

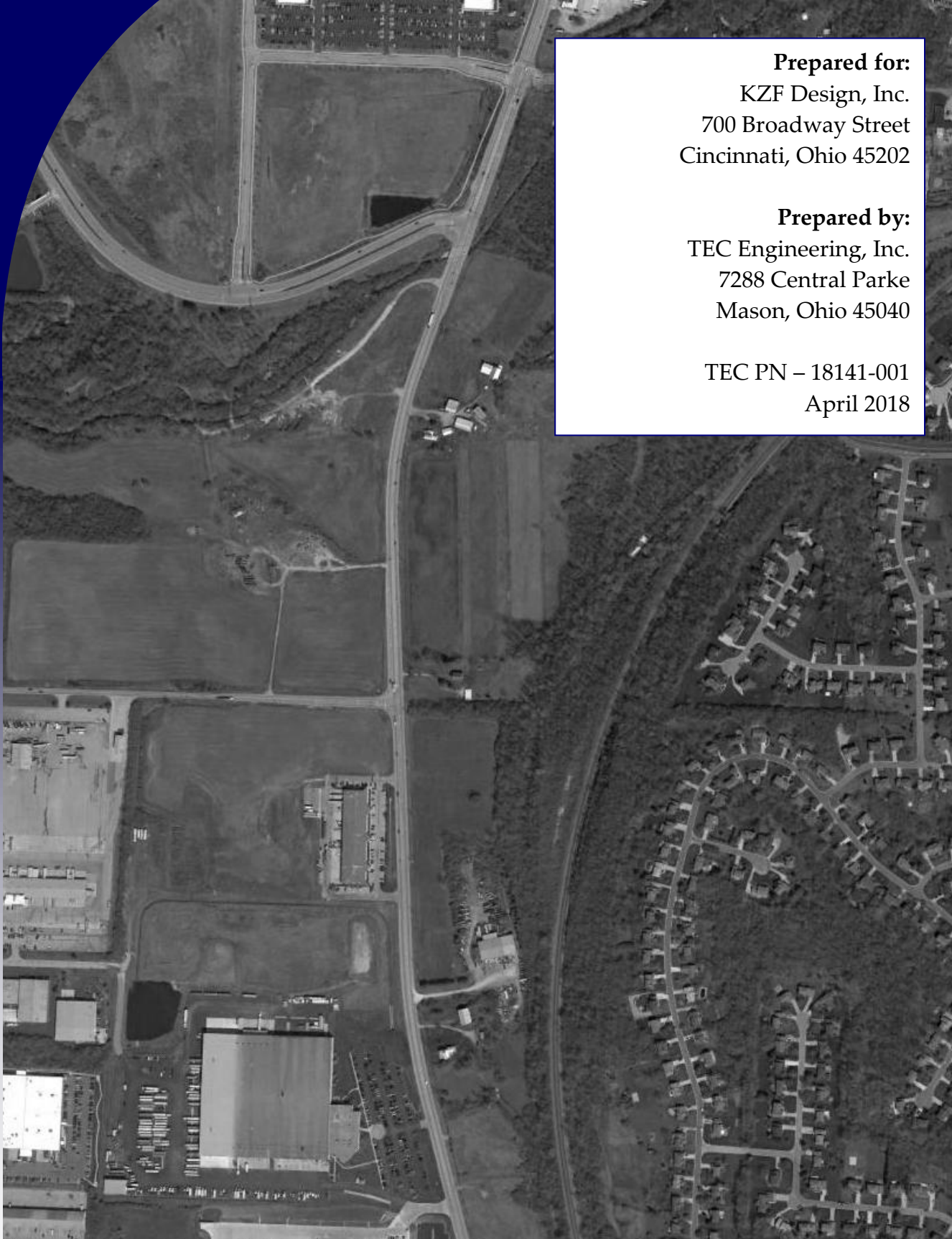
Traffic Impact Study-Equipment Depot West Chester Township, Ohio

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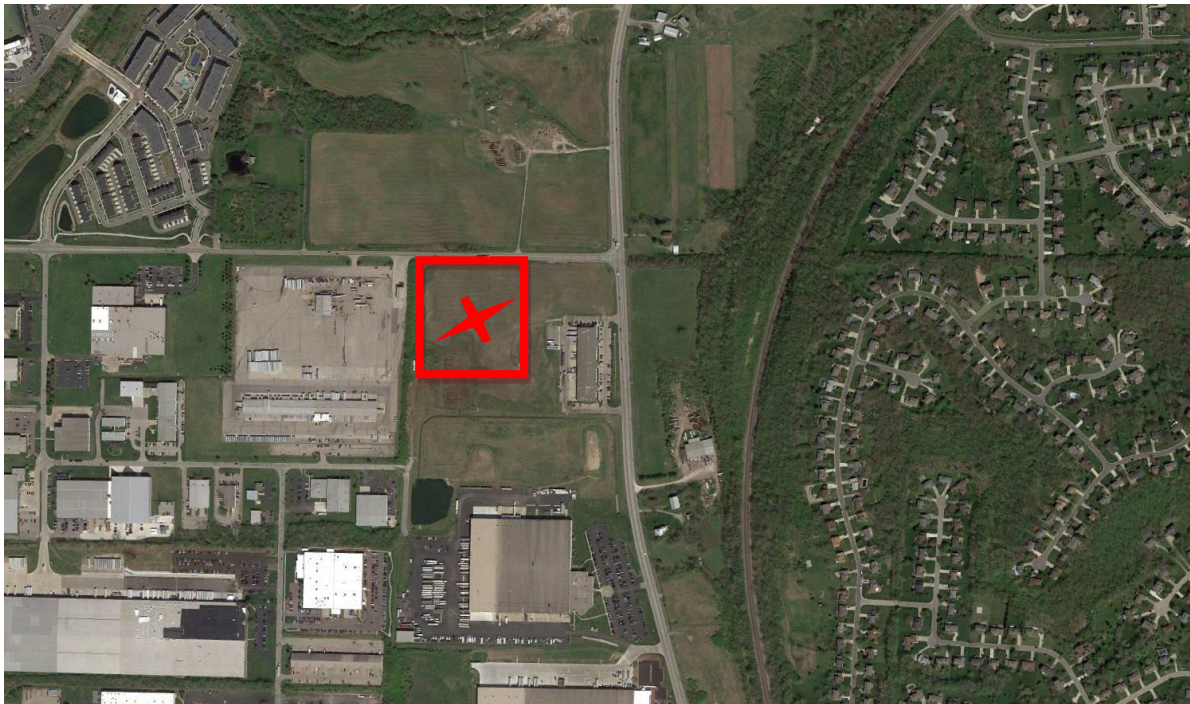
TEC PN – 18141-001
April 2018

Traffic Impact Study

Allen Road Equipment Depot

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Executive Summary

Purpose and Objectives

TEC Engineering, Inc. was retained by KZF Design Inc. to conduct a Traffic Impact Study for a proposed development on the south side of Allen Road west of Cincinnati-Dayton Road. The objective of this report is to document existing traffic conditions and patterns and evaluate the potential impacts of the proposed development on the surrounding transportation network.

Existing Conditions

The development is located on the south side of Allen Road. Allen Road is classified by Butler County as a Major Collector, with an Annual Average Daily Traffic (AADT) of 6,370 vehicles per day and a 40 mph speed limit. West of the site, Allen Road is only two lanes, one in each direction. However, at the development, a storage lane for the eastbound approach of the signalized intersection is added.

Proposed Development

The proposed development is an Equipment Depot that occupies about 16 Acres. There are two phases to the construction. Phase 1 will be a fully operational facility, consisting of 25,000 square feet of shop, 10,000 square feet of warehouse, 7,500 square feet of office space, and 2,000 square feet of parts. A Phase 2 addition will include 20,000 square feet of office, 35,000 square feet of warehouse, and 12,000 square feet of shop space.

Traffic Analyses

TEC completed traffic counts in February, 2018, in order to establish background traffic for existing volumes. The assumed opening year for Phase 1 of the proposed development is 2018. All proposed development trips were generated using the daily expected number of trips in and out provided by the developer. Using manual counts and generated trips, a capacity analysis for the surrounding road network was completed using the software program Synchro. This was used to determine intersection delay, level of service, and any future recommendations. The following scenarios were analyzed:

- 2018 AM/PM Peak No-Build and Build
- 2038 AM/PM Peak No-Build and Build

Conclusions and Recommendations

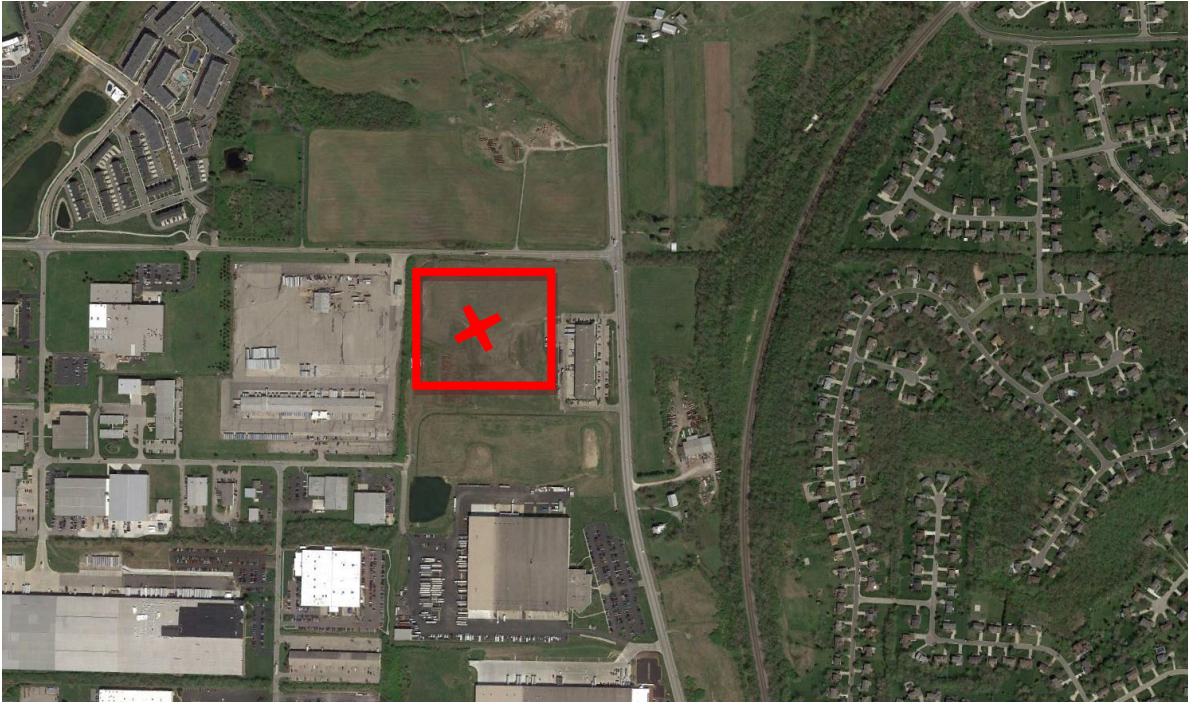
The development will have little effect on traffic at the intersection of Cincinnati-Dayton and Allen Road. TEC also recommends the addition of a 215' westbound left turn lane at the entrance to the development on Allen Road. With Phase 1 build out, only the left turn lane would be warranted by 2030. With Phase 1 and Phase 2 build out, the left turn lane would be warranted in the opening year of Phase 2.

Due to the relatively low volume of Phase 1 entering trips and the left turn lane not being warranted until year 2030 under Phase 1 development, the construction of the westbound left turn lane on Allen Road may be postponed to any future expansion (i.e. Phase 2) or 10 years from Phase 1 opening. No CO will be granted for future expansion until the westbound left turn lane is constructed per TIS recommendations. The BCEO or West Chester Township reserves the right to require the construction of the westbound left turn lane by the development prior to future expansion or 10 years from opening day if unsafe road conditions evolve due to higher than expected trips generated by development than what was analyzed in TIS.

1. Introduction

TEC Engineering, Inc. was retained by KZF Design Inc. to conduct a Traffic Impact Study for a proposed development on the south side of Allen Road west of Cincinnati-Dayton Road

Figure 1.1: Location Map



General Layout

The development is located on the south side of Allen Road, which is a Major Collector with an AADT of 6,370. Allen Road is 3 lanes wide at the intersection with Cincinnati-Dayton Road. The lanes are 12 feet wide and the eastbound right turn lane is a storage lane with 400 feet of storage. The speed limit on Allen Road is 40 MPH.

Cincinnati-Dayton Road is a Major Collector with an AADT of 17,105. Cincinnati-Dayton Road is 4 lanes wide north of the intersection and 3 lanes wide south of the intersection. The lanes are 12 feet wide and it has a speed limit of 45 MPH. There is a northbound protected/permitted left turn on Cincinnati-Dayton and an eastbound right turn overlap with this phase. In addition, there is a southbound right turn overlap with the eastbound movement. There are no crosswalks or pedestrian signals.

