Sixteenth Land Holdings Inc.
4134 16th Avenue Lands
City of Markham

Traffic Impact Assessment
4134 16th Avenue
West Side Plan of Subdivision
East Side Plan of Subdivision

Update Report

October 2017

Sixteenth Land Holdings Inc.
4134 16th Avenue Lands
City of Markham
4134 16th Avenue
Traffic Impact Study Update Report
West Side Plan of Subdivision
East Side Plan of Subdivision

Table of Contents

Contents

Sixteenth Land Holdings Inc.
4134 16th Avenue Lands
City of Markham
4134 16th Avenue
Traffic Impact Study Update Report
West Side Plan of Subdivision
East Side Plan of Subdivision

1 Introduction

Sixteenth Land Holdings Inc. has retained Poulos & Chung Limited (PC) to prepare analyses and studies in support of Draft Plans of Subdivision (West Side and East Side) application to permit the development of a residential community on the subject property.

The property is municipally known as 4134 16th Avenue, in the City of Markham, Region of York. The property is located in Part lots 16, 17 and 18, Concession 5. Except for an area adjacent to Kennedy Road, the balance of the property is currently used by its former owner York Downs Golf & Country Club for a golf course.

The location of the subject Property is shown in Figure 1.1.

The property is a total of 168.64 hectares (416.72 acres), and is located on the north side of 16th. Avenue, on the west side of Kennedy Road, and has a small amount of frontage onto the east side of Warden Avenue as well. There is existing residential development surrounding the property on all sides.

A tributary of the Berczy Creek crosses the western portion of the property, and the Bruce Creek traverses the property in a roughly north / south direction, bisecting the property into west and east tableland areas.

The current golf course use has been in operation since York Downs Golf & Country Club opened on site in the early 1970's. The current Official Plan designation of 'Private Open Space' for the areas outside of the valley lands reflects this historic golf course use.

Sixteenth Land Holdings Inc. intends to develop the property for a residential community and is submitting an OPA to redesignate the developable portion of the property from 'Private Open Space' to appropriate urban residential designations to permit the development of residential uses. A separate Transportation Assessment Study has also been filed in support of the OPA application.

Since the submission of the October 2016 Traffic Impact Study the Project Team has acquired input from the public and authorities. This has resulted in updated draft plans of subdivision for the east and west portions of the property.

The updated East draft plan of subdivision contains a total of 1,257 dwelling units

The updated West draft plan of subdivision contains a total of 1,164 dwelling units.

This submission updates the development impact assessment and also provides additional analyses and outputs to respond to comments received from the authorities.

2 Basis of Analysis

The key background information, parameters and analysis process steps presented in the October 2016 Traffic Impact Study continue to be applied in this update report.

3 Updated Draft Plans of Subdivision

The updated Composite Plan is shown in Figure 3.1.

The following table compares the resultant dwelling unit count in the updated plan to the original number of dwelling units contained in the October 2016 submission.

Table 1

Dwelling Unit Count Comparison Between Initial and Updated Draft Plans

Residential Unit Type	Original Plans	Updated Plans
Single Detached Lots	1087	988
Townhouses	597	660
Mid Rise Townhouses	227	323
Mid Rise Condominium	300	190
Mixed Use Residential	210	210
Total	2,421	2,371

It is evident that the updated composite plan has 50 dwelling units less than the original plan.

The updated West and East Draft Plans are shown in Figures 3.2 and 3.3 respectively.

4 Development Impact Assessment

4.1 Draft Plans of Subdivision

The new Composite Plan contains 2,371 dwelling units.

The Traffic Impact Assessment Study submitted in October, 2016 assessed 2, 421 dwelling units.

The new roadway network providing direct and convenient vehicular access to the subject lands is shown in Figure 4.1.

The internal roadway network now contains a continuous north south collector road between Major Mackenzie Drive and 16th Avenue via the extension of Yorkton Boulevard and connection to Prospectors Drive.

PC has examined in detail:

- The revised dwelling unit type mix (for the updated plan, which has 2,371 dwelling units) and concludes that a slight reduction in vehicle trips inbound and outbound occurs in both the roadway AM and PM peak hours;

- The previous detailed analysis outputs and concludes that the updated draft plan statistics do not change any of the results and performance measures as determined in the October 2016 Traffic Impact Assessment Study.

Therefore the findings and conclusions of the October 2016 Traffic Impact Study do not change and continue to remain valid.

4.2 Screenline and Intersection Capacity Analysis

An expanded traffic analysis was undertaken for this update analysis.

The expanded traffic analysis examined total traffic flows (background and development) for the typical weekday AM and PM peak hour peak direction of travel. The years examined included the anticipated development levels of 2021, 2024 and 2026.

The expanded analysis is based upon:

- The location of screenlines around the Block bounded by Major Mackenzie Drive, Kennedy Road, 16th Avenue and Warden Avenue;

- Calculating and examining at the sreenline locations the:

    - Arterial road intersection performance (based on the outputs produced by the Synchro Software program as contained in the October 2016 report);

    - The volume to capacity ratio produced at the screenline location by identifying the total peak hour peak direction of travel and dividing it by the available (screenline) individual lane capacity.

The findings of the screenline and intersection capacity analysis are presented in the following Figures:

- Figure 4.2 summarizes the roadway AM peak hour condition;
- Figure 4.3 summarizes the roadway PM peak hour condition.

It should be noted that years 2021 and 2024 did not include the road widening program. Year 2026 included the road widening program.

The expanded analysis clearly illustrates that in each year examined:

- The available screenline capacity is greater than the forecast total vehicle demand. The total demand does not exceed the available screenline capacity with the exception of one time period, however;

- The intersection capacity analysis shows that several arterial road intersections will experience vehicle demands greater than the capacity provided.

It is apparent that the above capacity analysis differences can be partially explained by the fact that the intersections are controlled by traffic signals. The traffic signals allocate time to serve through and turning vehicle demands. Inherent in this division of time is lost time to clear vehicles after each cycle (amber / all red and lost time). The reduction in available time serves to increase delays resulting in the build up queues.

However, the most significant reason for the difference between screenline and intersection capacity findings is the methodology and parameters set when the Synchro Software Program is used to assess intersection performance.

Typical analysis process steps set certain defined software parameters. (In York Region the default Synchro Software parameters are maintained). These parameters control the the Synchro software analysis process and resultant outputs. As an example upon examining existing intersection demands using Synchro, it is evident that the volume to capacity ratio output produced indicates that the theoretical capacity has been exceeded. This implies that more traffic travelled through the intersection than is considered physically feasible. As a result, it is likely that the default parameters in Synchro are resulting in an underestimation of the capacity of the intersection. Driver performance is more efficient than that calculated by the software program. The comparison to the screenline analysis indicates that this is likely the case. In actual fact since the total vehicle demand has been cleared by the intersection in the one hour period it can be concluded that the intersection has not reached capacity. It may be close to capacity but not over capacity. The parameters of the Synchro software program can be adjusted to reflect this efficiency and the result will be a better intersection volume to capacity ratio than that identified in the October 2016 analysis.

If these same parameter adjustments are applied to the assessment of future horizon years then the resultant volume to capacity ratios will also be better than that identified in the October 2016 analysis.

5 Active Transportation System

The Active Transportation System is shown in Figure 5.1.

The key active transportation components include:

- Sidewalks on both sides of all collector roads;
- Sidewalk on one side of all local roads;
- Exclusive bike lanes on the collector roads;
- Trails and walkways within the Berczy Creek open space area, connecting to all areas of the community, with:
- Connections to the bounding arterial roads including the existing trail network south of 16th Avenue. The connections to the existing trails south of 16th Avenue are accommodated at the pedestrian cross – walks located at existing and proposed intersections controlled by traffic signals.

6 Transit System

The Transit System is shown in Figure 6.1.

The transit system consists of:

- Existing transit services operated by York Region Transit which are in service on 16th Avenue, Kennedy Road and Warden Avenue. It is expected that York Region Transit will continue to increase frequency of service as demand continues to increase. The 16th Avenue service can be expected to be one of the first to be expanded when the High Occupancy Vehicle lanes are introduced through the planned widening program;

- The opportunity to introduce transit on Street A (extension of Bur Oak Avenue). York Region Transit can either introduce a new transit route pattern or modify an existing local transit route to place service on this road.

It is evident that the existing and planned transit system provides direct accessibility to all major attractors, generators and employment areas within the City of Markham. In addition direct transfers are available to the rapid transit network including VIVA and GO Transit.

7 Non – Automotive Demand Analysis and Operational Capacity Verification

7.1 Transit

PC used the following methodology to estimate transit demand (2026) generated by the subject lands.

The analysis steps included:

- Using the forecast total site generated traffic flows in horizon year 2026;

- Determining that the total auto related vehicle trips account for 79% (forecast auto related 2026) of total person trip making in the AM and PM peak hours;

- Calculating the total person trip making by dividing the number of AM and PM vehicle trips generated by 0.79 and then:

    - Multiplying the resultant number by 1.2 to account for the vehicle passenger ratio;

- This resulted in the total person trip making during the roadway peak hours. The resultant number was then used as follows:
    - A ratio of 0.13 was applied to estimate the total transit person trips;
    - A ration of 0.04 was applied to estimate the total walk person trips;
    - A ratio of 0.01 was applied to estimate the total bicycle person trips.

The resultant total person trip making by non – automotive modes of transportation during the roadway peak hours is shown in Figure 7.1.

It is expected that non – automotive trips will have a similar trip distribution pattern as the vehicle mode of transportation. In addition, the distribution pattern will be influenced by the frequency and location of transit services.

Figure 7.2 presents the transit demand during the roadway AM and PM peak hours.

The transit demand was determined in two parts. The first part examined the vehicle flow pattern as directed toward the bounding arterial roads of 16^{th} Avenue and Kennedy Road. A significant portion of the subject land population is located within a close proximity to the existing and planned arterial transit services.

The second part estimated the transit demand attracted to the Street "A" transit service.

For each part analyzed the governing criteria is the 5 minute or 400 meter walking distance to a transit service.

It is evident that the entire subject lands are within a 5 minute or 400 meter walking distance to transit.

PC can state that:

- The total transit demand from the entire subject lands can be easily serviced and provided sufficient operating capacity by buses running on a 20 or 30 minute headway. This can be secured for both roadway peak hours;

- It is anticipated that York Region Transit can modify and change service / route structures to constantly serve any change in demand at satisfactorily levels of service.

7.2 Pedestrians

The methodology to determine the pedestrian demand (2026) is presented in Section 7.1.

The determined pedestrian demand generated by the subject lands in the AM and PM peak hours is shown in Figure 7.3.

The determined pedestrian demand by collector road segment was subjected to speed, density and volume calculations as recommended by the Highway Capacity Manual (HCM).

These calculations enabled pedestrian volume space to be measured against walking speed within the sidewalk space.

Appendix A contains an excerpt from the HCM describing the calculation process and the relationship to determining the resultant level of service.

It is evident that all collector roads secure a Level of Service “A” during the roadway AM peak hour. Similarly the roadway PM peak hour secures the same level of service.

7.3 Bicyclists

The methodology to determine the bicycle demand (2026) is summarized in Section 7.1.

The determined bicycle demand generated by the subject lands in the AM and PM peak hour is shown in Figure 7.4.

Appendix B contains an excerpt from the HCM describing the capacity analysis for on – street bicycle facilities.

This excerpt defines a level of service based upon the bicycle flow rate (bike / hour) as measured against the bicycle mean speed.

Upon examining the bicycle demand and assuming the lowest bicycle speed it is evident that a Level of Service “A” can be secured. It is therefore concluded that all bicycle demands can be satisfactorily accommodated.

7.4 Recreational

The subject lands contain significant trails and walkways. These trails and walkways will mostly be used for recreational trip making.

It can be expected that some pedestrians and bicyclists will use the trails and walkways during the roadway peak hours.

The demand to use the trails and walkways either during the roadway peak hours or off peak hours can be expected to be low. The demand level in any hour of the day can be expected to be less that the pedestrian demand determined on the collector roads.

The 3.0 meter space allocated for the trails and paths can provide sufficient operating capacity to satisfactory serve all total demands

8 Phasing Plan

8.1 Updated Phasing Plan

The updated Phasing plan is shown in Figure 8.1.

8.2 Development Impact Assessment

The new phasing plan contains 509 dwelling units.

The Traffic Impact Assessment Study submitted in October, 2016 assessed 482 dwelling units as the initial stage of the phasing plan.

This phasing plan contains an increase of 27 dwelling units.

