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Memorandum

To: **Mike Jenkins**
MAJ Development Corporation

From: **Daniel Stumpf, PE**
Ken Kim, PE

Date: **October 12, 2023**

Subject: **Chipotle Mexican Grill Restaurant Transportation Analysis Letter**

REGISTERED PROFESSIONAL ENGINEER
88808PE
OREGON
MAR 12, 2019
DANIEL W STUMPF

Daniel W Stumpf
Digitally signed by Daniel W Stumpf
DN: c=US, o=Washington, dnQualifier=A01410C00000182365DC634000047E4, cn=Daniel W Stumpf
Date: 2023.10.12 12:32:45 -07'00'

RENEWS: 6/30/2024

Introduction

This Transportation Analysis Letter (TAL) reports the findings of a limited transportation study conducted for a proposed Chipotle Mexican Grill Restaurant, to be located at 597 SW 1st Avenue in Canby, Oregon. The proposal will repurpose an existing 2,750 square foot Dairy Queen fast-food restaurant as a Chipotle restaurant. Main access to the site will be provided via two existing driveways along SW 1st Avenue (OR-99E), noting alternative access to the nearby roadways of S Elm Street and SW 2nd Avenue are available via internal drive aisle connections to site adjacent properties.

Based on correspondence with the City of Canby's transportation consultant, the preparation of an abbreviated transportation study (i.e. TAL) is sufficient to capture the anticipated impacts associated with the proposed development. The following analysis items were conducted/reviewed:

- Conduct a trip generation analysis for the proposed development, which will include a review of AM peak hour, mid-day peak hour, PM peak hour, and average daily trip generation.
- Provide an estimate of site trip distribution.
- Review neighborhood through-trip impacts and evaluate potential impacts to residential areas and local streets (City of Canby code section 16.08.150.H).
- Evaluate potential impacts to pedestrian and bicycle routes, and review internal site circulation and connections to off-site vehicular, pedestrian, and bicycle facilities.
- Review access spacing standards and widths for site access driveways.
- Conduct a queuing analysis for the proposed drive-thru lane based on a review of trip generation and service times at two comparable Chipotle restaurants.
- Review sight distances at access locations, minimum paved driveway width standards, adequate frontage improvements, and compliance with mobility standards identified in the Transportation System Plan (Canby code section 16.08.160 B, D, E, and F).

Detailed information on trip generation/queuing data as well as other supporting materials are included as an attachment to this memorandum.

Project Site Description

The project site is located southeast of OR-99E, north of SW 2nd Avenue, and west of S Elm Street in Canby, Oregon. Located in a predominately commercial area of the City, the site is surrounded by a bank to the east, industrial uses to the west and south, and OR-99E and railroad tracks to the north.

The site includes a single property (tax lot 31E33CC-06501) which encompasses an approximate total of 0.60 acres. The site is currently developed as a 2,750 square foot Dairy Queen fast-food restaurant with a drive-thru window. Main access to the site is available via two existing driveways along OR-99E, noting alternative access to the nearby roadways of S Elm Street and SW 2nd Avenue are available via internal drive aisle connections to site adjacent properties.

Vicinity Roadways

The project site is located near four roadways. Table 1 provides a description of these roadways within the site vicinity.

Table 1: Vicinity Roadway Descriptions

Street Name	Jurisdiction	Functional Classification	Speed (MPH)	On-Street Parking	Curbs & Sidewalks	Bicycle Lanes
SW 1st Street (OR-99E)	ODOT	Regional Highway	35	Not Permitted	Partial Both Sides	None
SW 2nd Avenue	City of Canby	Collector	25	Partially Permitted	Partial Both Sides	None
Birch Street	City of Canby	Collector/ Local	25	Not Permitted	Partial Both Sides	None
S Elm Street	City of Canby	Arterial	25	Partially Permitted	Partial Both Sides	None

Table Notes: Functional Classification and Speed Limits based on City of Canby TSP.

Figure 1 presents an aerial image of the nearby vicinity with the project site outlined in yellow.

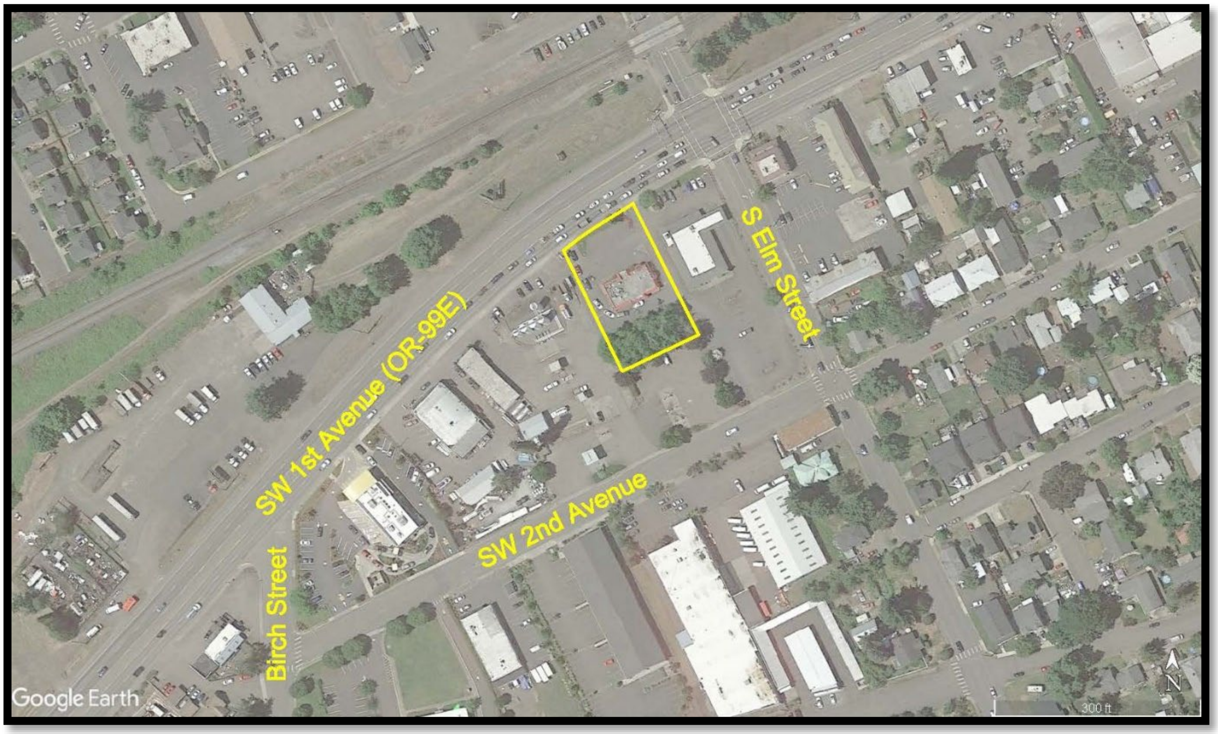


Figure 1: Aerial Photo of Site Vicinity (Image from Google Earth)

Trip Generation

Total Trips

To estimate the number of trips that are currently and will be generated by the existing and proposed uses, trip rates from the *Trip Generation Manual*[1] were used. Data from land use code 934, *Fast-Food Restaurant with Drive-Through Window*, was used to estimate existing and proposed site trip generation based on the square footage of the gross building floor area.

Pass-by Trips

According to the Institute of Transportation Engineers (ITE), retail, service, and restaurant land uses typically generate pass-by and diverted trips. Pass-by trips are trips that leave a site adjacent roadway to patronize a land use and then continue in their original direction of travel. Like pass-by trips, diverted trips are trips that divert from a nearby roadway not adjacent to the site to patronize a land use before continuing to their original destination. Pass-by trips do not add additional vehicles to the surrounding transportation system; however, they do add additional turning movements at site access intersections. Diverted trips may add turning movements at both site access and other nearby intersections.

[1] Institute of Transportation Engineers (ITE), *Trip Generation Manual*, 11th Edition, 2021.

To estimate pass-by trip generation for the existing and proposed restaurant uses, data from land use code 934, *Fast-Food Restaurant with Drive-Through Window*, was referenced. The following pass-by trip generation rates were used:

- Morning Peak Hour: 50% pass-by rate during a typical weekday.
- Evening Peak Hour: 55% pass-by rate during a typical weekday.

For the purposes of this analysis, it is assumed that the daily pass-by trip rate will approximately match the evening peak hour pass-by trip rate. Additionally, all diverted trips generated were treated as primary trips.

Analysis Findings

The trip generation calculations show that the proposed development is projected to generate zero additional morning peak hour, evening peak hour, and average weekday site trips. The trip generation estimates are summarized in a Table 2. Detailed trip generation calculations are included as an attachment to this memorandum.

Table 2: Trip Generation Summary

	ITE Code	Size/Rate	AM Peak Hour			PM Peak Hour			Weekday Total
			Enter	Exit	Total	Enter	Exit	Total	
Existing Conditions									
Fast-Food Restaurant with Drive-Through Window	934	2,750 SF	63	60	123	47	44	91	1,286
Pass-by Trips		*50% (55%)*	*31*	*31*	*62*	*25*	*25*	*50*	708
Primary Trips			32	29	61	22	19	41	578
Proposed Conditions									
Fast-Food Restaurant with Drive-Through Window	934	2,750 SF	63	60	123	47	44	91	1,286
Pass-by Trips		*50% (55%)*	*31*	*31*	*62*	*25*	*25*	*50*	708
Primary Trips			32	29	61	22	19	41	578
Net New Trips									
Net New Trips (Primary Trips)			0	0	0	0	0	0	0

Table Notes: AM peak hour and PM peak hour pass-by trip rates denoted as AM (PM)

The trip generation calculations show that the proposed development application will result in no additional site trip generation. Therefore, no additional impact to the transportation system is anticipated to occur as part of the application.

Note that the typical hours of operation for a Chipotle restaurant are between 10:45 AM to 11:00 PM, whereby little to no trips will be generated during the morning peak hour. Mid-day peak hour trip generation for the proposed development is reviewed in the *Drive-Thru Queuing Analysis* section of this report.

Trip Distribution

The directional distribution of site trips was estimated based on the locations of likely trip destinations and locations of major transportation facilities in the site vicinity. The following trip distribution was estimated and used for analysis:

Primary Trips

- Approximately 45% of site trips will travel to/from the east along OR-99E.
- Approximately 30% of site trips will travel to/from the west along OR-99E.
- Approximately 15% of site trips will travel to/from the south along S Elm Street.
- Approximately 10% of site trips will travel to/from the north along N Elm Street.

Pass-by Trips

All pass-by trips generated will be drawn from OR-99E.

Transportation Impacts

Neighborhood Through-Trip Impacts

According to City of Canby code section 16.08.150.H:

> *Any development projected to add more than 30 through-vehicles in a peak hour or 300 through-vehicle per day to an adjacent residential local street or neighborhood route will be require assessment and mitigation of residential street impacts.*

As described in the *Trip Generation* and *Trip Distribution* sections, the proposal will not result in an increase in site trip generation relative to the existing on-site use. Therefore, no additional impacts to adjacent residential local streets or neighborhood routes will occur.

If evaluating site trip impacts of the development regardless of whether these trips are already "existing" on the transportation system, the proposal is projected to added less than 30 peak hour trips and less than 300 daily trips to adjacent local streets or neighborhood routes for the following reasons:

- All site adjacent roadways are classified as Collectors, Arterials, or Highways (not Local Streets/Other Roadways or Neighborhood Connectors).
- Most, if not all, of primary site trips generated by the proposal are expected to utilize the nearby higher classified roadways of OR-99E and N/S Elm Street as through streets to access other major transportation facilities, municipalities, or more distant neighborhoods/communities within/outside the City of Canby.
- Based on the site trip distribution assumptions, with the exception of the segment of OR-99E between Birch Street and N/S Elm Street none of the roadways will be impacted by 30 or more morning or evening primary peak hour trips or 300 or more daily trips.

Per the above, no mitigation is necessary or recommended to address residential street impacts as part of the proposed development application.

Pedestrian/Bicycle Route Impacts and Connections

The project site's only street frontage is with the ODOT roadway of OR-99E. Along this segment of OR-99E, sidewalks are provided along the south side of the roadway. To the east of the site, N/S Elm Street generally provides sidewalks along both sides of the roadway with marked/signalized crosswalks at the intersection of OR-99E at N/S Elm Street. To the south of the site, SW 2nd Avenue provides sidewalks along both sides of the roadway with marked crosswalks at the intersection of SW 2nd Avenue at S Elm Street.

The development proposal will include the construction of a pedestrian path between the project site's north parking lot and the existing sidewalk along OR-99E at a location near the northeast corner of the site. The proposal will not remove or block any existing pedestrian/bicycle facilities in the vicinity of the project site. Additionally, the proposal is not projected to add additional traffic to the transportation system or result in a change in vehicle/trip types generated compared to the existing Dairy Queen fast-food restaurant. Therefore, no additional impacts to nearby pedestrian/bicycle routes or facilities will occur and connectivity between the project site and site adjacent street will be improved. No mitigation is necessary or recommended.

