Bowman

October 2, 2024

Maria Pellegrini
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CWV Homes
90 SW 3rd Street CU 5
Miami, FL 33130

RE: 1020 Pennsylvania Avenue Multi-Family Residence Traffic Study
Bowman Project No. 314188-01-001

Please accept this Traffic Study for the proposed development of the site located at 1020 Pennsylvania Avenue, Miami Beach, FL 33139 to be submitted to the City of Miami Beach (City). The proposed development will include six (6) multi-family residential units. The site plan is included in **Appendix A**. **Figure 1** graphically depicts the site location.

Figure 1 Site Location

Project Trip Generation

Using trip generation information obtained from the Institute of Transportation Engineers (ITE), *Trip Generation Manual*, 11th Edition, trip generation estimates were developed for the proposed land use. The trip generation analysis for daily, AM peak hour, and PM peak hour conditions are summarized in **Table 1**. The analysis indicates that the proposed development is anticipated to result in 114 daily trips, 25 AM peak hour trips, and 23 PM peak hour new trips. The excerpts from ITE are included in **Appendix B**.

Mr. Grant Webster, City's reviewer, conveyed during the traffic meeting discussion on August 20, 2024, that the trip generation analysis estimated higher trips than expected and thus the trip generation should be revised. However, ITE Land Use Code 220 - Multifamily Housing (Low-Rive) is the most appropriate land use for this type of development. Therefore, the traffic analysis as presented is conservative.

Table 1 Trip Generation Summary

LAND USE	ITE CODE	INTENSITY	TRIP GENERATION RATE (1)	IN	OUT	TOTAL TRIPS		
						IN	OUT	TOTAL
Daily								
Multifamily Housing (Low-Rise)	220	6 Units	T = 6.41 (X) + 75.31	50%	50%	57	57	114
AM Peak Hour								
Multifamily Housing (Low-Rise)	220	6 Units	T = 0.31 (X) + 22.85	24%	76%	6	19	25
PM Peak Hour								
Multifamily Housing (Low-Rise)	220	6 Units	T = 0.43 (X) + 20.55	63%	37%	14	9	23

(1) ITE Trip Generation Manual, 11th Edition.

Project Access Driveway and Trips

Access to the project site is proposed to be via one (1) right-in/right-out driveway connection to Pennsylvania Court. Pennsylvania Court is a northbound one-way, one (1) lane road, with no posted speed limit. **Figure 2** graphically depicts the project trip volumes on the driveway.

Pursuant to City ordinance Section 5.3.4 DRIVES, driveway connections that will provide access to less than 10 parking spaces can have a minimum width of 12 feet for two-way traffic operations. The access driveway connection proposed, shown in the site plan, has a width of 14 feet for the six (6) parking spaces provided. Also, a turnaround area for the ground floor parking is not needed because the minimum 20' wide back-up area is provided.

AutoTurn Analysis

An autoturn analysis has been prepared for the first and last parking space for the parking lot as requested by the City during the traffic meeting on August 20, 2024. The autoturn analysis is provided in **Appendix C**. The analysis indicated that a passenger vehicle has adequate area to enter and exit these two (2) parking spaces.