PC has examined in detail:

- The revised dwelling unit type mix (for the updated plan, which has 509 dwelling units) and concludes that a slight increase in vehicle trips inbound and outbound occurs in both the roadway AM and PM peak hours;

- This increase in vehicle trip making is negligible and only results in an increase of about 15 vehicle trips in the peak hour peak direction of travel. Inserting this new traffic flow into the intersection calculations did not cause a measurable change in the key output performance levels;

- The previous detailed analysis outputs. This leads PC to conclude that the updated Phase 1 statistics do not change any of the results and performance measures as determined in the October 2016 Traffic Impact Assessment Study.

Therefore the findings and conclusions of the October 2016 Traffic Impact Study do not change and continue to remain valid.

Detailed engineering continues to refine the delivery and location of services for the entire phasing plan. As these details are worked out minor adjustments could occur to the dwelling unit numbers. As these adjustments occur and if the dwelling unit number rises accordingly; further traffic analysis can be conducted. Such an approach, as stages are finalized will provide updated traffic flow information with additional accurate horizon year calculations.

.

8.3 Travel Demand Management Plan

Sixteenth Land Holdings Inc is committed to delivering the critical physical Travel Demand Management (TDM) elements and measures necessary to provide modal options and choices for residents to complete all trip purposes.

Sixteenth Land Holdings Inc also recognizes the importance of working with the City, the Region and York Region Transit (YRT) to educate and incentivize residents to consider sustainable modes of transportation other than the automobile as they move into their new home.

Residents after moving into their new home and living in the community for a few years have begun to establish travel modal choices. At this point in time it is important that authorities ask them about their travel behavior and determine the uptake of TDM measures. This review and monitoring process will acknowledge and permit strengthening of successful measures and identify measures to be modified or bring forth new ones to further encourage change.

It is recognized that detailed TDM plans will be prepared and submitted by phase of development. These TDM plans will take into account numerous transportation factors and opportunities including:

- The planned improvements and additions to the Regional Roadway Network;
- The incremental and planned improvements and additions to the transit system;
- The connection of the subject lands active transportation systems to the planned area pedestrian, bicycle, trail and path system;
- City of Markham municipal wide and York Region region-wide TDM initiatives;
- Supporting and encouraging the use of increasing York Region (YRT and VIVA) transit service enhancements;
- Supporting and encouraging the use of Smart Commute initiatives and incentives.

Each TDM plan to be formulated will have a combination of “soft” and “hard" measures. “Soft” measures are those defined as using incentives, educational material and follow up surveys to measure uptake and success and to identify new or modified measures to further encourage non automobile travel. “Hard” measures are those identified as physical infrastructure designed to support and encourage TDM activity. This includes accessibility to and integration with transit.

The City of Markham and York Region have introduced and continue to expand and modify:

- TDM Policies and Programs;
- Supporting Active Transportation facilities;

- Markham Active Transportation initiatives designed to support walking and bicycling.

These initiatives can be summarized as follows:

Table 8.1
Summary of Municipal and Region TDM Initiatives

Initial TDM Initiatives	Summary Description	Ongoing Authority Actions
Education, Promotion and Outreach	• Information and Education; • Target Marketing; • Special Events; • Recognition and Rewards; • Monitoring and Follow-Up	• Development Charge based program continually developing and implementation by Authorities;
Travel Incentives and Disincentives	• Ride matching; • Information Services; • Road and Transit Pricing; • Work and School Based Incentives; • Site Specific Support Facilities*.	• Smart Commute;
Active Transportation	• Transportation Master Plan Directions*; • Secondary Plan Directions*.	• Transit Target Modal Splits; • Pedestrian Networks; • Bicycle Networks; • Trails and Paths;
Transit	• Very good introductory transit service	• Continual transit route enhancements and increased frequency of service.

(*) Sixteenth Land Holdings Inc will deliver infrastructure to permit residents to easily choose sustainable transportation modal options.

The cornerstone of the Sixteenth Land Holdings Inc plan will be the delivery of the following hard measures:

- The on – street bicycle lanes within each collector road;

- The connecting trail and path network;

- Integration and connection to transit including the installation of bicycle racks at the key bus stops. Key bus stops include along the arterial road, and along Street "A" the extension of Bur Oak Avenue and path / trail connections.

The primary soft TDM measures are:

- Education, promotion and outreach;

- Information packages;
- Travel incentive (Presto Card purchase);
- Initial meeting with residents where YRT will distribute Presto Cards and provide information about YRT and modal choice options;
- Monitoring and survey program preparation by YRT and City of Markham;
- Second information meeting with residents (after 2 years or so) where YRT and City of Markham will distribute survey forms and provide further follow up TDM information;
- Third information meeting with residents (after 3 years or so) where YRT will present TDM uptake information, identify success and introduce further information packages

Sixteenth Land Holdings Inc will provide support to YRT and the City of Markham as these information meetings occur. This will include:

- Preparation of a Community Map illustrating scale and access to sustainable transportation services and facilities. This is to be made available to the authorities at the initial information meeting;
- Assistance to YRT as they distribute information packages to each of the three resident information meetings. This includes:
    - Coordination and liaison with YRT to establish information meeting dates;
    - Names and addresses of residents;
    - Identification and securing of meeting room sufficient in size to accommodate all residents invited. This will be done for each of the 3 information meetings with residents. A 4 hour booking period will be secured;
    - Assistance to YRT during the information meetings to direct and organize attending residents.

The initial stage of the phasing plan is to consist of 509 dwelling units.

York Region and the City of Markham will be responsible for the purchase / distribution of Presto Cards and the preparation of information packages and survey materials to be distributed at any of the resident information meetings.

Sixteenth Land Holdings Inc. will provide a Line of Credit amount of ($75 x 509 dwelling units) $38,175.00 to coordinate and secure the resident meeting dates and meeting room venues.

Remaining phases will include updated TDM plan submissions.

9 Conclusions and Recommendations

This updated transportation analysis provides the following conclusions:

- The October 2016 Traffic Impact Analysis containing the detailed performance analysis of 12 boundary road intersections continues to be valid for the:
    - The new Composite Plan and the new West and East Draft Plan of Subdivisions;
    - The updated Phase 1 development;

- The October 26, 2016 traffic analysis is very conservative based upon the use of Synchro software default settings when analyzing intersection operations. This evidenced by the updated analysis presented in section 4.2 of this report, where screenline capacity is compared to arterial road intersection capacity;

- Detailed engineering continues to refine the delivery and location of services for the entire phasing plan. As these details are worked out minor adjustments could occur to the dwelling unit numbers. As these adjustments occur and if the dwelling unit number rises accordingly; further traffic analysis can be conducted. Such an approach, as stages are finalized will provide updated traffic flow information with additional accurate horizon year calculations. As is evidenced by the screeline analysis; a more refined analysis can come forward as the phasing plan continues forward;

- The subject lands including a significant portion of the planned residential dwelling units have excellent accessibility to existing transit along 16th Avenue and Kennedy Road. Upon completion of Street “A” and with the introduction of internal transit all of the dwelling units will be within a 5 minute walk of transit;

- The active transportation system (sidewalks and exclusive bike lanes) along with the trail and path network provide:
    - Comfortable and convenient access to the internal public school, retail / commercial area and public school;
    - Direct and controlled connections to nearby retail commercial plaza and high school;

    - Direct and controlled connections to the existing trail and path system south of 16th Avenue;

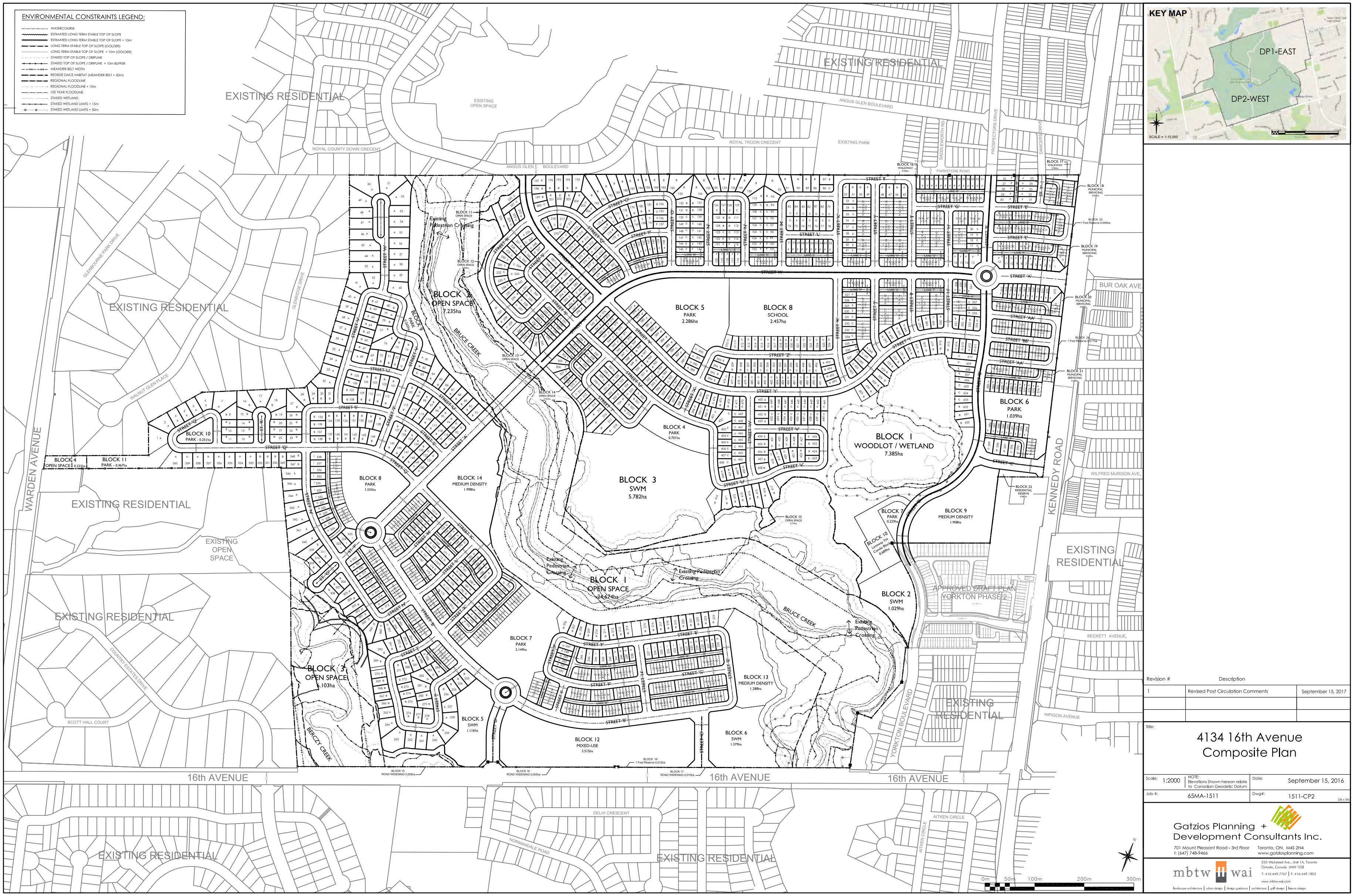
- The TDM plan presented contains the most recent enhancements and process steps identified by York Region and the City of Markham.

This updated transportation analysis continues to support the recommendations contained in the October Traffic Impact Assessment report.