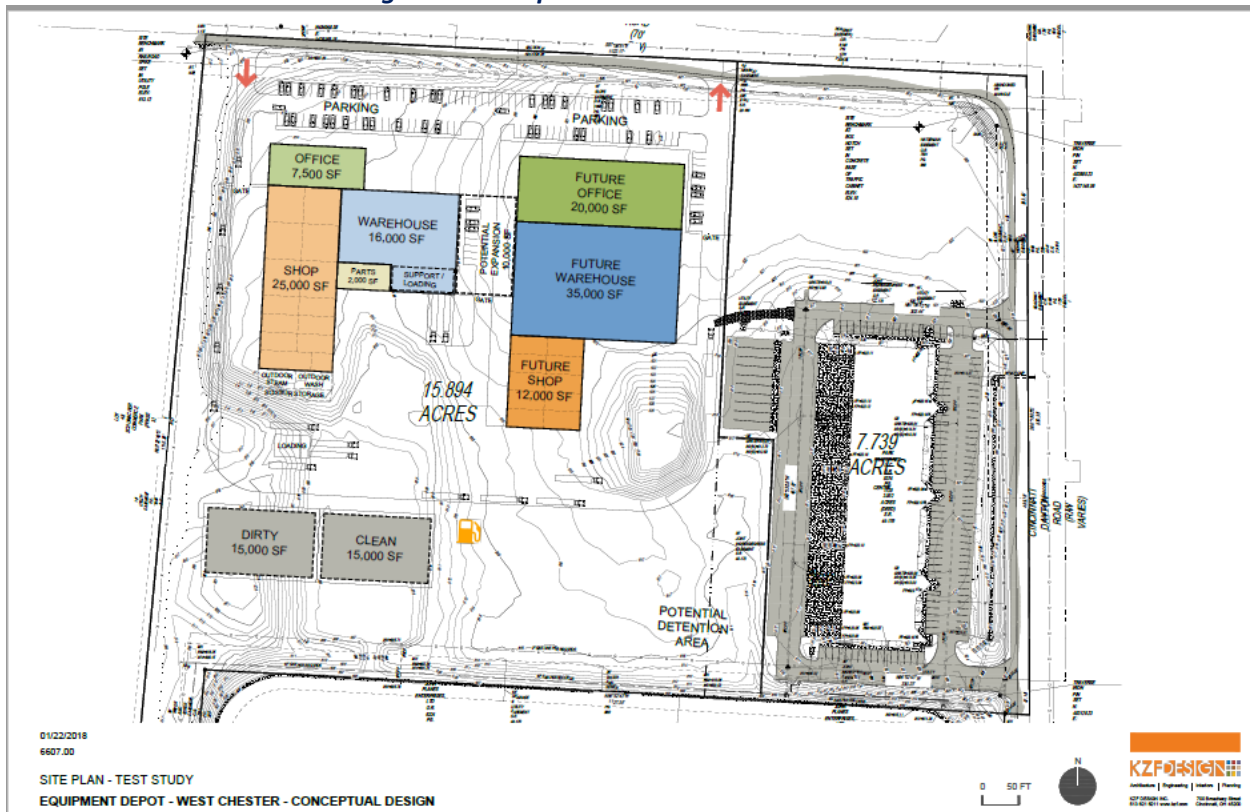
In total, there are three intersections in the study.

- Cincinnati-Dayton Road & Allen Road (Signalized)
- Allen Road & Development Entrance
- Allen Road & Development Exit

Proposed Site

The proposed development is approximately 16 acres. A proposed site plan can be seen below in Figure 1.2. Two accesses are planned for development. There are two proposed accesses for the site, one entrance and one exit. The entrance is approximately 1000 feet from the signal and the exit is 400 feet from the signal. The accesses are 600 feet apart. The development will be completed in two phases. Figure 1.2 shows both phases of construction. All things labeled with “Future” are for Phase 2 of construction.

Figure 1.2: Proposed Ground-Level Site Plan



2. Background Traffic

TEC completed manual turning movement counts at the intersection of Cincinnati-Dayton Road & Allen Road. Counts were completed using videos from 2/20/18 and 2/21/18. The peak hours were found to be 7:30-8:30 AM and 4:30-5:30 PM. These counts were used to form the “No-Build” scenarios in 2018 for the AM and PM. A 1% annual growth rate was applied to the volumes to produce the 2038 AM and PM volumes. The No-Build and Build volumes are shown in Section 4. Turning movement counts can be found in Appendix A.

3. Generated Traffic

Trips for the proposed development were generated based on details provided by the developer. Volume projections are based on specifics of the site usage. The trips generated by the proposed development site were projected using the number of expected employees.

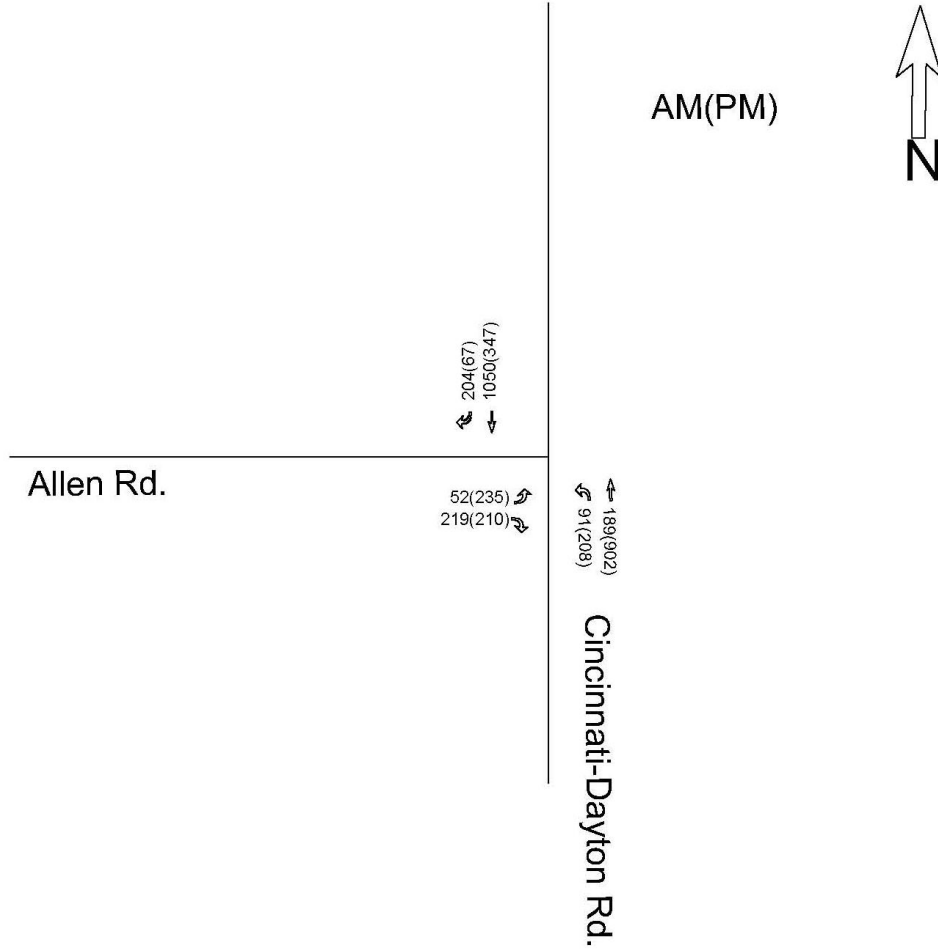
Table 3.1: Generated Trips

Phase 1			
	Total Trips	Enter	Exit
AM	60	50	10
PM	60	10	50
Phase 2			
	Total Trips	Enter	Exit
AM	140	125	15
PM	140	15	125

In phase 1, the generated trips were created based on the number of expected trips per day as provided by the developer. It was assumed that there would be 100 trips per day for general auto/pick-up truck/van (50 vehicles with average of 2 trips in and 2 trips out each day). This assumed one trip entering in the morning and one trip exiting in the evening, the other two were assumed to be mid day. In addition, there would be 40 Tractor-trailer trips per day (10 Tractor Trailers with average 4 trips in and 4 trips out each day). This assumes one trip exiting in the AM peak and one trip entering in the PM peak.

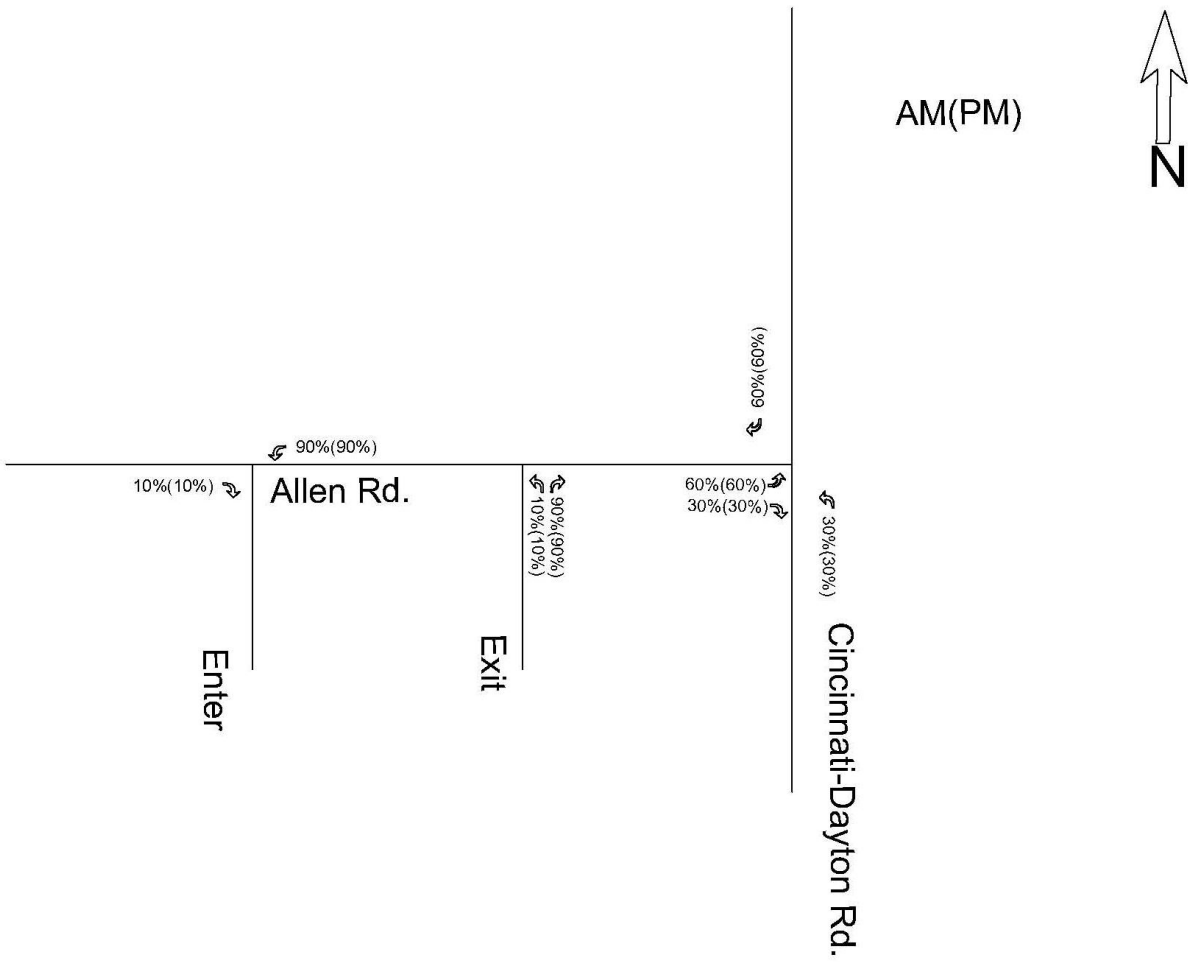
In phase 2 of construction the generated trips were assumed based off the expected increase in employees. There were 250 trips per day allotted for auto/pick-up truck/van, assuming 125 vehicles with one trip entering in the AM and one trip exiting in the PM. This includes 15 tractor trailers making one exiting trip in the AM peak and one entering trip in the PM.

Figure 3.1: Existing Volumes



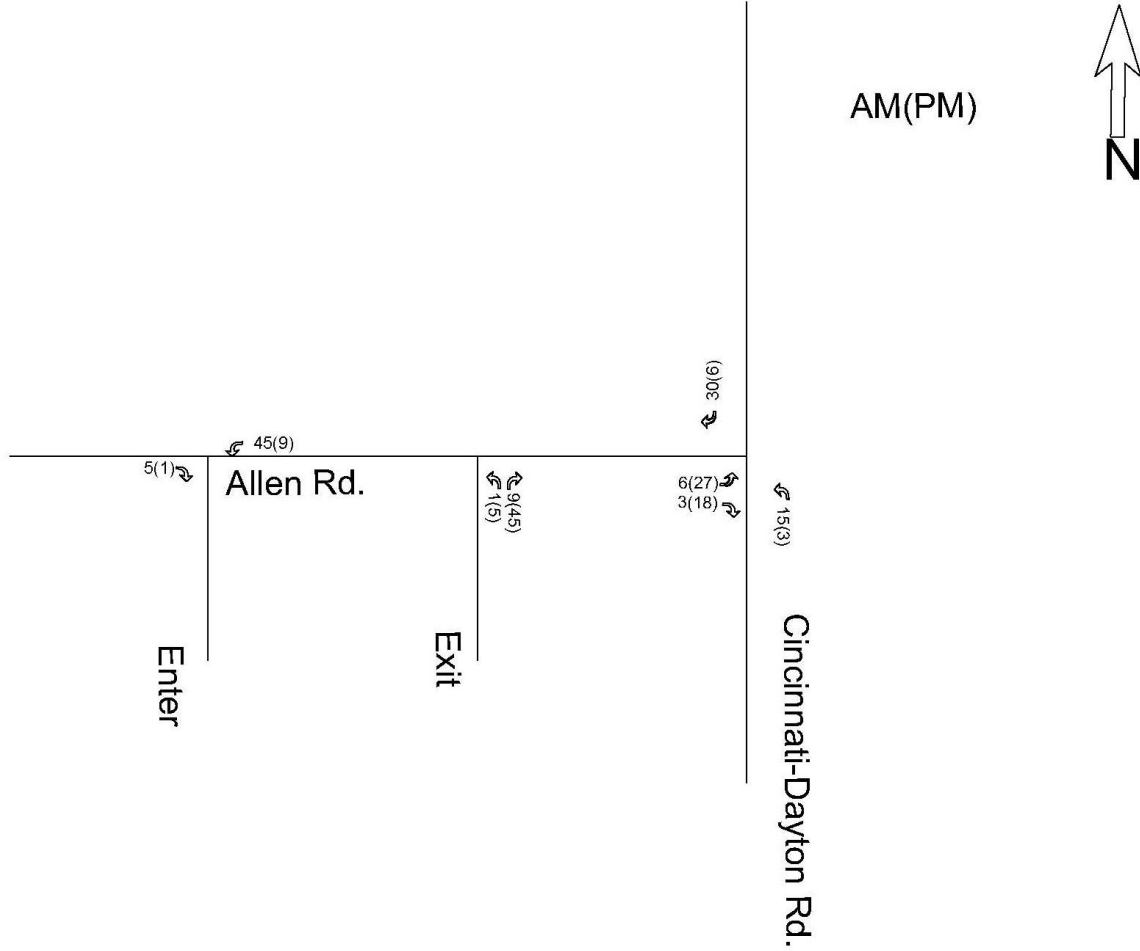
After reviewing the No-Build volumes, a projected trip distribution for the surrounding road network was determined based on the existing directional traffic distributions. The projected trip distribution for the development is provided in the following figures.