Access Spacing and Driveway Width Standards

Access Spacing

Per OAR 734-051-4020 Table 5, Regional Highways in urban areas with a posted speed of 35 mph have a minimum access spacing standard of 350 feet. The segment of OR-99E between Birch Street and N/S Elm Street is approximately 800 feet in length (measured near edge to near edge), where a maximum of 2 driveways (4 driveways if paired/located opposite each other) may be allowed along the highway per standards (in actuality 9 driveways currently take access along the north and south sides of the roadway segment).

Since the application does not constitute a change in use per ODOT standards (i.e., no increase or change in site trips generated will occur) and no modifications to the existing access driveways are proposed beyond revising the west access from two-way travel to ingress only, no mitigation is required at site access driveways as part of this application.

Driveway Widths

According to ODOT's Highway Design Manual (HDM), commercial driveways serving between 21 to 150 peak hour trips typically have a throat width of 28 to 32-feet. Note the HDM suggests, "*typical throat widths are only to be used as guides to the designer or permit specialist. The throat width needs to be checked to ensure traffic movements are accommodated acceptably*."

The east site access, which is shared with an adjacent bank, is approximately 24 feet wide and will serve two-way travel. The west site access is approximately 18.5 feet wide and will be revised to serve site ingress traffic. Since the existing driveways were able to accommodate two-way travel for both bank trips and the prior developed Dairy Queen restaurant trips, its expected both driveway widths are adequate to accommodate trips of the proposed Chipotle restaurant. Additionally, the development proposal will not constitute a change in use per ODOT standards (i.e., no increase or change in site trips generated will occur). Therefore, no mitigation is required at site access driveways as part of this application.

Drive-Thru Queuing Analysis

As part of the proposed Chipotle restaurant, the development will include an approximate 100-foot striped queue lane from the drive-thru window and the end of the striped queue storage area, and an additional 70 feet of space before queues extend back to OR-99E. No in-person ordering or financial transactions will be allowed at the drive-thru window. At the request of City of Canby, a queuing analysis was prepared to ensure potential drive-thru queues will not extend back to the site adjacent roadways of OR-99E and that queues will not or significantly obstruct/impede on-site circulation.

Methodology

To estimate potential drive-thru queuing which may occur at the site, queuing observations were conducted at two existing Chipotle Mexican Grill restaurants which are expected to operate similar to the proposed development. By similar, both facilities are located in urban settings, along/near major roadways, and operate with mobile order pick-up drive-thrus. The restaurants observed include the following:

- 3105 E Portland Road in Newberg, Oregon.
- 1201 SW Scotton Way in Battle Ground, Washington.

According to time-of-day distribution data retrieved from ITE's *Trip Generation Manual, 11th Edition*, the two-hour peak period of trip generation for land use code 934, *Fast-Food Restaurant with Drive-Through Window*, occurs between the hours of 11:00 AM – 1:00 PM (approximately 19.7% of the total daily trips generated). Therefore, video footage at each of the facilities was collected during this time period on Thursday, September 14, 2023. At the request of the City of Canby's transportation consultant, the following were captured from the video footage:

- Mid-day peak hour trip generation data for each facility.
- A percentage split of patrons utilizing the drive-thru relative to parking and entering each restaurant.
- Service times for vehicles at the drive-thru windows.

Observation Results

Of the observed Chipotles, the Newberg site typically had higher peak hour trip generation than the Battle Ground site by approximately 22%. However, the percentage of trips utilizing the drive-thrus and the observed queue lengths were relatively consistent between the two locations, with 95th percentile queues of 3 vehicles. On average both facilities generated 140 total peak hour trips, or 70 vehicles, with 25 vehicles utilizing the drive-thru (approximately 35.7% of trips). Based on the square footages of each facility, an average trip generation rate of 57.35 peak hour trips per 1,000 square feet of gross building floor area was calculated, with 50% of trips entering and 50% of trips exiting.

Due to the placement of cameras, accurate services times could only be captured at the Battle Ground Chipotle's drive-thru window. Although service times could not be retrieved from the Newberg site, it's expected service times will be consistent between the two facilities given queues were relatively the same, even with the higher recorded trip generation at the Newberg site, and the processes of conducting mobile orders and food pick up will be the same. Note that during the observations there were three vehicles at the drive-thru window that spent abnormally long periods of time at the window, greater than 90 seconds at approximately 2 minutes (1 vehicle) and 5 minutes (2 vehicles). These three extended service times are more reminiscent of a standard fast-food restaurant service time, where the ordering and payment process occurs at the window, however, it's unclear from the video footage if this was the case or if there was another circumstance that contributed to these extended service times. On average the service time at the drive-thru window was 51.2 seconds when considering all vehicles that entered the drive-thru. If these three outlier vehicles are removed, the average service time reduces to 31.8 seconds (median service time was recorded to be 28 seconds).

Table 3 presents a summary of the trip generation observations and calculations while Table 4 provides a summary of observed service times and queue lengths. The raw recorded data at each facility is included as an attachment to this memorandum.

Table 3: Trip Generation Observations and Calculations

Observed Peak Hour Trip Generation					Custom Trip Generation Rate				
Time	Enter	Exit	Total	Drive-Thru Vehicles	Building Area [SF]	Enter %	Exit %	Rate (Trips/KSF)	Drive-Thru Trips (% Of Total Trips)
Newberg Chipotle Mexican Grill									
11:46 AM - 12:46 PM	80	74	154	28	2,500	51.9%	48.1%	61.60	36.4%
Battle Ground Chipotle Mexican Grill									
11:33 AM - 12:33 PM	59	67	126	22	2,381	46.8%	53.2%	52.92	34.9%
Average of Observed Trip Generation									
-	70	70	140	25	2,441	50.0%	50.0%	57.35	35.7%

Table 4: Observed Service Times and Queuing

Observed Peak Hour Trip Generation	Observed Queues		Median Service Time [s] (Entire 2-Hr)	Avg. Service Time [s] (Entire 2-Hour, All Vehicles)	Avg. Service Time [s] (Entire 2-Hours, Outliers Removed)
	95th Percentile	Max			
Newberg Chipotle Mexican Grill					
11:46 AM - 12:46 PM	3	4	-	-	-
Battle Ground Chipotle Mexican Grill					
11:33 AM - 12:33 PM	3	3	28	51.2	31.8
Average of Observed Trip Generation					
-	3	4	28	51.2	31.8

Queuing Analysis

At the request of the City of Canby's transportation consultant, to estimate potential drive-thru queuing which may occur at the site a calculation of queuing based on Single Channel Queuing theory was conducted. Details pertaining to this methodology were referenced from the following two articles, both of which are included as attachments to this memorandum:

- *The Application of the Queuing Theory in the Traffic Flow of Intersection*.[2]
- *A Trip Generation Study of Coffee/Donut Shops in Western New York*.[3]

Referred to as M/M/1 queuing, Single Channel Queuing theory assumes that customers will arrive at the drive-thru lane randomly and projected queuing is estimated based on a Poisson distribution. Since the proposed development will repurpose an existing 2,750 square foot building, an arrival rate of 28 inbound drive-thru vehicles per hour was estimated when considering the calculated trip generation rate of 57.35 peak hour trips per 1,000 square feet of gross building floor area, the inbound trip split of 50%, and the 35.7% of trips expected to utilize the drive-thru verses parking and entering the restaurant. An average service time of 51.2 seconds per vehicles was utilized. Based on these inputs, the following queue lengths were projected:

- 95^{th} percentile = 3 vehicles (Approximately 2.5% chance to occur).
- 99^{th} percentile = 4 vehicles (Approximately 1.0% chance to occur).

Note the above calculated 95^{th} percentile and 99^{th} percentile queues, utilizing Single Channel Queuing theory, are consistent with the observed 95^{th} percentile and maximum queues at the existing Newberg and Battle Ground Chipotle restaurants. Based on these findings and assuming each queued vehicle occupies up to 25 feet of queue storage space, the calculated and observed 95^{th} percentile and maximum queues of 75 and 100 feet can be accommodated by the proposed 100-foot drive-thru queue lane. Therefore, the drive-thru lane will have sufficient storage space to accommodate expected queues which may form at the drive-thru pickup window, and queues will not extend back to the site adjacent roadway of OR-99E or impede vehicle circulation within the site. No mitigation is necessary or recommended with regard to the proposed drive-thru lane.

[2] Yang, X (2014). The Application of the Queuing Theory in the Traffic Flow of Intersection. *World Academy of Science, Engineering and Technology International Journal of Mathematical and Computational Sciences Volume 8*.

[3] Greene, C., & Kannan, V (2011, June). A Trip Generation Study of Coffee/Donut Shops in Western New York. *ITE Journal*.

Safety Analysis

According to Canby Municipal Code section 16.08.160 *Safety and Functionality Standards*:

> *The City will not issue any development permits unless the proposed development complies with the city's basic transportation safety and functionality standards, the purpose of which is to ensure that development does not occur in areas where the surrounding public facilities are inadequate.*

Based on correspondence with the City's transportation consultant, the following applicable code criteria are addressed below.

Criterion B

Safe access and clear vision at intersections, as determined by the city.

To evaluate access safety and clear vision, intersection sight distances were measured at the two site access driveways along OR-99E in accordance with the standards established in *A Policy of Geometric Design of Highways and Streets*[4]. According to AASHTO, the driver's eye is assumed to be approximately 15 feet (14.5 feet specifically) from the near edge of the nearest travel lane (or traveled way) of the intersecting street and at a height of 3.5 feet above the minor-street approach pavement. The vehicle driver's eye-height along the major-street approach is assumed to be 3.5 feet above the cross-street pavement.

Per the AASHTO manual, intersection sight distance is an operation measure intended to provide sufficient line of sight along the major-street so that a driver could turn from the minor-street approach without impeding traffic flow. Conversely, stopping sight distance is considered the minimum requirement to ensure safe operation of an intersection. This is the distance that allows an oncoming driver to see a hazard on the roadway, react, and come to a complete stop, if necessary, to avoid a collision.

Based on a posted speed of 35 mph along OR-99E, the minimum recommended intersection sight distances to allow for safe and efficient operation of the intersection is 440 feet to the east for northbound left-turning vehicles (when considering the need for minor-street turning vehicles to cross two additional travel lanes) and 335 feet to the west for northbound right-turning vehicles. At both existing access locations, sight distances to the east were measured to be in excess of 450 feet while sight distances to the west were measured to be in excess of 350 feet. Note the west site access intersection is planned to serve site ingress traffic only, whereby sight distance for minor-street approaching vehicles will not be applicable at this driveway following completion of the proposed development.

Based on the analysis, adequate intersection sight distances will be available at the site access approaches along OR-99E to allow for safe and efficient operation of each intersection. No mitigation is necessary or recommended at the access intersections with respect to intersection sight distance.

[4] American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets*, 6th Edition, 2011.

Criteria D & E

D. Access onto a public street with the minimum paved widths as stated in Subsection E below.

E. Adequate frontage improvements as follows:

1. *For local streets and neighborhood connectors, a minimum paved width of 16 feet along the site's frontage.*
2. *For collector and arterial streets, a minimum paved width of 20 feet along the site's frontage.*
3. *For all streets, a minimum horizontal right-of-way clearance of 20 feet along the site's frontage.*

The proposed development will take access to OR-99E via two existing driveways that currently serve the site. As part of the proposed development application, adequate horizontal right-of-way clearances will be provided along the site frontage with OR-99E to meet ODOT standards. No other mitigation is necessary or recommended.

Criterion F

Compliance with mobility standards identified in the TSP. If a mobility deficiency already exists, the development shall not create further deficiencies.

According to the City of Canby's TSP, the following minimum acceptable operation standards apply to intersections under City, Clackamas County, and ODOT jurisdiction:

- City of Canby
  - Signalized and all-way stop-controlled intersections are required to operate at Level of Service (LOS) D or better.
  - Two-way stop-controlled intersections are required to operate at LOS E or better.
- Clackamas County
  - All arterial and collector intersections are required to operate at LOS D or better.
- ODOT
  - OR-99E within or near City limits is required to operate with v/c ratios of 0.85 along >35 mph non-STA segments, 0.90 for ≤35 mph non-STA segments, and 1.0 for STA segments.

Since the development proposal will not result in an increase in site trip generation, no additional impacts to the transportation system will occur. Therefore, the development will not create further deficiencies to the system. No other mitigation is necessary or recommended.

Analysis Summary

Based on the above review of applicable safety and functionality standards detailed in Canby Municipal Code section 16.08.160, the proposed development will comply with these City standards. No other mitigation is necessary or recommended.

Conclusions

The proposed Chipotle Mexican Grill restaurant project will result in no additional site trip generation. Therefore, no additional impact to the transportation system is anticipated to occur as part of the application.