Report Figures

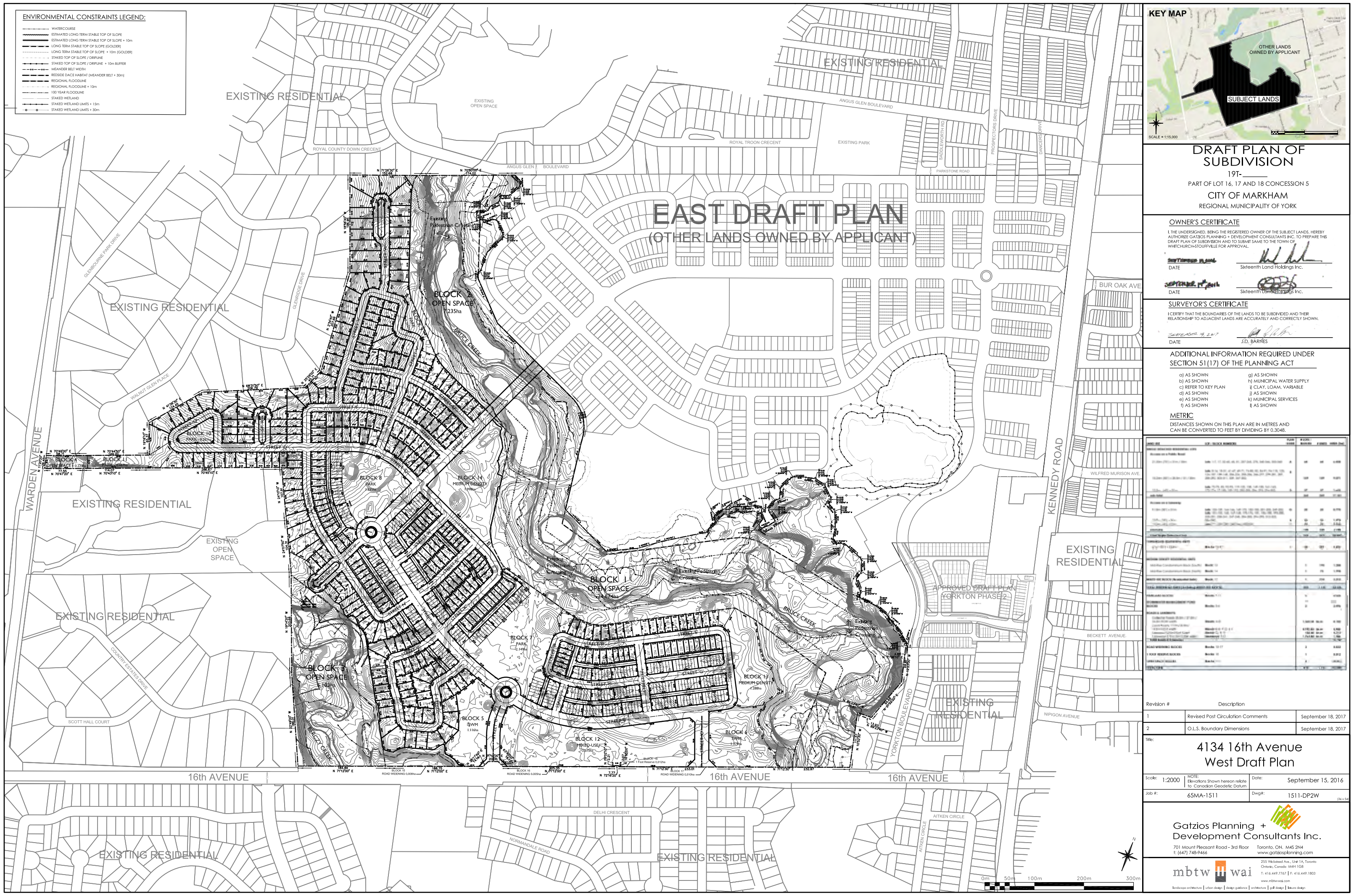
Poulos Chung

Subject Lands
Figure 1.1



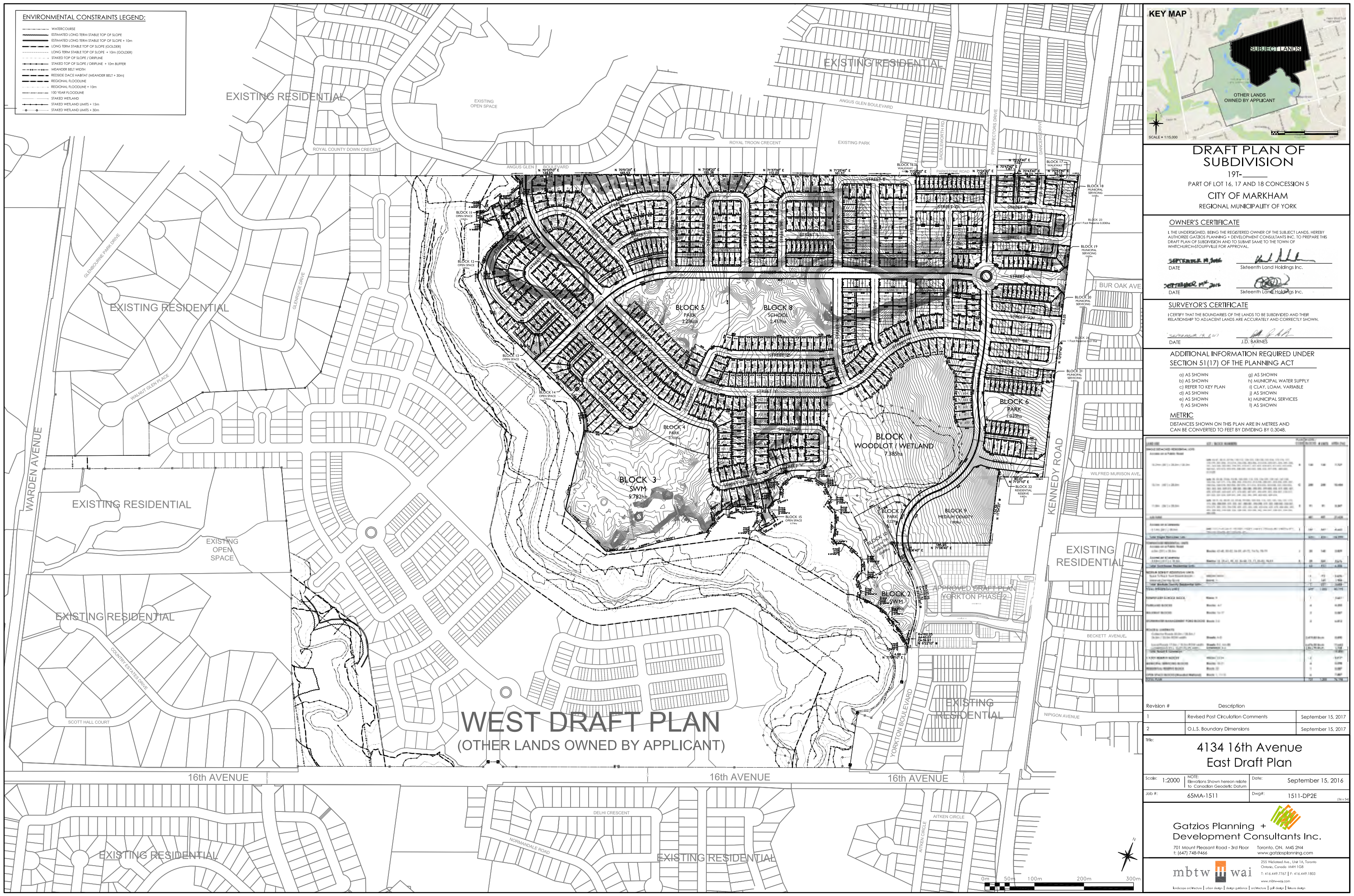
Poulos & Chung

Composite Plan
Figure 3.1



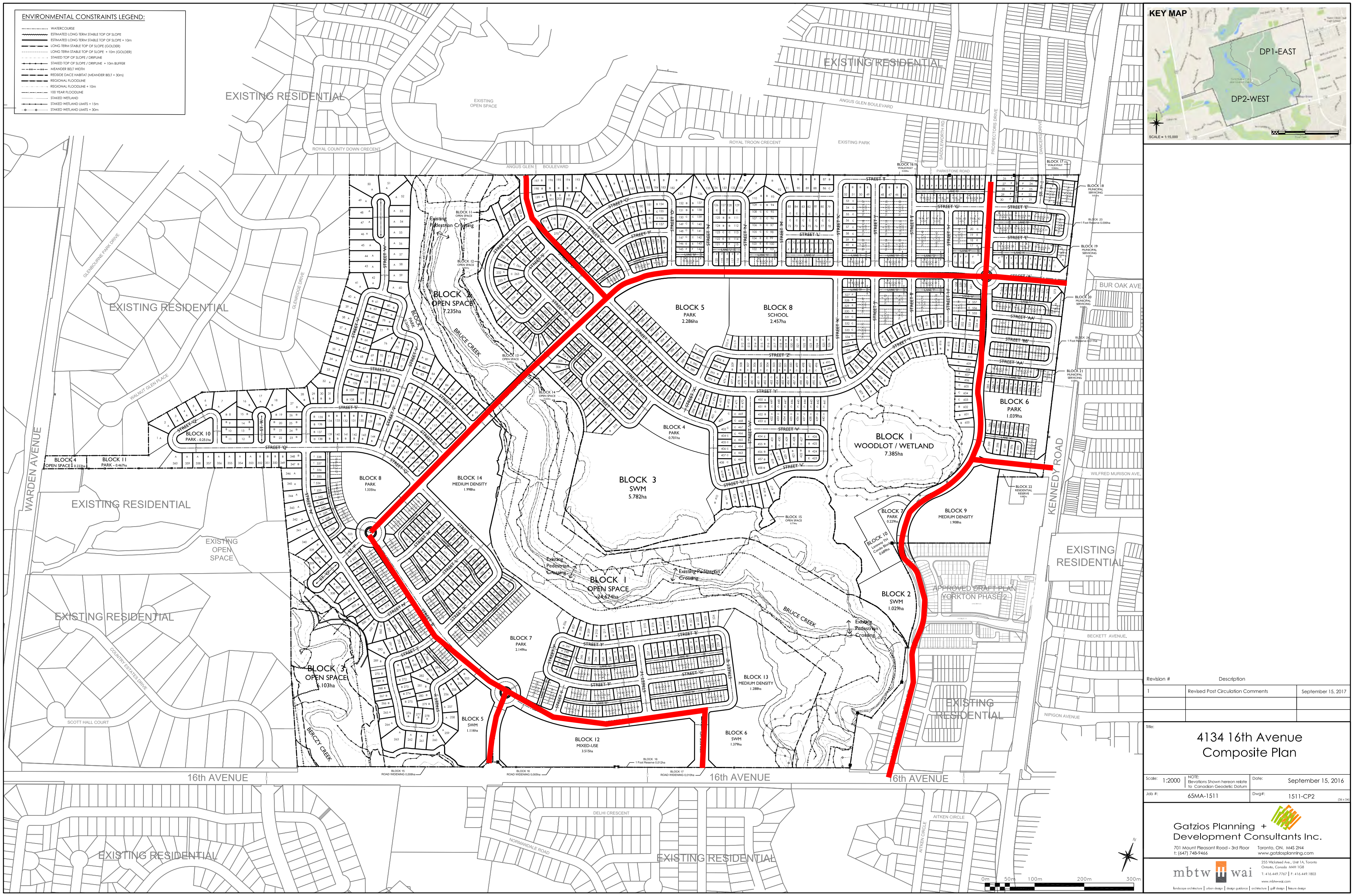
Poulos Chung

West Draft Plan
Figure 3.2

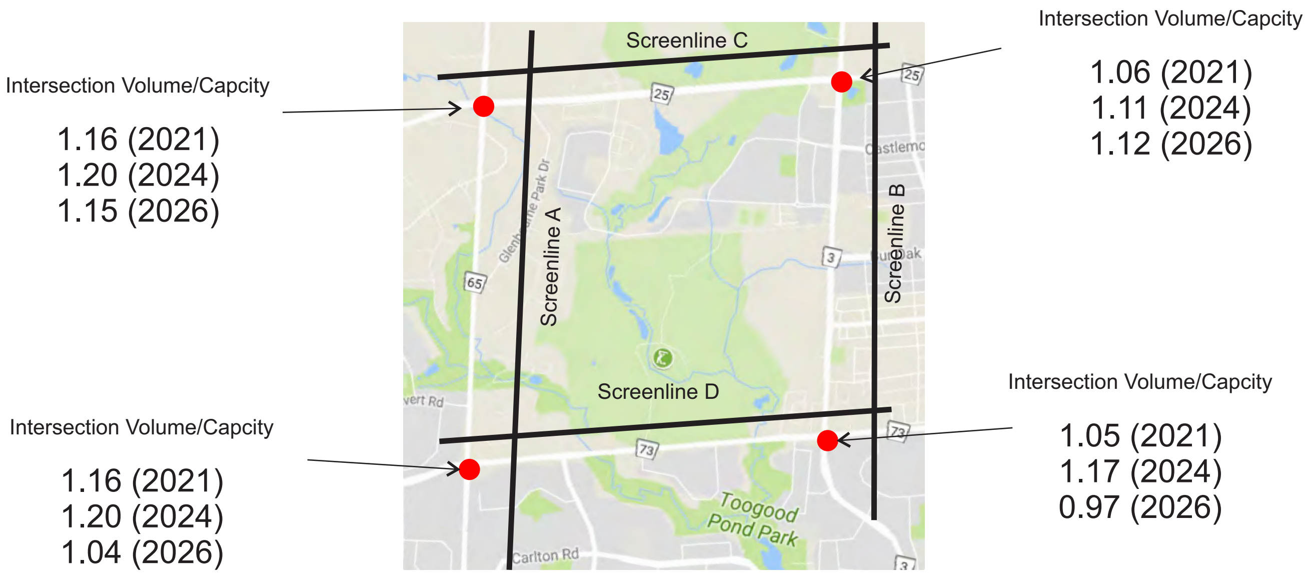


Poulos & Chung

East Draft Plan
Figure 3.3



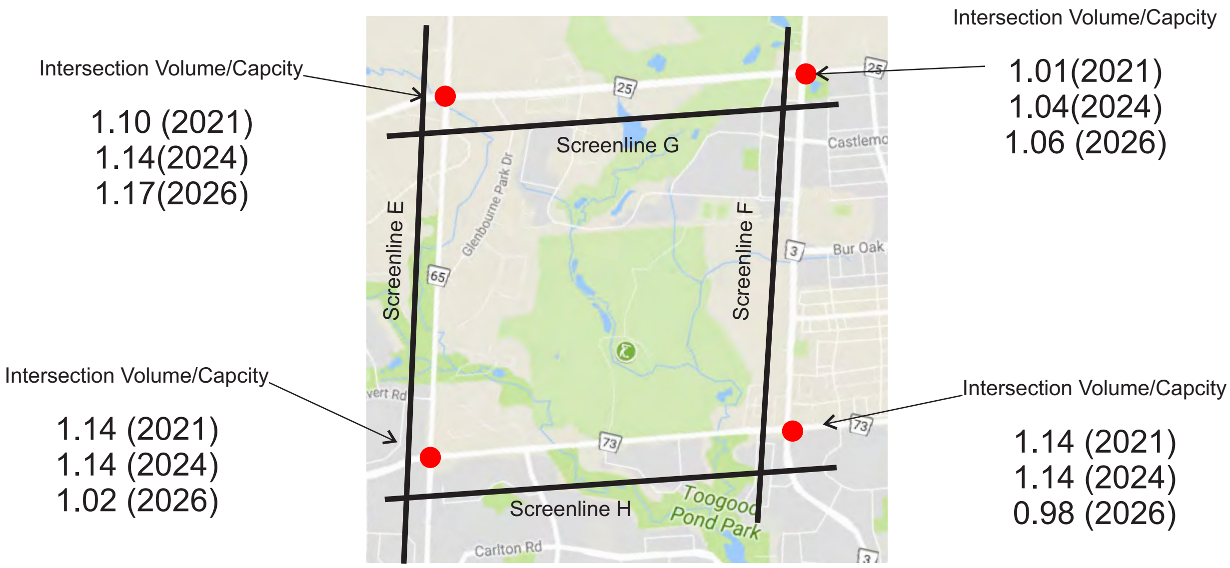
Road Network
Figure 4.1



AM Peak Direction - Westbound				AM Peak Direction - Southbound			
Horizon 2021							
North South Screeline A -East of Warden				**East West Screeline C - North of Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2471	3089	0.80	Warden Ave	1574	2176	0.72
16th Avenue	2099	2937	0.71	Kennedy Rd.	1191	1609	0.74
Total SL "A"	**4081**	**5077**	**0.80**	**Total SL "C"**	**2765**	**3785**	**0.73**
North South Screeline B - East of Kennedy				**East West Screeline D - 16 North of 16th Ave**			
Major Mackenzie	2085	2668	0.78	Warden Ave	1739	2008	0.87
16th Avenue	1538	2562	0.60	Kennedy Rd.	1946	1659	1.17
Bur Oak Ave.	651	976	0.67				
Total SL "B"	**1006**	**1413**	**0.71**	**Total SL "D"**	**3685**	**3667**	**1.00**
Horizon 2024							
North South Screeline A -East of Warden				**East West Screeline C - North of Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2547	3433	0.74	Warden Ave	1638	2069	0.79
16th Avenue	2258	2475	0.91	Kennedy Rd.	1236	1553	0.80
Total SL "A"	**4805**	**5908**	**0.81**	**Total SL "C"**	**2874**	**3622**	**0.79**
North South Screeline B - East of Kennedy				**East West Screeline D - 16 North of 16th Ave**			
Major Mackenzie	2139	2922	0.73	Warden Ave	1814	2249	0.81
16th Avenue	1583	1712	0.92	Kennedy Rd.	1946	2461	0.79
Bur Oak Ave.	670	1006	0.67				
Total SL "B"	**4392**	**5640**	**0.78**	**Total SL "D"**	**3760**	**4710**	**0.80**
Horizon 2026							
North South Screeline A -East of Warden				**East West Screeline C - North of Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2832	3433	0.82	Warden Ave	1686	2069	0.81
16th Avenue	2482	2441	1.02	Kennedy Rd.	1273	1545	0.82
Total SL "A"	**5314**	**5874**	**0.90**	**Total SL "C"**	**2959**	**3614**	**0.82**
North South Screeline B - East of Kennedy				**East West Screeline D - 16 North of 16th Ave**			
Major Mackenzie	2183	2916	0.75	Warden Ave	1893	2239	0.85
16th Avenue	1624	1694	0.96	Kennedy Rd.	3216	2320	1.39
Bur Oak Ave.	687	1022	0.67				
Total SL "B"	**4494**	**5632**	**0.80**	**Total SL "D"**	**5109**	**4559**	**1.12**

Poulos Chung

Screenline Volumes and Volume over Capacity
AM Peak Hour - Years 2021, 2024 and 2026
Figure 4.2



PM Peak Direction - Eastbound				PM Peak Direction - Norththbound			
Horizon 2021							
North South Screeline E -West of Warden				**East West Screeline G - Southof Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2052	2542	0.81	Warden Ave	1640	2021	0.81
16th Avenue	1946	2245	0.87	Kennedy Rd.	1020	2119	0.48
Total SL "E"	**3642**	**4245**	**0.86**	**Total SL "G"**	**2660**	**4140**	**0.64**
North South Screeline F- West of Kennedy				**East West Screeline H - South of 16th Ave.**			
Major Mackenzie	2026	2488	0.81	Warden Ave	1793	1943	0.92
16th Avenue	2033	2655	0.77	Kennedy Rd.	1760	1549	1.14
Bur Oak Ave.	70	575	0.12				
Total SL "F"	**123**	**911**	**0.14**	**Total SL "H"**	**3553**	**3492**	**1.02**
Horizon 2024							