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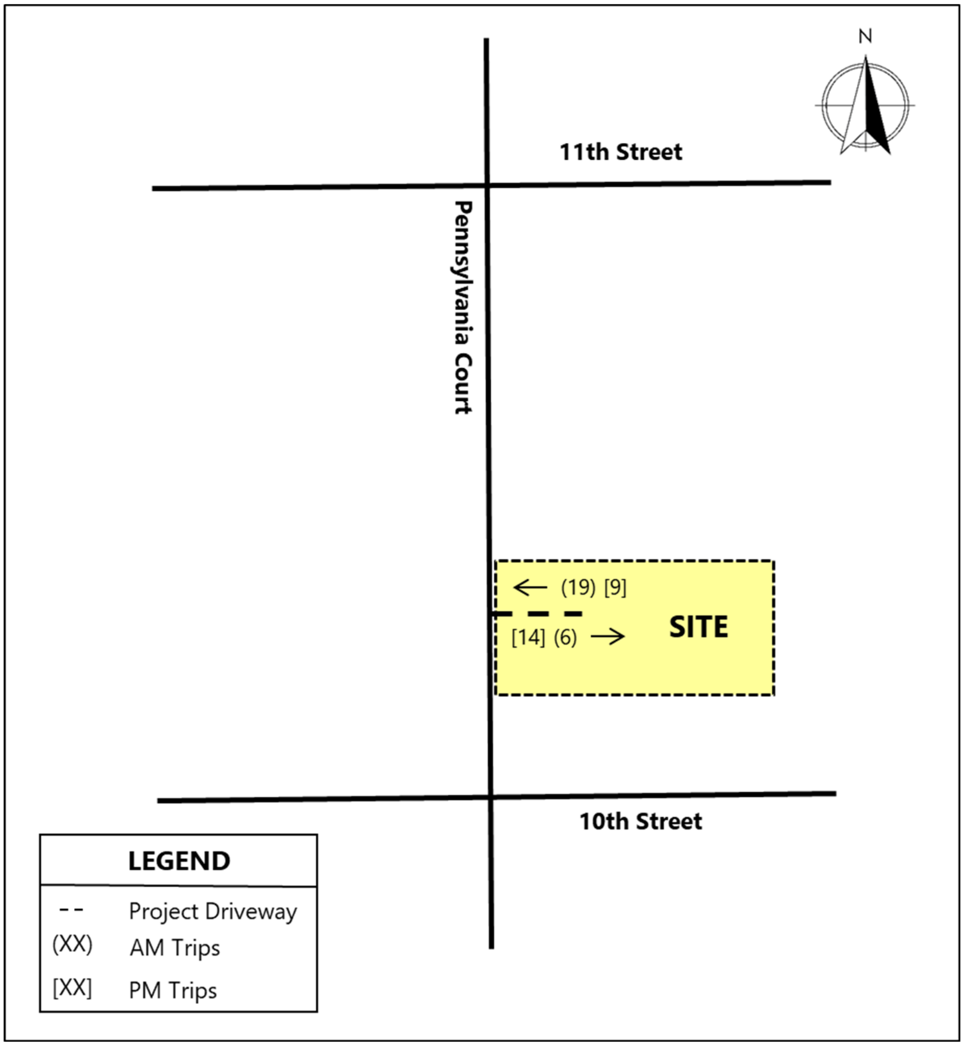
Figure 2 Project Trip Volumes



Access Gate Queue Analysis

An access gate queue analysis for the driveway access gate operations was performed based on the Transportation and Land Development, 1988, methodology published by ITE. Based on the analysis, a queue of 0.06 vehicle (1.5 feet) per hour is expected during the PM peak hour for the 14 inbound expected trips with a 1-minute per vehicle service rate for the gate. Thus, the provided distance of 16 feet from the access gate to the roadway is adequate for the expected queue. The analysis and ITE methodology excerpts are provided in **Appendix D.**

Valet Operations

The development is not proposing valet operations.

Transportation Demand Management Strategies

The project is proposing to install bicycle parking spaces. As shown in the site plan, there are 10 bicycle parking spaces.

Loading and Trash Operations

The trash will be taken by each unit resident to individual trash bins. On trash day, each resident will be responsible for taking the trash out to the designated area. There is no designated loading space required for six (6) units. The loading will be accomplished in any manner the City prefers.

Conclusion

Bowman has prepared the Traffic Study for the proposed development of the site located at 1020 Pennsylvania Avenue, Miami Beach, FL 33139. The proposed development will include six (6) multi-family residential units. Based on the study, the following is concluded:

- The trip generation analysis indicates that the proposed development is anticipated to result in 114 daily trips, 25 AM peak hour trips, and 23 PM peak hour new trips. Based on the City's reviewer, the trip generation appears higher than the expected trips for this type of development. Therefore, the traffic analysis as presented is conservative.
- Based on the autoturn analysis, a passenger vehicle has adequate area to enter and exit the first and last spaces in the parking garage.
- Based on the access gate queue analysis, a queue of 0.06 vehicle (1.5 feet) is expected during the PM peak hour for the 14 inbound expected trips. Thus, the provided distance of 16 feet from the access gate to the roadway is adequate.
- The project is proposing to install 10 bicycle parking spaces.

