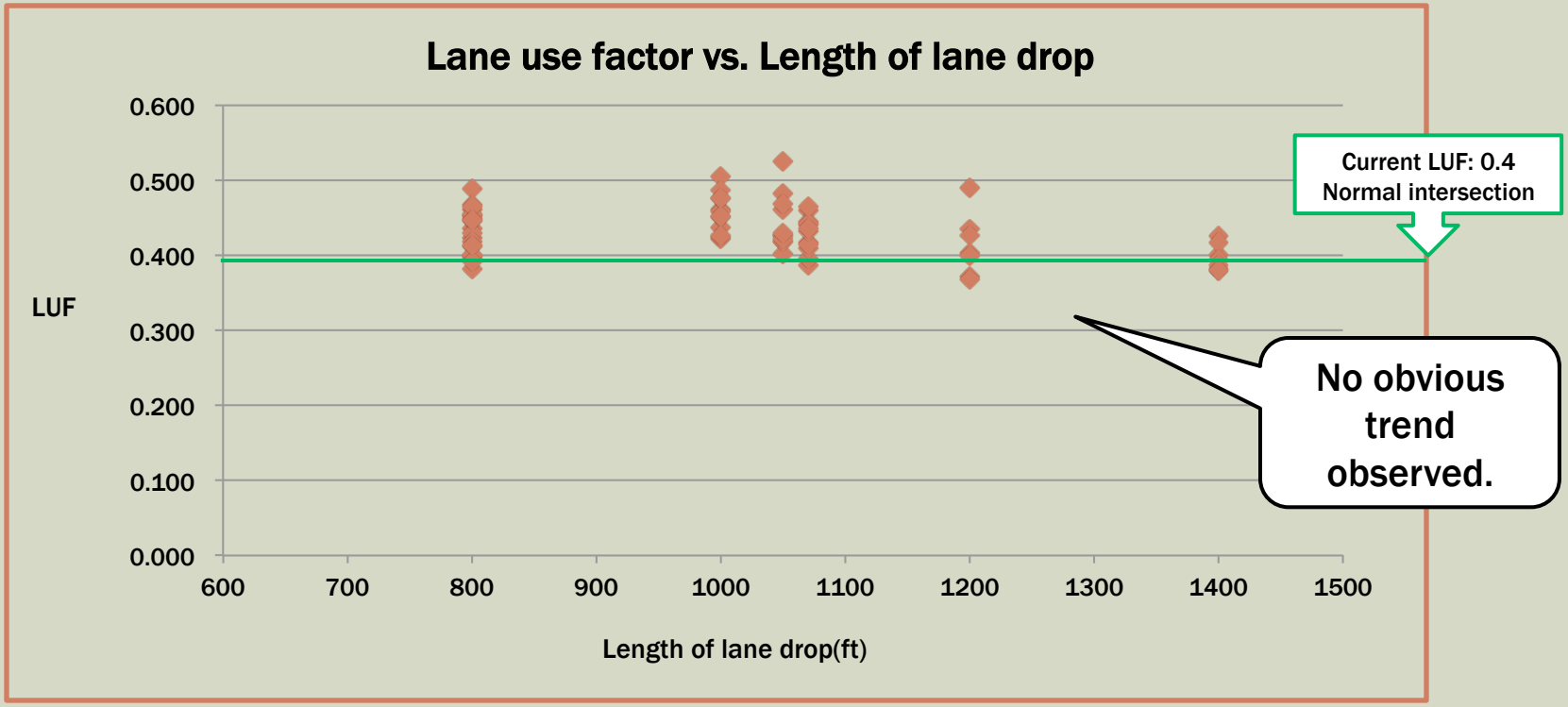
- 4. Scatter plot
  - (LUF vs. total volume):



DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- 4. Scatter plot
  - (LUF vs. length of lane drop):



DATA ANALYSIS AND PROPOSED LUF

Type 2: 3 through – 2

- Since the data in the scatter plots does not depend on factors (volume and distance to neighboring intersection), the data is not further categorized

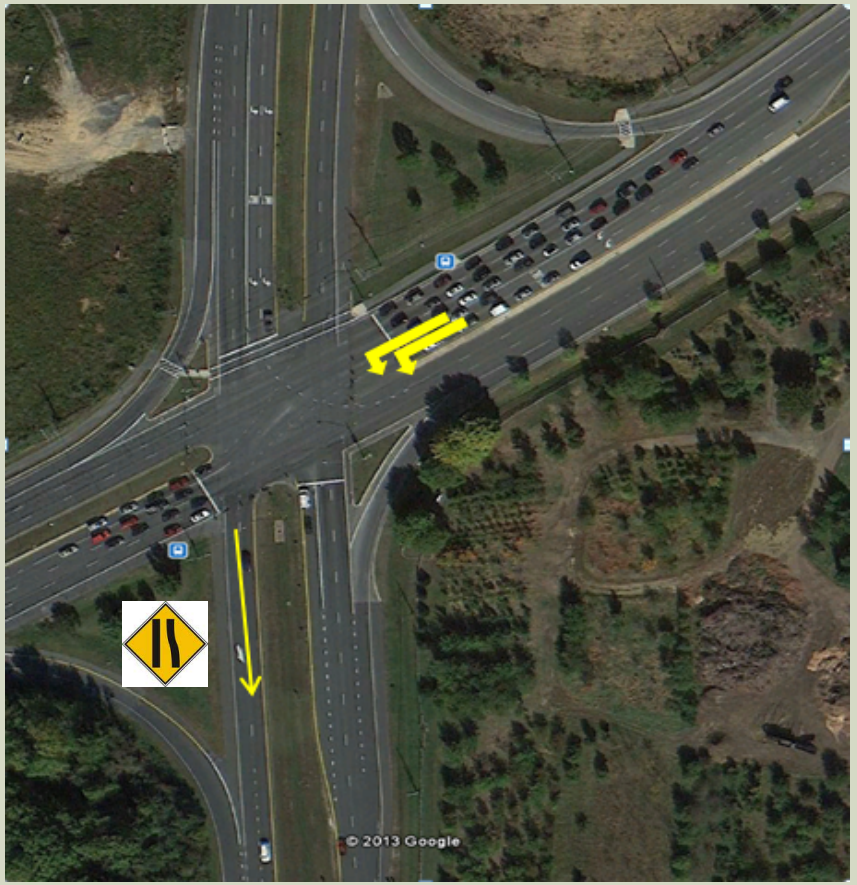
- 6. Conclusion
  - Suggested lane use factor for two lanes with one lane drop:

Suggested lane use factor	0.43
Normal lane use factor for three lanes	0.4

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- Example:
- Enterprise Road @ Annapolis Road
- Right lane merge to left lane after 640 feet from intersection



DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

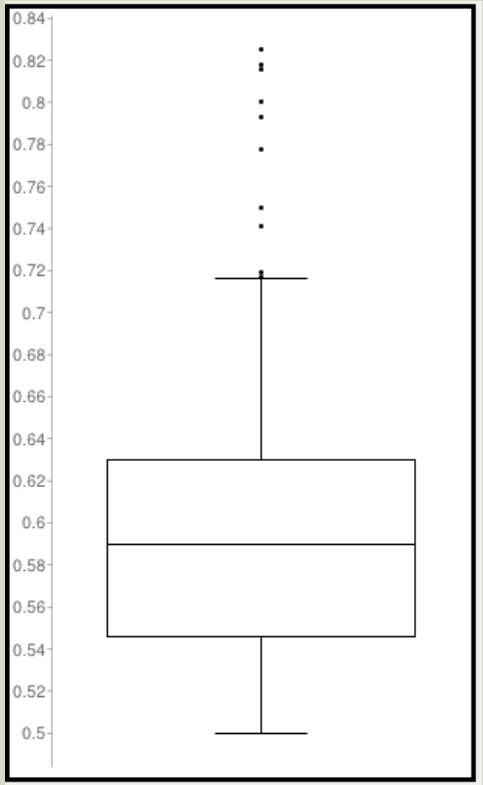
- 8 Locations
  - Paint Branch Dr & University Blvd (MD 193) @ Prince George
  - Baltimore Ave (US 1) & Contee Rd @ Prince George
  - Norback Rd (MD 28) & Georgia Ave (MD 97) @ Montgomery
  - Enterprise Rd (MD 193) & Annapolis Rd (MD 450) @ Prince George
  - Bel Air Rd (US 1) & Mountain Rd (MD 152) @ Harford
  - Greenbelt Rd (MD 193) & Lanham Severn Rd (MD 564) @ Prince George
    - North bound and south bound
  - Watkins Park Dr (MD 193) & Central Ave (MD 214)

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 1. Boxplot

Sample size	148
Median	0.590
Minimum	0.500
Maximum	0.825
First quartile	0.546
Third quartile	0.630
Outliers (10)	0.825 0.818 0.816 0.800 0.793 0.778 0.750 0.741 0.719 0.717



- Outliers happen when the volume is low (less than 200 vph), the LUF becomes fluctuated when the volume is low.

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 2. Compared with normal LUF
  - Descriptive statistics

Descriptive statistics	*LUF from field survey*
Mean	0.586
Standard Error	0.004
Median	0.585
Standard Deviation	0.052
Sample Variance	0.003
Range	0.234
Minimum	0.500
Maximum	0.716
Count	138
Confidence Level(95.0%)	0.009

- Test the difference:
  - H0: The mean of LUF from field survey is the same as normal LUF for double left turns(0.6);
  - H1: The mean of LUF from field survey is not the same as normal LUF for double left turns(0.6);
- Result:
  - T-test: 3.163
  - P value=0.0017<0.05
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Normal LUF is not suitable for this type of lane drop intersection

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 3. Test the model from NC University

$$LUF = 1/2 * (0.6161 + 0.8636 * Avg{\downarrow}InvloK)$$

Where $Avg{\downarrow}InvolK$: Average lane volume (vphpl) ÷ 1000;