North South Screeline E -West of Warden				**East West Screeline G - Southof Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2134	2639	0.81	Warden Ave	1696	1790	0.95
16th Avenue	2053	2128	0.96	Kennedy Rd.	1050	1936	0.54
Total SL "E"	**4187**	**4767**	**0.88**	**Total SL "G"**	**2746**	**3726**	**0.74**
North South Screeline F- West of Kennedy				**East West Screeline H - South of 16th Ave.**			
Major Mackenzie	2076	2731	0.76	Warden Ave	1898	2093	0.91
16th Avenue	2050	2016	1.02	Kennedy Rd.	1828	1695	1.08
Bur Oak Ave.	51	506	0.10				
Total SL "F"	**4177**	**5253**	**0.80**	**Total SL "H"**	**3726**	**3788**	**0.98**
Horizon 2026							
North South Screeline E -West of Warden				**East West Screeline G - Southof Major Mackenzie Dr.**			
	Volumes	Capacity	V/C		Volumes	Capacity	V/C
Major Mackenzie	2386	2644	0.90	Warden Ave	1737	1706	1.02
16th Avenue	2211	2094	1.06	Kennedy Rd.	1092	1924	0.57
Total SL "E"	**4597**	**4738**	**0.97**	**Total SL "G"**	**2829**	**3630**	**0.78**
North South Screeline F- West of Kennedy				**East West Screeline H - South of 16th Ave.**			
Major Mackenzie	2116	2723	0.78	Warden Ave	2048	2079	0.99
16th Avenue	2155	1967	1.10	Kennedy Rd.	1933	2169	0.89
Bur Oak Ave.	60	514	0.12				
Total SL "F"	**4331**	**5204**	**0.83**	**Total SL "H"**	**3981**	**4248**	**0.94**

Poulos Chung

Screenline Volumes and Volume over Capacity
PM Peak Hour - Years 2021, 2024 and 2026
Figure 4.3

ACTIVE TRANSPORTATION PLAN

October 25, 2017

4134 16TH AVENUE, CITY OF MARKHAM, REGION OF YORK

mbtw wai

Poulos Chung

Active Transportation System
Figure 5.1

PROPOSED TRANSIT ROUTE

October 19, 2017

4134 16TH AVENUE, CITY OF MARKHAM, REGION OF YORK

mbtw wai

Poulos & Chung

Proposed Transit Route
Figure 6.1

Vehicle Trips

Land Uses	Units	ITE Code	Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
Total Westside	1116		108	416	524	426	229	655
Total Eastside	1255		143	507	650	534	296	830
Net Commercial Vehicle Trips			22	55	77	20	30	50
Elementary School (Student)	600	600	149	122	270	44	46	90
Total (Vehicle Trips)	*2371*		*422*	*1100*	*1522*	*1025*	*600*	*1625*

Modal Reduction

Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
90	346	435	354	190	544
119	420	539	443	245	689
21	56	77	19	31	50
123	101	224	37	38	75
353	*923*	*1276*	*853*	*504*	*1357*

Person Trips (1.2 vehicle Occupancy)

Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
136	525	661	538	288	826
181	639	819	674	373	1046
32	86	118	29	47	76
900	900	1,800	200	200	400
1249	*2149*	*3398*	*1441*	*908*	*2348*

Estimates based on number of students plus parents

Estimated Transit Trips

Land Uses	Units	Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
Total Westside	1116	18	68	86	70	37	107
Total Eastside	1255	23	83	106	88	48	136
Net Commercial Vehicle Trips		4	11	15	4	6	10
Elementary School (Student)	600	0	0	0	0	0	0
Total (Vehicle Trips)	*2371*	*45*	*162*	*208*	*161*	*92*	*253*

Note No Public Transit is assumed for the school site

Estimated Walk Trips

Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
5	21	26	22	12	33
7	26	33	27	15	42
1	3	5	1	2	3
180	90	270	20	40	60
194	*140*	*334*	*70*	*68*	*138*

It is assumed 20% of school trips by walk to school (AM)
10%outbound(AM) , 10% In and20% Out in the pm

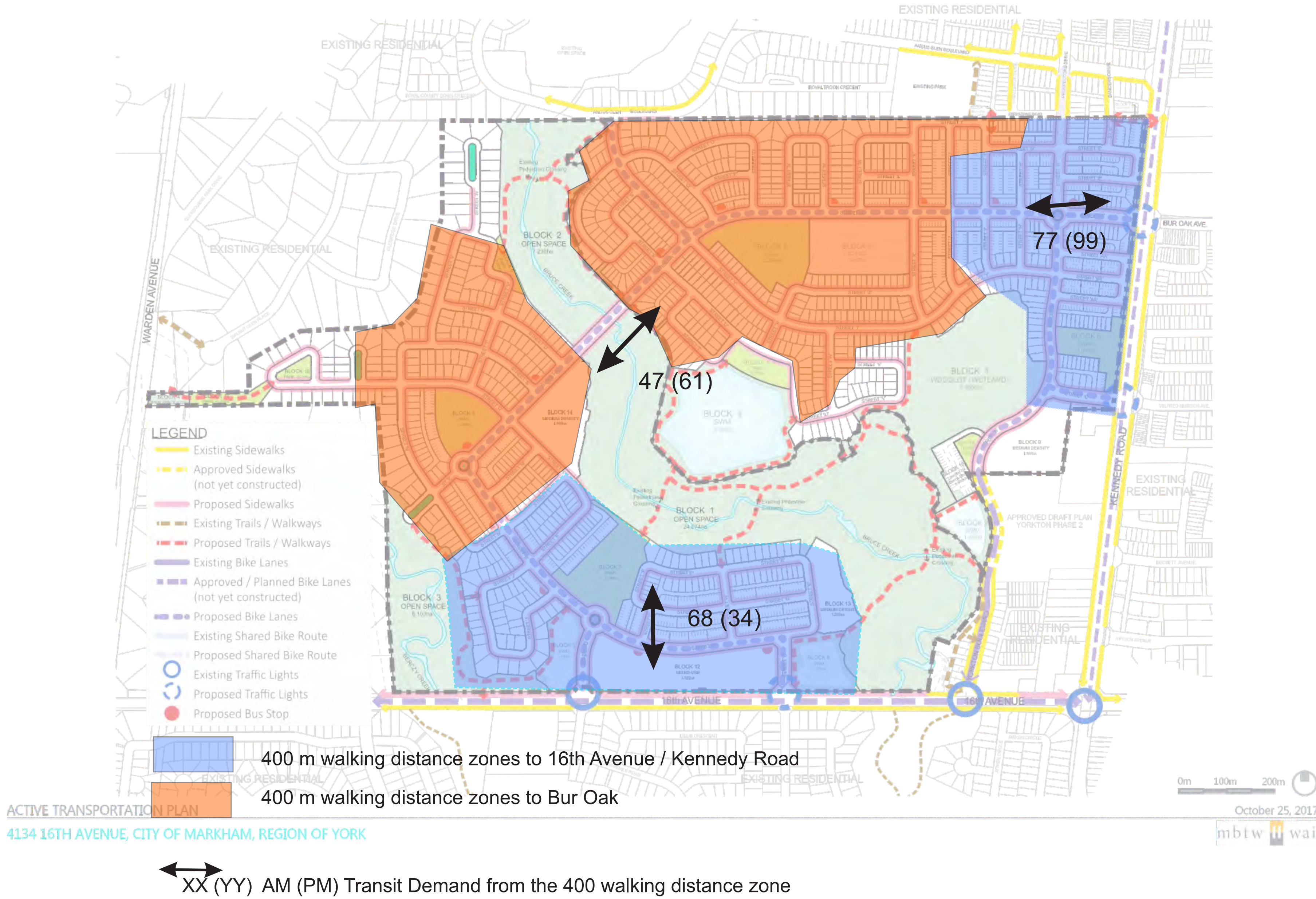
Estimated Cycling Trips

Weekday AM Peak Hour In	Out	Total	Weekday PM Peak Hour In	Out	Total
1	5	7	5	3	8
2	6	8	7	4	10
0	1	1	0	0	1
18	0	34	0	6	11
22	*12*	*50*	*12*	*13*	*31*

