Complete Street Analysis of a Road Diet: Orange Grove Boulevard, Pasadena, CA

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Abstract

As part of evaluating the feasibility of a road diet on Orange Grove Boulevard in Pasadena, California, Kittelson & Associates provided an assessment of the multimodal level of service (LOS) with and without a reduction of the number of vehicular travel lanes along the roadway to better accommodate bicycles and pedestrians.

This paper presents the multimodal level of service analysis of pedestrians, bicyclists, transit riders, and motorists performed to help answer the concerns that typically arise about road diets, including:

- Would the road diet negatively affect automobile delays and level of service (LOS)?
- How would transit operations be affected?
- How much better would travel be for bicyclists?
- To what extent would pedestrians benefit?

The analysis employed the procedures documented in the NCHRP Report 616: Multimodal Level of Service for Urban Streets, the precursor for the new multimodal analysis procedures in the recently published 2010 Highway Capacity Manual (HCM2010). The analysis of the Orange Grove Boulevard road diet project demonstrated quantitatively that automobile and transit LOS would remain the same, while bicycle and pedestrian LOS would improve.

The results of this multimodal evaluation of the Orange Grove Boulevard road diet would prove useful for transportation professionals because it shows how to analyze the LOS impacts of converting existing streets into more sustainable designs accommodating multiple modes.

ITE Western District Santa Barbara Meeting Paper 56:

This paper documents the results of a multimodal level of service analysis performed by Kittelson & Associates for a proposed road diet in Pasadena, California. A road diet is a reduction in the number of travel lanes along a roadway, often to accommodate bicycle lanes within the same roadway width, which can also lead to improved safety and reduced traffic volumes[i]. When implementing a road diet, many concerns related to traffic arise, including:

- Would the road diet negatively affect automobile delays and level of service (LOS)?
- How would transit operations be affected?
- How much better would travel be for bicyclists?
- To what extent would pedestrians benefit?

To help answer these types of questions, the level of service of pedestrians, bicyclists, transit riders and motorists were evaluated using the CompleteStreetsLOS™ multimodal analysis software[ii] and documented in a technical memorandum submitted to the City of Pasadena. The CompleteStreetsLOS™ software implements the analysis procedures of the Urban Street Facilities Chapter (16) of the 2010 Highway Capacity Manual (2010 HCM).