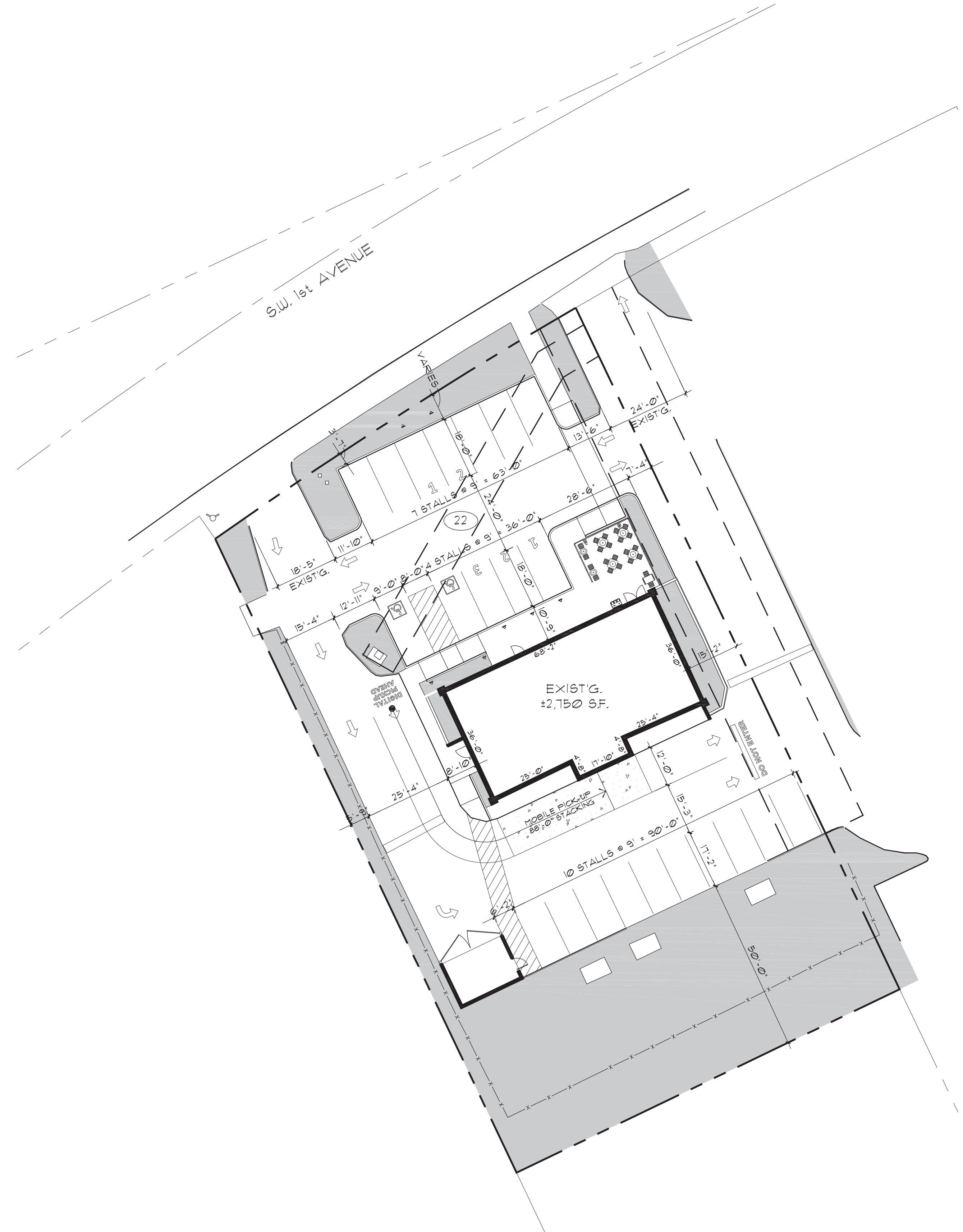
Since the proposal will not result in a change in site trip generation no additional impacts to residential streets, nearby pedestrian facilities, or bicycle routes occur. Additionally, connectivity between the project site and OR-99E will be improved via the construction of a pedestrian path between the north parking lot and existing street sidewalks. No mitigation is necessary or recommended to address street impacts or connectivity as part of the proposed development application.

Since the application does not constitute a change in use per ODOT standards (i.e., no increase or change in site trips generated will occur) and no modifications to the existing access driveways are proposed beyond revising the west access from two-way travel to ingress only, no mitigation is required at site access driveways related to access spacing and driveway widths as part of this application.

The drive-thru lane will have sufficient storage space to accommodate expected queues which may form at the drive-thru pickup window, and queues will not extend back to the site adjacent roadway of OR-99E or impede vehicle circulation within the site. No mitigation is necessary or recommended with regard to the proposed drive-thru lane.

Based on a review of applicable safety and functionality standards detailed in Canby Municipal Code section 16.08.160, the proposed development will comply with these City standards. No other mitigation is necessary or recommended.

If you have any questions regarding the preparation of the TIR, please don't hesitate to contact us.



SITE PLAN

0' 20' 40' 80'

NORTH

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MAJ @ CANBY 'QSR' REMODEL

597 SW 1st AVENUE
CANBY, OREGON

MAJ DEVELOPMENT

PROJECT NO.
2023-108

DATE :
08-14-2023

DRAWN BY :
GAH

CHECKED BY :
FMS

REVISIONS

2023-108\asp5 / Layout1

SP5

TRIP GENERATION CALCULATIONS
Source: Trip Generation Manual, 11th Edition

Land Use:	Fast-Food Restaurant with Drive-Through Window
Land Use Code:	934
Land Use Subcategory:	All Sites
Setting/Location	General Urban/Suburban
Variable:	1000 SF GFA
Trip Type:	Vehicle
Formula Type:	Rate
Variable Quantity:	2.75

AM PEAK HOUR

Trip Rate: 44.61

	Enter	Exit	Total
Directional Split	51%	49%	
Trip Ends	63	60	123

PM PEAK HOUR

Trip Rate: 33.03

	Enter	Exit	Total
Directional Split	52%	48%	
Trip Ends	47	44	91

WEEKDAY

Trip Rate: 467.48

	Enter	Exit	Total
Directional Split	50%	50%	
Trip Ends	643	643	1,286

SATURDAY

Trip Rate: 616.12

	Enter	Exit	Total
Directional Split	50%	50%	
Trip Ends	847	847	1,694

Vehicle Pass-By Rates by Land Use

Source: ITE *Trip Generation Manual* , 11th Edition

Land Use Code	934								
Land Use	Fast-Food Restaurant with Drive-Through Window								
Setting	General Urban/Suburban								
Time Period	Weekday AM Peak Period								
# Data Sites	5								
Average Pass-By Rate	50%								
	Pass-By Characteristics for Individual Sites								
	State or	Survey		Pass-By	Non-Pass-By Trips			Adj Street Peak	
GFA (000)	Province	Year	# Interviews	Trip (%)	Primary (%)	Diverted (%)	Total (%)	Hour Volume	Source
1.4	Kentucky	1993	—	62	22	16	38	1407	2
3	Kentucky	1993	—	43	14	43	57	2903	2
3.3	--	1996	—	68	—	—	32	—	21
3.6	Kentucky	1993	—	32	47	21	68	437	2
4.2	Indiana	1993	—	46	23	31	54	1049	2

Vehicle Pass-By Rates by Land Use

Source: ITE *Trip Generation Manual* , 11th Edition

Land Use Code	934
Land Use	Fast-Food Restaurant with Drive-Through Window
Setting	General Urban/Suburban
Time Period	Weekday PM Peak Period
# Data Sites	11
Average Pass-By Rate	55%

Pass-By Characteristics for Individual Sites

GFA (000)	State or Province	Survey Year	# Interviews	Pass-By Trip (%)	Non-Pass-By Trips Primary (%)	Diverted (%)	Total (%)	Adj Street Peak Hour Volume	Source
1.3	Kentucky	1993	—	68	22	10	32	2055	2
1.9	Kentucky	1993	33	67	24	9	33	2447	2
2.8	Florida	1995	47	66	—	—	34	—	30
2.9	Florida	1996	271	41	41	18	59	—	30
3	Kentucky	1993	—	31	31	38	69	4250	2
3.1	Florida	1995	28	71	—	—	29	—	30
3.1	Florida	1996	29	38	—	—	62	—	30
3.2	Florida	1996	202	40	39	21	60	—	30
3.3	—	1996	—	62	—	—	38	—	21
4.2	Indiana	1993	—	56	25	19	44	1632	2
4.3	Florida	1994	304	62	—	—	38	—	30

Hourly Distribution of Entering and Exiting Vehicle Trips by Land Use

Source: ITE *Trip Generation Manual* , 11th Edition

Land Use Code	934			934			934			934			934		
Land Use	Fast-Food Restaurant with Drive-Through Window			Fast-Food Restaurant with Drive-Through Window			Fast-Food Restaurant with Drive-Through Window			Fast-Food Restaurant with Drive-Through Window			Fast-Food Restaurant with Drive-Through Window		
Setting	General Urban/Suburban			General Urban/Suburban			General Urban/Suburban			Dense Multi-Use Urban			Dense Multi-Use Urban		
Time Period	Weekday			Saturday			Sunday			Weekday			Saturday		
# Data Sites	53			6			4			1			1		
	% of 24-Hour Vehicle Trips			% of 24-Hour Vehicle Trips			% of 24-Hour Vehicle Trips			% of 24-Hour Vehicle Trips			% of 24-Hour Vehicle Trips		
Time	Total	Entering	Exiting	Total	Entering	Exiting	Total	Entering	Exiting	Total	Entering	Exiting	Total	Entering	Exiting
12:00 - 1:00 AM	0.8%	0.8%	0.8%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.1%	0.4%	0.6%	0.2%	1.1%
1:00 - 2:00 AM	0.4%	0.4%	0.5%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.3%	0.2%	0.5%	0.1%	0.1%	0.1%
2:00 - 3:00 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.4%	0.2%	0.6%
3:00 - 4:00 AM	0.3%	0.2%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
4:00 - 5:00 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5:00 - 6:00 AM	0.7%	0.8%	0.7%	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.5%	0.5%	0.4%
6:00 - 7:00 AM	2.1%	2.3%	1.9%	0.4%	0.5%	0.4%	0.5%	0.6%	0.4%	0.1%	0.2%	0.0%	0.1%	0.1%	0.1%
7:00 - 8:00 AM	3.3%	3.4%	3.1%	1.0%	1.2%	0.8%	0.8%	0.9%	0.7%	0.2%	0.2%	0.1%	0.2%	0.3%	0.1%
8:00 - 9:00 AM	3.5%	3.5%	3.4%	1.5%	1.5%	1.4%	0.8%	0.9%	0.7%	0.3%	0.3%	0.2%	0.4%	0.4%	0.3%
9:00 - 10:00 AM	3.3%	3.4%	3.3%	2.1%	2.2%	2.0%	2.1%	2.5%	1.7%	0.3%	0.4%	0.2%	0.2%	0.3%	0.1%
10:00 - 11:00 AM	3.8%	4.0%	3.7%	3.0%	3.2%	2.7%	2.4%	2.2%	2.7%	1.3%	1.6%	1.0%	1.7%	1.9%	1.5%
11:00 - 12:00 PM	8.4%	9.1%	7.7%	6.6%	7.2%	6.0%	5.0%	5.7%	4.3%	8.3%	9.4%	7.2%	4.6%	5.4%	3.7%
12:00 - 1:00 PM	11.9%	11.9%	12.0%	10.1%	10.4%	9.8%	8.9%	9.7%	8.1%	10.6%	10.4%	10.8%	7.6%	7.5%	7.8%
1:00 - 2:00 PM	8.3%	7.9%	8.7%	8.7%	8.4%	9.0%	9.2%	8.7%	9.7%	7.0%	6.2%	7.8%	6.0%	6.0%	6.0%
2:00 - 3:00 PM	6.2%	5.9%	6.5%	7.8%	7.7%	8.0%	7.6%	7.4%	7.9%	4.3%	4.1%	4.4%	7.9%	8.1%	7.6%
3:00 - 4:00 PM	5.7%	5.7%	5.7%	7.3%	7.2%	7.3%	8.4%	8.5%	8.4%	5.7%	6.2%	5.2%	8.0%	7.5%	8.6%
4:00 - 5:00 PM	5.7%	5.9%	5.6%	7.4%	7.7%	7.2%	8.3%	8.5%	8.1%	5.8%	5.7%	5.8%	4.7%	4.6%	4.8%
5:00 - 6:00 PM	6.7%	6.9%	6.5%	8.4%	8.7%	8.1%	9.9%	10.7%	9.2%	7.2%	7.3%	7.0%	6.4%	7.1%	5.7%
6:00 - 7:00 PM	7.4%	7.4%	7.4%	8.2%	8.1%	8.3%	10.9%	10.4%	11.4%	8.1%	8.3%	7.9%	9.4%	9.3%	9.4%
7:00 - 8:00 PM	6.5%	6.3%	6.6%	8.0%	7.6%	8.4%	10.6%	10.5%	10.7%	8.2%	8.5%	7.8%	7.6%	7.5%	7.8%
8:00 - 9:00 PM	5.7%	5.6%	5.8%	7.3%	7.5%	7.2%	7.6%	7.0%	8.3%	8.6%	8.1%	9.1%	9.7%	9.0%	10.5%
9:00 - 10:00 PM	4.4%	4.1%	4.6%	6.7%	6.4%	7.0%	4.0%	3.7%	4.4%	8.9%	8.6%	9.2%	10.0%	11.6%	8.4%
10:00 - 11:00 PM	2.7%	2.5%	2.9%	3.2%	2.6%	3.8%	1.4%	0.9%	1.8%	9.4%	9.6%	9.1%	8.7%	7.2%	10.1%
11:00 - 12:00 AM	1.6%	1.4%	1.8%	1.4%	1.1%	1.6%	0.6%	0.5%	0.8%	5.3%	4.5%	6.1%	5.0%	4.9%	5.1%