Figure 3.2: Trip Distribution



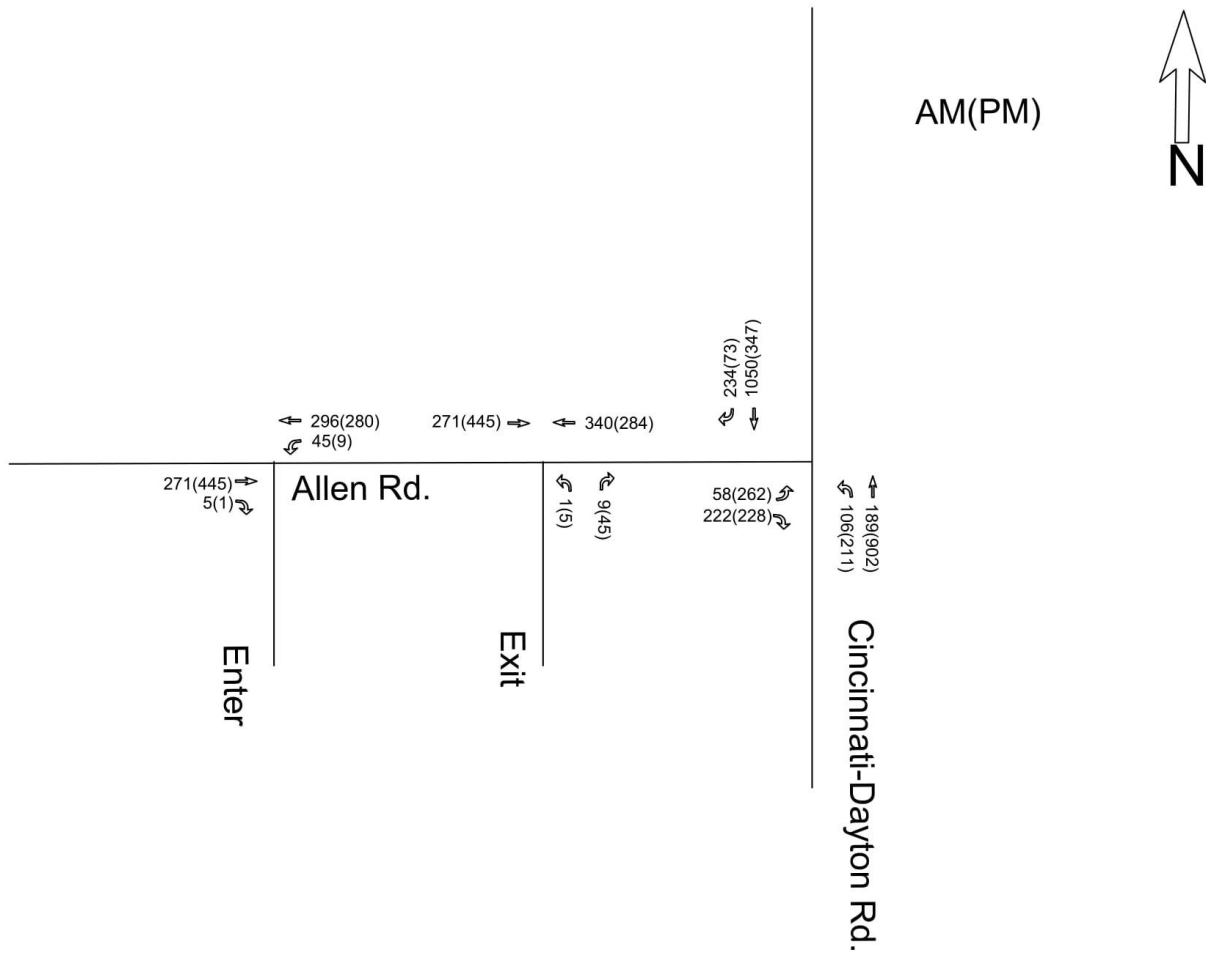
The generated trips as discussed above are shown in Figure 3.3.

Figure 3.3: Generated Trips Phase 1



Generated Trips were added to the Existing Volumes to produce the Opening Day volumes for 2018.

Figure 3.4: Opening Day Volumes



The existing volumes were increased at a 1% annual growth rate over a span of twenty years in order to produce the Design Year 2038 Volumes. The expected trips were then added to these volumes to produce the Design Year 2038 Build Volumes.

Figure 3.5a: 2038 No-Build

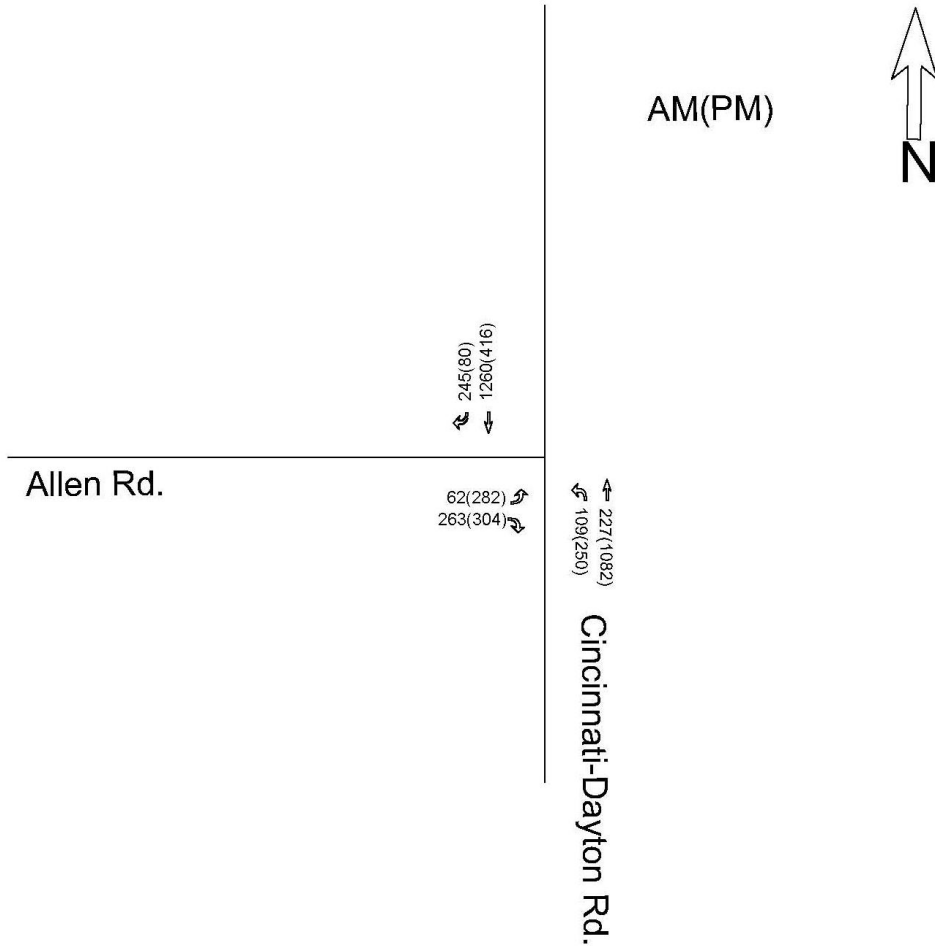
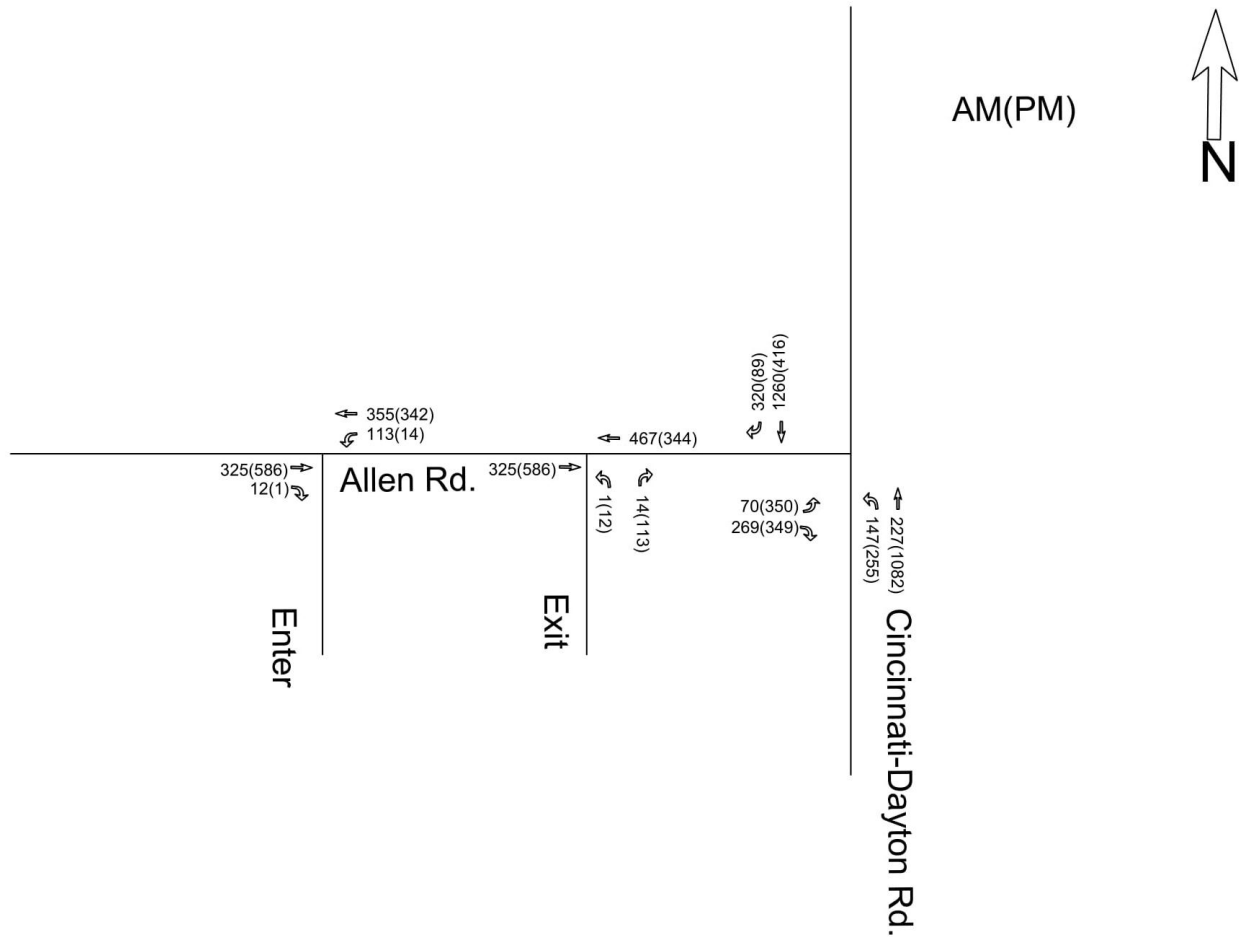


Figure 3.5b: Generated Trips Phases 1 & 2



Figure 3.5c: 2038 Build



4. Capacity Analysis

To determine any improvements necessary to accommodate the traffic generated by the proposed development, the following scenarios were compared and analyzed:

- 2018 No-Build AM & PM
- 2018 Build AM & PM
- 2038 No-Build AM & PM
- 2038 Build AM & PM

TEC used the software program Synchro 9 to evaluate each scenario individually. The capacity analysis was performed using the existing signal timing for both the build and no-build scenarios. The intersection cycle length was not optimized since it is part of a larger coordinated system. Changing the intersection cycle length at one intersection within a coordinated corridor would greatly affect the level of service of the entire corridor(s). The Level of Service (LOS) for the intersection is directly related to the average total delay per vehicle. The total delay is the sum of control delay and queue delay. Control delay is the component of delay caused by the downstream control device and is calculated using the Percentile Delay Method. Queue delay is an analysis of the affects of queues and blocking on short links and short turning bays. LOS is defined in terms of delay and is a measure of driver discomfort and intersection performance with respect to vehicular capacity and quality of service provided to road users. Delay refers to total average stopped delay experienced by motorists at the referenced intersection. The level of service is classified into six different levels, ranging from A to F, and is detailed in Table 5.1a for signalized intersections and 5.1b for unsignalized intersections. Capacity analysis reports from Synchro can be found in Appendix B.