It is assumed 15% of school trips by Bicycle in bound)
0% Outbound (AM), o% (inbound) and 10% outbound

Poulos Chung

Auto, Transit , Walk and Bicycle Trip Generation
Figure 7.1



Poulos Chung

Estimated Transit Demand from Subject Lands
AM (PM) Peak Hour
Figure 7.2

XX (YY) AM (PM) Peak Hour Volumes

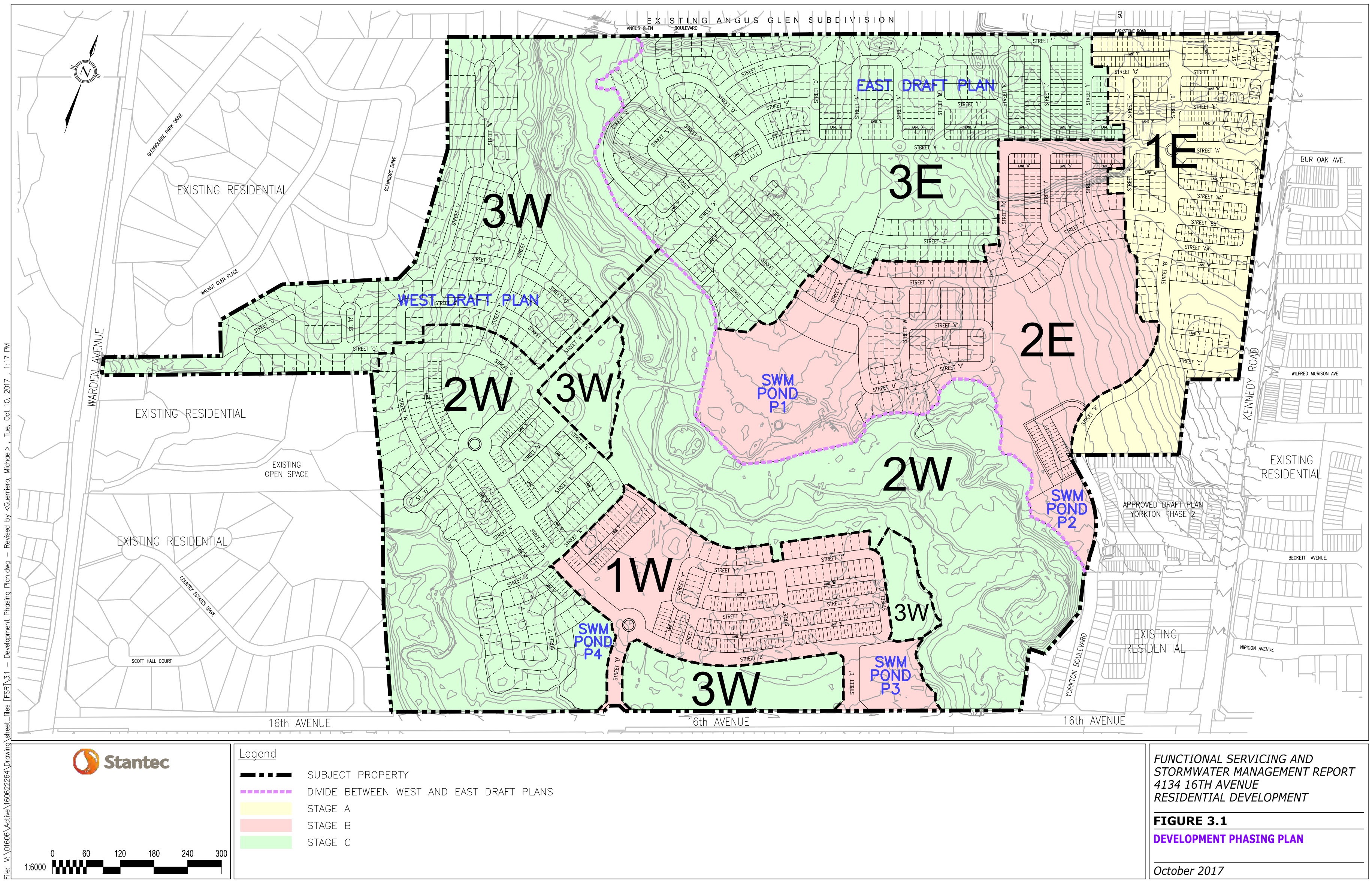
Poulos & Chung

Estimated Pedestrian Trips
AM (PM) Peak Hour)
Figure 7.3

Poulos Chung

XX (YY) AM (PM) Peak Hour Volumes

Estimated Bicycle Trips
AM (PM) Peak Hour)
Figure 7.4



Poulos Chung

Development Phasing Plan
Figure 8.1

Appendix A – Analytical Procedures for Bicycle and Pedestrian Analysis (HCM)

U.S. Department of Transportation
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590
202-366-4000

Federal Highway Administration Research and Technology
Coordinating, Developing, and Delivering Highway Transportation Innovations

Publication Number: FHWA-RD-98-108
Date: February 1998

Capacity Analysis of Pedestrian and Bicycle Facilities

Recommended Procedures for the "Bicycles" Chapter of the Highway Capacity Manual

2. UNINTERRUPTED BICYCLE FACILITIES

This section focuses on the operational analyses of uninterrupted bicycle facilities, including exclusive off–street bicycle paths, mixed–use off–street paths, and designated bicycle lanes (or paved shoulders). The concept of "frequency of events" is proposed as the service measure of effectiveness for all three types of uninterrupted bicycle facilities. Events, for these procedures, are bicycle maneuvers required by a bicyclist on a path, including passings (same direction encounters) and meetings (opposite direction encounters) as presented by Botma (*1995*).

The total frequency of events on a facility for these procedures is related to the service volumes of bicycles using or projected to be using the facility, and does not have to be observed directly. Botma has determined the relationship between service volumes of bicycles and the frequencies of passings and meetings under a variety of conditions with the use of field studies and simulation. These relationships are based on certain assumptions regarding the mean speeds and speed distributions of bicycles and pedestrians, which are listed with the various procedures. The speeds of pedestrians and bicycles and their variability affect the number of passings and meetings that occur. If an analyst has detailed information available regarding local pedestrian and bicycle speeds, alternate volume/frequency relationships can be developed (*Botma, 1995*). However, the development of alternate equations will not be covered here.

A "lane" for bicycles throughout the recommended procedures is considered to be approximately 1.0 m (3.3 ft). However, the actual width of a bicycle facility is much less important than the number of effective bicycle lanes the facility operates with for these analyses. Each additional effective lane being used by bicyclists dramatically increases capacity irrespective of the width of the facility. *While this report assumes that 2.1– to 2.4–m (7– to 8–ft) paths and 3–m (10–ft) paths will typically operate with two and three effective lanes, respectively, a particular facility may operate with a different number of effective lanes. Therefore, it is imperative that the number of effective bicycle lanes be observed in the field where possible prior to conducting these analyses.*

Pending the development of metric standards for bicycle facilities, it is expected that most of the existing 2.4–m– (8–ft–) wide bicycle facilities conforming to current American Association of State and Highway Transportation Officials (AASHTO) English unit standards (*AASHTO, 1991*) will operate as two–lane facilities. However, due to the additional width, one should keep in mind that the LOS derived using the two–lane procedures may be on the conservative side. Unfortunately, until further research is conducted regarding these procedures in the United States, it is impossible to quantify the effect of minor differences in path width for a given number of effective bicycle lanes. However, it is the opinion of the research team that the procedures contained in this document will apply to most of the current existing 2.4–m (8–ft) bicycle facilities in the United States.

When using the following procedures, the analyst should note that bicycle flows have different peaking characteristics than motor vehicles. Bicycle volumes peak more abruptly, especially in the vicinity of college and university campuses. Daily volumes, or even hourly volumes, may not appear to be very substantial until this peaking is considered. One study in Madison, Wisconsin (*Hunter and Huang, 1995*), measured peak hour volumes as 10 to 15 percent of total daily volume at various locations. Another study in the state of Washington (*Niemeier, 1996*), conducted primarily in the Seattle area, measured peak hour factors between 0.52 and 0.82 at various locations. The applicability of these particular observations to other areas is unknown, but it is obvious from these numbers that failure to account for peaking characteristics when determining flow rates will often result in overly optimistic estimates of LOS.

The two–lane path procedures have also been extended to three–lane paths using the three–lane volumes reported by Botma (*1995*) and the same weights between passings and meetings as for two–lane paths. Botma only reported frequencies for two–lane paths in his article because he was unsure of the extension to three lanes. Therefore, the three–lane facility analyses presented here should be used with caution. While it is expected that a two–way path with 3–m (10–ft) lanes will operate with more than two effective lanes, the exact relationship between number of lanes and lane width is not yet known for U.S. conditions, and may depend on local bicyclist behavior.

Perhaps the most important thing to note when using the uninterrupted bicycle facility procedures is that LOS "F" is not equivalent to capacityfor the facility. An unacceptable number of events is always reached prior to capacity, and, in some cases, capacity can be almost twice the volume at which LOS F is reached. *The procedures in this document are based on frequencies of events and perceived LOS, not on the carrying capacity of the facility.*

2.1 Exclusive Off–Street Bicycle Paths

Exclusive off–street bicycle paths are separated from motor vehicle traffic and do not allow pedestrians. These facilities are often constructed to serve areas not served by city streets or to provide recreational opportunities for the public, as illustrated in Figure 1. These bicycle facilities accommodate the highest volumes of bicycles among the three types of uninterrupted facilities addressed in this document, and provide the best LOS because the bicycles are not forced to share the facility with other modes traveling at much higher or lower speeds.

The following equations, which were originally presented by Botma (*1995*), are proposed for computing the total frequency of events on exclusive bicycle paths. The equations are set up for two–way bicycle paths. For one–way exclusive bicycle paths, a value of zero would be used for the bicycle volume traveling in the opposite direction of that being evaluated.

$$F_{pass} = 0.188\,(V_{bike\text{-}sm}) \qquad [1]$$

$$F_{meet} = 2\,(V_{bike\text{-}op}) \qquad [2]$$

$$F_{total} = 0.5(F_{meet}) + F_{pass} \qquad [3]$$

where:

F_{pass} = frequency of passing in events/h;

F_{meet} = frequency of meeting in events/h;

F_{total} = total weighted frequency of events in events/h;

$V_{bike\text{-}sm}$ = bike volume in the same direction being analyzed in bikes/h; and

$V_{bike\text{-}op}$ = bike volume in the opposite direction being analyzed in bikes/h.

The frequencies of meetings and passings resulting from these equations are based on the assumption that bicycle speeds on paths are normally distributed with a mean of 18 km/h (11.2 mi/h) and a standard deviation of 3 km/h (1.9 mi/h). These values are reasonable, based on the information reported in the Bicycle Literature Review Section of the *Research Report*for this project (*Rouphail et al., 1997*). If the observed mean speed or standard deviation of speed differs from these values, equations 1, 2, and 3 cannot be used. Consult Table 5 and Example 3 (described later) for such situations.

FIGURE 1: ***Exclusive bicycle path***

Tables 1 and 2, which are based on Botma's work, are then proposed to convert the total frequency of events to LOS. Service volumes for a 50:50 directional split are provided in the tables for reference. If a 50:50 directional split for the facility an be assumed, the LOS can be obtained directly by using the service volumes in the tables. For splits other than 50:50, Equations 1 through 3 can be used in combination with Tables 1 and 2.