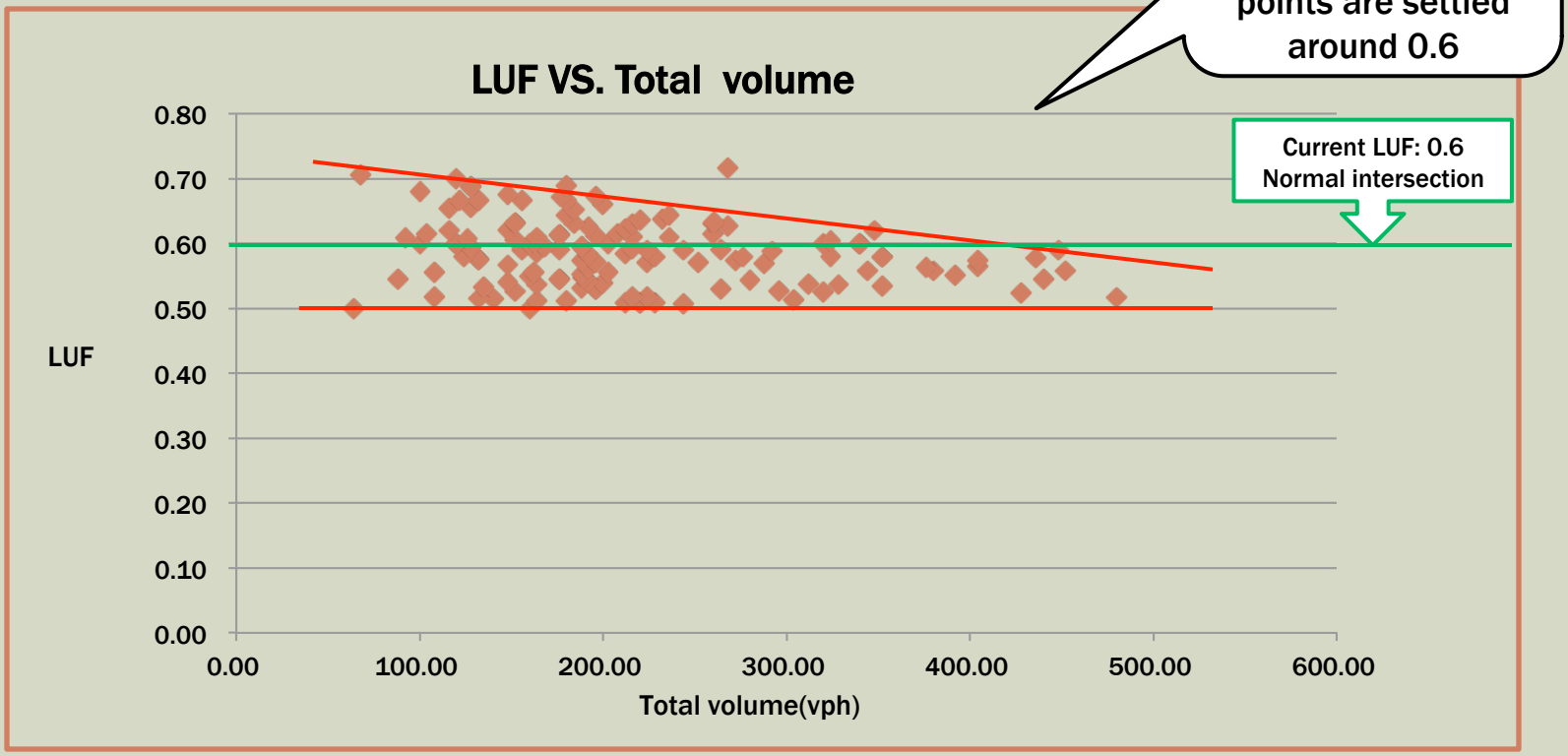
Descriptive statistics	Lane use factor from field survey	Lane use factor from the model
Mean	0.586	0.707
Standard Error	0.004	0.003
Median	0.585	0.714
Standard Deviation	0.052	0.037
Sample Variance	0.003	0.001
Range	0.234	0.169
Minimum	0.482	0.607
Maximum	0.716	0.777
Count	138	138
Confidence Level(95.0%)	0.009	0.006

- Test the difference:
  - H0: The means of two data groups are the same;
  - H1: The means of two data groups are not the same;
- Result:
  - T-test: 22.273
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - The model is not suitable for the LUF from field survey

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

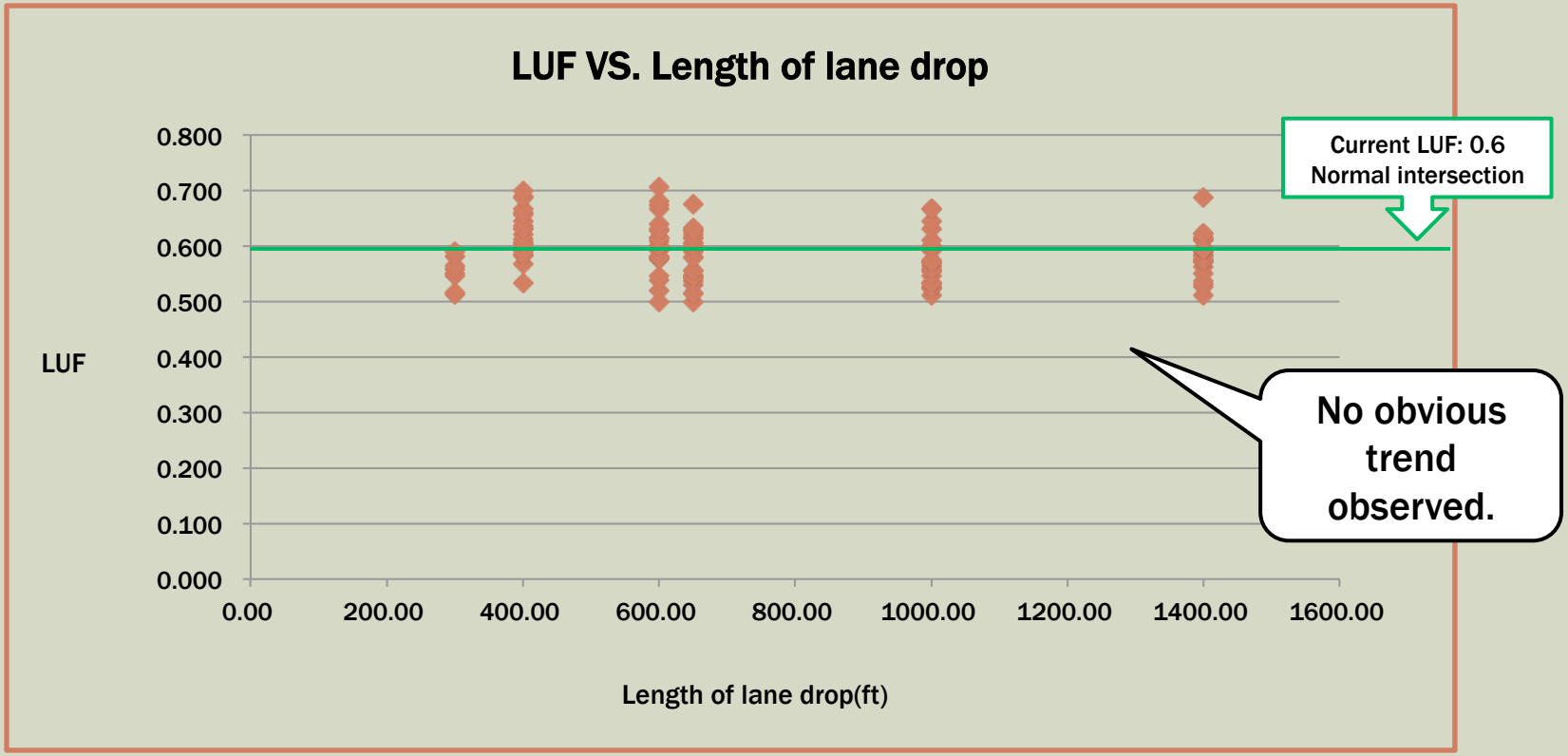
- 4. Scatter plot
  - (LUF vs. total volume):



DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

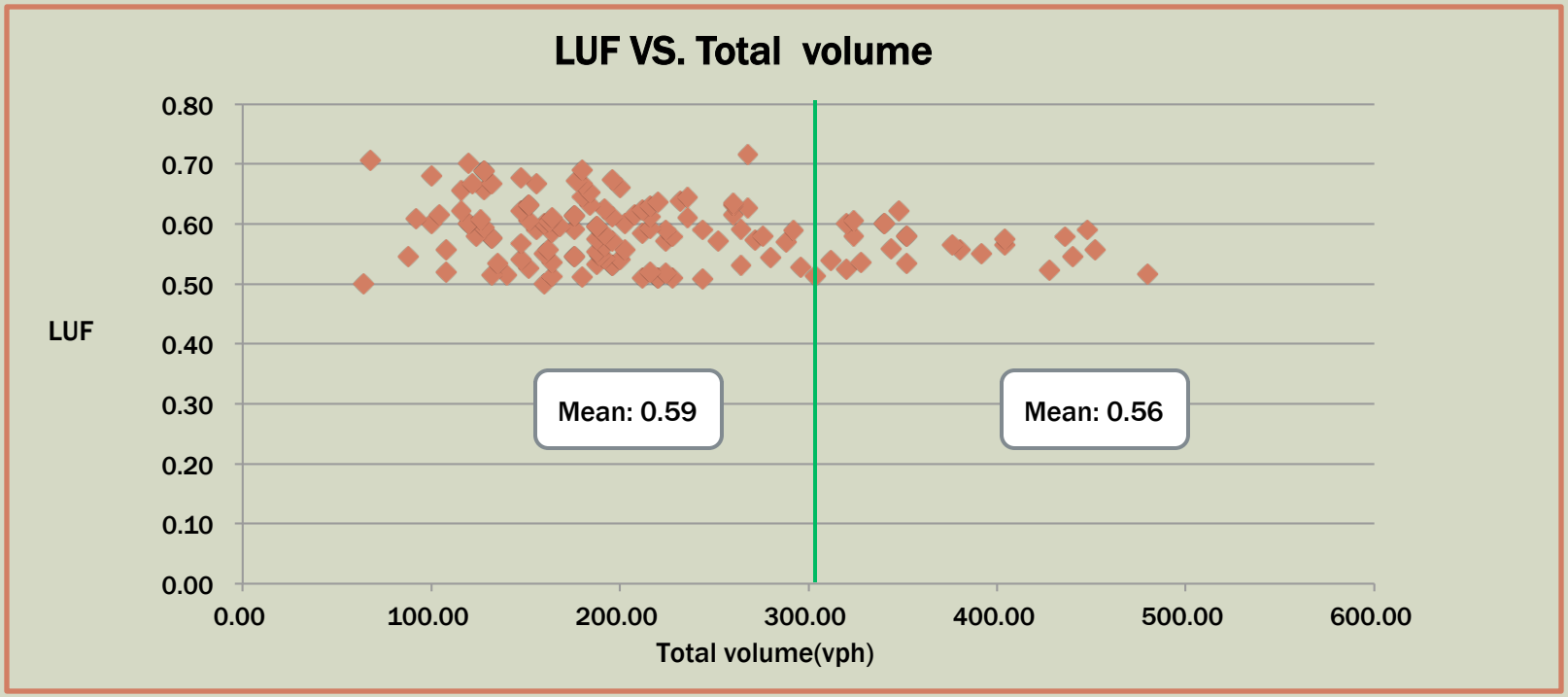
- 4. Scatter plot
  - (LUF vs. length of lane drop):



DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 5. Divide the data according to different volume range
  - Most LUF<0.60, when volume>300;
  - Ranges: less than 300vph; more than 300vph.



DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 5. Divide the data according to different volume range
  - Compare LUFs between ranges

Descriptive statistics	*Total volume: 0-600vph*	*Total volume: over 600vph*
Mean	0.591	0.564
Standard Error	0.005	0.006
Median	0.591	0.564
Standard Deviation	0.055	0.030
Sample Variance	0.003	0.001
Range	0.234	0.108
Minimum	0.500	0.513
Maximum	0.716	0.621
Count	113	25
Confidence Level(95.0%)	0.010	0.012
Confident interval for mean	(0.581,0.601)	(0.552,0.576)

- Test the difference:
  - H0: The means of two volume ranges are the same;
  - H1: The means of two volume ranges are not the same;
- Result:
  - T-test: 23.1
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Based on approach volume, two LUFs are suggested

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 5. Divide the data according to different volume range.
  - Since the LUF when volume is less than 300 vph is close to normal LUF, compare their difference.