Table 5.1a: Signalized Level of Service Classifications

Level of Service	Description	Delay
A	Very low delay	<10 seconds per vehicle
B	Good progression	10-20 seconds per vehicle
C	Limit of acceptable delay	20-35 seconds per vehicle
D	Start of traffic breakdown	35-55 seconds per vehicle
E	High delay	55-80 seconds per vehicle
F	Congested conditions, unacceptable delay	>80 seconds per vehicle

Table 5.1b: Unsignalized Level of Service Classifications

Level of Service	Description	Delay
A	Very low delay	<10 seconds per vehicle
B	Good progression	10-15 seconds per vehicle
C	Limit of acceptable delay	15-25 seconds per vehicle
D	Start of traffic breakdown	25-35 seconds per vehicle
E	High delay	35-50 seconds per vehicle
F	Congested conditions, unacceptable delay	>50 seconds per vehicle

All capacity analysis results can be found in Tables 5.2-5.4. All intersections were analyzed using No-Build conditions and Build traffic volumes with existing roadway geometrics. Currently the access points for the proposed site do not exist and therefore were not analyzed for the No-Build scenarios.

Table 5.2: Cincinnati-Dayton Road & Allen Road (Delay in Seconds)

Cincinnati Dayton & Allen Rd.									
Peak	Scenario	Eastbound		Northbound		Southbound		Total Intersection	
AM	2018 Existing	48.6	D	8.0	A	18.9	B	21.7	C
	2018 Build	51.3	D	7.9	A	16.3	B	20.2	C
	2038 No Build	52.1	D	12.6	B	74.1	E	61.2	E
	2038 Build	53.7	D	18.5	B	73.1	E	61.1	E
PM	2018 Existing	21.5	C	14.5	B	13.1	B	15.8	B
	2018 Build	21.6	C	16.8	B	13.7	B	17.3	B
	2038 No Build	36.0	D	24.8	C	12.6	B	25.0	C
	2038 Build	45.3	D	31.0	C	13.7	B	31.5	C

Table 5.3: Unsignalized Delay “Development Entrance” (Delay in Seconds)

Development Entrance							
Peak	Scenario	EB		WB		Total Intersection	
AM	2018 Build	0	A	1.4	A	0.8	A
	2038 Build	0	A	3.0	A	1.7	A
PM	2018 Build	0	A	0.4	A	0.1	A
	2038 Build	0	A	0.5	A	0.2	A

Table 5.4: Unsignalized Delay “Development Exit” (Delay in Seconds)

Development Exit									
Peak	Scenario	EB Left Turn		WB		NB		Total Intersection	
AM	2018 Build	0	A	0	A	10.3	B	0.2	A
	2038 Build	0	A	0	A	10.7	B	0.2	A
PM	2018 Build	0	A	0	A	12.3	B	0.8	A
	2038 Build	0	A	0	A	16.8	C	2	A

In all scenarios, increases in delay due to the development are minimal. The Level of Service as Allen Road and Cincinnati Dayton Road remain the same for each approach and the overall intersection.

5. Turn Lane Warrants

As part of this traffic impact study TEC completed turn lane warrants for the proposed accesses. TEC conducted left-turn-lane and/or right-turn-lane warrant analysis for the proposed new access. Using the ODOT Location and Design Manual Volume 1 for Turn Lane Analysis, it was determined that a left turn lane is required in multiple scenarios. The results of these turn lane analysis can be found in Appendix C.

TEC conducted Warrant Analysis for the Build 2018 scenario with Phase 1 and 2038 Build scenario with Phase 2. TEC also conducted a separate generation for just the AM Peak with Phase 1 generated trips and AM Peak with Phase 2 generated trips. The analysis started with the year 2018 volumes and they were grown in 5 year increments in both situations to determine when the turn lane would be necessary. It was found that Phase 1 will require a turn lane by 2030. With Phase 1 and Phase 2 requires a turn lane with 2018 opening day values.

Table 5.1: Turn Lane Requirements

Access	Build out phase	Left Turn Lane Warrant?	Required Turn Lane Length	Right Turn Lane Warrant?	Required Turn Lane Length
Development Entrance	Phase 1 Only	Yes (2030)	165'	No	-
	Phases 1&2	Yes (2018)	215'	No	-

6. Queue Analysis

Finally, in reviewing the capacity analysis and possible impacts of the development, it is important to look at the intersection queues to determine if any intersections or movement will be blocked by an adjacent queue. Queue analysis can also be used to determine if existing storage lanes are sufficient. For this study, Synchro's SimTraffic module was used to simulate the traffic flows and determine the expected queue length during the analysis periods. The queue analysis below looks at the queues directly affected by the development. Table 6.1 shows the results of the 2018 build traffic queue analysis.

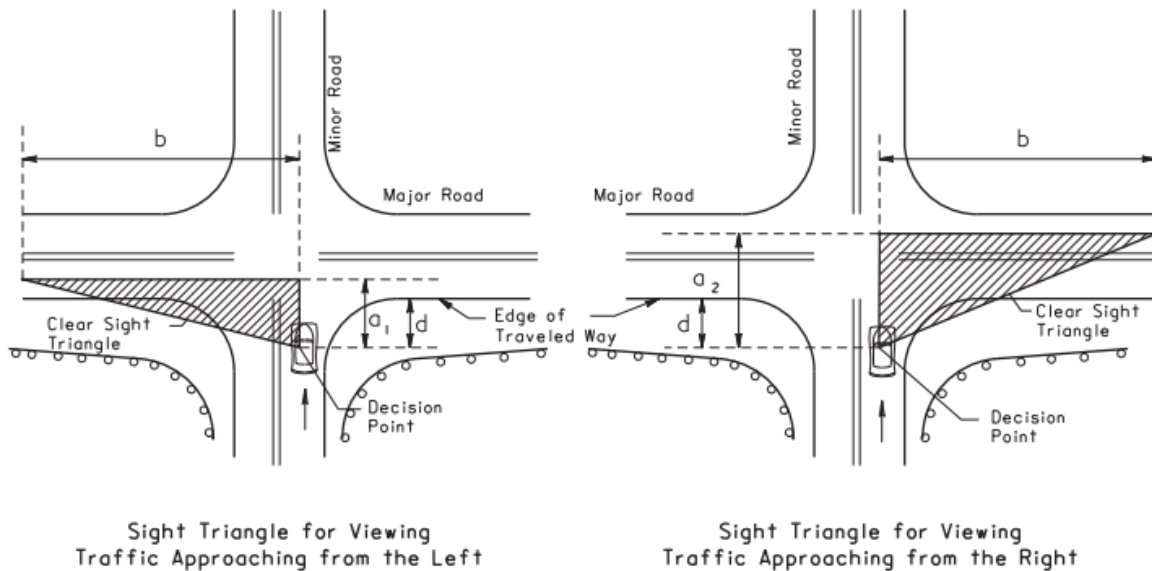
Table 6.1: 95th Percentile Queue Analysis Results (ft)

Intersection	Movement	Storage	AM No Build	AM Build	AM No Build	AM Build	PM No Build	PM Build	PM No Build	PM Build
			2018	2018	2038	2038	2018	2018	2038	2038
Cin-Day Rd. & Allen Rd.	EBL	863	97	97	140	125	177	184	185	185
	EBR	536	193	195	240	243	80	62	112	112
	NBL	439	107	95	146	168	98	120	599	599
	NBT	-	51	75	54	64	267	229	1124	1124
	SBT	-	745	780	979	962	177	173	201	201
	SBR	520	441	480	734	771	33	57	51	51
Development Entrance	WBLT	559	-	31	-	56	-	18	-	-
Development Exit	NBLR	262	-	27	-	30	-	53	-	-

Queue analysis for the no build scenario was reviewed for the signalized intersections to determine the extent to which the proposed site traffic affects the queues. The 95th percentile queues were reviewed. The analysis shows that the eastbound approach at Cincinnati Dayton will not extend past the proposed access.

7. Sight Distance

To determine if there are any objects that obstruct the visibility of traffic, an intersection sight distance study was performed, according to the standards provided by the Ohio Department of Transportation (ODOT).



An important determination in the sight distance triangle is dimension “b” which is a calculated value based on the speed of the vehicle on the major road. This is the distance at which a driver on the minor road can see the vehicle on the minor road, and vice versa. The length of dimension “b” is calculated as:

$$\text{Intersection Sight Distance (ISD)} = 1.47 * V_{\text{major}} * t_g$$

V_{major} = Design Speed of Major Road (in mph)

t_g = Time Gap for Minor Road to Enter Major Road (7.5 secs as set forward by AASHTO)

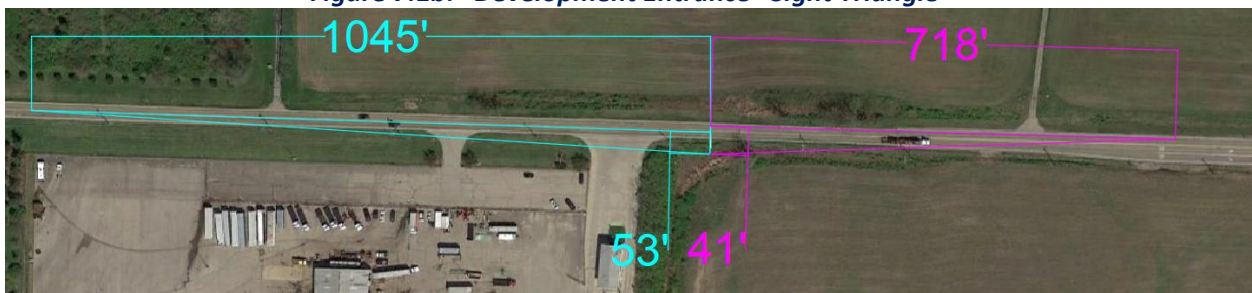
The other important measurement is the decision point. This is where the eye of the driver on the minor street would be located. For our scenario, when determining the location of the decision point for vehicular traffic, the point was set at 14.4' back from the edge of pavement, the minimum required by the ODOT Location and Design Manual. The speed limit on Allen Road is 40 mph.

Figure 7.1a: “Development Exit” Sight Triangle



According to ODOT the required sight distance for a left turn is 441 feet from the access and 382 feet for a right turn. The above figure shows a sight distance of 1020' to the west and 481' to the east; therefore, the sight distance requirement is met.

Figure 7.1b: “Development Entrance” Sight Triangle



The “Enter Only” Access was also analyzed for sight distance for future planning. According to the guidelines set forth by ODOT this entrance satisfies the sight distance requirement.

The sight distance was also reviewed from a position of a car 12' further back at the proposed access to check for future sight distance once a turn lane is added. The sight distance is adequate for both drives.

8. Recommendations

TEC proposes the following improvements to the roadway network. A left turn lane is warranted for the entrance access. With Phase 1 build out only a left turn lane would be warranted by 2030. With Phase 1 and Phase 2 build out, a left turn lane would be warranted in opening year. This meets warrants using existing (2018) traffic.