Should you have any questions or comments regarding this traffic study, please do not hesitate to call me.

THIS ITEM HAS BEEN DIGITALLY
SIGNED AND SEALED BY

Veronica A. Altuve

Digitally signed by Veronica A. Altuve
Date: 2024.10.03 10:07:31 -04'00'

ON THE DATE ADJACENT TO THE SEAL

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BOWMAN
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WEST PALM BEACH, FL 33409
VERONICA A. ALTUVE, P.E. 68194

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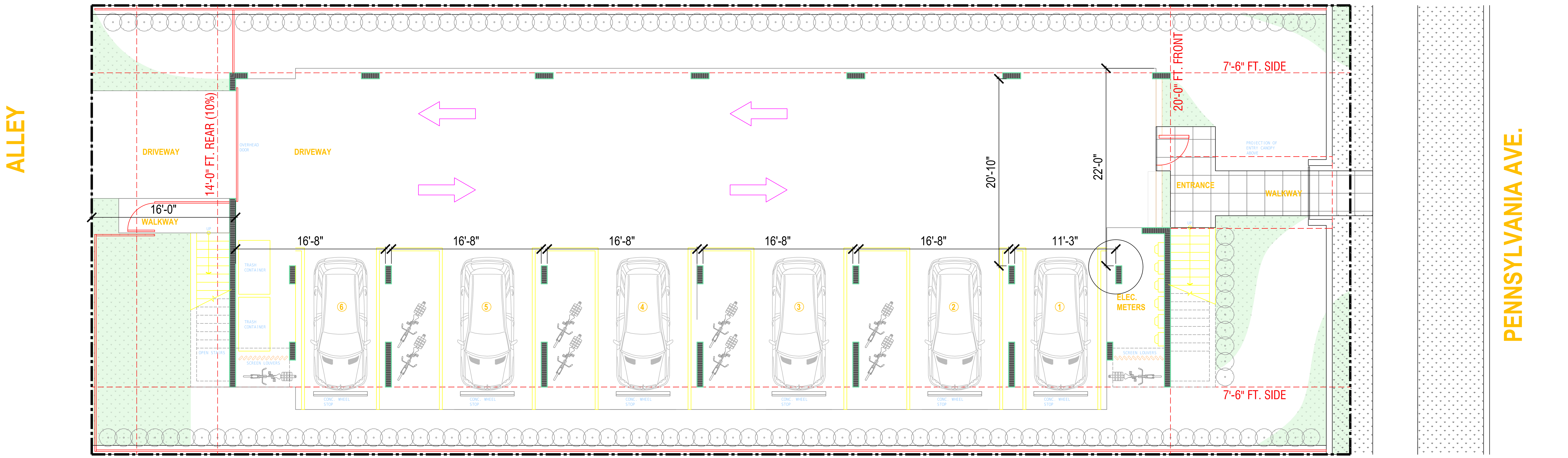
Appendix A

Site Plan

concept floor plans



sketch #
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Appendix B

ITE 11th Edition Trip Generation Excerpts

Multifamily Housing (Low-Rise) Not Close to Rail Transit (220)