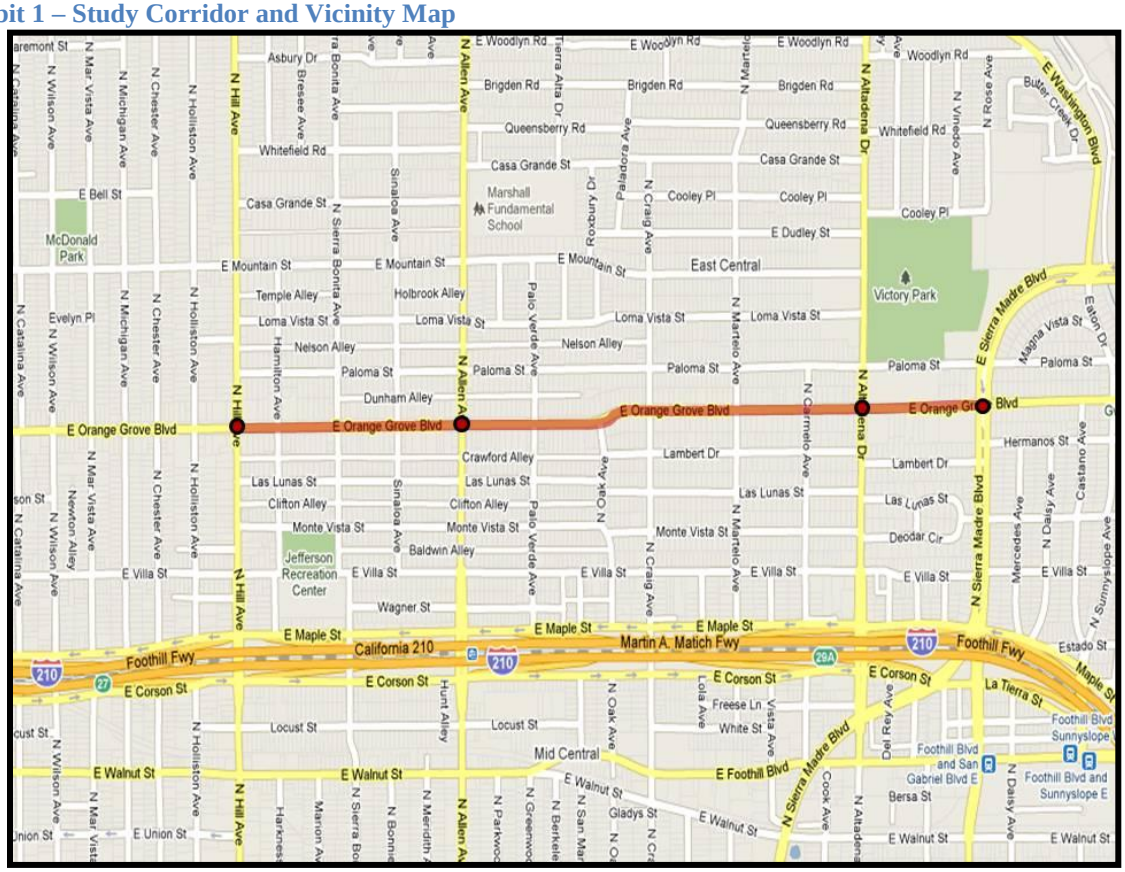
Project Description

Orange Grove Boulevard was analyzed within the limits of Hill Avenue on the west and Sierra Madre Boulevard on the east, as shown in Exhibit 1. Orange Grove Boulevard is fronted entirely by residential properties throughout the study area.

There are currently four travel lanes (two lanes in each direction), a center two-way left-turn lane, and two parking lanes for the vast majority of the study limits. Orange Grove Boulevard near Oak Avenue is the one exception to this typical right-of-way (ROW) where the alignment of Orange Grove Boulevard is curved.

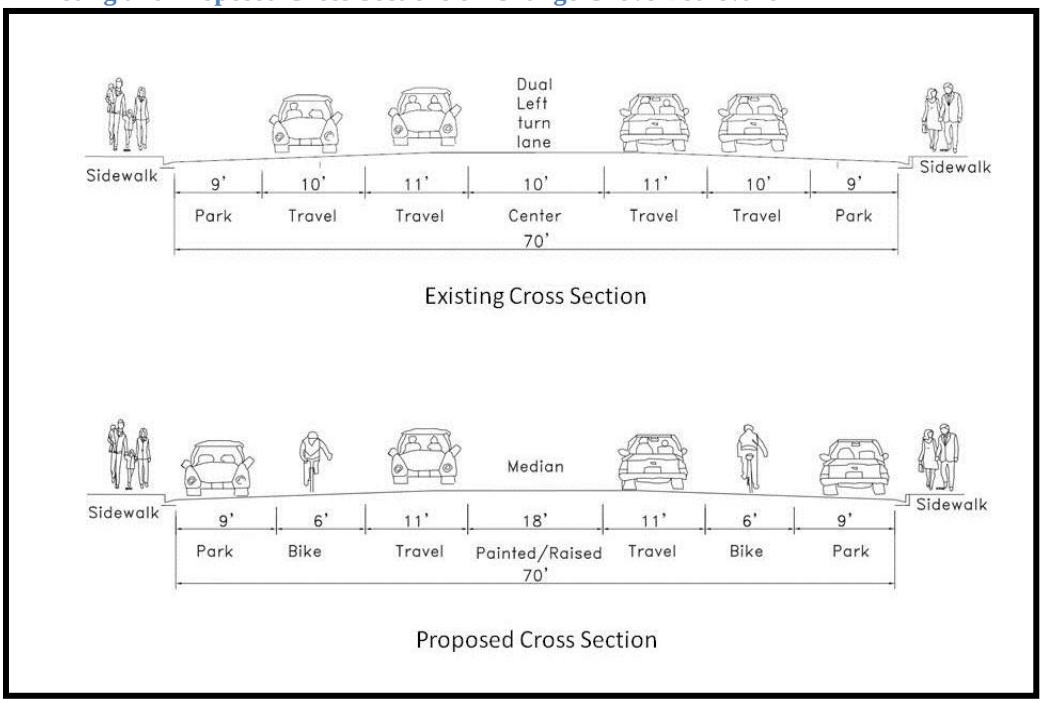
The existing and proposed cross sections of Orange Grove Boulevard are shown schematically in Exhibit 2 (the exact locations of the sidewalks, however, are further separated from the roadway by a wide landscaped buffer area). The proposed cross section adds bike lanes, widens the median, and reduces the travel lanes to one-lane in each direction.