Descriptive statistics	*LUF when volume < 300 vph*
Mean	0.591
Standard Error	0.005
Median	0.591
Standard Deviation	0.055
Sample Variance	0.003
Range	0.234
Minimum	0.500
Maximum	0.716
Count	113
Confidence Level(95.0%)	0.010

- Test the difference:
  - H0: The mean of LUF when volume is less than 300 vph is the same as normal LUF for double left turns(0.6);
  - H1: The mean of LUF when volume is less than 300 vph is not the same as normal LUF for double left turns(0.6);
- Result:
  - T-test: 1.74
  - P value=0.083>0.05
  - Not reject H0
- Conclusion:
  - The difference is not statistically significant
  - Normal LUF is suitable for this type of lane drop intersection when volume is less than 300 vph.

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- 6. Conclusion
  - Suggested lane use factor for two lanes with one lane drop:

Total volume	Less than 300 vph	More than 300 vph
Lane use factor	0.60	0.56
Normal lane use factor for two lanes	0.60	

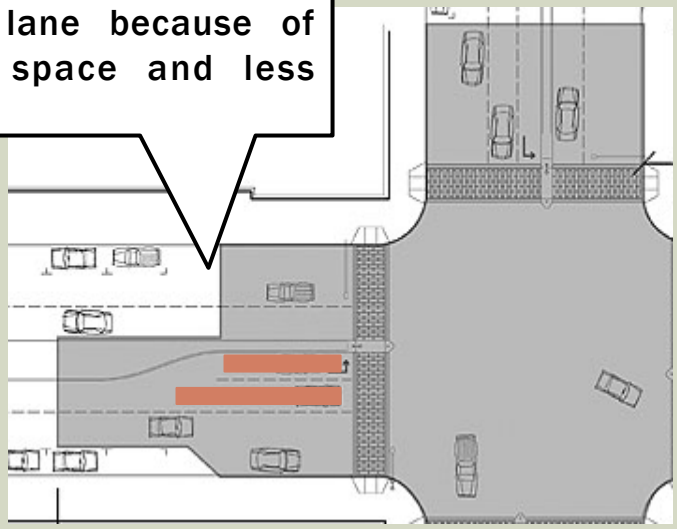
  - Different from other situations, the LUF is less than normal LUF.

DATA ANALYSIS AND PROPOSED LUF

Type 3: 2 left– 1

- Possible reasons:
  - Double left turns at normal intersection
    - Outer lane volume is higher;
  - Double left turns with lane drop
    - Inner lane volume is higher (this pattern is observed while collecting data);

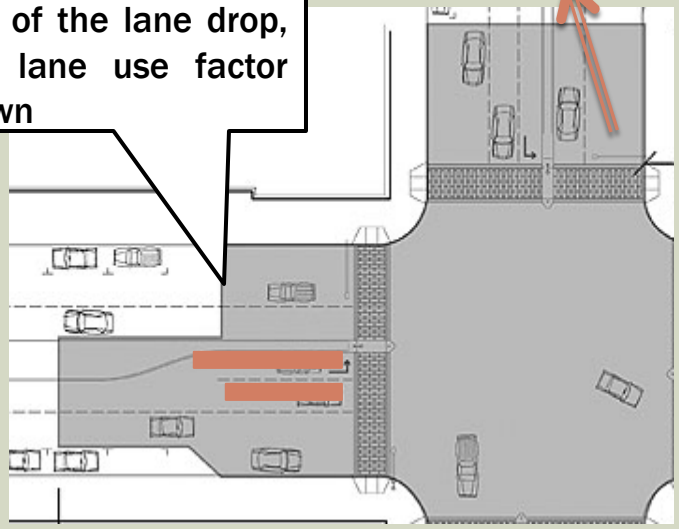
Traffic usually prefers outer lane rather than inner lane because of more space and less stress.



40% Traffic
60% Traffic

Traffic shift from from outer lane to inner lane because of the lane drop, but the lane use factor goes down

Lane drop

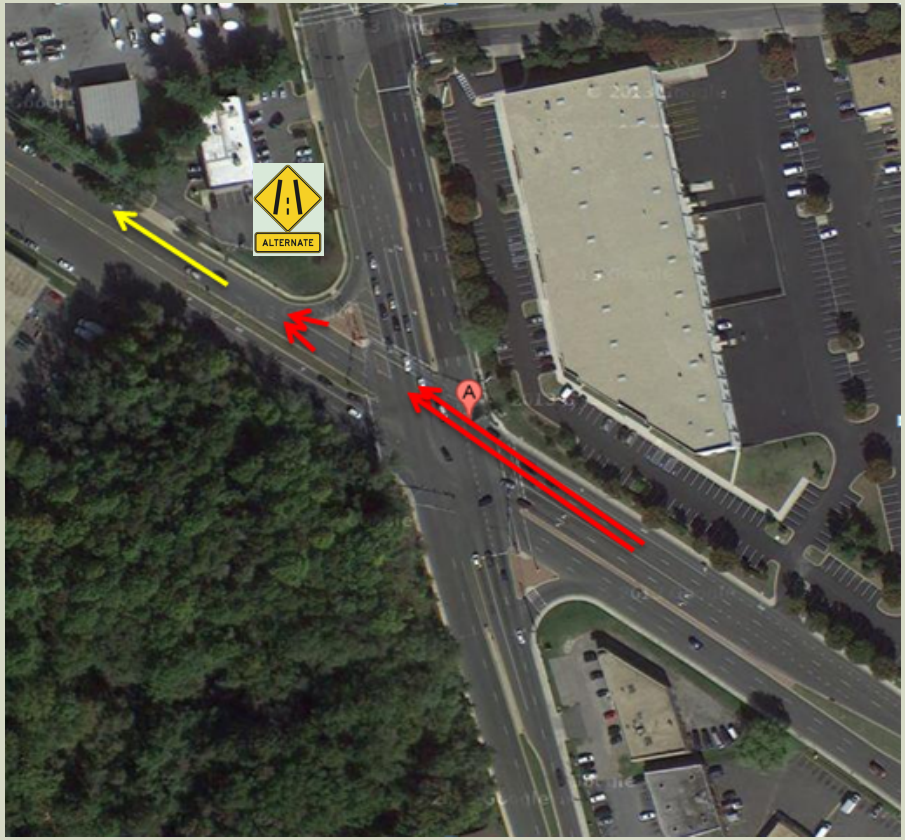


58% Traffic
42% Traffic

DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

- Example:
- MD 650 @ MD 410
- Form a single lane after 200 feet from the intersection



DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

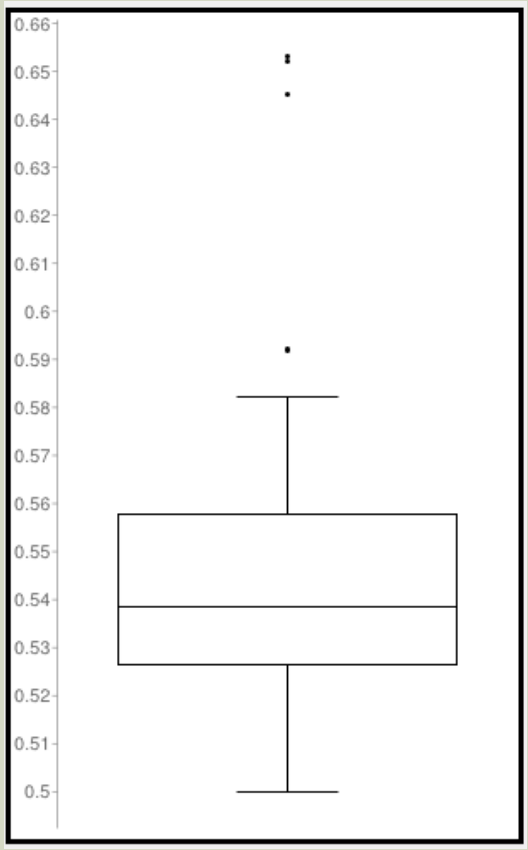
- 3 Locations
  - Ritchie Rd at Walker Mill Rd @ Prince George
  - Ethan Allen Ave (MD 410) & New Hampshire Ave (MD 650) @ Prince George
  - Spencerville Rd(MD 28) & Norbeck Rd (MD 650) @ Montgomery

DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

- 1. Boxplot

Sample size	45
Median	0.538
Minimum	0.500
Maximum	0.653
First quartile	0.526
Third quartile	0.558
Outliers (5)	0.653 0.652 0.645 0.592 0.592



- Most LUFs are located between 0.53 and o.56

DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

- 2. Compared with normal LUF
  - Descriptive statistics

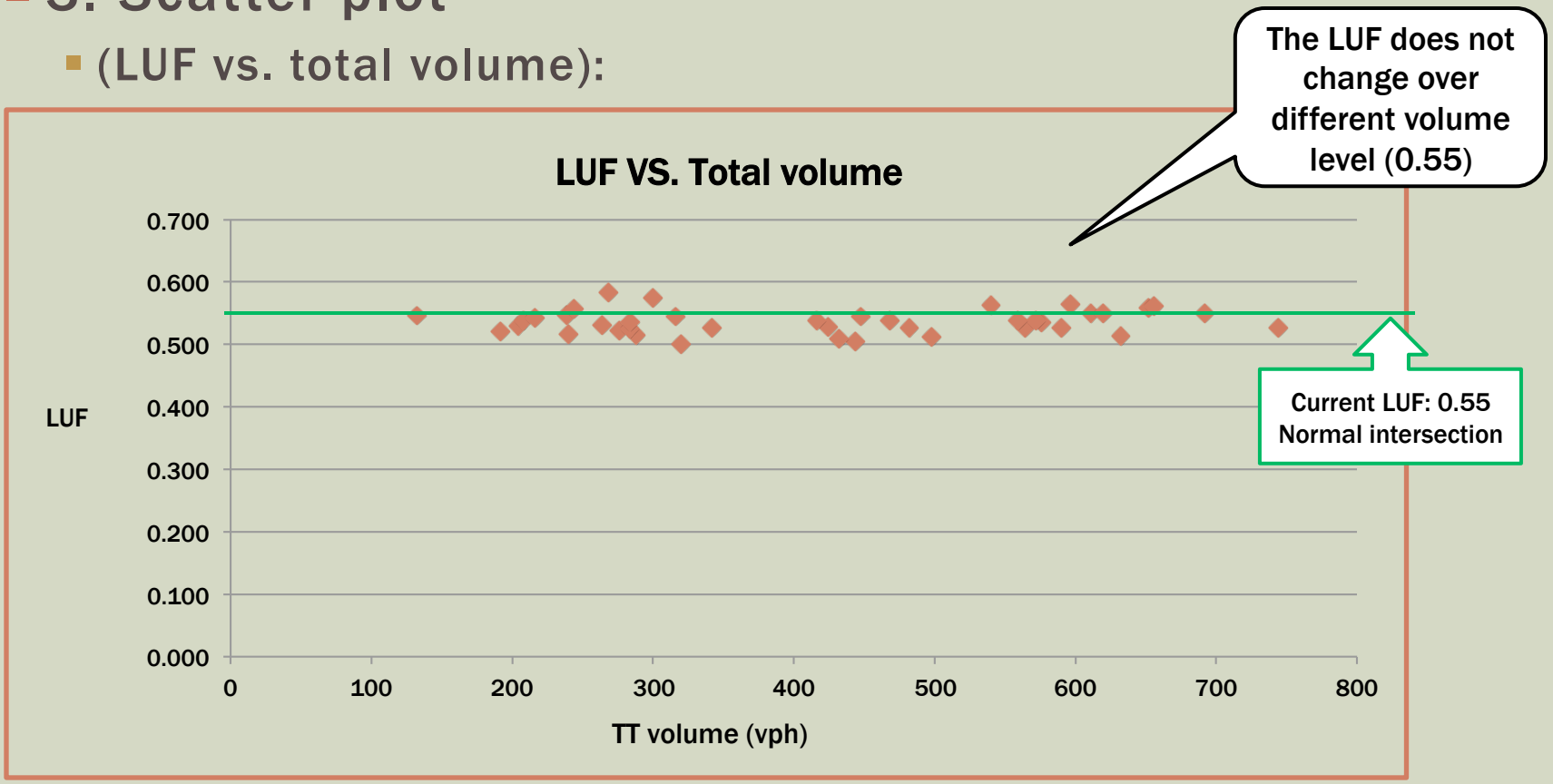
Descriptive statistics	*LUF from field survey*
Mean	0.543
Standard Error	0.003
Median	0.537
Standard Deviation	0.023
Sample Variance	0.0004
Range	0.082
Minimum	0.500
Maximum	0.582
Count	40
Confidence Level(95.0%)	0.01