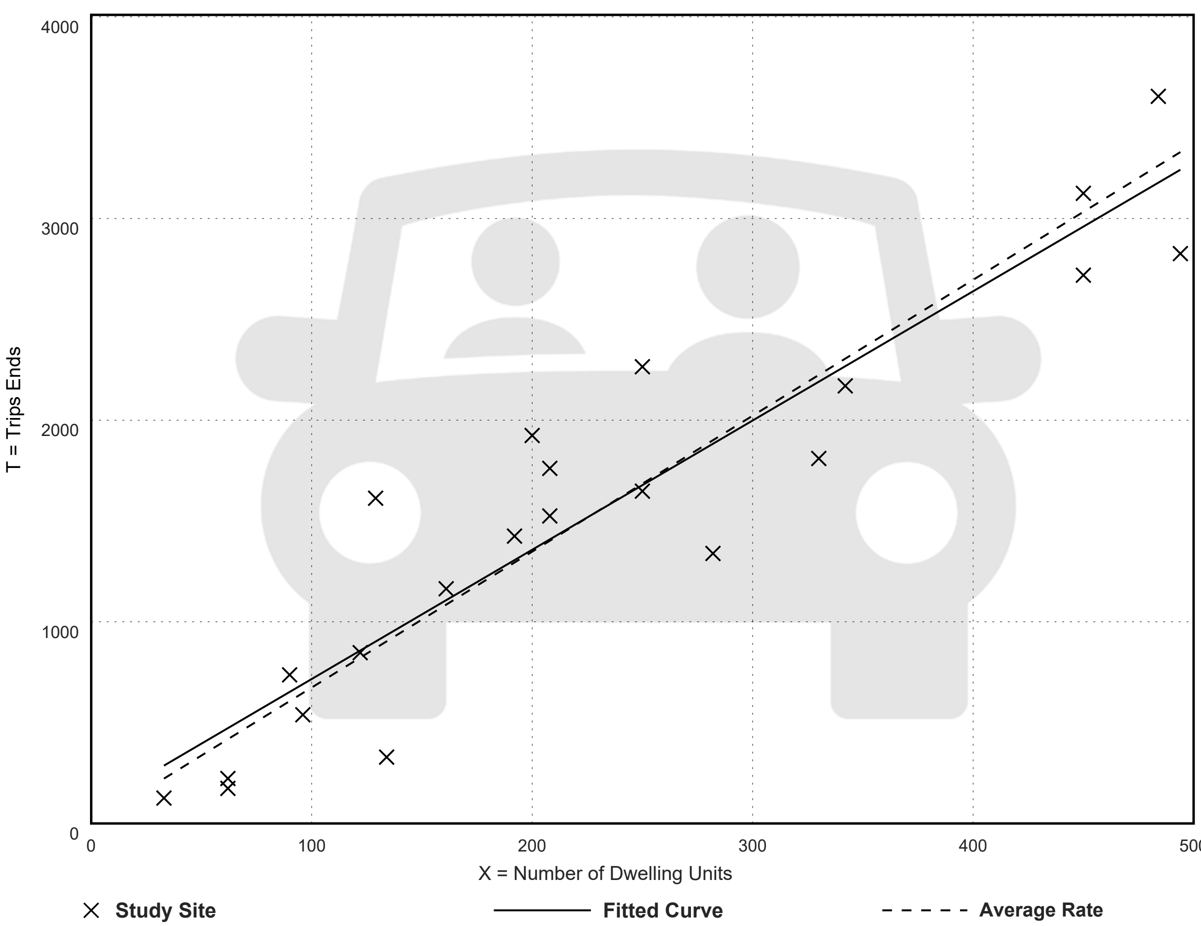
Vehicle Trip Ends vs: Dwelling Units
On a: Weekday

Setting/Location: General Urban/Suburban
Number of Studies: 22
Avg. Num. of Dwelling Units: 229
Directional Distribution: 50% entering, 50% exiting