TABLE 1 Level of Service (LOS) for two-lane, two-way exclusive bicycle paths (2.1- to 2.4-m paths)

LOS	Total frequency of events (events/h)	Two-lane service volume (bikes/h) in both directions (50:50 split)
A	< 40	65
B	< 60	105
C	< 100	170
D	< 150	250
E	< 195	325
F	≥ 195	------

SOURCE: Adapted from *Botma*, 1995.

TABLE 2 Level of Service (LOS) for three-lane, two-way exclusive bicycle paths (3–m paths)

LOS	Total frequency of events (events/h)	Three-lane service volume (bikes/h) in both directions (50:50 split)
A	< 90	150
B	< 140	230
C	< 210	350
D	< 300	500
E	< 375	630
F	≥ 375	------

SOURCE: Adapted from *Botma*, 1995.

All the service volumes given in this section for exclusive paths assume "ideal" conditions. Lateral obstructions, extended sections with appreciable grades, and other local factors may reduce the LOS for a facility. Unfortunately, such factors have not been sufficiently documented to date to make a quantitative assessment of their effects.

2.2 Mixed–Use, Off-Street Paths

Mixed-use, off-street paths, like exclusive bicycle paths, are separated from motor vehicle traffic. However, mixed-use paths allow others to use the path, including pedestrians, rollerbladers, rollerskaters, skateboarders, and those in wheelchairs and any other imaginable mode of non-motorized transportation, as illustrated in Figure 2. Mixed-use paths are often constructed for the same reasons as exclusive bicycle paths: to serve areas not served by city streets or to provide recreational opportunities for the public. Mixed-use paths are also very common on university campuses in the United States because motor vehicle traffic and parking are often heavily restricted. In the United States, there are very few paths limited exclusively to bicycles. Most off-street paths in this country fall into the mixed-use path category.

FIGURE 2: ***Mixed–use off–street bicycle path***

On mixed–use facilities, the presence of pedestrians can be detrimental to bicycle capacity because they move at much lower speeds. However, it is very difficult to establish a single bicycle/pedestrian equivalent value because the relationship between the two modes differs depending on their respective volumes, directional splits, and other conditions.

Note that the LOS on a mixed–use facility is not necessarily the same from the viewpoint of pedestrians and bicycles. Pedestrian LOS on mixed–use paths is discussed separately in the pedestrian chapter of the *Research Report*for this project (*Rouphail et al., 1997*).

The following equations, which were originally presented by Botma (*1995*), are proposed for computing the total frequency of events on mixed–use bicycle paths. The equations are set up for two–way bicycle paths. For the rare case of one–way mixed–use bicycle paths (i.e., a 100/0 directional split), the analyst would enter a value of zero for both the bicycle and pedestrian volumes traveling in the opposite direction of that being evaluated.

$$F_{pass} = 3\,(V_{ped\text{–}sm}) + 0.188\,(V_{bike\text{–}sm}) \quad [4]$$

$$F_{meet} = 5\,(V_{ped\text{–}op}) + 2\,(V_{bike\text{–}op}) \quad [5]$$

$$F_{total} = 0.5(F_{meet}) + F_{pass} \quad [6]$$

where:

F_{pass} = frequency of passing in events/h;

F_{meet} = frequency of meeting in events/h;

F_{total} = total weighted frequency of events in events/h;

$V_{ped\text{-}sm}$ = pedestrian volume in the same direction being analyzed in ped/h;

$V_{ped\text{-}op}$ = bike volume in the opposite direction being analyzed in ped/h;

$V_{bike\text{-}sm}$ = bike volume in the same direction being analyzed in bikes/h; and

$V_{bike\text{-}op}$ = bike volume in the opposite direction being analyzed in bikes/h.

As in the previous section, the frequencies of meetings and passings resulting from these equations are also based on the assumption that bicycle speeds are normally distributed with a mean of 18 km/h (11.2 mi/h), and that pedestrian speeds are normally distributed with a mean of 4.5 km/h (2.8 mi/h). Slower average pedestrian speeds would cause an increase in the frequency of both passings and meetings.

The frequency of events for mixed-use paths for several different bicycle volumes and directional splits has been computed at selected pedestrian volumes for the convenience of the user. These are presented in Table 3. Alternatively, the user may utilize Equations 4 through 6 to compute the total frequency of events. Once computed, the number of events is entered in Table 4 to estimate the prevailing LOS.

TABLE 3 Total frequency of events for mixed-use paths

Bike vol both dir (bikes/h)	Directional split of bikes (same:opp)	Total frequency of events (events/h)			
		Two-way pedestrian volumes of			
		0 (ped/h)*	20 (ped/h)*	40 (ped/h)*	80 (ped/h)*
100	30:70	76	131	186	296
100	40:60	68	123	178	288
100	50:50	59	114	169	279
100	60:40	51	106	161	271
100	70:30	43	98	153	263
200	30:70	151	206	261	371
200	40:60	135	190	245	355
200	50:50	119	174	229	339
200	60:40	103	158	213	323
200	70:30	86	141	196	306
400	30:70	303	358	413	523
400	40:60	270	325	380	490
400	50:50	238	293	348	458
400	60:40	205	260	315	425
400	70:30	173	228	283	393

800	30:70	605	660	715	825
800	40:60	540	595	650	760
800	50:50	475	530	585	695
800	60:40	410	465	520	630
800	70:30	345	400	455	565
* 50:50 directional split assumed for pedestrians					

SOURCE: Adapted from *Botma*, 1995.

It is important to note that all the service volumes given in this section for mixed-use paths assume "ideal" geometric and traffic conditions. Lateral obstructions, extended sections with appreciable grades, and other local factors may reduce the LOS for a facility. Unfortunately, such factors have not been sufficiently documented to date to make a quantitative assessment of their effects.

TABLE 4 Bicycle Level of Service (LOS) for mixed-use paths

LOS	Total frequency of events (events/h) for two-lane paths (2.1- to 2.4-m paths)	Total frequency of events (events/h) for three-lane paths (3-m paths)
A	< 40	< 90
B	< 60	< 140
C	< 100	< 210
D	< 150	< 300
E	< 195	< 375
F	≥ 195	≥ 375

SOURCE: Adapted from *Botma*, 1995.

2.3 On-Street Bicycle Facilities

Bicycle lanes are lanes on a street designated exclusively for the use of bicycles. These lanes are separated from motor vehicle traffic by pavement markings, as illustrated in Figure 3. Bicycle lanes are normally placed on streets where bicycle use is fairly high and the separation of bicycles from motor vehicle traffic is warranted. For additional information about the planning for on-street bicycle facilities, the user is referred to a study by Harkey et al. (*1998*).

Paved shoulders are part of the cross section of the street, but not part of the traveled way for motor vehicles. Bicycles using paved shoulders are separated from motor vehicles by the right edge line (shoulder stripe). Paved shoulders are often constructed on new roadway facilities when allowed by right-of-way requirements.

Bicycles generally use paved shoulders as one-way facilities in the same direction as motor vehicle traffic, much like bicycle lanes. For the purpose of analysis, designated bicycle lanes and paved shoulders will be treated the same. The procedures in this section are appropriate for on-street facilities where there are significant distances between interruptions, such as traffic signals or STOP signs. See the Combined Bicycle Facility section of this document for a discussion of on-street bicycle lanes or paved shoulders with frequent interruptions.

FIGURE 3: ***Designated on-street bicycle lane***

The widths of on-street bicycle facilities vary greatly in the United States, ranging from 1.2-m (4-ft) designated bicycle lanes to 3-m-(10-ft-) wide paved shoulders. However, due to the fact that bicycles using on-street facilities can "borrow" space from the adjacent lane under low to moderate motor vehicle volumes, there are very few on-street facilities that do not operate with at least two effective lanes (allowing passing). Due to this and the fact that on-street bicycle facilities are normally provided for the exclusive use of bicycles, it is recommended that the procedures for exclusive bicycle paths presented previously in this document also be used here for on-street facilities.

It is expected that on-street bicycle lanes and paved shoulders with widths up to 1.8 m (6 ft) will operate with two effective lanes and that wider paved shoulders will operate as three effective lanes. However, heavy motor vehicle volumes, high speeds, roadway debris, or other local conditions may affect the actual width available to the bicyclists. *As mentioned earlier, an observation of facility operation prior to analysis is recommended to determine the actual number of effective lanes.*

One important distinction between on-street facilities and exclusive off-street facilities is the multitude of possible factors affecting LOS for on-street facilities, including adjacent motor vehicle traffic (which is often moving much faster than the bicycles), heavy vehicle traffic, commercial and residential driveways, and adjacent on-street parking. The service volumes given in this section for on-street facilities are for "ideal" conditions. The factors mentioned here, in addition to lateral obstructions, extended sections with appreciable grades, and other local factors, may reduce the LOS for a facility. Unfortunately, such factors have not been sufficiently documented to date to make a quantitative assessment of their effects. One possible approach to determining LOS for on-street bicycle facilities is to quantify the impact of prevailing geometric and traffic conditions on the *average and standard deviation of bicycle speeds on the facility*. Under this framework, the expectation is that friction with vehicular traffic, parked vehicles, and driveway density would result in a lower mean speed and higher standard deviation than on a comparable off-street path. To illustrate this effect, Table 5 gives the number of events and corresponding LOS for a range of bicycle volumes and average and standard deviations of bicycle speeds. As indicated in the table, the number of events

increases (and LOS drops) as speed decreases and standard deviation increases. For example, with a bicycle flow rate of 200 bicycles/h, the LOS may vary from A to E depending on the observed values of mean and standard deviation of bicycle speeds. With proper calibration of these two parameters, the proposed methodology could, therefore, be equally applied to on-street bicycle facilities. The standard deviation of speeds describes the variation in speeds about the average or mean bicycle speed for the facility. The standard deviation will be relatively smaller for those facilities used primarily by commuters, and relatively larger for recreational facilities.

TABLE 5 Effect of bicycle mean and standard deviation of speeds on events and Level of Service (LOS) for one-way, on-street bicycle facilities

Bicycle flow rate (bike/h)	Standard deviation [a] (km/h)	Number of events and LOS								
		Bicycle mean speed (km/h)								
		12	13	14	15	16	17	18	19	20
100	1.5	28 (A)	26 (A)	24 (A)	---	21 (A)	20 (A)	19 (A)	18 (A)	17 (A)
100	3.0	56 (B)	52 (B)	48 (B)	23 (A)	42 (B)	40 (B)	38 (A)	36 (A)	34 (A)
100	4.5	85 (C)	78 (C)	73 (C)	68 (C)	63 (C)	60 (C)	56 (B)	53 (B)	51 (B)
200	1.5	56 (B)	52 (B)	48 (B)	45 (B)	42 (B)	40 (B)	38 (A)	36 (A)	34 (A)
200	3.0	113 (D)	104 (D)	97 (C)	90 (C)	85 (C)	80 (C)	75 (C)	71 (C)	68 (C)
200	4.5	169 (E)	156 (E)	145 (D)	135 (D)	127 (D)	119 (D)	113 (D)	107 (D)	102 (D)
300	1.5									

		85 (C)	78 (C)	73 (C)	68 (C)	63 (C)	60 (C)	56 (B)	53 (B)	51 (B)
300	3.0	169 (E)	156 (E)	145 (D)	135 (D)	127 (D)	119 (D)	113 (D)	107 (D)	102 (D)
300	4.5	254 (F)	234 (F)	218 (F)	203 (F)	190 (E)	179 (E)	179 (E)	160 (E)	152 (E)

[a]Standard deviation of bicycle speeds. If standard deviation data are unavailable, use the following default values:
1.5 km/h for facilities used primarily by commuters
2.0 km/h for facilities used by various user types
4.5 km/h for facilities used primary by recreational users

SOURCE: Adapted from *Botma*, 1995.

Previous | Table of Contents | Next

Page Owner: Office of Research, Development, and Technology, Office of Safety, RDT

Topics: research, safety, pedestrian & bicycle safety, bicyclists and pedestrians
Keywords: research, safety, bicycle, mixed-use, level of service
Scheduled Update: Archive - No Update needed

This page last modified on 03/08/2016

Pedestrian Levels of Service

CHAPTER 2.

CURRENT HCM METHODOLOGY

The Highway Capacity Manual (HCM) by the Transportation Research Board (TRB) is used as the industry standard for analyzing traffic of different transportation modes. The HCM uses the concept of level of service (LOS) as a qualitative measure to describe operational conditions of vehicular and pedestrian traffic, "based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience." The section of the HCM dedicated to the level of service analysis of pedestrian flow on sidewalks, crosswalks, and street corners is mainly derived from John Fruin's research. In this chapter, the HCM's current pedestrian and vehicular methodologies will be discussed, compared and contrasted. A discussion of the strengths and weaknesses of the pedestrian level of service methodology in the HCM concludes the chapter.