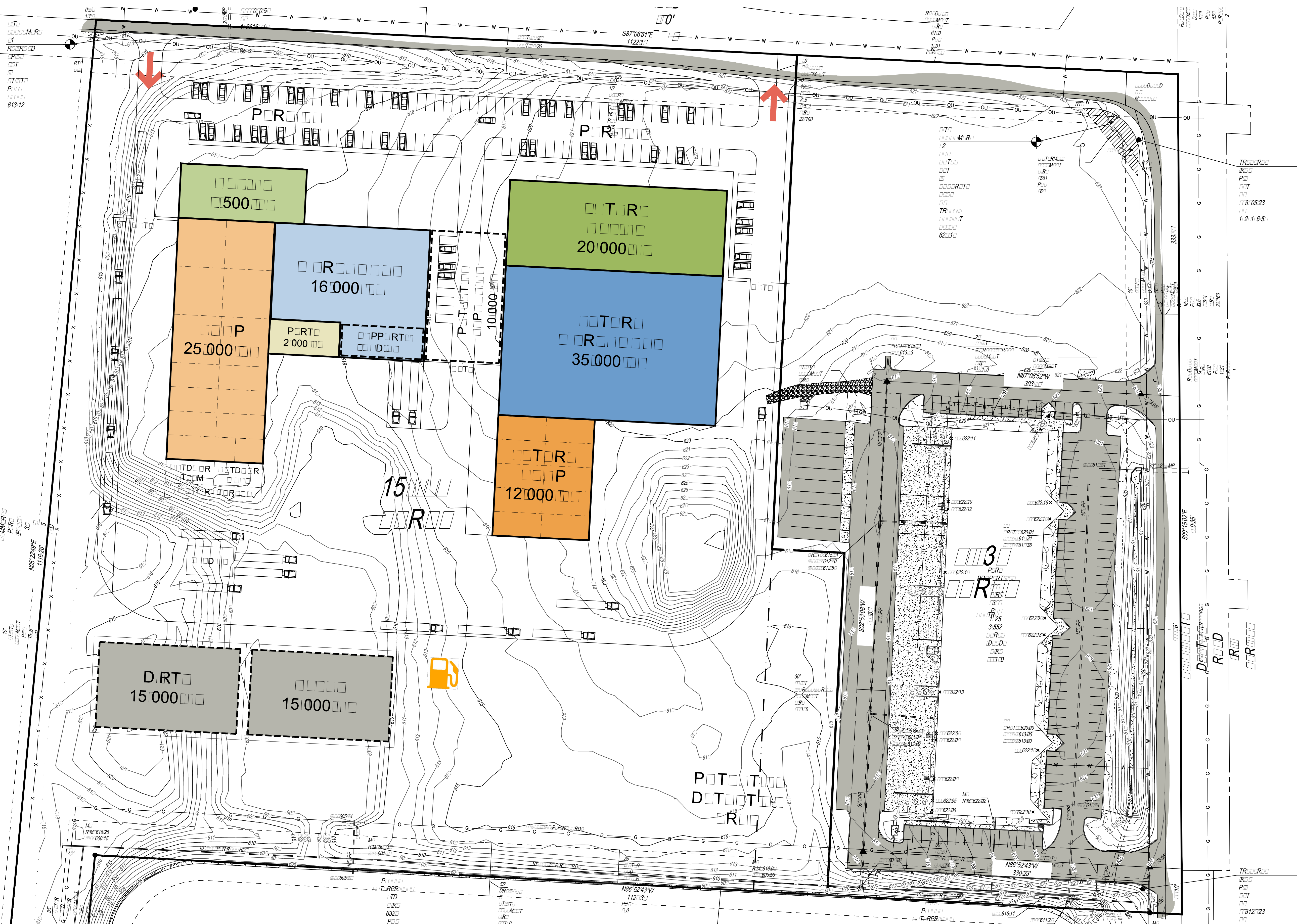
Figure 8.1 shows the proposed turn lane. It is 215' in total length, with 165' of storage and a diverging 50' taper. The widening taper to add a 12' lane at 40 mph is 320'. This drawing can also be found in Appendix E.

Figure 8.1: Recommended Improvements



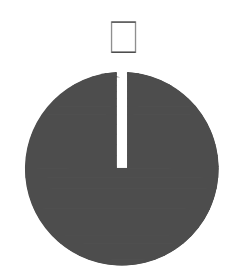
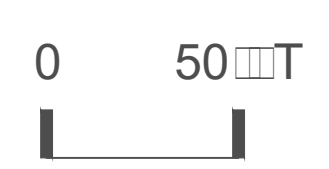
Due to the relatively low volume of Phase 1 entering trips and the left turn lane not being warranted until year 2030 under Phase 1 development, the construction of the westbound left turn lane on Allen Road may be postponed to any future expansion (i.e. Phase 2) or 10 years from Phase 1 opening. No CO will be granted for future expansion until westbound left turn lane is constructed per TIS recommendations. The BCEO or West Chester Township reserve the right to require the construction of the westbound left turn lane by the development prior to future expansion or 10 years from opening day if unsafe road conditions evolve due to higher than expected trips generated by development than what was analyzed in TIS.

Appendix A: Site Plan



01/22/201
66000

EQUIPMENT DEPOT - WEST CHESTER - CONCEPTUAL DESIGN



Appendix B: Traffic Counts

Start Time	Allen Rd Eastbound					Westbound					Cincinnati-Dayton Rd Northbound					Cincinnati-Dayton Rd Southbound					Int. Total
	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	Left	Thru	Right	Peds	App. Total	
7:00 AM	13	0	51	0	64	0	0	0	0	0	20	36	0	0	56	0	260	33	0	293	413
7:15 AM	14	0	53	0	67	0	0	0	0	0	20	50	0	0	70	0	278	49	0	327	464
7:30 AM	5	0	47	0	52	0	0	0	0	0	23	39	0	0	62	0	257	42	0	299	413
7:45 AM	17	0	60	0	77	0	0	0	0	0	26	42	0	0	68	0	247	71	0	318	463
Total	49	0	211	0	260	0	0	0	0	0	89	167	0	0	256	0	1042	195	0	1237	1753
PHF	0.7206	0	0.8792		0.8442	0	0	0		0	0.8558	0.835	0		0.9143	0	0.9371	0.6866		0.9457	0.9445
HV%	26.5%	0.0%	5.2%		9.2%	0.0%	0.0%	0.0%		0.0%	12.4%	12.6%	0.0%		12.5%	0.0%	2.4%	6.2%		3.0%	5.3%
8:00 AM	16	0	59	0	75	0	0	0	0	0	22	58	0	0	80	0	268	42	0	310	465
8:15 AM	11	0	42	0	53	0	0	0	0	0	25	67	0	0	92	0	170	40	0	210	355
8:30 AM	13	0	38	0	51	0	0	0	0	0	16	72	0	0	88	0	170	21	0	191	330
8:45 AM	10	0	39	0	49	0	0	0	0	0	11	66	0	0	77	0	159	32	0	191	317
Total	50	0	178	0	228	0	0	0	0	0	74	263	0	0	337	0	767	135	0	902	1467
PHF	0.7813	0	0.7542		0.76	0	0	0		0	0.74	0.9132	0		0.9158	0	0.7155	0.8036		0.7274	0.78871
HV%	18.0%	0.0%	7.3%		9.6%	0.0%	0.0%	0.0%		0.0%	4.1%	17.5%	0.0%		14.5%	0.0%	6.6%	5.9%		6.5%	8.9%
4:00 PM	36	0	39	0	75	0	0	0	0	0	29	192	0	0	221	0	99	13	0	112	408
4:15 PM	39	0	53	0	92	0	0	0	0	0	45	189	0	0	234	0	94	18	0	112	438
4:30 PM	63	0	50	0	113	0	0	0	0	0	48	228	0	0	276	0	92	17	0	109	498
4:45 PM	41	43	0	0	84	0	0	0	0	0	47	205	0	0	252	0	85	13	0	98	434
Total	179	43	142	0	364	0	0	0	0	0	169	814	0	0	983	0	370	61	0	431	1778
PHF	0.7103	0.25	0.6698		0.8053	0	0	0		0	0.8802	0.8925	0		0.8904	0	0.9343	0.8472		0.9621	0.89257
HV%	1.7%	0.0%	9.2%		4.4%	0.0%	0.0%	0.0%		0.0%	3.0%	1.7%	0.0%		1.9%	0.0%	11.4%	11.5%		11.4%	4.7%
5:00 PM	76	0	64	0	140	0	0	0	0	0	47	242	0	0	289	0	90	16	0	106	535
5:15 PM	55	0	53	0	108	0	0	0	0	0	66	227	0	0	293	0	80	21	0	101	502
5:30 PM	49	0	39	0	88	0	0	0	0	0	45	191	0	0	236	0	83	19	0	102	426
5:45 PM	39	0	37	0	76	0	0	0	0	0	51	179	0	0	230	0	85	17	0	102	408
Total	219	0	193	0	412	0	0	0	0	0	209	839	0	0	1048	0	338	73	0	411	1871
PHF	0.7204	0	0.7539		0.7357	0	0	0		0	0.7917	0.8667	0		0.8942	0	0.9389	0.869		0.9693	0.8743
HV%	0.5%	0.0%	5.7%		2.9%	0.0%	0.0%	0.0%		0.0%	2.4%	1.5%	0.0%		1.7%	0.0%	3.8%	11.0%		5.1%	2.7%

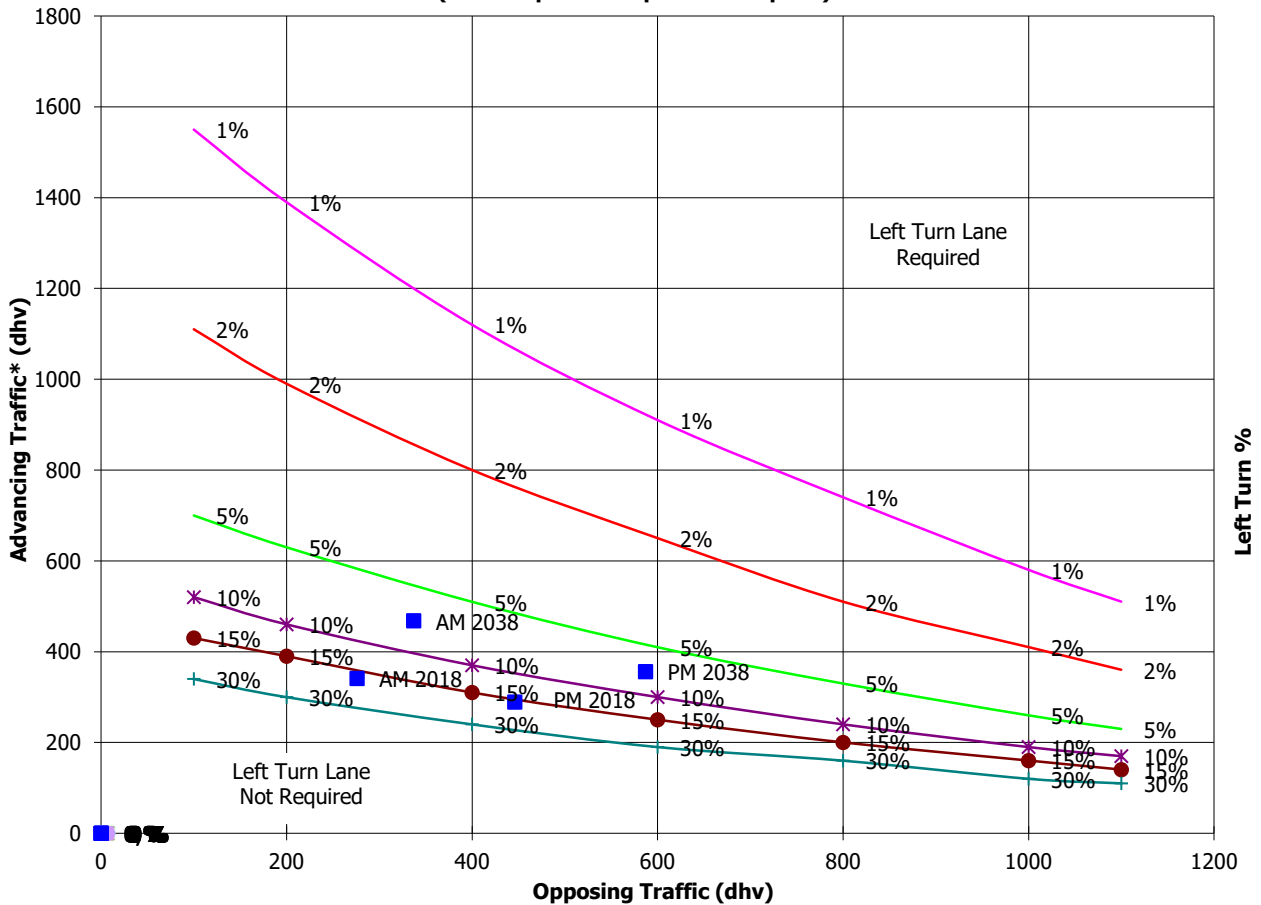
Appendix C: Turn Lane Warrants

2-Way LT Graphs

**FIGURE A: 2-LANE HIGHWAY LEFT TURN LANE WARRANT
(=<40 MPH OR 70 KPH POSTED SPEED)**

Location	Advancing Traffic					Opposing Traffic			
	Left	Thru	Right	Total	% Left	Left	Thru	Right	Total
AM	45	296	0	341	13%	0	271	5	276
PM	9	280	0	289	3%	0	445	1	446
AM 2038	113	355	0	468	24%	0	325	12	337
PM 2038	14	342	0	356	4%	0	586	1	587
	0	0	0	0		0	0	0	0
	0	0	0	0		0	0	0	0
	0	0	0	0		0	0	0	0