Exhibit 1 – Study Corridor and Vicinity Map



Source: Kittelson & Associates

Exhibit 2 - Existing and Proposed Cross Sections on Orange Grove Boulevard



Source: City of Pasadena

1. Summary of Key Issues and Results

This section presents a brief summary of the findings, which are discussed in further detail in later text.

Issues Related to Current Cross Section:

- No facilities for bicyclists
- Light traffic volumes for a large right-of-way (ROW) roadway
- Higher speeds and wider crossing width which detract from a neighborhood feel

Analysis Results of Proposed Cross Section (with Road Diet):

- Auto and transit LOS grades would remain the same at LOS B and LOS C respectively in both the AM and PM peaks
- Bicycle LOS grade would be improved from LOS C to LOS B in both the AM and PM peaks
- Pedestrian LOS grade would remain the same at LOS B in the AM Peak, but would improve from LOS C to LOS B in the PM peak

Orange Grove Boulevard, with its light traffic volumes and wide roadway width, was an obvious choice for performing a road diet. The CompleteStreetsLOS analysis easily confirmed this choice using quantitative methods that are useful for demonstrating its effectiveness to various stakeholders. Rather than just assuming that the road diet would be beneficial to bicyclists and pedestrians, the CompleteStreetsLOS analysis quantifies that to be the case. Rather than qualitatively estimating that the automobile and transit LOS wouldn't be affected too much, the CompleteStreetsLOS analysis provides a detailed technical assessment to stake that claim. The Orange Grove Boulevard analysis also suggests that similar roadways with similar attributes and traffic levels would operate in a likewise manner with the implementation of a road diet.

2. Data Collection

A field visit was performed on November 18, 2010 to observe the local conditions and verify the validity of satellite imagery and camera car surveys of Orange Grove Boulevard. Data dealing with traffic counts and signal information were obtained from the City of Pasadena. Additionally, transit information was obtained from transit agency websites.

Field Observations and Satellite Imagery

Field observations and satellite imagery were used to determine most of the information required to perform the multimodal LOS analysis. This information included:

- Crosswalk Widths
- Segment Lengths
- Number of Lanes
- Speed Limits
- Number of Large Barrier Objects
- Cross Sectional Widths
- Number of left/right access points along the segment

- Number of Bus Stops on Each Segment
- Presence of Right Turn Islands
- Median Type
- Bus Stop Amenities
- Pavement Condition
- Presence of Left Turn Pockets

Spot check measurements of lengths and widths were taken in the field and then compared with values measured using Google Earth[iii] for the same location. These spot checks all yielded the same values, allowing Kittelson & Associates to verify the accuracy of the satellite collected measurements throughout the study area.