12:00 - 1:00 AM	0.8%	0.8%	0.8%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.1%	0.4%	0.6%	0.2%	1.1%
12:15 - 1:15 AM	0.7%	0.6%	0.7%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.2%	0.1%	0.3%	0.2%	0.1%	0.3%
12:30 - 1:30 AM	0.6%	0.5%	0.6%	0.1%	0.1%	0.1%	0.3%	0.3%	0.3%	0.3%	0.2%	0.5%	0.2%	0.1%	0.3%
12:45 - 1:45 AM	0.5%	0.4%	0.5%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.2%	0.5%	0.1%	0.1%	0.1%
1:00 - 2:00 AM	0.4%	0.4%	0.5%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.3%	0.2%	0.5%	0.1%	0.1%	0.1%
1:15 - 2:15 AM	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.3%	0.1%	0.5%	0.5%	0.3%	0.7%
1:30 - 2:30 AM	0.3%	0.3%	0.4%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.0%	0.3%	0.5%	0.3%	0.7%
1:45 - 2:45 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.0%	0.3%	0.5%	0.3%	0.7%
2:00 - 3:00 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.4%	0.2%	0.6%
2:15 - 3:15 AM	0.3%	0.3%	0.3%	0.1%	0.0%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%
2:30 - 3:30 AM	0.3%	0.3%	0.3%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
2:45 - 3:45 AM	0.3%	0.2%	0.3%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
3:00 - 4:00 AM	0.3%	0.2%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
3:15 - 4:15 AM	0.2%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3:30 - 4:30 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3:45 - 4:45 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4:00 - 5:00 AM	0.3%	0.3%	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4:15 - 5:15 AM	0.4%	0.5%	0.4%	0.2%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%
4:30 - 5:30 AM	0.5%	0.6%	0.5%	0.2%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.5%	0.4%
4:45 - 5:45 AM	0.6%	0.7%	0.6%	0.2%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.5%	0.4%
5:00 - 6:00 AM	0.7%	0.8%	0.7%	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.5%	0.5%	0.4%
5:15 - 6:15 AM	1.0%	1.1%	0.9%	0.2%	0.2%	0.1%	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%	0.2%	0.3%	0.1%
5:30 - 6:30 AM	1.2%	1.3%	1.1%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
5:45 - 6:45 AM	1.6%	1.8%	1.4%	0.4%	0.4%	0.3%	0.4%	0.4%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
6:00 - 7:00 AM	2.1%	2.3%	1.9%	0.4%	0.5%	0.4%	0.5%	0.6%	0.4%	0.1%	0.2%	0.0%	0.1%	0.1%	0.1%
6:15 - 7:15 AM	2.4%	2.6%	2.3%	0.6%	0.6%	0.5%	0.5%	0.6%	0.5%	0.1%	0.2%	0.0%	0.3%	0.4%	0.2%

6:30 - 7:30 AM	2.8%	2.9%	2.6%	0.6%	0.7%	0.6%	0.6%	0.7%	0.6%	0.1%	0.2%	0.0%	0.3%	0.4%	0.1%
6:45 - 7:45 AM	3.1%	3.2%	2.9%	0.7%	0.8%	0.6%	0.7%	0.7%	0.6%	0.2%	0.3%	0.1%	0.3%	0.4%	0.1%
7:00 - 8:00 AM	3.3%	3.4%	3.1%	1.0%	1.2%	0.8%	0.8%	0.9%	0.7%	0.2%	0.2%	0.1%	0.2%	0.3%	0.1%
7:15 - 8:15 AM	3.4%	3.5%	3.2%	1.2%	1.2%	1.2%	0.8%	0.9%	0.7%	0.3%	0.4%	0.1%	0.2%	0.2%	0.1%
7:30 - 8:30 AM	3.5%	3.6%	3.3%	1.2%	1.4%	1.1%	0.8%	1.0%	0.6%	0.3%	0.4%	0.1%	0.2%	0.2%	0.1%
7:45 - 8:45 AM	3.5%	3.6%	3.4%	1.4%	1.6%	1.3%	0.8%	1.0%	0.7%	0.3%	0.4%	0.1%	0.3%	0.3%	0.3%
8:00 - 9:00 AM	3.5%	3.5%	3.4%	1.5%	1.5%	1.4%	0.8%	0.9%	0.7%	0.3%	0.3%	0.2%	0.4%	0.4%	0.3%
8:15 - 9:15 AM	3.4%	3.4%	3.4%	1.6%	1.7%	1.5%	0.9%	1.2%	0.7%	0.2%	0.3%	0.2%	0.2%	0.3%	0.2%
8:30 - 9:30 AM	3.4%	3.3%	3.4%	1.8%	1.9%	1.7%	1.3%	1.4%	1.3%	0.3%	0.3%	0.2%	0.3%	0.3%	0.3%
8:45 - 9:45 AM	3.4%	3.4%	3.3%	1.9%	2.0%	1.7%	1.5%	1.8%	1.3%	0.3%	0.3%	0.3%	0.2%	0.3%	0.1%
9:00 - 10:00 AM	3.3%	3.4%	3.3%	2.1%	2.2%	2.0%	2.1%	2.5%	1.7%	0.3%	0.4%	0.2%	0.2%	0.3%	0.1%
9:15 - 10:15 AM	3.4%	3.5%	3.3%	2.2%	2.5%	1.9%	2.4%	2.6%	2.2%	0.2%	0.3%	0.2%	0.5%	0.5%	0.4%
9:30 - 10:30 AM	3.5%	3.6%	3.3%	2.3%	2.5%	2.1%	2.4%	2.6%	2.2%	0.4%	0.7%	0.2%	0.8%	1.2%	0.3%
9:45 - 10:45 AM	3.5%	3.6%	3.4%	2.5%	2.7%	2.3%	2.6%	2.7%	2.5%	0.9%	1.2%	0.7%	1.5%	1.9%	1.1%
10:00 - 11:00 AM	3.8%	4.0%	3.7%	3.0%	3.2%	2.7%	2.4%	2.2%	2.7%	1.3%	1.6%	1.0%	1.7%	1.9%	1.5%
10:15 - 11:15 AM	4.4%	4.8%	4.1%	3.4%	3.8%	3.0%	2.6%	2.8%	2.4%	2.5%	3.0%	1.9%	2.0%	2.6%	1.4%
10:30 - 11:30 AM	5.4%	5.9%	4.9%	4.2%	4.8%	3.6%	3.1%	3.5%	2.8%	4.1%	5.4%	2.8%	2.4%	2.7%	2.0%
10:45 - 11:45 AM	6.9%	7.7%	6.2%	5.6%	6.1%	5.1%	4.3%	4.7%	3.8%	5.9%	7.2%	4.6%	3.2%	4.4%	2.0%
11:00 - 12:00 PM	8.4%	9.1%	7.7%	6.6%	7.2%	6.0%	5.0%	5.7%	4.3%	8.3%	9.4%	7.2%	4.6%	5.4%	3.7%
11:15 - 12:15 PM	10.0%	10.8%	9.3%	7.7%	8.3%	7.2%	6.3%	6.9%	5.6%	10.2%	11.7%	8.7%	5.0%	5.6%	4.3%
11:30 - 12:30 PM	11.3%	11.9%	10.7%	8.9%	9.6%	8.2%	7.3%	8.1%	6.5%	10.8%	11.1%	10.5%	7.1%	7.7%	6.5%
11:45 - 12:45 PM	11.8%	12.0%	11.6%	9.4%	10.1%	8.8%	7.8%	9.0%	6.6%	11.3%	11.4%	11.3%	7.6%	7.5%	7.8%
12:00 - 1:00 PM	11.9%	11.9%	12.0%	10.1%	10.4%	9.8%	8.9%	9.7%	8.1%	10.6%	10.4%	10.8%	7.6%	7.5%	7.8%
12:15 - 1:15 PM	11.3%	10.9%	11.7%	10.3%	10.4%	10.2%	9.3%	9.9%	8.7%	10.0%	9.1%	10.9%	8.2%	7.9%	8.4%
12:30 - 1:30 PM	10.2%	9.6%	10.8%	10.0%	9.7%	10.4%	9.7%	9.8%	9.6%	9.0%	8.1%	9.9%	6.6%	6.0%	7.2%
12:45 - 1:45 PM	9.2%	8.8%	9.7%	9.5%	9.1%	9.8%	9.5%	8.7%	10.2%	7.8%	6.9%	8.6%	6.1%	5.6%	6.5%
1:00 - 2:00 PM	8.3%	7.9%	8.7%	8.7%	8.4%	9.0%	9.2%	8.7%	9.7%	7.0%	6.2%	7.8%	6.0%	6.0%	6.0%
1:15 - 2:15 PM	7.7%	7.3%	8.1%	8.3%	8.1%	8.5%	8.6%	8.0%	9.2%	5.6%	4.8%	6.3%	6.3%	5.8%	6.7%
1:30 - 2:30 PM	7.1%	6.8%	7.5%	8.0%	8.1%	8.0%	8.1%	7.4%	8.8%	5.3%	4.8%	5.7%	6.5%	6.5%	6.5%
1:45 - 2:45 PM	6.7%	6.3%	7.0%	8.1%	7.9%	8.3%	7.9%	7.6%	8.3%	4.9%	4.9%	4.9%	7.6%	8.1%	7.1%
2:00 - 3:00 PM	6.2%	5.9%	6.5%	7.8%	7.7%	8.0%	7.6%	7.4%	7.9%	4.3%	4.1%	4.4%	7.9%	8.1%	7.6%
2:15 - 3:15 PM	5.8%	5.7%	5.9%	7.7%	7.6%	7.9%	8.0%	8.0%	8.0%	5.0%	5.4%	4.6%	9.0%	9.8%	8.2%
2:30 - 3:30 PM	5.6%	5.4%	5.7%	7.5%	7.1%	7.8%	8.3%	8.7%	7.9%	4.9%	5.1%	4.8%	9.5%	10.0%	9.0%
2:45 - 3:45 PM	5.5%	5.4%	5.6%	7.2%	6.9%	7.5%	8.4%	8.5%	8.3%	5.2%	5.4%	5.0%	8.0%	7.5%	8.5%
3:00 - 4:00 PM	5.7%	5.7%	5.7%	7.3%	7.2%	7.3%	8.4%	8.5%	8.4%	5.7%	6.2%	5.2%	8.0%	7.5%	8.6%
3:15 - 4:15 PM	5.6%	5.6%	5.7%	7.3%	7.3%	7.3%	8.4%	8.3%	8.6%	5.3%	5.2%	5.5%	6.8%	6.5%	7.1%
3:30 - 4:30 PM	5.6%	5.6%	5.7%	7.4%	7.5%	7.4%	8.0%	8.3%	7.8%	5.7%	6.0%	5.4%	6.1%	5.6%	6.5%
3:45 - 4:45 PM	5.7%	5.8%	5.7%	7.3%	7.6%	7.1%	8.1%	8.4%	7.9%	5.8%	5.7%	6.0%	5.7%	5.2%	6.2%
4:00 - 5:00 PM	5.7%	5.9%	5.6%	7.4%	7.7%	7.2%	8.3%	8.5%	8.1%	5.8%	5.7%	5.8%	4.7%	4.6%	4.8%
4:15 - 5:15 PM	6.0%	6.2%	5.8%	7.4%	7.7%	7.1%	8.6%	9.1%	8.0%	6.0%	6.2%	5.9%	4.3%	4.2%	4.5%
4:30 - 5:30 PM	6.3%	6.6%	6.0%	7.6%	7.9%	7.4%	9.4%	9.4%	9.4%	6.5%	6.2%	6.7%	4.3%	4.4%	4.3%
4:45 - 5:45 PM	6.5%	6.8%	6.2%	8.3%	8.8%	7.8%	9.5%	9.9%	9.1%	6.8%	6.8%	6.7%	4.9%	5.4%	4.4%
5:00 - 6:00 PM	6.7%	6.9%	6.5%	8.4%	8.7%	8.1%	9.9%	10.7%	9.2%	7.2%	7.3%	7.0%	6.4%	7.1%	5.7%
5:15 - 6:15 PM	7.0%	7.2%	6.8%	8.5%	8.6%	8.5%	10.3%	10.5%	10.1%	7.3%	7.8%	6.8%	6.9%	7.5%	6.4%
5:30 - 6:30 PM	7.3%	7.4%	7.1%	8.6%	8.7%	8.5%	10.3%	10.7%	9.8%	7.4%	8.0%	6.8%	8.2%	8.6%	7.7%
5:45 - 6:45 PM	7.4%	7.4%	7.3%	8.3%	8.0%	8.6%	11.1%	11.0%	11.1%	7.7%	8.5%	7.0%	9.0%	9.3%	8.7%
6:00 - 7:00 PM	7.4%	7.4%	7.4%	8.2%	8.1%	8.3%	10.9%	10.4%	11.4%	8.1%	8.3%	7.9%	9.4%	9.3%	9.4%
6:15 - 7:15 PM	7.3%	7.2%	7.3%	8.4%	8.3%	8.6%	10.8%	10.7%	10.9%	8.1%	8.3%	7.9%	9.7%	9.6%	9.7%
6:30 - 7:30 PM	7.0%	6.8%	7.2%	8.3%	8.0%	8.6%	10.9%	10.5%	11.3%	7.9%	8.0%	7.8%	8.8%	9.1%	8.4%
6:45 - 7:45 PM	6.7%	6.6%	6.9%	8.2%	8.0%	8.4%	10.6%	10.3%	11.0%	8.3%	7.8%	8.8%	8.2%	8.3%	8.0%
7:00 - 8:00 PM	6.5%	6.3%	6.6%	8.0%	7.6%	8.4%	10.6%	10.5%	10.7%	8.2%	8.5%	7.8%	7.6%	7.5%	7.8%
7:15 - 8:15 PM	6.2%	6.0%	6.4%	7.6%	7.5%	7.6%	10.2%	10.0%	10.5%	8.6%	8.1%	9.2%	8.3%	9.1%	7.4%
7:30 - 8:30 PM	6.0%	5.9%	6.2%	7.5%	7.6%	7.3%	9.6%	9.3%	9.9%	8.8%	8.7%	9.0%	9.8%	9.8%	9.9%
7:45 - 8:45 PM	5.9%	5.8%	6.1%	7.5%	7.5%	7.4%	8.5%	8.1%	8.9%	7.8%	8.1%	7.5%	9.8%	9.4%	10.3%
8:00 - 9:00 PM	5.7%	5.6%	5.8%	7.3%	7.5%	7.2%	7.6%	7.0%	8.3%	8.6%	8.1%	9.1%	9.7%	9.0%	10.5%
8:15 - 9:15 PM	5.5%	5.3%	5.7%	7.1%	6.9%	7.3%	6.8%	6.0%	7.7%	9.1%	9.4%	8.9%	9.1%	7.9%	10.2%
8:30 - 9:30 PM	5.3%	5.0%	5.5%	7.0%	6.9%	7.1%	5.6%	4.8%	6.5%	9.0%	8.8%	9.2%	8.5%	8.7%	8.4%
8:45 - 9:45 PM	4.8%	4.6%	4.9%	6.9%	7.0%	6.9%	4.8%	4.4%	5.3%	9.5%	9.3%	9.7%	9.1%	10.5%	7.6%
9:00 - 10:00 PM	4.4%	4.1%	4.6%	6.7%	6.4%	7.0%	4.0%	3.7%	4.4%	8.9%	8.6%	9.2%	10.0%	11.6%	8.4%
9:15 - 10:15 PM	3.9%	3.7%	4.2%	6.1%	5.8%	6.5%	3.1%	2.6%	3.7%	8.0%	7.8%	8.1%	12.0%	11.5%	12.5%
9:30 - 10:30 PM	3.4%	3.2%	3.6%	5.2%	4.6%	5.9%	2.5%	2.0%	3.0%	7.6%	7.9%	7.4%	10.8%	9.7%	11.8%
9:45 - 10:45 PM	3.1%	2.9%	3.4%	4.0%	3.2%	4.8%	1.8%	1.4%	2.2%	8.8%	8.8%	8.8%	10.2%	8.6%	11.7%
10:00 - 11:00 PM	2.7%	2.5%	2.9%	3.2%	2.6%	3.8%	1.4%	0.9%	1.8%	9.4%	9.6%	9.1%	8.7%	7.2%	10.1%