A. Pedestrian LOS

The HCM's methods for analyzing pedestrian LOS are based on the measurement of pedestrian flow rate and sidewalk space. The pedestrian flow rate, which incorporates pedestrian speed, density, and volume, is equivalent to vehicular flow. According to the HCM:

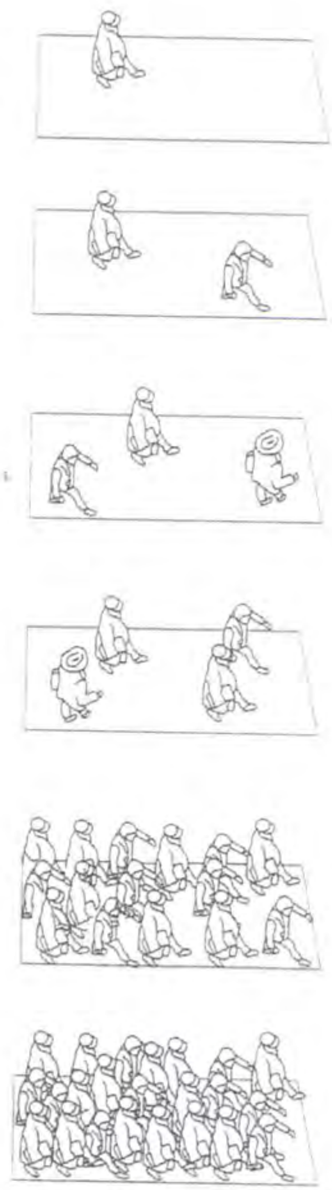
> "As volume and density increase, pedestrian speed declines. As density increases and pedestrian space decreases, the degree of mobility afforded to the individual pedestrian declines, as does the average speed of the pedestrian stream."

The analysis of the sidewalk level of service for the midblock uses the calculation of pedestrians per minute per foot (ped/min/ft) as the basis for LOS classification (see Table 2.1.). According to this measurement, on a walkway with LOS A, pedestrians move freely without altering their speed in response to other pedestrians or to a decrease in the sidewalk width. On the other hand, on a walkway with LOS F, all walking speeds are severely restricted and forward progress is made only by "shuffling." See Figure 2.1. for the HCM's description for each pedestrian LOS.

The pedestrian unit flow rate (ped/min/ft) is obtained by taking the pedestrian 15-minute flow rate (ped/15-min) and dividing by the effective walkway width. The HCM suggests collecting pedestrian opposing flow volumes at 15-minute intervals. The sum of the two directional flows is used as the 15-minute flow rate. Effective width of the sidewalk is calculated by taking the total width of the sidewalk and subtracting obstacle widths and a 1 to 1.5 ft buffer width per obstacle. Obstacle widths can be measured from the field. The additional buffer width is based on an estimation provided by the HCM. The HCM cites Pushkarev and Zupan (1975) as their source for the method of buffer width calculation; however, no studies the TD has found, including the cited Pushkarev and Zupan volume, describe any method of buffer width calculation. Using the pedestrian

Table 2.1. Average Flow LOS Criteria for Walkways and Sidewalks

LOS	Space (ft^2/p)	Flow Rate (p/min/ft)	Speed (ft/s)	V/C Ratio
A	> 60	≤ 5	> 4.25	≤ 0.21
B	> 40-60	> 5-7	> 4.17-4.25	> 0.21-0.31
C	> 24-40	> 7-10	> 4.00-4.17	> 0.31-0.44
D	>15-24	> 10-15	> 3.75-4.00	> 0.44-0.65
E	> 8-15	> 15-23	> 2.50-3.75	> 0.65-1.00
F	≤ 8	variable	≤ 2.50	variable



LOS A
Pedestrian Space > 60 ft^2/p, Flow Rate = 5 p/min/ft
At a walkway LOS A, pedestrians move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.

LOS B
Pedestrian Space > 40-60 ft^2/p, Flow Rate > 5-7 p/min/ft
At LOS B, there is sufficient area for pedestrians to select walking speeds freely to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians, and to response to their presence when electing a walking path.

LOS C
Pedestrian Space > 24-40 ft^2/p, Flow Rate > 7-10 p/min/ft
At LOS C, space is sufficient for normal walking speeds, and for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, and speeds and flow rate are somewhat lower.

LOS D
Pedestrian Space > 15-24 ft^2/p, Flow Rate > 10-15 p/min/ft

At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Crossing or reverse-flow movements face a high probability of conflict, requiring frequent changes in speed and position. The LOS provides reasonably fluid flow, but friction and interaction between pedestrians is likely.

LOS E
Pedestrian Space > 8-15 ft^2/p, Flow Rate > 15-23 p/min/ft

At LOS E, virtually all pedestrians restrict their normal walking speed, frequently adjusting their gait. At the lower range, forward movement is possible only by shuffling. Space is not sufficient for passing slower pedestrians. Cross- or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with stoppages and interruptions to flow.

LOS F
Pedestrian Space = 8 ft^2/p, Flow Rate varies p/min/ft
At LOS F, all walking speeds are severely restricted, and forward progress is made only by shuffling. There is frequent unavoidable contact with other pedestrians. Cross-and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams.

Figure 2.1. Pedestrian LOS according to HCM

unit flow rate in the "Average Flow LOS Criteria for Walkways and Sidewalks" (see Table 2.1), pedestrian LOS can be calculated. In addition to LOS grades A to F, space (ft^2/p), speed (ft/s), and the volume-to-capacity (v/c) ratio can also be derived from the table. Capacity is "the maximum number of persons that can be accommodated along a given point of a sidewalk or transit corridor, or that can be accommodated within a crosswalk, intersection, corner reservoir, transit vehicle or turnstile" (CEQR). The volume-to-capacity ratio is "the ratio of flow rate to capacity for a transportation facility" (HCM).

Pedestrians often travel together as a group, voluntarily or involuntarily, due to signal control, geometrics, or other factors. This phenomenon is called platooning and it occurs, for example, when a large number of bus or subway riders exit onto the sidewalk. To account for the impact of platooning on pedestrian travel behavior, the HCM introduces the "Platoon-Adjusted LOS Criteria for Walkways and Sidewalks," a table which can be used to obtain the platoon LOS. Using research done by Pushkarev and Zupan in *Urban Space for Pedestrians*, impeded flow in the HCM platoon LOS starts at 530 ft^2/p, 0.5 ped/min/ft (LOS A); while "jammed flow" begins at 11 ft^2/p, 18ped/min/ft (LOS F) (see Table 2.2.). The HCM states that the LOS which occurs in platoons is generally one level poorer than that determined by average flow criteria.

Table 2.2. Platoon-Adjusted LOS Criteria for Walkways and Sidewalks

LOS	Space (ft^2/p)	Flow Rate (p/min/ft)
A	> 530	≤ 0.5
B	> 90-530	> 0.5-3
C	> 40-90	> 3-6
D	> 23-40	> 6-11
E	> 11-23	> 11-18
F	≤ 11	> 18

B. Vehicular LOS

Similarly to the pedestrian HCM LOS analysis, vehicular LOS analysis is based on a scale from A through F, with A representing the best and F representing the worst traveling conditions. There are three street categories in the vehicular LOS analysis: urban streets, freeways, and highways. Within the urban street analysis, there are sub-analyses for arterial, signalized and unsignalized intersections. The main criterion for evaluating the LOS of arterial streets is travel speed (Table 2.3). The criterion for determining LOS at signalized and unsignalized intersections is control delay per vehicle, in seconds per vehicle (Tables 2.4. and 2.5). Delay is the "additional travel time experienced by a driver, passenger or pedestrian" (HCM). Control delay is defined by "initial deceleration delay, queue move-up, stopped delay, and final acceleration delay" (HCM). Signals are often put in place to handle high traffic flow at intersections. Combining higher volumes with drivers' perceptions and reaction times to traffic signals, signalized intersections often have higher delays than unsignalized intersections. A roundabout is defined by the Federal Highway Administration as "a one-way, circular intersection without traffic signal equipment in which traffic flows around a center island". Roundabout analysis in the HCM is based on gap acceptance - or "the process by which a minor-street vehicle accepts an available gap to maneuver" (HCM) – and it is evaluated in terms of capacity and v/c ratio. For vehicular traffic, capacity is defined as "the maximum numbers of vehicles that can pass a point on a street or highway during a specified time period, usually expressed as vehicles per hour" (CEQR). No formal LOS has been established for roundabouts by the HCM.

The two-lane highway LOS analysis is separated into Class I and Class II categories. The HCM explains that, on Class I highways, "efficient mobility is paramount, and LOS is defined in terms of both percent time-spent-following and average travel speed." (see Table 2.6.). On Class II highways, however, "mobility is less critical and LOS is defined only in terms of per time-spent-following, without consideration of average travel speed" (see Table 2.7.). According to

Table 2.3. Urban Street LOS by Class

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	50-45 mi/h	45-35 mi/h	35-30 mi/h	35-25 mi/h
Typical FFS	50 mi/h	40 mi/h	35 mi/h	30 mi/h
LOS	Average Travel Speed (mi/h)			
A	> 42	> 35	> 30	> 25
B	> 34-42	> 28-35	> 24-30	> 19-25
C	> 27-34	> 22-28	> 18-24	> 13-19
D	> 21-27	> 17-22	> 14-18	> 9-13
E	> 16-21	> 13-17	> 10-14	> 7-9
F	≤ 16	≤ 13	≤ 10	≤ 7

Table 2.4. LOS Criteria for Signalized Intersections

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10-20
C	> 20-35
D	> 35-55
E	> 55-80
F	>80

Table 2.5. LOS Criteria for Two-Way (TWSC) and All-Way Stop-Controlled (AWSC) Intersections

LOS	Control Delay per Vehicle (s/veh)
A	0-10
B	>10-15
C	>15-25
D	>25-35
E	>35-50
F	>50

Table 2.6. LOS Criteria for Two-Lane Highways in Class I

LOS	Percent Time-Spent-Following	Average Travel Speed (mi/h)
A	≤ 35	> 55
B	> 35-50	> 50-55
C	> 50-65	> 45-50
D	> 65-80	> 40-45
E	> 80	≤ 40

Table 2.7. LOS Criteria for Two-Lane Highways in Class II

LOS	Percent Time-Spent-Following
A	≤ 40
B	> 40-55
C	>55-70
D	> 70-85
E	> 85

the HCM, drivers usually have a higher tolerance for delay on Class II highways because Class II highways tend to serve shorter trips.

The HCM's Multilane Highway analysis focuses on uninterrupted highway flow segments. The characteristics of a multilane highway include a 12-foot minimum lane width, a 12-foot minimum total lateral clearance, facilities for passenger cars only, the absence of direct access points, a divided highway, and free-flow speeds higher than 60 mi/hr. The LOS criteria for multilane highways are based on "typical speed-flow" and "density-flow relationships" (see Table 2.8.). Since LOS F indicates that the flow rate exceeds capacity, it is not listed in the table.

Table 2.8. LOS Criteria for Multilane Highways

Free Flow Speed	Criteria	A	B	C	D	E
60 mi/h	Maximum density (pc/mi/l)	11	18	26	35	40
	Average speed (mi/h)	60.0	60.0	59.4	56.7	55.0
	Maximum v/c	0.30	0.49	0.70	0.90	1.00
	Maximum service flow rate (pc/h/ln)	660	1,080	1,550	1,980	2,200
55 mi/h	Maximum density (pc/mi/l)	11	18	26	35	41
	Average speed (mi/h)	55.0	55.0	54.9	52.9	51.2
	Maximum v/c	0.29	0.47	0.68	0.88	1.00
	Maximum service flow rate (pc/h/ln)	600	990	1,430	1,850	2,100
50 mi/h	Maximum density (pc/mi/l)	11	18	26	35	43
	Average speed (mi/h)	50.0	50.0	50.0	48.9	47.5
	Maximum v/c	0.28	0.45	0.65	0.86	1.00
	Maximum service flow rate (pc/h/ln)	550	900	1,330	1,710	2,000
45 mi/h	Maximum density (pc/mi/l)	11.0	18.0	26.0	35.0	45.0
	Average speed (mi/h)	45	45	45	44.4	42.2
	Maximum v/c	0.26	0.43	0.62	0.82	1.00
	Maximum service flow rate (pc/h/ln)	490	810	1,170	1,550	1,900

The HCM LOS analysis methodology for freeway facilities is separated into three categories: basic freeway segments, ramp segments, and weaving segments. The HCM assumes that the performance of each of the freeway components does not affect the performance of the others. The freeway segment methodology treats each segment in terms of an individual scenario, with no impact on adjacent segments. Therefore, there is no one general LOS designation for freeway facilities; instead there are basic freeway, ramp, and weaving LOS ratings. Basic freeway LOS analysis is defined by density (vehicle per mile per lane), speed, and the volume to capacity ratio for passenger cars (see Table 2.9.). In the weaving analysis, LOS is defined by the weaving segment density (vehicle per mile per lane) (Table 2.10.). In the ramp segments analysis, the HCM focuses on the merging and diverging areas of ramps to freeways. LOS is denoted from A to E only, as LOS F represents a demand over capacity conditions (see Table 2.11.).