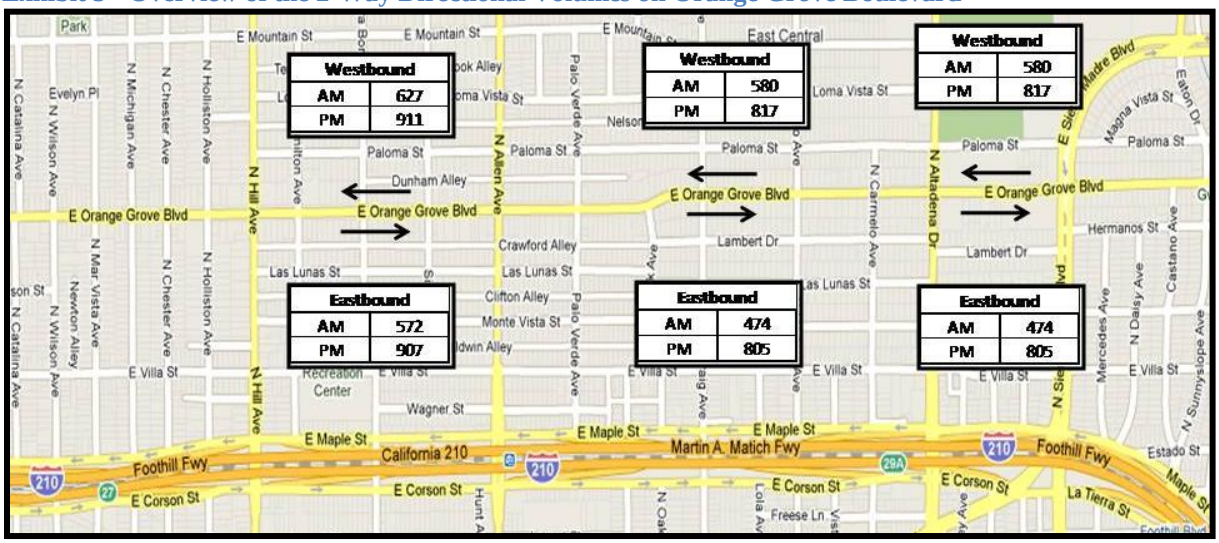
Traffic and Signal Information

City staff provided traffic counts at two locations (between Hill Avenue and Allen Avenue, and between Allen Avenue and Sierra Madre Boulevard) and signal information for the four signals along the analysis corridor (Orange Grove Boulevard at Hill Avenue, at Allen Avenue, at Altadena Drive, and at Sierra Madre Boulevard). This information was used to get the following:

- g/C Ratio for Through Movement
- Walk Phase Timing
- PHF
- "K" Factor
- Cycle Length
- Whether Signal System is Coordinated
- Peak Hour 2-way volumes
- Directional Volume Distribution

Exhibit 3 shows the directional volumes in the AM and PM that were extracted from tube counts sent by City staff. The segments of Allen Avenue to Altadena Drive and Altadena Drive to Sierra Madre Boulevard only had one count available covering both segments. It was therefore assumed that each of these segments would have roughly the same peak hour two-way volumes.

Exhibit 3 - Overview of the 2-Way Directional Volumes on Orange Grove Boulevard



Source: Kittelson & Associates

Transit Information
Transit information was gathered from the internet by visiting the websites of the two transit agencies serving this corridor (LA's Metro and the City of Pasadena's ARTS system). This information included which routes served the corridor, frequency, and schedule speed of each route.

Other Information
Additional information required for the multimodal analysis was gathered using standard defaults and engineering judgment (since the scope of this study did not include a full data collection effort). The data acquired using these methods were:

- On-street parking: the percent of the total segment length occupied by on-street parking was estimated at 10%, based on field observation
- Pedestrian volumes: set at 50 pedestrians per hour
- Left/right turn percentages at each downstream intersection: assumed to be 20% of traffic midblock
- Adjusted saturation flow rates: taken from base default values recommended in HCM 2000 depending on the movements allowed from the through lanes
- The bus load factor: assumed to be 80% for all transit routes
- Transit on-time performance: assumed to be 80%
- Average passenger trip length: used the national average of 3.7 miles

3. Results and Analysis

To understand the results of this analysis, it is first necessary to review the level of service thresholds for each letter grade set forth by the multimodal methodology[iv]. These threshold values are shown in Exhibit 4. As this exhibit shows, higher scores mean a worse LOS grade. Therefore, improvements in LOS will display as negative differences while worsening LOS will show a positive difference between the existing and road diet scenarios.

Exhibit 4 - Threshold Values for Each LOS Letter Grade

LOS Model Outputs	LOS Letter Grade
Model <=2.00	A
2.00 < Model <= 2.75	B
2.75 < Model <= 3.50	C
3.50 < Model <= 4.25	D
4.25 < Model <= 5.00	E
Model > 5.00	F

Source: NCHRP Report 616, Transportation Research Board

Exhibit 5 shows the results for the AM peak period for each segment and direction. Given the low volume on this segment and wide cross section, the LOS scores for the four lane facility are generally in the LOS B to LOS C range. The one exception is transit service between Hill Avenue and Allen Avenue which operates at a LOS of E due to the infrequent bus service along this segment at 1.25 buses per hour. The other segments are generally operating at 3 busses per hour in the peak hour.