10:15 - 11:15 PM	2.3%	2.1%	2.5%	2.7%	2.2%	3.2%	1.0%	0.9%	1.1%	10.0%	9.5%	10.6%	5.5%	5.2%	5.7%
10:30 - 11:30 PM	2.1%	1.9%	2.2%	2.0%	1.7%	2.3%	0.8%	0.9%	0.8%	9.8%	8.6%	11.1%	6.0%	6.0%	5.9%
10:45 - 11:45 PM	1.8%	1.6%	1.9%	1.8%	1.5%	2.1%	0.8%	0.6%	1.1%	7.2%	6.3%	8.0%	5.4%	5.1%	5.7%
11:00 - 12:00 AM	1.6%	1.4%	1.8%	1.4%	1.1%	1.6%	0.6%	0.5%	0.8%	5.3%	4.5%	6.1%	5.0%	4.9%	5.1%
11:15 - 12:15 AM	1.4%	1.2%	1.5%	1.0%	0.9%	1.2%	0.5%	0.3%	0.6%	2.9%	2.5%	3.3%	4.6%	4.4%	4.8%
11:30 - 12:30 AM	1.2%	1.1%	1.2%	1.0%	0.8%	1.2%	0.4%	0.2%	0.6%	1.5%	1.5%	1.5%	2.6%	2.1%	3.1%
11:45 - 12:45 AM	1.0%	0.9%	1.0%	0.6%	0.5%	0.6%	0.3%	0.3%	0.3%	1.0%	0.9%	1.1%	1.8%	1.3%	2.4%

A Trip Generation Study of Coffee/ Donut Shops in Western New York

DUE TO THE LIMITED AMOUNT OF TRIP GENERATION DATA AVAILABLE IN THE ITE *TRIP GENERATION MANUAL*, SRF & ASSOCIATES PERFORMED TRAFFIC STUDIES OF 14 DIFFERENT COFFEE/DONUT SHOPS FOR THE PURPOSES OF DOCUMENTING TRIP GENERATION VOLUMES DURING THE A.M. PEAK PERIOD. THE RESULT OF THE INVESTIGATION YIELDS A FORMULA THAT CAN BE USED TO ESTIMATE A.M. PEAK HOUR TRIP GENERATION VOLUMES FOR A PROPOSED COFFEE/DONUT SHOP.

BY CORY GREENE, P.E., PTOE AND VIJAY KANNAN, P.E.

INTRODUCTION

The recently published Institute of Transportation Engineers *Trip Generation Manual,* 8th Edition includes additional information for the new land uses 936 (Coffee/Donut Shop without Drive-Through Window) and 937 (Coffee/Donut Shop with Drive-Through Window). However, opportunity exists to more accurately forecast trip generation volumes from this type of store. Current data for ITE land use code 937 for coffee shops has large variations in rates and standard deviations and does not contain fitted curve equations. The purpose of this study is to develop best fit equations that will accurately predict morning peak hour trip generation volumes for coffee/donut shops.

Currently, the *Trip Generation Manual* contains three variables for determining trip generation volumes: gross floor area, number of seats, and peak hour adjacent street traffic. This study not only considers gross floor area and peak hour traffic volumes but also the following site specific factors to determine if any statistical relationships exist: average daily traffic data and geographic and demographic variables.

At a limited number of sites, video recording was used to document vehicles entering and exiting the site. A secondary benefit of using video recording for data collection is the ability to observe and document drive-through window operations and associated vehicle queues. Based on this limited data, a planning-level vehicle queue length prediction equation was developed for the drive-through service windows at coffee/donut shops.

DATA COLLECTION

Data were collected at 13 different coffee/donut shops around western New York, USA via manual traffic counts or video recordings of the drive-through lanes. Two national retail chains were used for data collection purposes. The majority of business conducted at these particular shops occurs during the morning peak hour period. Therefore, the trip generation data collection and subsequent analysis was limited to the a.m. peak hour period only.

A majority of the data was collected during the first half of December 2007 on typical weekdays; Mondays and Fridays were excluded from the data collection. Twelve out of the 13 shops studied were standalone buildings with one or two points of access, which made it easier to document trip generation volumes. The number of entering, exiting, parking lot, and drive-through vehicles was documented at each of the stores between the hours of 7:00 a.m. to 9:00 a.m. in 15-minute intervals. The intervals were reviewed to determine the peak hour of traffic generation. It should be noted that 12 out of the 13 shops had drive-through windows; only one store did not.

Figure 1 indicates approximate locations of stores included in this analysis. The stores studied for this analysis are located in Erie, Monroe, Livingston, and Ontario counties in upstate New York. The results of the data collection are shown in Figure 2. Figure 2 includes the existing store size (in square feet) and the associated trip generation rate. The trip generation rate was calculated by dividing the total number of trips by the square footage of the store.

Surprisingly, the trip generation rates vary significantly from 0.019 to 0.110 trips per square footage. For example, a 2,500-square-foot store could have as many as 275 trips or as little as 48 trips based on the high and low rates. Less than half of the stores have similar and/or comparable trip generation rates.

Results of this data and conversations with coffee/donut shop store owners led us to investigate other variables that may more accurately define trip generation characteristics of these types of stores.

ADDITIONAL DATA ANALYSIS

In the *Trip Generation Manual*, the square footage of a store is an important characteristic. In attempt to determine other relevant correlating factors for coffee/donut shop trip generation, we derived other independent variables for consideration. Data for the following variables were considered at all 13 locations included in this study:

- Number of through-travel lanes adjacent to store;
- Population within a three-quarter-mile radius;
- Median age within a three-quarter-mile radius;
- Distance from interstate/highway;
- Average daily traffic volume on adjacent roadway;
- Morning peak hour volume on adjacent roadway;
- Store size (square footage); and
- Presence of drive through.

The number of lanes adjacent to the store was determined by on-site observations. The population and median age within a three-quarter-mile radius of the store was determined by 2000 census data. Average daily traffic (ADT) volumes on the adjacent roadway were obtained from most recent data available on the study section of roadway adjacent to the study store. Morning peak hour volume on the adjacent roadway was obtained either from the ADT data or manual counts. Store size was either obtained from actual building plans or scaled accordingly from recent aerial photography.

Although there were many other factors that were considered, the following variables were not used for this analysis due to the difficulty of obtaining or uncertainty of the variables:

- Ethnic diversity;
- Number of seats;
- Hours of operation; and
- Distance from similar store.

The data were analyzed using STATGRAPHICS Plus version 5.0 software and the multiple regression analysis. This software produces a P value that indicates the confidence rate of the relationship of the variables being analyzed. For example, a P value of 0.10 indicates a 90 percent confidence rate. The higher the confidence rate, the better the statistical relationship between the variables being analyzed.

The results in Figure 3 illustrate P values below the desired 90 percent confidence rate for parking lot and drive-through trip variables using the multiple regression analysis. The data illustrate a better correlation between variables for drive-through trips than parking lot trips.

The overall P value for the models indicates a 92 percent confidence rate for drive-through trips, but only a 59 percent confidence rate for the parking lot trips. As previously mentioned, the

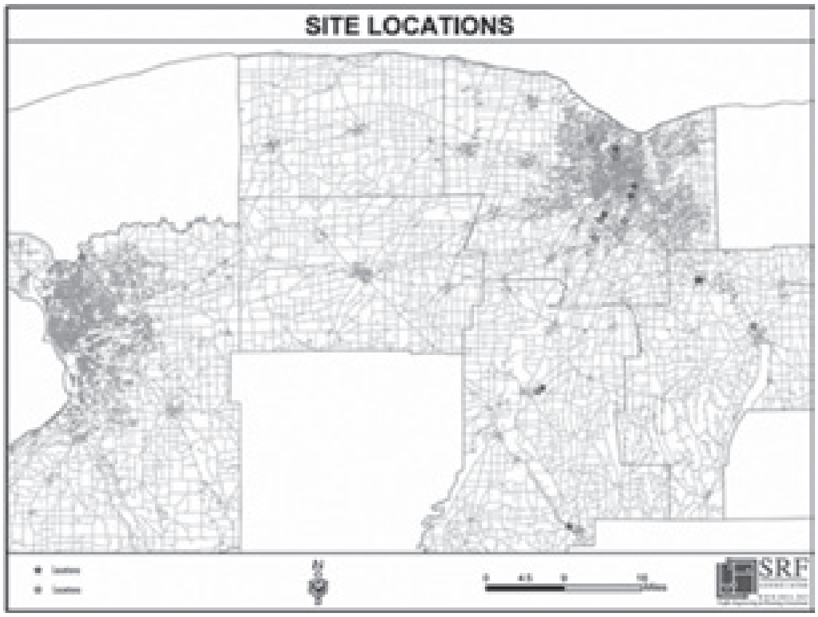

Figure 1.