**2-Lane Highway Left Turn Lane Warrant
(=<40 mph or 70 kph Posted Speed)**



*Includes Left Turns

**There is no minimum number of turns

Is Left Turn Lane Warrant met? YES

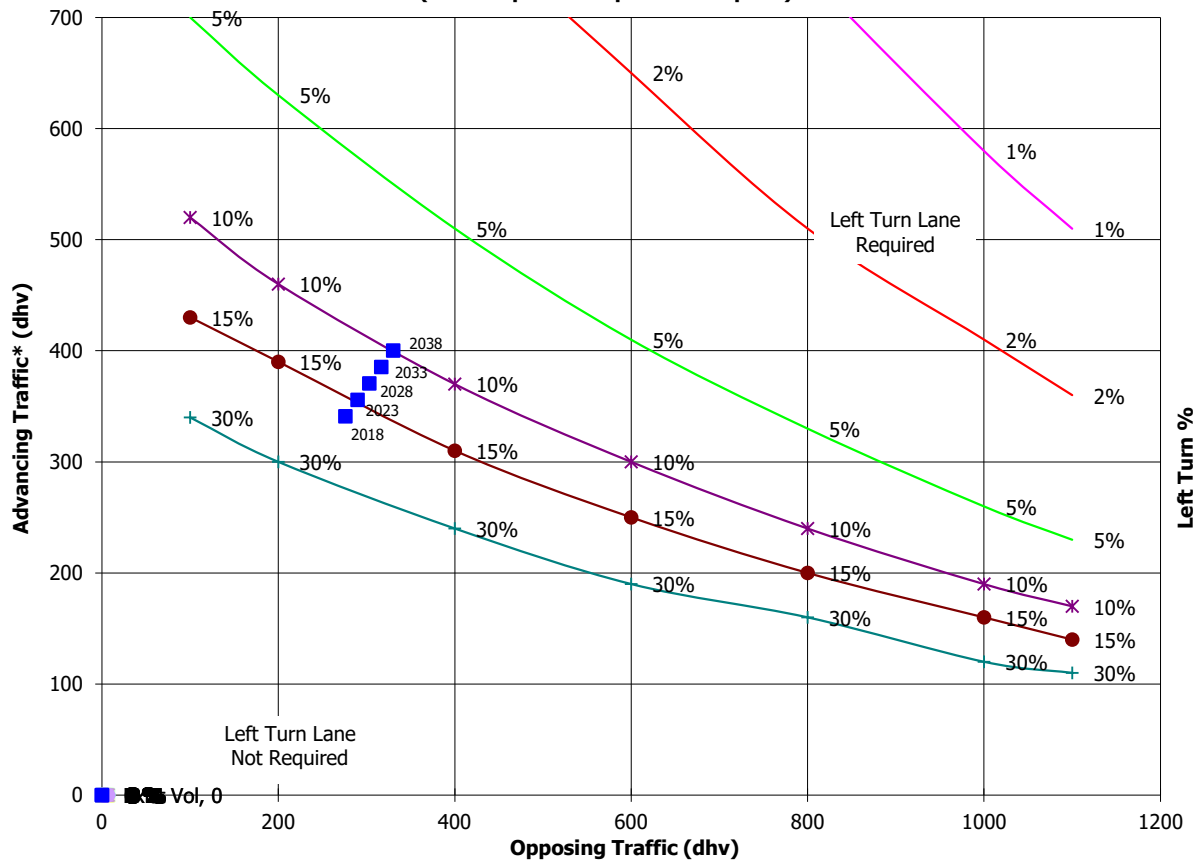
2-Way LT Graphs

**FIGURE A: 2-LANE HIGHWAY LEFT TURN LANE WARRANT
(=<40 MPH OR 70 KPH POSTED SPEED)**

AM BUILD WITH PHASE 1 GENERATED TRIPS

Location	Advancing Traffic					Opposing Traffic			
	Left	Thru	Right	Total	% Left	Left	Thru	Right	Total
AM 2018	45	296	0	341	13%	0	271	5	276
AM 2023	45	311	0	356	13%	0	285	5	290
AM 2028	45	326	0	371	12%	0	298	5	303
AM 2033	45	340	0	385	12%	0	312	5	317
AM 2038	45	355	0	400	11%	0	325	5	330
	0	0	0	0		0	0	0	0
	0	0	0	0		0	0	0	0

**2-Lane Highway Left Turn Lane Warrant
(=<40 mph or 70 kph Posted Speed)**



*Includes Left Turns

**There is no minimum number of turns

Is Left Turn Lane Warrant met?

YES

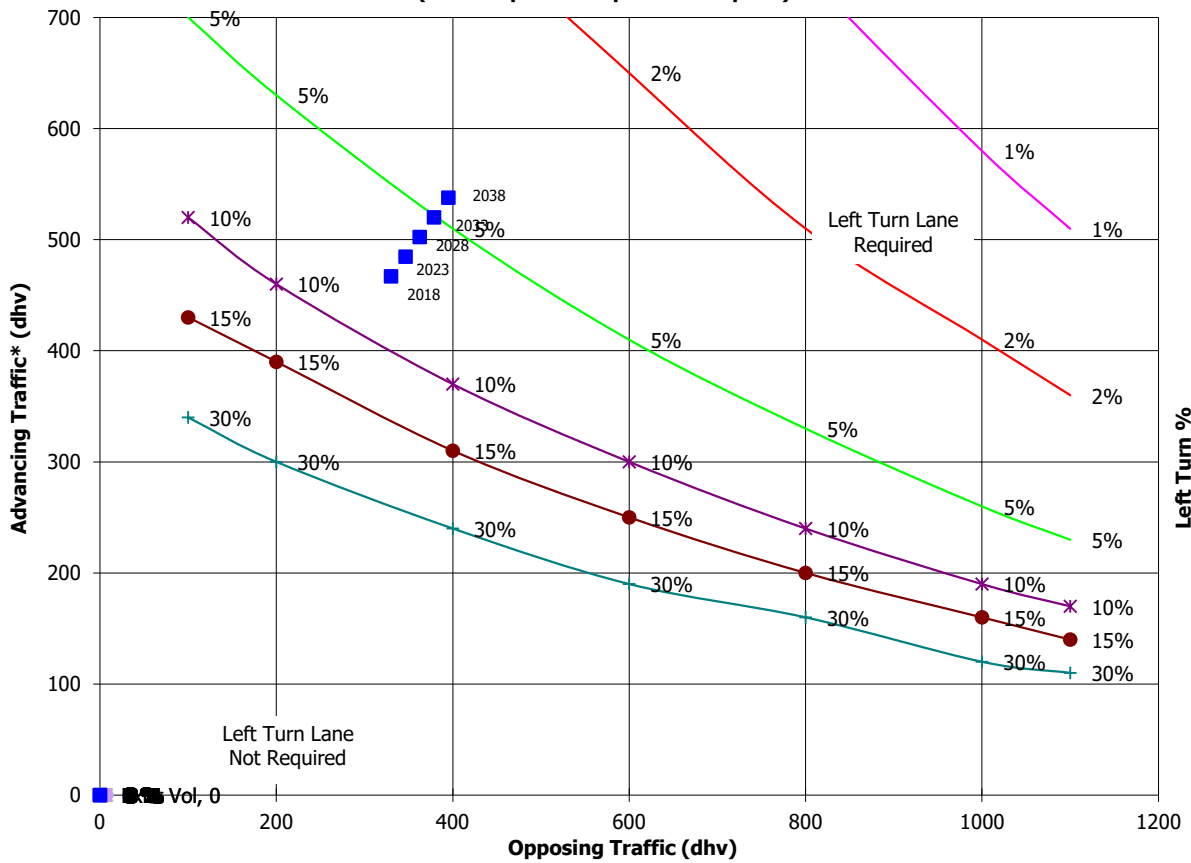
2-Way LT Graphs

**FIGURE A: 2-LANE HIGHWAY LEFT TURN LANE WARRANT
(=<40 MPH OR 70 KPH POSTED SPEED)**

AM BUILD WITH PHASE 2 GENERATED TRIPS

Location	Advancing Traffic					Opposing Traffic			
	Left	Thru	Right	Total	% Left	Left	Thru	Right	Total
AM 2018	113	354	0	467	24%	0	325	5	330
AM 2023	113	372	0	485	23%	0	341	5	347
AM 2028	113	389	0	502	22%	0	358	5	363
AM 2033	113	407	0	520	22%	0	374	5	379
AM 2038	113	425	0	538	21%	0	390	5	395
	0	0	0	0		0	0	0	0
	0	0	0	0		0	0	0	0

**2-Lane Highway Left Turn Lane Warrant
(=<40 mph or 70 kph Posted Speed)**



*Includes Left Turns

**There is no minimum number of turns

Is Left Turn Lane Warrant met?

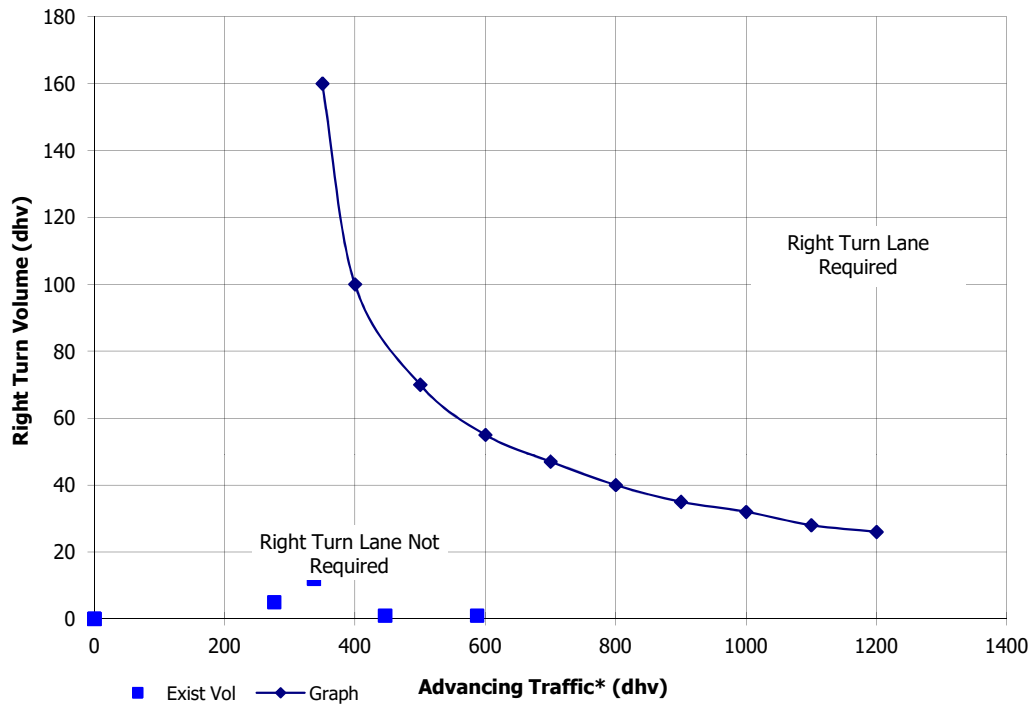
YES

2-Way RT Graphs

2-LANE HIGHWAY RIGHT TURN LANE WARRANT =<40 MPH OR 70 KPH POSTED SPEED

Location	Right Turn Volume	Advancing Traffic			
	Right	Left	Thru	Right	Total
AM 2018	5	0	271	5	276
PM 2018	1	0	445	1	446
AM 2038	12	0	325	12	337
PM 2038	1	0	586	1	587
	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0

**2-Lane Highway Right Turn Lane Warrant
=<40 mph or 70 kph Posted Speed**



*Includes Right Turns

Is Right Turn Lane Warrant met? NO

Appendix D: Synchro Printouts

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/02/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	52	219	91	189	1050	204
Future Volume (vph)	52	219	91	189	1050	204
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1399	1524	1656	1652	1827	1538
Flt Permitted	0.95	1.00	0.09	1.00	1.00	1.00
Satd. Flow (perm)	1399	1524	151	1652	1827	1538
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	57	241	100	208	1154	224
RTOR Reduction (vph)	0	81	0	0	0	50
Lane Group Flow (vph)	57	160	100	208	1154	174
Heavy Vehicles (%)	29%	6%	9%	15%	4%	5%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	7.2	15.0	91.6	91.6	78.1	85.3
Effective Green, g (s)	7.2	15.0	91.6	91.6	78.1	85.3
Actuated g/C Ratio	0.07	0.14	0.83	0.83	0.71	0.78
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	91	281	232	1375	1297	1192
v/s Ratio Prot	0.04	c0.04	0.03	0.13	c0.63	0.01
v/s Ratio Perm		0.06	0.33			0.10
v/c Ratio	0.63	0.57	0.43	0.15	0.89	0.15
Uniform Delay, d1	50.1	44.5	19.9	1.8	12.6	3.1
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	9.3	1.6	0.5	0.2	9.4	0.0
Delay (s)	59.4	46.0	20.4	2.0	22.0	3.1
Level of Service	E	D	C	A	C	A
Approach Delay (s)	48.6			8.0	18.9	
Approach LOS	D			A	B	

Intersection Summary

HCM 2000 Control Delay	21.7	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.87		
Actuated Cycle Length (s)	110.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	78.6%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/08/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	235	210	208	902	347	67
Future Volume (vph)	235	210	208	902	347	67
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1805	1509	1752	1863	1776	1495
Flt Permitted	0.95	1.00	0.37	1.00	1.00	1.00
Satd. Flow (perm)	1805	1509	688	1863	1776	1495
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	258	231	229	991	381	74
RTOR Reduction (vph)	0	156	0	0	0	31
Lane Group Flow (vph)	258	75	229	991	381	43
Heavy Vehicles (%)	0%	7%	3%	2%	7%	8%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	11.6	19.1	36.0	36.0	22.8	34.4
Effective Green, g (s)	11.6	19.1	36.0	36.0	22.8	34.4
Actuated g/C Ratio	0.20	0.32	0.61	0.61	0.39	0.59
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	356	626	556	1140	688	874
v/s Ratio Prot	c0.14	0.02	0.05	c0.53	0.21	0.01
v/s Ratio Perm		0.03	0.20			0.02
v/c Ratio	0.72	0.12	0.41	0.87	0.55	0.05
Uniform Delay, d1	22.1	13.9	5.9	9.4	14.0	5.2
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	6.1	0.0	0.2	7.0	0.6	0.0
Delay (s)	28.2	14.0	6.1	16.5	14.6	5.2
Level of Service	C	B	A	B	B	A
Approach Delay (s)	21.5			14.5	13.1	
Approach LOS	C			B	B	