Exhibit 5 - LOS Scores and Letter Grades for Each Segment during the AM Peak

Orange Grove Boulevard - Combined AM						
	Segment	**Mode**	**Existing Score (LOS)**	**Road Diet Score (LOS)**	**Difference**	**% Change**
EB	Hill Ave to Allen Ave	Auto	2.34 (B)	2.39 (B)	0.05	2.1%
		Transit	4.46 (E)	4.47 (E)	0.01	0.2%
		Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
		Pedestrian	2.45 (B)	2.55 (B)	0.10	4.1%
	Allen Ave to Altadena Dr	Auto	2.25 (B)	2.26 (B)	0.01	0.4%
		Transit	2.60 (B)	2.57 (B)	-0.03	-1.2%
		Bicycle	3.40 (C)	2.70 (B)	-0.70	-20.6%
		Pedestrian	2.43 (B)	2.26 (B)	-0.17	-7.0%
	Altadena Dr to Sierra Madre Blvd	Auto	2.52 (B)	2.60 (B)	0.08	3.2%
		Transit	2.61 (B)	2.59 (B)	-0.02	-0.8%
		Bicycle	3.23 (C)	2.65 (B)	-0.58	-18.0%
		Pedestrian	2.52 (B)	2.39 (B)	-0.13	-5.2%
WB	Sierra Madre Blvd to Altadena Dr	Auto	2.50 (B)	2.56 (B)	0.06	2.4%
		Transit	1.87 (A)	1.85 (A)	-0.02	-1.1%
		Bicycle	2.92 (C)	2.47 (B)	-0.45	-15.4%
		Pedestrian	2.50 (B)	2.37 (B)	-0.13	-5.2%
	Altadena Dr to Allen Ave	Auto	2.25 (B)	2.27 (B)	0.02	0.9%
		Transit	2.60 (B)	2.57 (B)	-0.03	-1.2%
		Bicycle	3.38 (C)	2.67 (B)	-0.71	-21.0%
		Pedestrian	2.44 (B)	2.28 (B)	-0.16	-6.6%
	Allen Ave to Hill Ave	Auto	2.34 (B)	2.51 (B)	0.17	7.3%
		Transit	4.45 (E)	4.47 (E)	0.02	0.4%
		Bicycle	3.39 (C)	2.72 (B)	-0.67	-19.8%
		Pedestrian	2.41 (B)	2.52 (B)	0.11	4.6%

Source: Kittelson & Associates

Removing two through lanes to create bike lanes and a wider median had a significant impact on the bicycle LOS score while only slightly affecting the auto score during the AM peak as shown in Exhibit 5. Performing a weighted average based on segment length shows that auto score worsened by an average of 0.03 points in the eastbound direction and 0.07 points in the

westbound direction or a 1.3% and 3.0% change respectively. The rest of the LOS scores showed improvement overall, with transit improving by about 0.3%, pedestrian improving by about 3.1%, and bicycle improving by about 20.1% for the eastbound and westbound directions. The weighted averages for each direction are shown in Exhibit 6.

The transit score shows a small impact due to two conflicting influences on transit service. Road narrowing slows auto traffic which affects the bus speed because it uses the same facility. This negative affect is then counteracted by the improvement to pedestrian score which is tied into the transit LOS score. These counteracting effects are why the transit service improves on some segments (Allen Avenue to Altadena Drive) while worsening in others (Hill Avenue to Allen Avenue).

The pedestrian LOS also has two counteracting attributes that contributed to some segments having an improvement in LOS score while others worsened. Reducing the number of lanes concentrates more of the vehicle volume into the lane closest to the pedestrian which has a negative effect. However, the road narrowing also made it easier for pedestrians to cross midblock given the smaller acceptable gap needed for a two lane road. Generally, the pedestrian scores improve with the road diet. However, the segment between Hill Avenue and Allen Avenue had the highest traffic volumes making for more concentrated traffic that the easier midblock crossing could not overcome. Therefore, this segment had a slightly worse LOS score for pedestrians between the four lane existing road and the proposed two lane cross section.

The addition of a bicycle lane showed dramatic improvements to the LOS score of the bicycle mode with a one letter grade improvement for each segment and direction. Had the street had higher traffic volumes or had the on street parking been more occupied, the improvement to bicycle LOS would have been even greater.

Exhibit 6 - Overall Facility Scores during the AM Peak

Orange Grove Boulevard - Facility AM					
	Mode	**Existing Score (LOS)**	**Road Diet Score (LOS)**	**Difference**	**% Change**
EB	Auto	2.32 (B)	2.35 (B)	0.03	1.3%
	Transit	3.16 (C)	3.15 (C)	-0.01	-0.3%
	Bicycle	3.39 (C)	2.70 (B)	-0.69	-20.4%
	Pedestrian	2.45 (B)	2.37 (B)	-0.08	-3.3%
WB	Auto	2.32 (B)	2.39 (B)	0.07	3.0%
	Transit	3.03 (C)	3.02 (C)	-0.01	-0.3%
	Bicycle	3.31 (C)	2.65 (B)	-0.66	-19.9%
	Pedestrian	2.44 (B)	2.37 (B)	-0.07	-2.9%

Source: Kittelson & Associates

Exhibit 5 and Exhibit 6 dealt with the AM peak which did not have as much traffic as the PM peak. The results of the PM peak analysis for all three segments and for each direction are shown in Exhibit 7. These results are roughly the same as those obtained for the AM peak with existing conditions operating in the LOS B to LOS C range and the road diet scenario maintaining the same LOS grades except for a one letter grade improvement to the bicycle score going from LOS C to LOS B.