Figure 2. Trip generation results.

	Town/City	AM Peak (Veh) Parked	Drive-Thru	Total	Store Size (SF)	Trip Generation Rate (Trips/SF)
1	Rochester	73	125	198	1,800	**0.110**
2	Brighton	81	0	81	2,090	0.039
3	Brighton	41	98	139	2,087	0.067
4	Victor	35	81	116	1,894	0.061
5	Geneseo	37	33	70	1,250	0.056
6	Irondequoit	38	82	120	2,400	0.050
7	Henrietta	26	93	119	2,500	0.048
8	Henrietta	40	115	155	3,030	0.051
9	Victor	19	86	105	2,200	0.048
10	Greece	42	119	161	2,440	0.066
11	Geneseo	18	39	57	3,080	**0.019**
12	Irondequoit	38	61	99	3,200	0.031
13	Henrietta	30	97	127	3,500	0.036

Figure 3. Preliminary analysis results.		
	Parking Lot Trips	Drive-Thru Trips
Variable	**P-Value**	**P-Value**
ADT	0.9709	0.1799
Age	0.7168	0.1550
AM Major St	0.7679	0.2977
Dist from Interstate	0.8439	0.6850
Drive Thru Presence	0.1168	0.0588
Lanes	0.5318	0.1439
Population	0.5553	0.3581
Store Size	0.6501	0.4951
Model P-Value	**0.4106**	0.0805

Figure 4. Secondary analysis results.		
	Parking Lot Trips	Drive-Thru Trips
Variable	**P-Value**	**P-Value**
Lanes	0.1964	0.0548
Population	0.0373	0.0137
Age	-	0.0785
Dist from Interstate	-	-
ADT	-	0.1435
AM Major St	0.2869	0.0234
Drive Thru_Y or N	0.0119	0.0166
Model P-Value	**0.0306**	**0.0122**

desired confidence levels for the overall models are above 90 percent for both parking lot and drive-through trips.

In an effort to derive equations for both parking lot and drive-through trips with 90 percent or greater confidence rates, three variables were removed from the analysis. These three variables were considered not statistically significant from the results of the first analysis. Therefore, the analysis was performed a second time with the following variables removed from the equation:

- Age;
- Distance from interstate; and
- Average daily traffic.

The results of the revised analysis are shown in Figure 4.

Although some P-values are above 0.10, Figure 4 indicates generally acceptable P values for the variables analyzed. The resulting equations are shown below:

Parking Lot Trips = 76.509 - 7.231 * Dist from Interstate + 0.003 * Population + 0.007 * AM Peak hour - 43.927 * Presence of Drive- through

Model P - Value = 0.0306

Drive-Through Trips = -113.414 - 21.215 * Number of Lanes on Major Street + 0.007 * Population + 2.108 * Median Age + 0.037 * AM Peak hour + 0.002 * ADT + 68.607 * Presence of Drive- through

Model P - Value = 0.0122

Note: The value for drive-through presence should be entered as "1" if a drive through exists, and "0" if a drive through is not present.

The overall P values for the secondary model indicate confidence levels of 97 percent for the parking lot trips and a 99 percent level for the drive-through trips.

Upon completion of determination of the equations listed above, two additional stores were counted to test the accuracy of the equations derived with 97 percent and 99 percent confidence levels. The two additional locations were stores in Dansville and Buffalo, New York.

Based on the input variables for the Dansville store, the equations estimated the number of parked cars would be 39; the actual number was 37. The estimated number of drive-through trips was 17, and the actual number was 39. In total, the equations estimated a total number of 56 trips, when the actual number of trips was 76. This equates to a 26 percent difference. Although the actual size of this store is unknown, assuming an approximate size of 3,000 square feet using ITE land use code 937, yields trip generation of 169 entering and 163 exiting vehicles. The trip generation formulas developed estimated 56 entering and 56 exiting vehicles (drive-through plus parked vehicles), while the actual counts were 76 entering and 76 exiting. It is evident that the ITE trip generation volumes overestimate the actual number of trips by more than two times.

Using the derived equations to estimate trip generation for the Buffalo store yields 66 parked cars, and the actual number of trips was 58. The estimated number of drive-through trips was 149, and the actual number of trips was 135. The total estimated trips was 215 and the actual recorded was 193. This equates to an 11 percent difference.

Although the results for the Dansville store were not as accurate as expected, it was noted that this store is located right next an interstate, which could have an impact on the trip generation results, even though the distance from the interstate variable was removed from the preliminary analysis because of the low confidence level. In summary, this site indicates the need for data from additional locations to more accurately define the trip generation equations and estimates.

VEHICLE QUEUING ESTIMATION

Once the estimated number of vehicle trips generated by a proposed coffee/donut shop has been completed, the next factor that should be considered in the site planning process is the number of vehicles that will queue during the a.m. peak hour at a drive-through window. While trip generation is the key factor in estimating vehicle queues, the following factors must also be considered:

- Temporal distribution of traffic;
- Time to place order;
- Time at service window;
- Number of people at drive-through window.

Two coffee/donut shops with drive-through windows were observed during the a.m. peak hour periods to document variables shown in the list above, with the exception of the number of people at the service window. These data were directly obtained by the store manager on duty in the store at the time.

Considering that all of the factors that affect vehicle queuing vary from day to day, averages were developed based on our observations and combined into a simplified planning level formula. This formula with averages (or defaults) can be used to determine vehicle queues based on confidence levels.

The formula is based on two user inputs: arrival rate (vehicles/hour) and service rate (vehicles/hour). The arrival rate is based on the expected number of vehicles that will use the drive through. Based on our observations, the average service time during the a.m. peak hour was 30 seconds per vehicle. This corresponds to two vehicles every minute or 120 vehicles per hour. A default of 120 vehicles per hour can be based for the service rate, unless more specific data are available. Regardless of the values used, the service rate must be higher than arrival rate for the formula to produce an accurate result.

Using arrival and service rates, as discussed previously, the following information can be determined:

- Average vehicle queue;
- Average time in the drive-through;
- Average wait time;
- Maximum expected vehicle queue.

Formulas were developed using the stochastic queuing analysis method. To use this queuing analysis method for the drive-through lane, the traffic intensity must be less than one. Traffic intensity is defined as follows:

$$\rho = \frac{\lambda}{\mu}$$

Where ρ = traffic intensity
λ = mean arrival rate per hour
μ = mean service rate per hour

The average vehicle queue in the drive-through lane can be calculated as follows:

$$E(n) = \frac{\rho}{1-\rho}$$

The results from this formula can also be used to calculate the average vehicle queue length in the drive through. For example, an arrival rate of 60 vehicles per hour and a service rate of 120 vehicles per hour yields an average vehicle queue of one. Assuming one vehicle occupies approximately 25 feet, then the average queue length in the drive-through lane would be 25 feet. The start of the vehicle queue begins from the service window (not the ordering board) and extends backward in the drive-through lane.

The average time vehicles spend in the drive through (in hours) can be calculated as follows:

$$E(v) = \frac{1}{\mu(1-\rho)}$$

The results from the equation shown above can be multiplied by 60 minutes/hour to determine the average wait time in minutes. This represents the total time in the drive through—from arrival in the queue to queue departure.

The average wait time (in hours) vehicles spend in the drive through from the time a driver leaves the ordering board until he or she arrives at the service window can be calculated as follows:

$$E(w) = \frac{\rho}{\mu(1-\rho)}$$

In order to estimate the probability of exactly "n" vehicles in the drive-through lane, the following formula is used, where n = number of vehicles:

$$P(n) = \rho^{n}(1-\rho)$$

The following formula calculates the 95 percent expected vehicle queue n using the cumulative probabilities:

$$\sum_{n=0}^{n=a} P(n) \geq 0.95$$

The preceding formula is calculated until a value greater than or equal to 0.95 is achieved. Once this value is attained, the resulting number of vehicles indicates a 95 percent confidence factor that there will be less than that number of vehicles in the drive-through lane. As previously mentioned, this value n can be multiplied by 25 feet per vehicle to determine a corresponding queue length required for the drive-through lane, where the start of the vehicle queue begins from the service window (not the ordering board) and extends backward in the drive-through lane.

These formulas assume that both arrival and service rates are random. This is based on our observations that vehicle arrivals are random and that service times in the drive through vary based on type and number of items ordered. For example, service time for ordering a coffee is less than that of a customer who orders coffee and a breakfast sandwich or donuts.

It should be noted that the recommended default values for service rates were derived based on observations at two sites. The arrival rates are based on the trip generation equations for drive through trips. Due to the limited number of drive through operations observed, the vehicle queuing equations should be used for planning purposes only.

FINDINGS AND CONCLUSIONS

The results of this analysis, while limited in the number of studies and geographical area, indicate that coffee/donut shop square footage is one of the least statistically significant variables. There are six other important variables that should be considered when determining the estimated number of a.m. peak hour generated trips.

It has been shown that ITE trip generation land use code 937 (coffee/donut shop) square footage trip generation rates yield widely varied results from actual count data. Overestimation of trip generation volumes can potentially have a significant impact on a project during the approval process. Therefore, it is recommended that careful consideration be given when using the ITE data estimates for land use code 937.

In addition to the number of estimated a.m. peak hour trips, the vehicle queuing formulas will aid civil engineers, store owners, and approval agencies in the design of drive-through lanes for coffee/donut shops. ■

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The Application of the Queuing Theory in the Traffic Flow of Intersection

Shuguo Yang, Xiaoyan Yang

***Abstract*—It is practically significant to research the traffic flow of intersection because the capacity of intersection affects the efficiency of highway network directly. This paper analyzes the traffic conditions of an intersection in certain urban by the methods of queuing theory and statistical experiment, sets up a corresponding mathematical model and compares it with the actual values. The result shows that queuing theory is applied in the study of intersection traffic flow and it can provide references for the other similar designs.**

***Keywords*—Intersection, Queuing theory, Statistical experiment, System metrics.**

I. Introduction

WITH the development of economy, vehicles maintain a substantial increase in volume of China, queuing phenomenon is so common in road traffic. Intersection is the main concentrated area of stream of people and vehicles; also, it is one infrastructure construction that connecting the roads to make it play network functions. In daily life, traffic congestion responses to the intersection directly. It is so clear that road intersection will be the bayonet of traffic capacity and safety. Therefore, it is significant to study the intersection flow to improve the congested traffic and maintain social order.

In the early 20th century, queuing theory originated from the Danish engineer Erlang's study of telephone exchange efficiency of communication system. After the section world war, especially with the rapid development of computer and communication technology, queuing theory got attention and developed fast, also, it became an important branch of operations research and its corresponding disciplines theory and reliability theory were developed.

In the mid-1930-s, queuing theory was recognized one important subject when W.Feller recommended birth and death process. In the early 1950s, D.G.Kendall researched queuing theory systematically by the method of Markov chain and made it develop further. In the 1960s, the projects studied complicatedly in queuing theory, it is so difficult to get the exact solution that people began to study the approximate method [1], [6], [8].

In the traffic engineering, 1936, Adams considered the pedestrian delay problem by queuing theory that the intersection which not set the traffic signals, then, queuing theory had been widely used in traffic control. Such as the study of vehicle delay, traffic capacity, configuration light time, the design and management of traffic facilities for the park and station and so on.

At present, queuing system model has been widely used in all kinds of management system. Such as production management, inventory management, business management, transportation, banking, medical services, computer design and performance evaluation, and so on.

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II. Basic Knowledge

Queuing theory is the mathematical theory and method of queuing system (stochastic system). In daily life, people will encounter all sorts of queuing problems, such as, standing at bus stops, going to hospital, and going to the ticket office to buy the tickets and so on. In these problems, bus and passengers, doctor and patients, conductor and the buyers forms a queuing system or service system respectively; the former can be regarded as service agencies and the latter can be regarded as customers.

The queue can be tangible queue may also be intangible queue. For example, several passengers make telephone call to order train tickets at the same time, if a passenger is on the phone, can only wait for the other passengers, this form of queue is invisible. The people or some objects can be the queue, such as semi-finished products for processing in the production line, machine waiting for maintenance, and the information waiting for computing center to process, etc.

Queuing theory consists of three parts: input process, queuing rules and service agencies. The schematic diagram as follows:

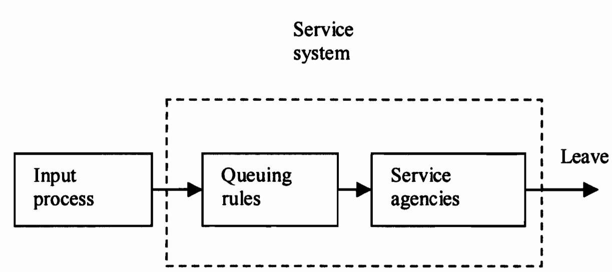

Fig. 1 The composition of queuing system

Queuing theory mainly studies three aspects:

1) Statistical inference: in this part, it mainly sets up the

mathematical model based on data, solves the problem by appropriate method of Queuing theory, and achieves the rationalization of queuing system.