- Test the difference:
  - H0: The mean of LUF from field survey is the same as normal LUF for two lanes(0.55);
  - H1: The mean of LUF from field survey is not the same as normal LUF for two lanes (0.55);
- Result:
  - T-test: 1.925
  - P value=0.058>0.05
  - Not reject H0
- Conclusion:
  - The difference is not statistically significant

DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

- 3. Scatter plot
  - (LUF vs. total volume):



DATA ANALYSIS AND PROPOSED LUF

Type 4: 2 through form a single lane

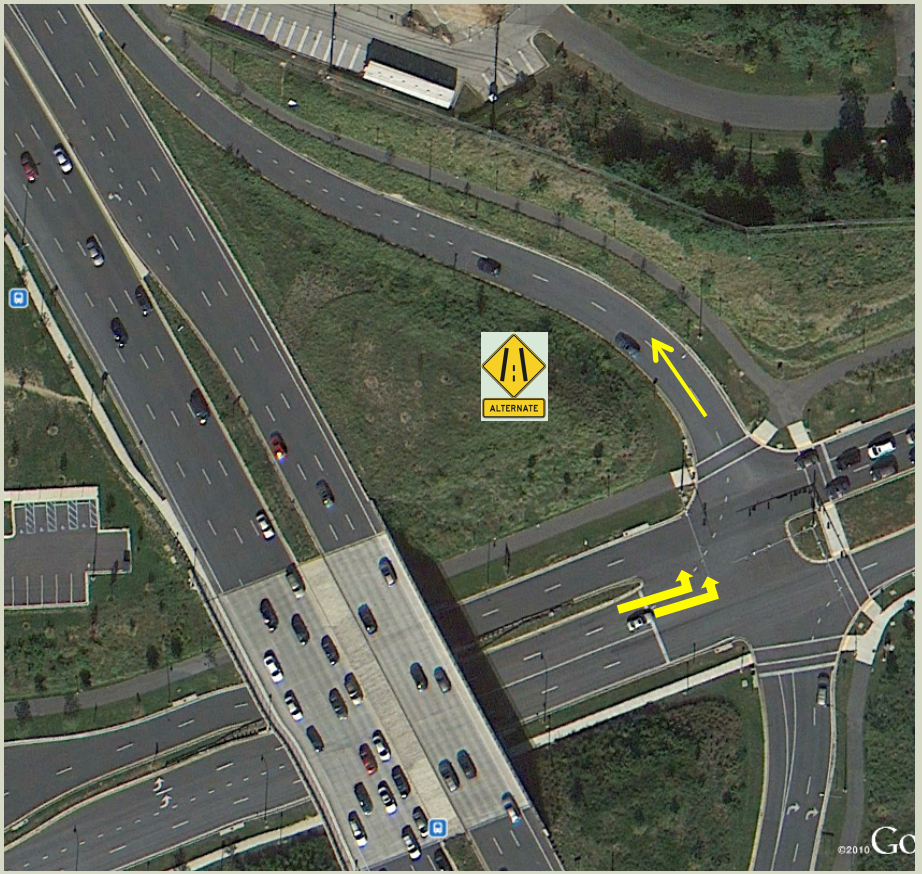
- 4. Conclusion
  - LUFs from field survey are stable;
  - The mean of the LUF from field survey is not statistically different from the normal LUF.
  - No changes on LUF for two lanes form a single lane:

Suggested lane use factor	0.55
Normal lane use factor for three lanes	0.55

DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

- Example:
- Montrose Parkway @ MD 355
- Alternate merging after 350 feet from the intersection



DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

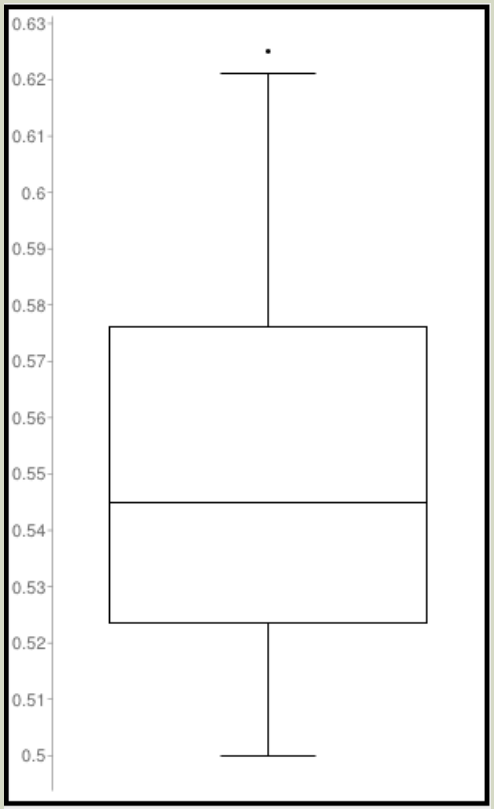
- 2 Locations
  - Martin Luther King Jr Hwy (MD 704) & John Hanson Hwy (US 50) @ Prince George
  - Rockville Pike (MD 355) & Montrose Pkwy @ Montgomery

DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

- 1. Boxplot

Sample size	44
Median	0.545
Minimum	0.500
Maximum	0.625
First quartile	0.524
Third quartile	0.576
Outliers (5)	0.625



- Most LUFs are located between 0.52 and o.58

DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

- 2. Compared with normal LUF
  - Descriptive statistics

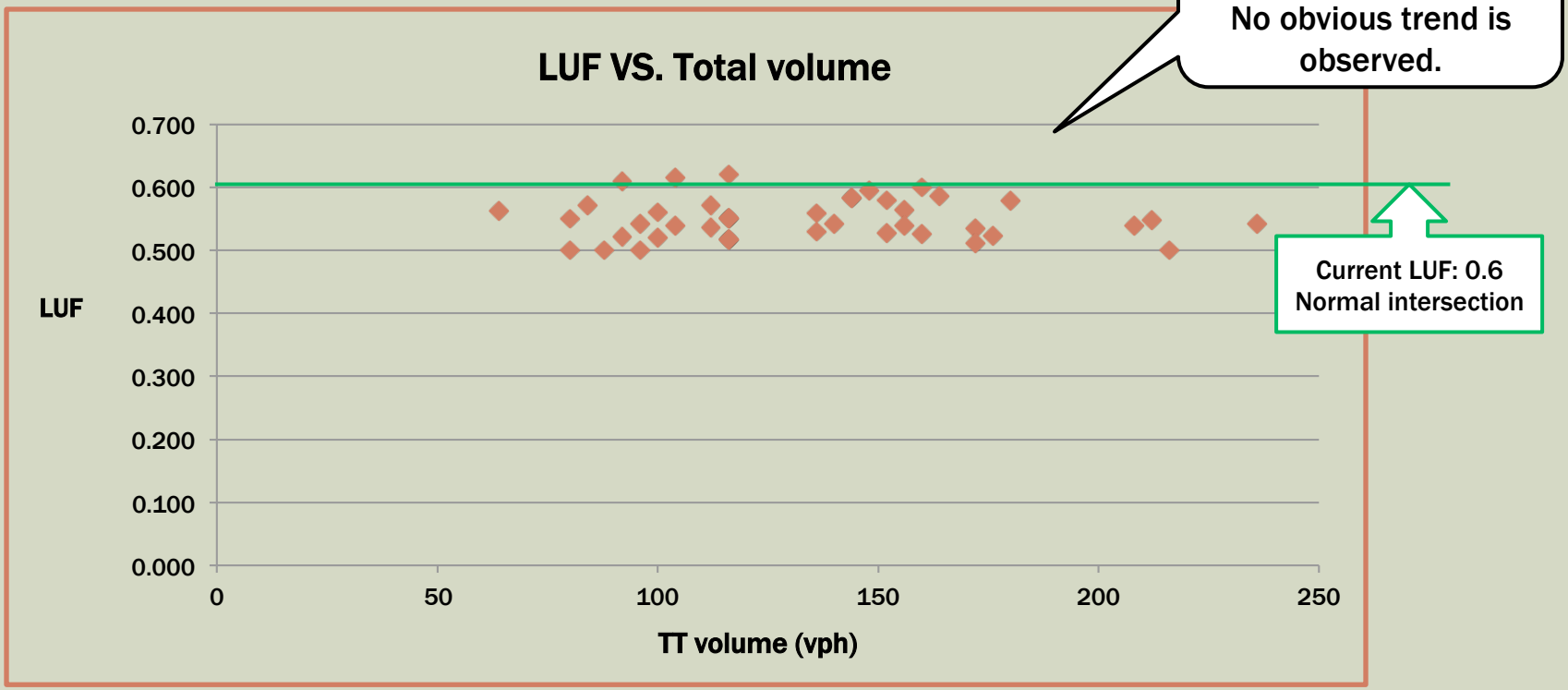
Descriptive statistics	*LUF from field survey*
Mean	0.549
Standard Error	0.0049
Median	0.543
Standard Deviation	0.032
Sample Variance	0.001
Range	0.121
Minimum	0.500
Maximum	0.621
Count	43
Confidence Level(95.0%)	0.010

- Test the difference:
  - H0: The mean of LUF from field survey is the same as normal LUF for two lanes(0.60);
  - H1: The mean of LUF from field survey is not the same as normal LUF for two lanes (0.60);
- Result:
  - T-test: 10.451
  - P value<0.0001
  - Reject H0
- Conclusion:
  - The difference is statistically significant
  - Normal LUF is not suitable for this type of lane drop intersection

DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

- 3. Scatter plot
  - (LUF vs. total volume):



DATA ANALYSIS AND PROPOSED LUF

Type 5: 2 left form a single lane

- 4. Conclusion
  - LUFs from field survey are stable;
  - The mean of the LUF from field survey is statistically different from the normal LUF.
  - Suggested lane use factor for two lanes form single lane:

Suggested lane use factor	0.55
Normal lane use factor for three lanes	0.6

SUMMARY

- Suggested lane use factor values with lane drop conditions:

Types	Minimum	Maximum	Suggested LUF value		Current LUF value
3 through →2	0.37	0.51	0.43		0.40
2 through → 1 (exclusive)	0.50	0.73	Total volume Less than 600 vph	0.62	0.55
	0.54	0.64	Total volume More than 600 vph	0.59	
2 left →1	0.50	0.72	Total volume Less than 300 vph	0.60	0.60
	0.51	0.62	Total volume More than 300 vph	0.56	
2 through “form a single lane”	0.50	0.58	0.55		0.55
2 left “form a single lane”	0.50	0.62	0.55		0.60

- Thank you very much!