C. Pedestrian LOS and Vehicular LOS Comparison

The HCM's pedestrian LOS analysis criteria are based on space, average speed, flow rate, and the ratio of volume to capacity. There are some similarities in the pedestrian analysis to the determination of vehicular LOS. For example, pedestrian space (ft^2/ped) is equivalent to vehicular density on multi-lane highway and freeway facilities, including basic freeway, ramp, and weaving segments. Pedestrian average speed (ft/min) is equivalent to vehicular average travel speed (mi/hr) for urban streets, Class I two-lane and multilane highways, and basic freeways. The pedestrian flow rate (ped/min/ft) is equivalent to vehicular flow rate (passenger car/hr/lane) on multilane highways and basic freeways. In addition, the pedestrian's volume to capacity ratio is the equivalent of the volume to capacity ratio on multilane highways and basic freeway segments.

In contrast to pedestrian LOS calculations, vehicular LOS analysis includes a "control delay per vehicle" component in the analysis of signalized and unsignalized intersections. Control delay is the travel

Table 2.9. LOS Criteria for Basic Freeway Sections

Level of Service	Maximum Density (pc/mi/ln)	Maximum Speed (mph)	Max Service Flow Rate (PCPHPL)	Maximum v/c ratio
Free-flow Speed = 70 mph				
A	10.0	70.0	700	0.318/0.304
B	16.0	70.0	1,120	0.509/0.487
C	24.0	68.5	1,644	0.747/0.715
D	32.0	63.0	2,015	0.916/0.876
E	36.7/39.7	60.0/58.0	2,200/2,300	1.000
F	var	var	var	Var
Free-flow Speed = 65 mph				
A	10.0	65.0	650	0.295/0.283
B	16.0	65.0	1,040	0.473/0.452
C	24.0	64.5	1,548	0.704/0.673
D	32.0	61.0	1,952	0.887/0.849
E	39.3/43.4	56.0/53.0	2,200/2,300	1.000
F	var	var	var	var
Free-flow Speed = 60 mph				
A	10.0	60.0	600	0.272/0.261
B	16.0	60.0	960	0.436/0.417
C	24.0	60.0	1,440	0.655/0.626
D	32.0	57.0	1,824	0.829/0.793
E	41.5/46.0	53.0/50.0	2,200/2,300	1.000
F	var	var	var	var
Free-flow Speed = 55 mph				
A	10.0	55.0	550	0.250/0.239
B	16.0	55.0	880	0.400/0.383
C	24.0	55.0	1,320	0.600/0.574
D	32.0	54.8	1,760	0.800/0.765
E	44.0/47.9	50.0/48.0	2,200/2,300	1.000
F	var	var	var	var

Table 2.10. LOS Criteria for Weaving Segments

LOS	Density (pc/mi/ln)	
	Freeway Weaving Segment	Multilane and Collector-Distributor Weaving Segments
A	≤ 10.0	≤ 12.0
B	> 10.0-20.0	>12.0-24.0
C	> 20.0-28.0	>24.0-32.0
D	> 29.0-35.0	>32.0-36.0
E	> 35.0-43.0	>36.0-40.0
F	> 43.0	> 40.0

Table 2.11. LOS Criteria for Merge and Diverge Areas

LOS	Density (pc/mi/ln)
A	≤ 10
B	> 10-20
C	> 20-28
D	> 28-35
E	> 35
F	Demand exceeds capacity

time vehicles waste due to signal timing, queuing and stop and start time; it is the travel time that one would incur on stop controlled street facilities in excess of the time it would take to traverse the same distance with no control devices. In addition, the pedestrian LOS analysis lacks percent time-spent-following criteria, a measurement found in analyses of Class I and Class 2 two-lane highways. Percent time-spent-following is defined by the HCM as "...the average percentage of travel time that vehicles must travel in platoons behind slower vehicles due to the inability to pass."

D. Pedestrian HCM LOS Strengths and Weaknesses

The HCM pedestrian LOS methodology's foremost advantage is its simplicity. It is relatively easy to collect data and calculate the pedestrian LOS for a location. For the midblock pedestrian LOS, the only data necessary is a pedestrian count, the effective width of the sidewalk, and an indication whether or not platooning was occurring.

Second, the pedestrian LOS methodology attempts to create a universal standard in pedestrian analysis regardless of the size of the city, the type of pedestrians, or various environmental factors. This allows planners to easily compare the LOS derived across locations and time.

Third, although the standard LOS calculation is fixed, the HCM's pedestrian LOS methodology allows for local flexibility based on actual conditions. For example, the HCM encourages planners to consider their own LOS methodologies in areas with significant elderly populations or with a dominant trip purpose.

Finally, the pedestrian LOS methodology is not static—it evolves as researchers discover new relationships between factors or as they discover new ways to collect and model data. In fact, the TRB made significant changes to the pedestrian LOS chapters as recently as 2000.

However, the pedestrian LOS methodology does have shortcomings. Pedestrian flow rate is used to assign LOS in the HCM. For example, from the sum of two directional counts, a count of 800 pedestrians on a 12-foot effective sidewalk width yields a flow rate of 4.44 ped/ft/min. Looking up the flow rate on the "Average Flow LOS Criteria for Walkways and Sidewalks" tables (Tables 2.1. and 2.2.), an LOS of A and C for normal and platoon conditions are identified respectively. From the tables, one can also get the values of speed, space, and the V/C ratio based on the flow rates from previous research. Using the HCM methodology, the flow rate calculation does not account for possible bi-directional or multi-directional effects. Flow rate is calculated using the sum of the two directional counts. Therefore, friction introduced by the opposing pedestrian flow is not accounted for.

The HCM methodology also generalizes the makeup of the study population without much consideration for individual pedestrian characteristics. For example, pedestrians' gender, age, and trip purpose could have significant impact on their speed and comfort level on different sidewalk segments. Different times of a day, surrounding land uses, and weather could also affect the sidewalk LOS.

The sidewalk effective width is calculated in the HCM's methodology by taking the total width and subtracting sidewalk obstacle widths and a "shy distance", which is the buffer distance that pedestrians typically walk from obstacles. The shy distance is estimated in the HCM to be 1 to 1.5 feet. No detailed studies the TD has come across, including the Pushkarev and Zupan (1975) book which the HCM cited as the source of the shy distance measurement, have described how to calculate a shy distance. It would seem that the shy distance of pedestrians on an individual sidewalk could be affected by the number of pedestrians on the sidewalk, the time of day, and by the surrounding land use. It is important to find out what the real effective width is for each sidewalk if flow rate is to be used as the determining factor for LOS; this would involve developing a repeatable methodology for calculating a sidewalk's shy distance.

The HCM's pedestrian LOS methodology appears to be too insensitive to changes in pedestrian volume and sidewalk width. For example, a case study was done by the Department of City Planning, Transportation Division to examine whether the reduction of sidewalk space by sidewalk café's would induce a significant impact on the pedestrian LOS. A series of tests were done using the HCM's LOS methodology.

The tests revealed that the number of pedestrians that would need to be added to a sidewalk to degrade the sidewalk's LOS was insensitive (see Table 2.12.). For example, on a sidewalk with twelve-foot effective width, with 1,300 pedestrians in a fifteen-minute period, the LOS was C; it would take an additional 600 pedestrians for the LOS to change to D. This translates into an hourly volume of 7,600 pedestrians

Table 2.12. Sidewalk Width, Pedestrian Volume and Level of Service

The following chart shows the pedestrian level of service for sidewalks with varying clear paths.
- The top portion of the chart shows café width alternatives for various sidewalk widths. (Café widths that would be unavailable under current zoning restrictions are italicized.)
- The bottom portion of the chart shows the clear path for adjacent sidewalks along the top. On the vertical axis, possible pedestrian volumes are shown. The center of the chart shows the pedestrian Level of Service (LOS), based on those two inputs.

Café Widths	**Sidewalk Width (ft)**								
8' Sidewalk Café	*12*			*15*			18		20
7' Sidewalk Café		*12*			15			18	
6' Sidewalk Café			*12*			15			18
5' Sidewalk Café				*12*			15		
4' Sidewalk Café					12			15	
	Clear Path*								
15 Min Peak Flow Rate (ped/15 min)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
200	A	A	A	A	A	A	A	A	A
300	B	A	A	A	A	A	A	A	A
400	B	B	A	A	A	A	A	A	A
500	C	B	B	A	A	A	A	A	A
600	C	C	B	B	B	A	A	A	A
700	D	C	C	B	B	B	A	A	A
800	D	D	C	C	B	B	B	A	A
900	D	D	C	C	C	B	B	B	B
1000	E	D	D	C	C	C	B	B	B
1100	E	D	D	D	C	C	C	B	B
1200	E	E	D	D	C	C	C	C	B
1300	E	E	D	D	D	C	C	C	C
1400	F	E	E	D	D	D	C	C	C
1500	F	E	E	D	D	D	C	C	C
1600	F	E	E	E	D	D	D	C	C
1700	F	E	E	E	D	D	D	D	C
1800	F	F	E	E	D	D	D	D	C
1900	F	F	E	E	E	D	D	D	D
2000	F	F	E	E	E	D	D	D	D
2100	F	F	F	E	E	E	D	D	D

* For the purposes of this chart, Clear Path is defined as the perpendicular distance from the edge of the sidewalk café to the curb. LOS is typically calculated using the effective sidewalk width, which deducts sidewalk width for street furniture and other obstructions. However, the LOS figures shown on this chart are calculated with the clear path and are intended for illustrative purposes.

NYC Department of City Planning, Transportation Division, 25 June 2002 on a 12-foot wide sidewalk in order to have a LOS D. During odata collection, the highest pedestrian traffic during the AM peak was on the north sidewalk (12.4 feet wide) of Wall Street between William and Hanover, the volume was just over 3,000 pedestrians per hour. During the midday peak, on the east sidewalk (11.5 feet wide) of Broadway between Wall and Pine Street, there were 4,200 pedestrians hourly. Therefore, it seems almost impossible for a sidewalk to get an LOS D.

In order to help conceptualize the HCM's measurement of LOS, two series of thirty still images from a 15-minute video of a sidewalk's pedestrian traffic were captured in Lower Manhattan. These images were part of the data collection effort for this project (see Chapters 4 and 5 for further explanation of the methodology and the data analysis). One frame was exported from the 15-minute video clip every thirty seconds. In Figure 2.2, these frames are shown in sequence by time from left to right and top to bottom.

The first location, chosen to illustrate a LOS A and platoon LOS C, is this project's control location, the west sidewalk of Broadway between Duane Street and Reade Street (see Figure 2.2.). The control location is where the TD goes back repeatedly to collect data to study for daily, monthly, or seasonal variation. The fifteen-minute video for this location was filmed on April 19, 2004, at 3:15 pm. A total of 562 pedestrians were counted on the sidewalk during this fifteen-minute period. The total sidewalk width is 16.2 ft and the effective width is 14.2 ft, based on the HCM's effective width calculation methodology. According to the HCM, this section has an LOS A for overall conditions, and an LOS C for platoon conditions. A square with an approximate area of 60 ft^2 was drawn in frame 0:05:30. Using this square space, it is possible to compare a real life street condition in a 60 ft^2 space to the HCM's illustration in Figure 2.1., and consider what LOS ratings means in terms of space. 60 ft^2/pedestrian is the minimum space that has to be available for each pedestrian for a sidewalk to achieve LOS A. However, based on the observation of the image sequence, pedestrians seem to have less than 60 ft^2 of available space on average. Using the platoon condition LOS C (24-40 ft^2/pedestrian) to describe the location maybe closer to reality.

The second location is the south sidewalk of John Street between Cliff Street and Pearl Street (see Figure 2.3.). The video at this location was filmed on April 20, 2004, at 1:20 pm. A total of 471 pedestrians were counted on the sidewalk during the fifteen minute filming time. The total sidewalk width is 12 ft, and the HCM-calculated effective width is 5 ft. According to the HCM, this section has LOS B for overall conditions and LOS D for platoon conditions. Frame 0:08:00 shows the 60 ft^2 area. As in the previous location, the images show a sidewalk that, on average, seems more congested than a sidewalk should if it corresponded to the HCM's criteria and diagrams of LOS B. The platoon condition of LOS D (15-24 ft^2/pedestrian) may be better in describing this sidewalk's crowdedness.