2) The inertia of system: namely the probability of regularity of quantity index about queuing, mainly concludes: the distribution of the waiting time of a customer, busying period distribution, the distribution of the queuing length that the customer waiting and so on. It mainly includes two states: the steady state under statistical equilibrium; instantaneous state.
3) The system optimization problems: its purpose is to make all systems produce best results, design correctly, and move effectively. In general, the system optimization problem is divided into two categories: the system design optimization and the system control optimization. The former is called a static optimization problem, which goal is to make the system achieve maximum benefit, or under a certain index, the system is the most economical. The latter is called dynamic optimization problem. It is to say, for a given system, how to run to make a objective function value to the optimal.

III. Modeling

Queuing theory can be divided into single channel queuing system and multi-channel queuing system. This paper mainly researches the performance index under the steady state.

A. Single Channel Queuing System

The single channel queuing system is called $M/M/1$ system. Assume that customers arrive randomly, follows Poisson distribution, λ is the average arrival rate, μ is the average output rate, $\rho = \frac{\lambda}{\mu}$ is traffic intensity or utilization coefficient [6].

When $\rho < 1$, the arrival rate is less than the rate of output, then the intersection traffic will be smooth. If $\rho \geq 1$, the arrival rate is greater than the rate of output and then the queuing length will be infinity, the system is not steady. Therefore, $\rho < 1$ is the necessary and sufficient condition for the system to be steady.

Combined with the Little formula, the quantity indexes of single channel queuing system can be obtained, as follows:

1) The probability of no vehicle in the system:

$$P_0 = 1 - \rho$$

2) The probability of n vehicles in the system:

$$P_n = \rho^n (1 - \rho)$$

3) The average number of vehicles in the system:

$$L = \frac{\rho}{1 - \rho}$$

4) The average queuing length of vehicles in the system:

$$L_q = L \cdot \rho$$

5) The average staying time of vehicles in the system:

$$W = \frac{L_q}{\lambda} + \frac{1}{\mu}$$

6) The average waiting time of vehicles in the system:

$$W_q = W - \frac{1}{\mu}$$

B. Multi-Channel Queuing System

The multi-channel queuing system is called $M/M/N$ system. Its traffic intensity is $\frac{\rho}{N}$ which is different from the single channel queuing system. The system is stable when $\frac{\rho}{N} < 1$, otherwise, it is not. At the same time, $\frac{\rho}{N} < 1$ is the necessary and sufficient condition for the system to be steady[8].

1) The probability of no vehicles in the system:

$$P_0 = \frac{1}{\sum_{k=0}^{N-1} \frac{\rho^k}{k!} + \frac{\rho^N}{N!\left(1 - \rho/N\right)}}$$

2) The probability of k vehicles in the system:

$$\begin{cases} P_k = \frac{\rho^k}{k!} P_0 \left(when, k < N\right) \\ P_k = \frac{\rho^k}{\mathrm{N!N}^{k-N}} P_0 \left(when, k \geq N\right) \end{cases}$$

3) The average queuing length of vehicles in the system:

$$L_q = \frac{\rho^{N+1}}{N!N} \cdot \frac{P_0}{\left(1 - \rho/N\right)^2}$$

4) The average number of vehicles in the system:

$$L = L_q + \rho$$

5) The average staying time of vehicles in the system:

$$W = \frac{L_q}{\lambda} + \frac{1}{\mu}$$

6) The average waiting time of vehicles in the system:

$$W_q = \frac{L_q}{\lambda}$$

C. Establish the Statistical Law of Intersection

Takes the traffic of several intersections of Laoshan District of Qingdao for example, especially, the Shenzhen intersection. We note the numbers of vehicles in every direction when the traffic lights change each cycle [2]. The data can be divided into 5 groups, X_t is the number of vehicles and f_t is the time that belongs to the every part of vehicles. Now we list the statistical result in the west as shown in the Table I:

TABLE I

TIME : 2014/4/15 10:00-11:00 DIRECTION: WEST

The number of vehicles X_t	12-14	15-17	18-20	21-23	24-26	above 27
Times f_t	7	12	10	8	7	1

We validate the number of the arrived vehicles in the input process weather obey the Poisson distribution by the χ^2 hypothesis testing method [7].

First, it needs to estimate the parameter λ in Poisson distribution by the maximum likelihood method.

Assume the whole

$$X \sim \pi(\lambda)$$

$$P(X = k) = \frac{\lambda^k}{k!} e^{-\lambda}, k = 0,1,2,\cdots \quad (1)$$

Then the likelihood function of parameter λ :

$$L(\lambda) = \prod_{i=1}^{n} P(X = x_i) = \prod_{i=1}^{n} \frac{\lambda^{x_i}}{x_i!} e^{-\lambda} = \frac{\lambda \sum_{i=1}^{n} x_i}{x_1! \ldots x_i!} e^{-n\lambda} \quad (2)$$

Take the logarithm on both sides and the likelihood equation is obtained:

$$\frac{d \ln L(\lambda)}{d\lambda} = -n + \frac{1}{\lambda} \sum_{i=1}^{n} x_i = 0 \quad (3)$$

Solve it:

$$\hat{\lambda} = \frac{1}{n} \sum_{i=1}^{n} x_i = \bar{x} \quad (4)$$

Also

$$\frac{d^2 \ln L(\lambda)}{d\lambda^2}\Big|_{\lambda=\bar{x}} = \frac{-n\bar{x}}{\lambda^2}\Big|_{\lambda=\bar{x}} = -\frac{n}{\bar{x}} < 0 \quad (5)$$

So the maximum likelihood estimator of parameter λ is $\hat{\lambda} = \bar{x}$.

The average arrival rate is 18.8 per cycle based the Table I.

Apart, the probability is $P(X_t) = \frac{\lambda^{X_t}}{X_t!} e^{-\lambda}$ when the number of vehicles is X_t, the probability is $P_n = \sum_{k=a_{n-1}}^{a_n} \frac{\lambda^k}{k!} e^{-\lambda}$ of each group, a_{n-1} is the lower limit of the $n-1$ group, a_n is the upper limit of the $n-1$ group, $\overline{f_n} = 45P_n$ is the theoretical frequency, λ is the average number of arrival vehicles.

From the above data and formulas, we can calculate the $\chi^2 = \sum_{n=0}^{5} \frac{\left(f_n - \overline{f_n}\right)^2}{\overline{f_n}} = 3.092$. Because of estimating a parameter λ when calculates the probability, $r = 1$. The degree of freedom is $k - r - 1 = 4$, $\alpha = 0.05$ is selected, referring the Chi-square distribution table, $\chi^2_{0.95}(6-1-1) = \chi^2_{0.95}(4) = 9.488$, $\chi^2 < \chi^2_{0.95}(4)$. So the number of the arrived vehicles per unit time obeys the Poisson distribution. And the other 3 directions can be verified through the same method, but their parameters are different.

IV. APPLICATION EXAMPLE

It takes money and people to cut or add the fixed lanes that the number of the lanes should be confirmed in the beginning of construction design [3]. Weather the existing establishment of the lanes is reasonable, the model can validate it.

We select the 3 lanes of Shenzhen intersection in one direction, take the vehicle flow of April 13, 2014 to April 15, 2014 as research objects. Suppose the time of every vehicle through the intersection is 5s in view of pedestrian and traffic singles. Measure the vehicle flow of April 13, 2014 from 10:00 to11:00 am is 734, the vehicle flow of April 13, 2014 from 10:00 to11:00am is 795, the vehicle flow of April 15, 2014 from 10:00 to11:00am is 847. Because of undergoing 45 cycles in one hour, now note the data of the vehicles flow of 3 cycles as shown in the Table II:

TABLE II
THE MEASURED DATA

time		1	2	3	4	5	6	7	8
13	vehicles	51	50	43	46	47	51	55	45
14	vehicles	45	52	54	48	53	67	58	60
15	vehicles	75	54	67	52	54	63	47	60
time		9	10	11	12	13	14	15	sum
13	vehicles	57	45	55	56	44	55	44	734
14	vehicles	49	55	60	45	60	50	39	795
15	vehicles	62	59	46	56	58	52	52	847

Takes the average traffic volume as standard, we use the model to validate the existing establishment of driveways is reasonable or not.

1) If the driveway is single, then

$$\lambda=\frac{792}{3600}=\frac{11}{50},\mu=\frac{1}{5},\rho=\frac{\lambda}{\mu}=\frac{11}{10}>1$$

2) Conversely, the system metrics [4] of intersection as shown in Table III, the probability of k vehicles in the system is shown in Table IV:

TABLE III
THE SYSTEM METRICS OF INTERSECTION

system	metrics			
	L_q	L	W	W_q
$M/M/2$	0.405	1.505	6.841	1.841
$M/M/3$	0.240	1.340	6.089	1.089
$M/M/4$	0.009	1.109	5.042	0.042

TABLE IV
THE PROBABILITY OF K VEHICLES IN THE SYSTEM

system	P_k			
	P_0	P_1	P_2	P_3
$M/M/2$	0.290	0.319	0.176	0.097
$M/M/3$	0.327	0.360	0.198	0.073
$M/M/4$	0.332	0.365	0.201	0.074
system	P_k			
	P_4	P_5	P_6	$P(k>6)$
$M/M/2$	0.053	0.029	0.016	0.009
$M/M/3$	0.027	0.010	0.004	0.001
$M/M/4$	0.020	0.006	0.002	0

By analyzing the data in the Table III, the service indicators of system are in decline with the increasing of the driveways. Therefore the increasing of the lanes has a positive impact on the vehicle flow. By analyzing the data in the Table IV, the probability of six or more vehicles is 0 in the intersection in the system of $M/M/4$. So the 4 driveways is the first selection of the design. At the same time, the establishment of the driveway needs to consider various factors. The more lanes, the shorter the vehicles queue length. But it will be unnecessary waste in some degree if the scale of the construction is large, the large investment, and the high operating costs. So the system of $M/M/3$ is the ideal selection to ensure the smooth and fast traffic and save resources. This application example only proves it is feasible that the model can be used to confirm the number of the lanes by analyzing the vehicle flow of the intersection.

V. CONCLUSION

The paper sets up the queuing model, analyses the traffic flow [5] of Shenzhen intersection through analyzing the queuing theory deeply, and uses the model to analyze the settings of the lane that based on the certain degree of accuracy. From the paper, the theoretical data is consistent with the reality. Therefore, it is economic that the method of the system metrics in confirming the number of the lanes of the intersection and it can provide references for similar design.

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Battle Ground Chipotle Mexican Grill (Approximately 2,381 SF)
Location: 1201 SW Scotton Way, Battle Ground, WA 98604
Date: Thursday, September 14, 2023

Mid-day Peak (Lunch)
11:00 AM - 1:00 PM

Time	In	Out	Total	Vehicles in DT	Service Time (s	Max Queue				
11:00 AM	1	1	2	1	38	0				
11:01 AM	0	0	0			0				
11:02 AM	1	0	1	1		1				
11:03 AM	0	2	2		58	0				
11:04 AM	4	0	4			0				
11:05 AM	0	0	0			0				
11:06 AM	1	1	2			0				
11:07 AM	1	0	1			0				
11:08 AM	0	2	2			0				
11:09 AM	1	0	1			0				
11:10 AM	1	1	2	1		1				
11:11 AM	0	1	1		45	0				
11:12 AM	1	0	1	1		1				
11:13 AM	1	2	3		54	0				
11:14 AM	1	1	2	1		1				
11:15 AM	0	2	2		72	0				
11:16 AM	0	0	0			0				
11:17 AM	1	2	3			0				
11:18 AM	2	2	4	1	8	0				
11:19 AM	2	3	5			0				
11:20 AM	0	0	0			0				
11:21 AM	0	1	1			0				
11:22 AM	0	1	1			0				
11:23 AM	0	0	0			0				
11:24 AM	0	0	0			0				
11:25 AM	0	0	0			0				
11:26 AM	0	0	0			0				
11:27 AM	0	0	0			0				
11:28 AM	1	0	1			0				
11:29 AM	0	0	0			0				
11:30 AM	2	0	2			0				
11:31 AM	1	0	1			0				
11:32 AM	0	0	0			0				
11:33 AM	2	1	3	1		1				
11:34 AM	1	3	4	1	40	1				
11:35 AM	1	2	3		20	0				
11:36 AM	4	0	4	3		3				
11:37 AM	0	3	3		44	1				
11:38 AM	1	0	1		8	1				
11:39 AM	2	0	2	1		2				
11:40 AM	3	3	6	1		3				
11:41 AM	1	1	2			3				
11:42 AM	1	2	3	1	308	3				
11:43 AM	0	4	4		8	1				
11:44 AM	0	2	2		33	0				
11:45 AM	1	1	2		58	0				
11:46 AM	1	0	1			0				
11:47 AM	1	0	1			0				
11:48 AM	0	0	0			0				
11:49 AM	0	0	0			0				
11:50 AM	1	0	1			0				
11:51 AM	1	1	2			0				
11:52 AM	1	0	1			0				
11:53 AM	0	1	1			0				
11:54 AM	1	3	4	1	10	0				
11:55 AM	1	0	1			0				
11:56 AM	0	0	0			0				
11:57 AM	0	0	0			0		Peak Hour		
11:58 AM	0	1	1			0	Total	In	Out	Drive-thru In
11:59 AM	1	1	2	1	17	0	98	47	51	16
12:00 PM	1	1	2			0	98	47	51	15
12:01 PM	2	0	2			0	100	49	51	15
12:02 PM	0	0	0			0	99	48	51	14
12:03 PM	2	1	3			0	100	50	50	14
12:04 PM	0	1	1			0	97	46	51	14
12:05 PM	2	1	3			0	100	48	52	14
12:06 PM	1	1	2			0	100	48	52	14
12:07 PM	2	0	2	1		1	101	49	52	15
12:08 PM	3	1	4	1		2	103	52	51	16
12:09 PM	0	1	1			2	103	51	52	16