Exhibit 7 - LOS Scores and Letter Grades for Each Segment during the PM Peak

Orange Grove Boulevard - Combined PM						
	Segment	**Mode**	**Existing Score (LOS)**	**Road Diet Score (LOS)**	**Difference**	**% Change**
EB	Hill Ave to Allen Ave	Auto	2.35 (B)	2.65 (B)	0.30	12.8%
		Transit	4.52 (E)	4.48 (E)	-0.04	-0.9%
		Bicycle	3.49 (C)	2.74 (B)	-0.75	-21.5%
		Pedestrian	2.87 (C)	2.62 (B)	-0.25	-8.7%
	Allen Ave to Altadena Dr	Auto	2.25 (B)	2.36 (B)	0.11	4.9%
		Transit	2.66 (B)	2.63 (B)	-0.03	-1.1%
		Bicycle	3.46 (C)	2.74 (B)	-0.72	-20.8%
		Pedestrian	2.87 (C)	2.62 (B)	-0.25	-8.7%
	Altadena Dr to Sierra Madre Blvd	Auto	2.55 (B)	3.23 (C)	0.68	26.7%
		Transit	2.68 (B)	2.64 (B)	-0.04	-1.5%
		Bicycle	3.30 (C)	2.70 (B)	-0.60	-18.2%
		Pedestrian	2.97 (C)	2.69 (B)	-0.28	-9.4%
WB	Sierra Madre Blvd to Altadena Dr	Auto	2.51 (B)	2.65 (B)	0.14	5.6%
		Transit	1.93 (A)	1.89 (A)	-0.04	-2.1%
		Bicycle	2.94 (C)	2.49 (B)	-0.45	-15.3%
		Pedestrian	2.91 (C)	2.64 (B)	-0.27	-9.3%
	Altadena Dr to Allen Ave	Auto	2.25 (B)	2.29 (B)	0.04	1.8%
		Transit	2.66 (B)	2.62 (B)	-0.04	-1.5%
		Bicycle	3.41 (C)	2.69 (B)	-0.72	-21.1%
		Pedestrian	2.85 (C)	2.59 (B)	-0.26	-9.1%
	Allen Ave to Hill Ave	Auto	2.35 (B)	2.63 (B)	0.28	11.9%
		Transit	4.51 (E)	4.47 (E)	-0.04	-0.9%
		Bicycle	3.40 (C)	2.71 (B)	-0.69	-20.3%
		Pedestrian	2.78 (C)	2.54 (B)	-0.24	-8.6%

Source: Kittelson & Associates

Taking the segment length weighted average, the auto mode score worsened by about 0.24 points or a 10.3% change in the eastbound direction and a 0.13 point or 5.6% worsening in the westbound direction. The pedestrian LOS also showed a larger affect than was seen in the AM with about a 0.26 point improvement (9%) to the pedestrian score for both analysis directions,

improving the pedestrian LOS grade to LOS B with the road diet compared to LOS C for existing conditions. The greater improvement to pedestrian score in the PM peak also yielded a PM peak transit score that was better for each of the three segments. The transit score averaged about a 0.04 point improvement (1.3%) over the existing four lane facility for both analysis directions. The effect on the bicycle score was about the same as the AM period with about a 20% improvement to score for each analysis direction. These averages can be seen in Exhibit 8.