Intersection Summary

HCM 2000 Control Delay	15.8	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.95		
Actuated Cycle Length (s)	58.8	Sum of lost time (s)	16.9
Intersection Capacity Utilization	69.8%	ICU Level of Service	C
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/02/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	62	263	109	227	1260	245
Future Volume (vph)	62	263	109	227	1260	245
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1399	1524	1656	1652	1827	1538
Flt Permitted	0.95	1.00	0.05	1.00	1.00	1.00
Satd. Flow (perm)	1399	1524	88	1652	1827	1538
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	68	289	120	249	1385	269
RTOR Reduction (vph)	0	46	0	0	0	70
Lane Group Flow (vph)	68	243	120	249	1385	199
Heavy Vehicles (%)	29%	6%	9%	15%	4%	5%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	7.7	19.3	91.1	91.1	73.8	81.5
Effective Green, g (s)	7.7	19.3	91.1	91.1	73.8	81.5
Actuated g/C Ratio	0.07	0.18	0.83	0.83	0.67	0.74
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	97	340	238	1368	1225	1139
v/s Ratio Prot	0.05	c0.08	0.05	0.15	c0.76	0.01
v/s Ratio Perm		0.08	0.37			0.12
v/c Ratio	0.70	0.71	0.50	0.18	1.13	0.17
Uniform Delay, d1	50.0	42.8	33.5	1.9	18.1	4.2
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	17.0	5.8	0.6	0.3	69.5	0.0
Delay (s)	67.0	48.6	34.2	2.2	87.6	4.3
Level of Service	E	D	C	A	F	A
Approach Delay (s)	52.1			12.6	74.1	
Approach LOS	D			B	E	

Intersection Summary

HCM 2000 Control Delay	61.2	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	1.08		
Actuated Cycle Length (s)	110.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/08/2018



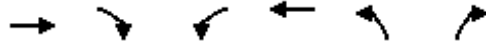
Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	58	222	106	189	1050	234
Future Volume (vph)	58	222	106	189	1050	234
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1399	1524	1656	1652	1827	1538
Flt Permitted	0.95	1.00	0.10	1.00	1.00	1.00
Satd. Flow (perm)	1399	1524	178	1652	1827	1538
Peak-hour factor, PHF	0.76	0.91	0.88	0.81	0.94	0.71
Adj. Flow (vph)	76	244	120	233	1117	330
RTOR Reduction (vph)	0	88	0	0	0	73
Lane Group Flow (vph)	76	156	120	233	1117	257
Heavy Vehicles (%)	29%	6%	9%	15%	4%	5%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	8.1	15.4	90.7	90.7	77.7	85.8
Effective Green, g (s)	8.1	15.4	90.7	90.7	77.7	85.8
Actuated g/C Ratio	0.07	0.14	0.82	0.82	0.71	0.78
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	103	286	244	1362	1290	1199
v/s Ratio Prot	c0.05	c0.04	0.03	0.14	c0.61	0.02
v/s Ratio Perm		0.07	0.37			0.15
v/c Ratio	0.74	0.55	0.49	0.17	0.87	0.21
Uniform Delay, d1	49.9	44.0	18.2	2.0	12.2	3.2
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	20.9	1.1	0.6	0.3	8.0	0.0
Delay (s)	70.8	45.2	18.8	2.2	20.2	3.2
Level of Service	E	D	B	A	C	A
Approach Delay (s)	51.3			7.9	16.3	
Approach LOS	D			A	B	

Intersection Summary

HCM 2000 Control Delay	20.2	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.84		
Actuated Cycle Length (s)	110.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	79.4%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

HCM Unsignalized Intersection Capacity Analysis
6: Access In & Allen Rd

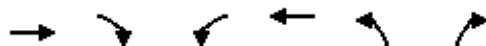
03/08/2018



Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↔			↔		
Traffic Volume (veh/h)	271	5	45	296	0	0
Future Volume (Veh/h)	271	5	45	296	0	0
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	295	5	49	322	0	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None		None			
Median storage (veh)						
Upstream signal (ft)	1108					
pX, platoon unblocked						
vC, conflicting volume			300		718	298
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			300		718	298
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			96		100	100
cM capacity (veh/h)			1261		381	742
Direction, Lane #						
	EB 1	WB 1				
Volume Total	300	371				
Volume Left	0	49				
Volume Right	5	0				
cSH	1700	1261				
Volume to Capacity	0.18	0.04				
Queue Length 95th (ft)	0	3				
Control Delay (s)	0.0	1.4				
Lane LOS		A				
Approach Delay (s)	0.0	1.4				
Approach LOS						
Intersection Summary						
Average Delay			0.8			
Intersection Capacity Utilization			39.3%	ICU Level of Service	A	
Analysis Period (min)			15			

HCM Unsignalized Intersection Capacity Analysis
 12: Access Out & Allen Rd/Allen Rd.

03/08/2018



Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑			↑	↘	↘
Traffic Volume (veh/h)	271	0	0	340	1	9
Future Volume (Veh/h)	271	0	0	340	1	9
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	295	0	0	370	1	10
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	511					
pX, platoon unblocked						
vC, conflicting volume			295	665		295
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			295	665		295
tC, single (s)			4.1	6.4		6.2
tC, 2 stage (s)						
tF (s)			2.2	3.5		3.3
p0 queue free %			100	100		99
cM capacity (veh/h)			1266	425		744
Direction, Lane #	EB 1	WB 1	NB 1			
Volume Total	295	370	11			
Volume Left	0	0	1			
Volume Right	0	0	10			
cSH	1700	1700	697			
Volume to Capacity	0.17	0.22	0.02			
Queue Length 95th (ft)	0	0	1			
Control Delay (s)	0.0	0.0	10.2			
Lane LOS				B		
Approach Delay (s)	0.0	0.0	10.2			
Approach LOS				B		
Intersection Summary						
Average Delay			0.2			
Intersection Capacity Utilization			27.9%	ICU Level of Service	A	
Analysis Period (min)			15			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/08/2018



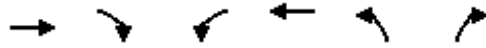
Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	262	228	211	902	347	73
Future Volume (vph)	262	228	211	902	347	73
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1805	1509	1752	1863	1776	1495
Flt Permitted	0.95	1.00	0.37	1.00	1.00	1.00
Satd. Flow (perm)	1805	1509	676	1863	1776	1495
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	288	251	232	991	381	80
RTOR Reduction (vph)	0	165	0	0	0	32
Lane Group Flow (vph)	288	86	232	991	381	48
Heavy Vehicles (%)	0%	7%	3%	2%	7%	8%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	13.3	20.9	36.6	36.6	23.3	36.6
Effective Green, g (s)	13.3	20.9	36.6	36.6	23.3	36.6
Actuated g/C Ratio	0.22	0.34	0.60	0.60	0.38	0.60
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	392	647	538	1115	677	895
v/s Ratio Prot	c0.16	0.02	0.05	c0.53	0.21	0.01
v/s Ratio Perm		0.04	0.20			0.02
v/c Ratio	0.73	0.13	0.43	0.89	0.56	0.05
Uniform Delay, d1	22.3	13.9	6.6	10.5	14.9	5.1
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	6.1	0.0	0.2	8.6	0.6	0.0
Delay (s)	28.3	13.9	6.8	19.1	15.5	5.1
Level of Service	C	B	A	B	B	A
Approach Delay (s)	21.6			16.8	13.7	
Approach LOS	C			B	B	

Intersection Summary

HCM 2000 Control Delay	17.3	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.96		
Actuated Cycle Length (s)	61.1	Sum of lost time (s)	16.9
Intersection Capacity Utilization	71.3%	ICU Level of Service	C
Analysis Period (min)	15		
c Critical Lane Group			

HCM Unsignalized Intersection Capacity Analysis
6: Access In & Allen Rd.

03/08/2018



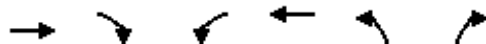
Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↩			↩		
Traffic Volume (veh/h)	445	1	9	280	0	0
Future Volume (Veh/h)	445	1	9	280	0	0
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	484	1	10	304	0	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	1108					
pX, platoon unblocked						
vC, conflicting volume			485		808	484
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			485		808	484
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			99		100	100
cM capacity (veh/h)			1078		347	582

Direction, Lane #	EB 1	WB 1
Volume Total	485	314
Volume Left	0	10
Volume Right	1	0
cSH	1700	1078
Volume to Capacity	0.29	0.01
Queue Length 95th (ft)	0	1
Control Delay (s)	0.0	0.4
Lane LOS		A
Approach Delay (s)	0.0	0.4
Approach LOS		

Intersection Summary			
Average Delay		0.1	
Intersection Capacity Utilization	26.8%	ICU Level of Service	A
Analysis Period (min)	15		

HCM Unsignalized Intersection Capacity Analysis
 12: Access Out & Allen Rd.

03/08/2018



Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑			↑	↘	↘
Traffic Volume (veh/h)	445	0	0	284	5	45
Future Volume (Veh/h)	445	0	0	284	5	45
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	484	0	0	309	5	49
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	511					
pX, platoon unblocked						
vC, conflicting volume			484		793	484
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			484		793	484
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			100		99	92
cM capacity (veh/h)			1079		358	583
Direction, Lane #	EB 1	WB 1	NB 1			
Volume Total	484	309	54			
Volume Left	0	0	5			
Volume Right	0	0	49			
cSH	1700	1700	551			
Volume to Capacity	0.28	0.18	0.10			
Queue Length 95th (ft)	0	0	8			
Control Delay (s)	0.0	0.0	12.2			
Lane LOS				B		
Approach Delay (s)	0.0	0.0	12.2			
Approach LOS				B		
Intersection Summary						
Average Delay			0.8			
Intersection Capacity Utilization			33.4%	ICU Level of Service	A	
Analysis Period (min)			15			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/02/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	62	263	109	227	1260	245
Future Volume (vph)	62	263	109	227	1260	245
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1399	1524	1656	1652	1827	1538
Flt Permitted	0.95	1.00	0.05	1.00	1.00	1.00
Satd. Flow (perm)	1399	1524	88	1652	1827	1538
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	68	289	120	249	1385	269
RTOR Reduction (vph)	0	46	0	0	0	70
Lane Group Flow (vph)	68	243	120	249	1385	199
Heavy Vehicles (%)	29%	6%	9%	15%	4%	5%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	7.7	19.3	91.1	91.1	73.8	81.5
Effective Green, g (s)	7.7	19.3	91.1	91.1	73.8	81.5
Actuated g/C Ratio	0.07	0.18	0.83	0.83	0.67	0.74
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	97	340	238	1368	1225	1139
v/s Ratio Prot	0.05	c0.08	0.05	0.15	c0.76	0.01
v/s Ratio Perm		0.08	0.37			0.12
v/c Ratio	0.70	0.71	0.50	0.18	1.13	0.17
Uniform Delay, d1	50.0	42.8	33.5	1.9	18.1	4.2
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	17.0	5.8	0.6	0.3	69.5	0.0
Delay (s)	67.0	48.6	34.2	2.2	87.6	4.3
Level of Service	E	D	C	A	F	A
Approach Delay (s)	52.1			12.6	74.1	
Approach LOS	D			B	E	

Intersection Summary

HCM 2000 Control Delay	61.2	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	1.08		
Actuated Cycle Length (s)	110.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
 4: Cincinnati Dayton Rd. & Allen Rd.

03/08/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	282	304	250	1082	416	80
Future Volume (vph)	282	304	250	1082	416	80
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1805	1509	1752	1863	1776	1495
Flt Permitted	0.95	1.00	0.36	1.00	1.00	1.00
Satd. Flow (perm)	1805	1509	665	1863	1776	1495
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	310	334	275	1189	457	88
RTOR Reduction (vph)	0	196	0	0	0	27
Lane Group Flow (vph)	310	138	275	1189	457	61
Heavy Vehicles (%)	0%	7%	3%	2%	7%	8%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	16.5	24.7	55.4	55.4	41.5	58.0
Effective Green, g (s)	16.5	24.7	55.4	55.4	41.5	58.0
Actuated g/C Ratio	0.20	0.30	0.67	0.67	0.50	0.70
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	358	544	550	1242	886	1043
v/s Ratio Prot	c0.17	0.02	0.05	c0.64	0.26	0.01
v/s Ratio Perm		0.07	0.28			0.03
v/c Ratio	0.87	0.25	0.50	0.96	0.52	0.06
Uniform Delay, d1	32.2	22.2	7.0	12.8	14.0	4.0
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	18.6	0.1	0.3	16.1	0.2	0.0
Delay (s)	50.8	22.3	7.2	28.9	14.2	4.0
Level of Service	D	C	A	C	B	A
Approach Delay (s)	36.0			24.8	12.6	
Approach LOS	D			C	B	

Intersection Summary

HCM 2000 Control Delay	25.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	1.02		
Actuated Cycle Length (s)	83.1	Sum of lost time (s)	16.9
Intersection Capacity Utilization	81.9%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/08/2018



Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	70	269	147	227	1260	320
Future Volume (vph)	70	269	147	227	1260	320
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1399	1524	1656	1652	1827	1538
Flt Permitted	0.95	1.00	0.05	1.00	1.00	1.00
Satd. Flow (perm)	1399	1524	88	1652	1827	1538
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	77	296	162	249	1385	352
RTOR Reduction (vph)	0	46	0	0	0	82
Lane Group Flow (vph)	77	250	162	249	1385	270
Heavy Vehicles (%)	29%	6%	9%	15%	4%	5%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	8.1	19.7	90.7	90.7	73.4	81.5
Effective Green, g (s)	8.1	19.7	90.7	90.7	73.4	81.5
Actuated g/C Ratio	0.07	0.18	0.82	0.82	0.67	0.74
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	103	346	237	1362	1219	1139
v/s Ratio Prot	0.06	c0.08	0.07	0.15	c0.76	0.02
v/s Ratio Perm		0.09	0.49			0.16
v/c Ratio	0.75	0.72	0.68	0.18	1.14	0.24
Uniform Delay, d1	49.9	42.6	37.2	2.0	18.3	4.5
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	22.5	6.2	6.3	0.3	71.8	0.0
Delay (s)	72.4	48.8	43.5	2.3	90.1	4.5
Level of Service	E	D	D	A	F	A
Approach Delay (s)	53.7			18.5	72.8	
Approach LOS	D			B	E	

Intersection Summary

HCM 2000 Control Delay	61.1	HCM 2000 Level of Service	E
HCM 2000 Volume to Capacity ratio	1.09		
Actuated Cycle Length (s)	110.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	92.7%	ICU Level of Service	F
Analysis Period (min)	15		
c Critical Lane Group			

HCM Unsignalized Intersection Capacity Analysis
6: Access In & Allen Rd

03/08/2018



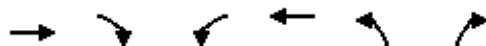
Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↔		↔		↔	
Traffic Volume (veh/h)	325	12	113	355	0	0
Future Volume (Veh/h)	325	12	113	355	0	0
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	353	13	123	386	0	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)				1108		
pX, platoon unblocked						
vC, conflicting volume			366		992	360
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			366		992	360
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			90		100	100
cM capacity (veh/h)			1193		245	685

Direction, Lane #	EB 1	WB 1
Volume Total	366	509
Volume Left	0	123
Volume Right	13	0
cSH	1700	1193
Volume to Capacity	0.22	0.10
Queue Length 95th (ft)	0	9
Control Delay (s)	0.0	2.9
Lane LOS		A
Approach Delay (s)	0.0	2.9
Approach LOS		

Intersection Summary			
Average Delay		1.7	
Intersection Capacity Utilization	49.4%	ICU Level of Service	A
Analysis Period (min)	15		

HCM Unsignalized Intersection Capacity Analysis
 12: Access Out & Allen Rd/Allen Rd.