12:10 PM	1	1	2			2	103	51	52	15
12:11 PM	0	3	3			2	105	51	54	15
12:12 PM	3	1	4	1	290	2	108	53	55	15
12:13 PM	1	3	4	1	13	0	109	53	56	16
12:14 PM	1	0	1		18	0	108	53	55	15
12:15 PM	0	1	1		10	0	107	53	54	15
12:16 PM	1	1	2			0	109	54	55	15
12:17 PM	1	0	1	1		1	107	54	53	16
12:18 PM	2	1	3		27	0	106	54	52	15
12:19 PM	0	0	0			0	101	52	49	15
12:20 PM	0	2	2			0	103	52	51	15
12:21 PM	1	1	2	1		1	104	53	51	16
12:22 PM	0	2	2		67	0	105	53	52	16
12:23 PM	1	0	1	1		1	106	54	52	17
12:24 PM	0	1	1		75	0	107	54	53	17
12:25 PM	2	2	4			0	111	56	55	17
12:26 PM	1	3	4	1	15	0	115	57	58	18
12:27 PM	1	1	2	1		1	117	58	59	19
12:28 PM	1	2	3	1	80	1	119	58	61	20
12:29 PM	3	1	4	1	28	1	123	61	62	21
12:30 PM	0	1	1		15	0	122	59	63	21
12:31 PM	0	0	0			0	121	58	63	21
12:32 PM	1	4	5	1		1	126	59	67	22
12:33 PM	1	0	1			1	124	58	66	21
12:34 PM	3	2	5	1	136	0	125	60	65	21
12:35 PM	0	0	0		30	0	122	59	63	21
12:36 PM	0	0	0			0	118	55	63	18
12:37 PM	1	0	1	1		1	116	56	60	19
12:38 PM	0	3	3		28	0	118	55	63	19
12:39 PM	0	0	0			0	116	53	63	18
12:40 PM	0	0	0			0	110	50	60	17
12:41 PM	1	0	1			0	109	50	59	17
12:42 PM	1	1	2			0	108	50	58	16
12:43 PM	0	1	1			0	105	50	55	16
12:44 PM	0	1	1			0	104	50	54	16
12:45 PM	2	3	5	2	5	0	107	51	56	18
12:46 PM	0	1	1		12	0	107	50	57	18
12:47 PM	0	1	1			0	107	49	58	18
12:48 PM	0	0	0			0	107	49	58	18
12:49 PM	1	0	1	1		1	108	50	58	19
12:50 PM	0	1	1		18	0	108	49	59	19
12:51 PM	1	0	1			0	107	49	58	19
12:52 PM	1	0	1			0	107	49	58	19
12:53 PM	0	0	0			0	106	49	57	19
12:54 PM	0	1	1			0	103	48	55	18
12:55 PM	2	0	2			0	104	49	55	18
12:56 PM	0	0	0			0	104	49	55	18
12:57 PM	0	1	1			0	105	49	56	18
12:58 PM	1	3	4			0	108	50	58	18
12:59 PM	0	0	0			0	106	49	57	17
	96	108		33		Max	126			
				Average Service Time	**51.2**					
				Avg Service Time						
				(Remove 3 Outliers)	**31.8**					
				Median Service Time	**28.0**					
				Max Queue	**3**					
				95th Percentile	**3**					

Newberg Chipotle Mexican Grill (Approximately 2,500 SF)
Location: 3105 E Portland Road, Newberg, OR 97132
Date: Thursday, September 14, 2023

Mid-day Peak (Lunch)
11:00 AM - 1:00 PM

Time	In	Out	Total	Vehicles in DT	Max Queue	Peak Hour Total	Peak Hour In	Peak Hour Out	Peak Hour Drive-thru In
11:00 AM	0	1	1	0	0				
11:01 AM	1	0	1	0	0				
11:02 AM	1	1	2	1	1				
11:03 AM	2	1	3	0	0				
11:04 AM	2	0	2	0	0				
11:05 AM	1	1	2	0	0				
11:06 AM	1	2	3	0	0				
11:07 AM	1	0	1	1	1				
11:08 AM	1	3	4	1	2				
11:09 AM	0	0	0	0	2				
11:10 AM	0	4	4	0	1				
11:11 AM	1	0	1	1	2				
11:12 AM	0	0	0	0	2				
11:13 AM	3	1	4	1	2				
11:14 AM	0	4	4	0	1				
11:15 AM	1	1	2	0	0				
11:16 AM	0	1	1	0	0				
11:17 AM	0	0	0	0	0				
11:18 AM	0	0	0	0	0				
11:19 AM	1	1	2	0	0				
11:20 AM	4	0	4	2	2				
11:21 AM	2	0	2	0	2				
11:22 AM	0	1	1	0	1				
11:23 AM	0	1	1	0	0				
11:24 AM	0	2	2	0	0				
11:25 AM	1	0	1	1	1				
11:26 AM	4	3	7	1	1				
11:27 AM	0	2	2	0	0				
11:28 AM	1	0	1	0	0				
11:29 AM	3	0	3	1	1				
11:30 AM	0	2	2	0	0				
11:31 AM	1	1	2	1	1				
11:32 AM	1	1	2	0	0				
11:33 AM	0	0	0	0	0				
11:34 AM	0	1	1	0	0				
11:35 AM	2	0	2	0	0				
11:36 AM	0	0	0	0	0				
11:37 AM	1	0	1	0	0				
11:38 AM	0	0	0	0	0				
11:39 AM	2	1	3	1	1				
11:40 AM	1	1	2	0	0				
11:41 AM	0	1	1	0	0				
11:42 AM	0	1	1	0	0				
11:43 AM	1	0	1	0	0				
11:44 AM	0	1	1	0	0				
11:45 AM	0	0	0	0	0				
11:46 AM	0	0	0	0	0				
11:47 AM	0	2	2	0	0				
11:48 AM	1	0	1	0	0				
11:49 AM	2	0	2	0	0				
11:50 AM	3	0	3	1	1				
11:51 AM	1	0	1	0	1				
11:52 AM	0	1	1	0	1				
11:53 AM	1	3	4	0	1				
11:54 AM	0	0	0	0	1				
11:55 AM	0	0	0	0	1				
11:56 AM	1	0	1	1	2				
11:57 AM	1	1	2	1	2				
11:58 AM	2	1	3	0	1				
11:59 AM	1	2	3	0	1	103	53	50	15
12:00 PM	0	1	1	0	0	103	53	50	15
12:01 PM	0	1	1	0	0	103	52	51	15
12:02 PM	2	1	3	2	2	104	53	51	16
12:03 PM	2	1	3	1	3	104	53	51	17
12:04 PM	2	3	5	1	2	107	53	54	18
12:05 PM	3	1	4	1	3	109	55	54	19
12:06 PM	1	2	3	0	2	109	55	54	19
12:07 PM	3	3	6	2	1	114	57	57	20
12:08 PM	4	3	7	1	0	117	60	57	20
12:09 PM	0	0	0	0	0	117	60	57	20

12:10 PM	3	0	3	1	1	116	63	53	21
12:11 PM	3	2	5	1	1	120	65	55	21
12:12 PM	2	1	3	2	2	123	67	56	23
12:13 PM	3	2	5	0	1	124	67	57	22
12:14 PM	2	2	4	1	1	124	69	55	23
12:15 PM	0	1	1	0	0	123	68	55	23
12:16 PM	2	0	2	1	1	124	70	54	24
12:17 PM	0	2	2	0	0	126	70	56	24
12:18 PM	1	2	3	1	1	129	71	58	25
12:19 PM	2	0	2	1	2	129	72	57	26
12:20 PM	2	0	2	2	4	127	70	57	26
12:21 PM	2	6	8	0	3	133	70	63	26
12:22 PM	1	3	4	0	1	136	71	65	26
12:23 PM	5	1	6	2	2	141	76	65	28
12:24 PM	1	2	3	1	2	142	77	65	29
12:25 PM	1	3	4	1	2	145	77	68	29
12:26 PM	0	5	5	0	0	143	73	70	28
12:27 PM	0	1	1	0	0	142	73	69	28
12:28 PM	0	0	0	0	0	141	72	69	28
12:29 PM	0	1	1	0	0	139	69	70	27
12:30 PM	2	1	3	0	0	140	71	69	27
12:31 PM	4	0	4	1	1	142	74	68	27
12:32 PM	0	1	1	0	0	141	73	68	27
12:33 PM	0	0	0	0	0	141	73	68	27
12:34 PM	2	1	3	0	0	143	75	68	27
12:35 PM	1	0	1	0	0	142	74	68	27
12:36 PM	3	0	3	0	0	145	77	68	27
12:37 PM	1	0	1	0	0	145	77	68	27
12:38 PM	2	1	3	0	0	148	79	69	27
12:39 PM	2	2	4	2	2	149	79	70	28
12:40 PM	1	3	4	0	0	151	79	72	28
12:41 PM	1	2	3	0	0	153	80	73	28
12:42 PM	0	0	0	0	0	152	80	72	28
12:43 PM	1	0	1	0	0	152	80	72	28
12:44 PM	0	1	1	0	0	152	80	72	28
12:45 PM	0	2	2	0	0	154	80	74	28
12:46 PM	0	0	0	0	0	154	80	74	28
12:47 PM	0	1	1	0	0	153	80	73	28
12:48 PM	0	0	0	0	0	152	79	73	28
12:49 PM	1	0	1	1	1	151	78	73	29
12:50 PM	1	1	2	0	0	150	76	74	28
12:51 PM	0	1	1	0	0	150	75	75	28
12:52 PM	0	0	0	0	0	149	75	74	28
12:53 PM	0	0	0	0	0	145	74	71	28
12:54 PM	0	0	0	0	0	145	74	71	28
12:55 PM	0	0	0	0	0	145	74	71	28
12:56 PM	0	0	0	0	0	144	73	71	27
12:57 PM	1	0	1	1	1	143	73	70	27
12:58 PM	1	1	2	0	0	142	72	70	27
12:59 PM	2	0	2	2	2	141	73	68	29
	126	118		44	Max	154			

Max Queue **4**

95th Percentile **3**

QUEUE LENGTHS

Single-Channel Queue

Arrival Rate:	L (veh/hr)=	28	
Service Time:	T (sec/veh)=	51.2	
Service Rate:	M (1/T)=	0.02	
Utilization Factor:	R (L/M)=	0.40	
Avg. queue length:	E (veh)=	0	

			Accum. Prob.	
Probability of	0	0.6018	0.602	
	1	0.2396	0.841	
	2	0.0954	0.937	
	3	0.0380	0.975	95th Percentile Queue
	4	0.0151	0.990	99th Percentile Queue
	5	0.0060	0.996	
	6	0.0024	0.998	
	7	0.0010	0.999	
	8	0.0004	1.000	
	9	0.0002	1.000	
	10	0.0001	1.000	
	11	0.0000	1.000	
	12	0.0000	1.000	
	13	0.0000	1.000	
	14	0.0000	1.000	
	15	0.0000	1.000	
	16	0.0000	1.000	
	17	0.0000	1.000	
	18	0.0000	1.000	
	19	0.0000	1.000	
	20	0.0000	1.000	
	21	0.0000	1.000	
	22	0.0000	1.000	
	23	0.0000	1.000	
	24	0.0000	1.000	
	25	0.0000	1.000	
	26	0.0000	1.000	
	27	0.0000	1.000	
	28	0.0000	1.000	
	29	0.0000	1.000	
	30	0.0000	1.000	
	31	0.0000	1.000	
	32	0.0000	1.000	
	33	0.0000	1.000	
	34	0.0000	1.000	
	35	0.0000	1.000	
	36	0.0000	1.000	
	37	0.0000	1.000	
	38	0.0000	1.000	
	39	0.0000	1.000	
	40	0.0000	1.000	