Exhibit 8 - Overall Facility Scores during the PM Peak

Orange Grove Boulevard - Facility PM					
	Mode	**Existing Score (LOS)**	**Road Diet Score (LOS)**	**Difference**	**% Change**
EB	Auto	2.33 (B)	2.57 (B)	0.24	10.3%
	Transit	3.23 (C)	3.19 (C)	-0.04	-1.2%
	Bicycle	3.44 (C)	2.73 (B)	-0.71	-20.6%
	Pedestrian	2.89 (C)	2.63 (B)	-0.26	-9.0%
WB	Auto	2.32 (B)	2.45 (B)	0.13	5.6%
	Transit	3.09 (C)	3.05 (C)	-0.04	-1.3%
	Bicycle	3.33 (C)	2.66 (B)	-0.67	-20.1%
	Pedestrian	2.84 (C)	2.58 (B)	-0.26	-9.2%

Source: Kittelson & Associates

4. Summary and Conclusions

Currently, Orange Grove Avenue between Hill Avenue and Sierra Madre Boulevard is a four lane facility with parking in both directions carrying an average daily traffic (ADT) of around 11,200 vehicles. A proposal to perform a road diet on this facility would remove two of the four lanes to make room for bicycle lanes and a wider raised median. This analysis looked into the feasibility of this road diet by analyzing how it would affect each of the four main travel modes: auto, transit, pedestrian, and bicycle, using the CompleteStreetsLOS™ software.

Exhibit 9 presents a summary table of the length weighted average of the segment scores for each peak hour, direction, and mode. Additionally, an overall score for each direction assuming all modes are weighted the same is presented.

Exhibit 9 - Summary of Facility Scores for Each Mode and a Combined LOS Grade

Direction	**Mode**	**AM Peak**		**PM Peak**	
		Existing	**Road Diet**	**Existing**	**Road Diet**
Eastbound	Auto	2.32 (B)	2.35 (B)	2.33 (B)	2.57 (B)
	Transit	3.16 (C)	3.15 (C)	3.23 (C)	3.19 (C)
	Bicycle	3.39 (C)	2.70 (B)	3.44 (C)	2.73 (B)
	Pedestrian	2.45 (B)	2.37 (B)	2.89 (C)	2.63 (B)

	Overall	2.83 (C)	2.64 (B)	2.97 (C)	2.78 (C)
Westbound	Auto	2.32 (B)	2.39 (B)	2.32 (B)	2.45 (B)
	Transit	3.03 (C)	3.02 (C)	3.09 (C)	3.05 (C)
	Bicycle	3.31 (C)	2.65 (B)	3.33 (C)	2.66 (B)
	Pedestrian	2.44 (B)	2.37 (B)	2.84 (C)	2.58 (B)
	Overall	2.78 (C)	2.61 (B)	2.90 (C)	2.69 (B)

Source: Kittelson & Associates

With such a small amount of traffic, the auto LOS on this facility is currently operating at LOS B. Reducing the number of travel lanes to one lane in each direction would only worsen the auto LOS score by about 2.2% in the AM and 8.0% in the PM peak hours. This is an insignificant amount, not even enough to change the auto LOS grade from the existing LOS B conditions.

Transit and pedestrian scores are both improved by the road diet. Transit would become slightly better with a 0.3% and a 1.3% change in the AM and PM peak respectively, maintaining LOS C conditions. The pedestrian score generally benefited from the improved ability of pedestrians to cross at midblock locations. This improvement was enough to counteract the negative effects of more vehicles concentrated in the lane nearest pedestrians. Pedestrian conditions remained at LOS B for the AM peak, and improved from LOS C to LOS B for the PM peak conditions.

The biggest improvement resulting from this road diet analysis was to the bicycle LOS score. The addition of bicycle lanes showed a roughly 20% improvement to the score which results in a one letter grade improvement during each peak period and for each direction analyzed, from LOS C with existing conditions to LOS B with the road diet.

In conclusion, this analysis has shown that a road diet is a feasible option for this corridor. The resulting LOS letter grade for bicycles (LOS B) is improved by one letter grade for both peak hours. The LOS grade for pedestrians is improved by one letter grade for the PM peak going from LOS C to LOS B, while all other modes remain at the same LOS grade.

Additionally, if this road diet is combined with a slightly better transit frequency on the segment between Hill Avenue and Allen Avenue, all four modes would operate at LOS B during the AM and PM peak periods.

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[i] *Transportation Planning Handbook*, 3rd edition. Institute of Transportation Engineers, 2009.

[ii] The CompleteStreetsLOS™ software is authored and distributed by Kittelson & Associates, Inc. Please see www.CompleteStreetsLOS.com for more information.

[iii] Google Inc. (2010). Google Earth (Version 5.2.1.1588) [Software]. Available from http://www.google.com/earth/index.html.

[iv] R. Dowling, et al. *National Highway Cooperative Research Program Report 616: Multimodal Level of Service Analysis for Urban Streets*. Transportation Research Board, 2008.