03/08/2018



Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑			↑	↘	↘
Traffic Volume (veh/h)	325	0	0	467	1	14
Future Volume (Veh/h)	325	0	0	467	1	14
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	353	0	0	508	1	15
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	511					
pX, platoon unblocked						
vC, conflicting volume	353			861	353	
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	353			861	353	
tC, single (s)	4.1			6.4	6.2	
tC, 2 stage (s)						
tF (s)	2.2			3.5	3.3	
p0 queue free %	100			100	98	
cM capacity (veh/h)	1206			326	691	
Direction, Lane #	EB 1	WB 1	NB 1			
Volume Total	353	508	16			
Volume Left	0	0	1			
Volume Right	0	0	15			
cSH	1700	1700	646			
Volume to Capacity	0.21	0.30	0.02			
Queue Length 95th (ft)	0	0	2			
Control Delay (s)	0.0	0.0	10.7			
Lane LOS	B					
Approach Delay (s)	0.0	0.0	10.7			
Approach LOS	B					
Intersection Summary						
Average Delay	0.2					
Intersection Capacity Utilization	34.6%			ICU Level of Service	A	
Analysis Period (min)	15					

HCM Signalized Intersection Capacity Analysis
4: Cincinnati Dayton Rd. & Allen Rd.

03/07/2018



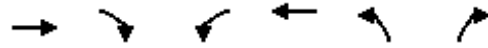
Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (vph)	350	349	255	1082	416	89
Future Volume (vph)	350	349	255	1082	416	89
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00
Frt	1.00	0.85	1.00	1.00	1.00	0.85
Flt Protected	0.95	1.00	0.95	1.00	1.00	1.00
Satd. Flow (prot)	1805	1509	1752	1863	1776	1495
Flt Permitted	0.95	1.00	0.35	1.00	1.00	1.00
Satd. Flow (perm)	1805	1509	652	1863	1776	1495
Peak-hour factor, PHF	0.91	0.91	0.91	0.91	0.91	0.91
Adj. Flow (vph)	385	384	280	1189	457	98
RTOR Reduction (vph)	0	183	0	0	0	28
Lane Group Flow (vph)	385	201	280	1189	457	70
Heavy Vehicles (%)	0%	7%	3%	2%	7%	8%
Turn Type	Prot pm+ov	pm+pt	NA	NA	pm+ov	
Protected Phases	4	5	5	2	6	4
Permitted Phases		4	2			6
Actuated Green, G (s)	19.7	28.2	57.5	57.5	43.3	63.0
Effective Green, g (s)	19.7	28.2	57.5	57.5	43.3	63.0
Actuated g/C Ratio	0.22	0.32	0.65	0.65	0.49	0.71
Clearance Time (s)	5.3	5.3	5.3	5.9	6.3	5.3
Vehicle Extension (s)	0.2	0.2	0.2	0.2	0.2	0.2
Lane Grp Cap (vph)	402	571	529	1211	869	1065
v/s Ratio Prot	c0.21	0.03	0.05	c0.64	0.26	0.01
v/s Ratio Perm		0.10	0.29			0.03
v/c Ratio	0.96	0.35	0.53	0.98	0.53	0.07
Uniform Delay, d1	33.9	23.1	8.1	14.9	15.5	3.8
Progression Factor	1.00	1.00	1.00	1.00	1.00	1.00
Incremental Delay, d2	33.5	0.1	0.4	21.4	0.3	0.0
Delay (s)	67.4	23.2	8.5	36.3	15.8	3.8
Level of Service	E	C	A	D	B	A
Approach Delay (s)	45.3			31.0	13.7	
Approach LOS	D			C	B	

Intersection Summary

HCM 2000 Control Delay	31.5	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	1.05		
Actuated Cycle Length (s)	88.4	Sum of lost time (s)	16.9
Intersection Capacity Utilization	85.7%	ICU Level of Service	E
Analysis Period (min)	15		
c Critical Lane Group			

HCM Unsignalized Intersection Capacity Analysis
6: Access In & Allen Rd

03/07/2018



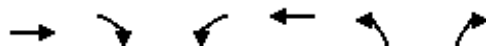
Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↔		↔		↔	
Traffic Volume (veh/h)	586	1	14	342	0	0
Future Volume (Veh/h)	586	1	14	342	0	0
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	637	1	15	372	0	0
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	1108					
pX, platoon unblocked						
vC, conflicting volume			638		1040	638
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			638		1040	638
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			98		100	100
cM capacity (veh/h)			946		251	477

Direction, Lane #	EB 1	WB 1
Volume Total	638	387
Volume Left	0	15
Volume Right	1	0
cSH	1700	946
Volume to Capacity	0.38	0.02
Queue Length 95th (ft)	0	1
Control Delay (s)	0.0	0.5
Lane LOS		A
Approach Delay (s)	0.0	0.5
Approach LOS		

Intersection Summary			
Average Delay		0.2	
Intersection Capacity Utilization	34.2%	ICU Level of Service	A
Analysis Period (min)	15		

HCM Unsignalized Intersection Capacity Analysis
 12: Access Out & Allen Rd/Allen Rd.

03/07/2018



Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑			↑	↘	↘
Traffic Volume (veh/h)	586	0	0	344	13	113
Future Volume (Veh/h)	586	0	0	344	13	113
Sign Control	Free			Free	Stop	
Grade	0%			0%	0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	637	0	0	374	14	123
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						
Median type	None			None		
Median storage (veh)						
Upstream signal (ft)	511					
pX, platoon unblocked						
vC, conflicting volume			637		1011	637
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol			637		1011	637
tC, single (s)			4.1		6.4	6.2
tC, 2 stage (s)						
tF (s)			2.2		3.5	3.3
p0 queue free %			100		95	74
cM capacity (veh/h)			947		265	477
Direction, Lane #	EB 1	WB 1	NB 1			
Volume Total	637	374	137			
Volume Left	0	0	14			
Volume Right	0	0	123			
cSH	1700	1700	441			
Volume to Capacity	0.37	0.22	0.31			
Queue Length 95th (ft)	0	0	33			
Control Delay (s)	0.0	0.0	16.8			
Lane LOS			C			
Approach Delay (s)	0.0	0.0	16.8			
Approach LOS			C			
Intersection Summary						
Average Delay			2.0			
Intersection Capacity Utilization			45.2%	ICU Level of Service		A
Analysis Period (min)			15			

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	111	213	182	72	825	545
Average Queue (ft)	46	98	57	17	336	119
95th Queue (ft)	91	193	107	51	745	441
Link Distance (ft)	863		1752		786	
Upstream Blk Time (%)					5	
Queuing Penalty (veh)					0	
Storage Bay Dist (ft)	400		439		520	
Storage Blk Time (%)					6	
Queuing Penalty (veh)					13	

Network Summary

Network wide Queuing Penalty: 14

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	241	99	116	406	187	44
Average Queue (ft)	100	47	60	139	93	10
95th Queue (ft)	177	80	98	267	177	33
Link Distance (ft)	863			1752	786	
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)						
Queuing Penalty (veh)						

Network Summary

Network wide Queuing Penalty: 0

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	194	247	204	73	826	545
Average Queue (ft)	61	164	75	16	682	314
95th Queue (ft)	140	240	146	54	979	734
Link Distance (ft)	863			1752	786	
Upstream Blk Time (%)					16	
Queuing Penalty (veh)					0	
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)					17	0
Queuing Penalty (veh)					43	1

Network Summary

Network wide Queuing Penalty: 44

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	362	159	464	2398	244	51
Average Queue (ft)	125	65	375	1587	112	16
95th Queue (ft)	244	120	631	2735	196	39
Link Distance (ft)	863			2364	786	
Upstream Blk Time (%)				9		
Queuing Penalty (veh)				0		
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)			0	24		
Queuing Penalty (veh)			0	60		

Network Summary

Network wide Queuing Penalty: 60

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	107	212	114	90	826	545
Average Queue (ft)	47	106	54	25	372	132
95th Queue (ft)	97	195	95	75	780	480
Link Distance (ft)	439		1752		786	
Upstream Blk Time (%)					2	
Queuing Penalty (veh)					0	
Storage Bay Dist (ft)	400		439		520	
Storage Blk Time (%)					6	
Queuing Penalty (veh)					18	

Intersection: 6: Access In & Allen Rd

Movement	WB
Directions Served	LT
Maximum Queue (ft)	53
Average Queue (ft)	10
95th Queue (ft)	31
Link Distance (ft)	559
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 12: Access Out & Allen Rd/Allen Rd.

Movement	NB
Directions Served	LR
Maximum Queue (ft)	31
Average Queue (ft)	7
95th Queue (ft)	27
Link Distance (ft)	274
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 18

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	221	66	132	342	236	89
Average Queue (ft)	106	34	72	132	85	25
95th Queue (ft)	184	62	120	229	173	57
Link Distance (ft)	439			1752	786	
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 6: Access In & Allen Rd.

Movement	WB
Directions Served	LT
Maximum Queue (ft)	53
Average Queue (ft)	2
95th Queue (ft)	18
Link Distance (ft)	559
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 12: Access Out & Allen Rd.

Movement	NB
Directions Served	LR
Maximum Queue (ft)	76
Average Queue (ft)	31
95th Queue (ft)	53
Link Distance (ft)	274
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 0

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	156	308	246	97	839	545
Average Queue (ft)	58	146	98	24	758	458
95th Queue (ft)	125	243	188	64	962	771
Link Distance (ft)	439			1752	786	
Upstream Blk Time (%)					23	
Queuing Penalty (veh)					0	
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)					24	0
Queuing Penalty (veh)					76	2

Intersection: 6: Access In & Allen Rd

Movement	WB
Directions Served	LT
Maximum Queue (ft)	74
Average Queue (ft)	19
95th Queue (ft)	56
Link Distance (ft)	559
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Intersection: 12: Access Out & Allen Rd/Allen Rd.

Movement	NB
Directions Served	LR
Maximum Queue (ft)	53
Average Queue (ft)	7
95th Queue (ft)	30
Link Distance (ft)	274
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 77

Intersection: 4: Cincinnati Dayton Rd. & Allen Rd.

Movement	EB	EB	NB	NB	SB	SB
Directions Served	L	R	L	T	T	R
Maximum Queue (ft)	451	425	464	1445	242	51
Average Queue (ft)	203	102	346	778	135	18
95th Queue (ft)	355	260	634	1313	224	49
Link Distance (ft)	439			2844	786	
Upstream Blk Time (%)	0	0				
Queuing Penalty (veh)	1	0				
Storage Bay Dist (ft)		400	439			520
Storage Blk Time (%)	1	0	0	25		
Queuing Penalty (veh)	4	0	0	64		

Intersection: 6: Access In & Allen Rd

Movement	WB
Directions Served	LT
Maximum Queue (ft)	27
Average Queue (ft)	4
95th Queue (ft)	18
Link Distance (ft)	559
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

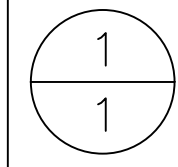
Intersection: 12: Access Out & Allen Rd/Allen Rd.

Movement	NB
Directions Served	LR
Maximum Queue (ft)	142
Average Queue (ft)	50
95th Queue (ft)	100
Link Distance (ft)	274
Upstream Blk Time (%)	
Queuing Penalty (veh)	
Storage Bay Dist (ft)	
Storage Blk Time (%)	
Queuing Penalty (veh)	

Network Summary

Network wide Queuing Penalty: 70

Appendix E: Turn Lane Design



WEST CHESTER, OH

EQUIPMENT DEPOT ENTRANCE PLAN
ALLEN ROAD WEST OF CIN-DAY ROAD

CALCULATED

CHECKED

0 20 40 80

HORIZONTAL
SCALE IN FEET