Vehicle Trip Generation per Dwelling Unit

Average Rate	Range of Rates	Standard Deviation
6.74	2.46 - 12.50	1.79

Data Plot and Equation



Fitted Curve Equation: T = 6.41(X) + 75.31 **R^2= 0.86**

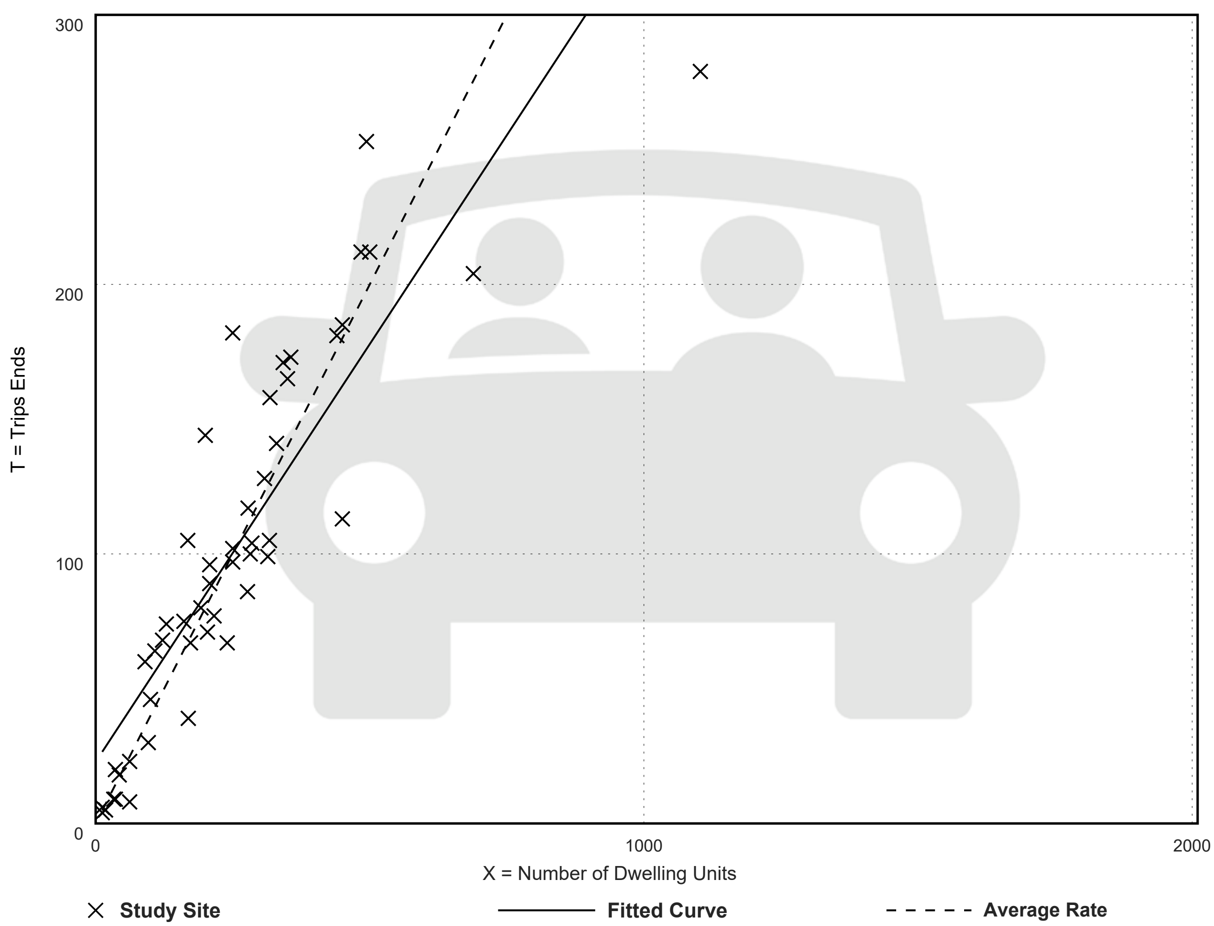
Multifamily Housing (Low-Rise) Not Close to Rail Transit (220)

Vehicle Trip Ends vs:	**Dwelling Units**
On a:	**Weekday,**
	Peak Hour of Adjacent Street Traffic,
	One Hour Between 7 and 9 a.m.
Setting/Location:	**General Urban/Suburban**
Number of Studies:	49
Avg. Num. of Dwelling Units:	249
Directional Distribution:	24% entering, 76% exiting

Vehicle Trip Generation per Dwelling Unit

Average Rate	Range of Rates	Standard Deviation
0.40	0.13 - 0.73	0.12

Data Plot and Equation



Fitted Curve Equation: $T = 0.31(X) + 22.85$

R^2= 0.79

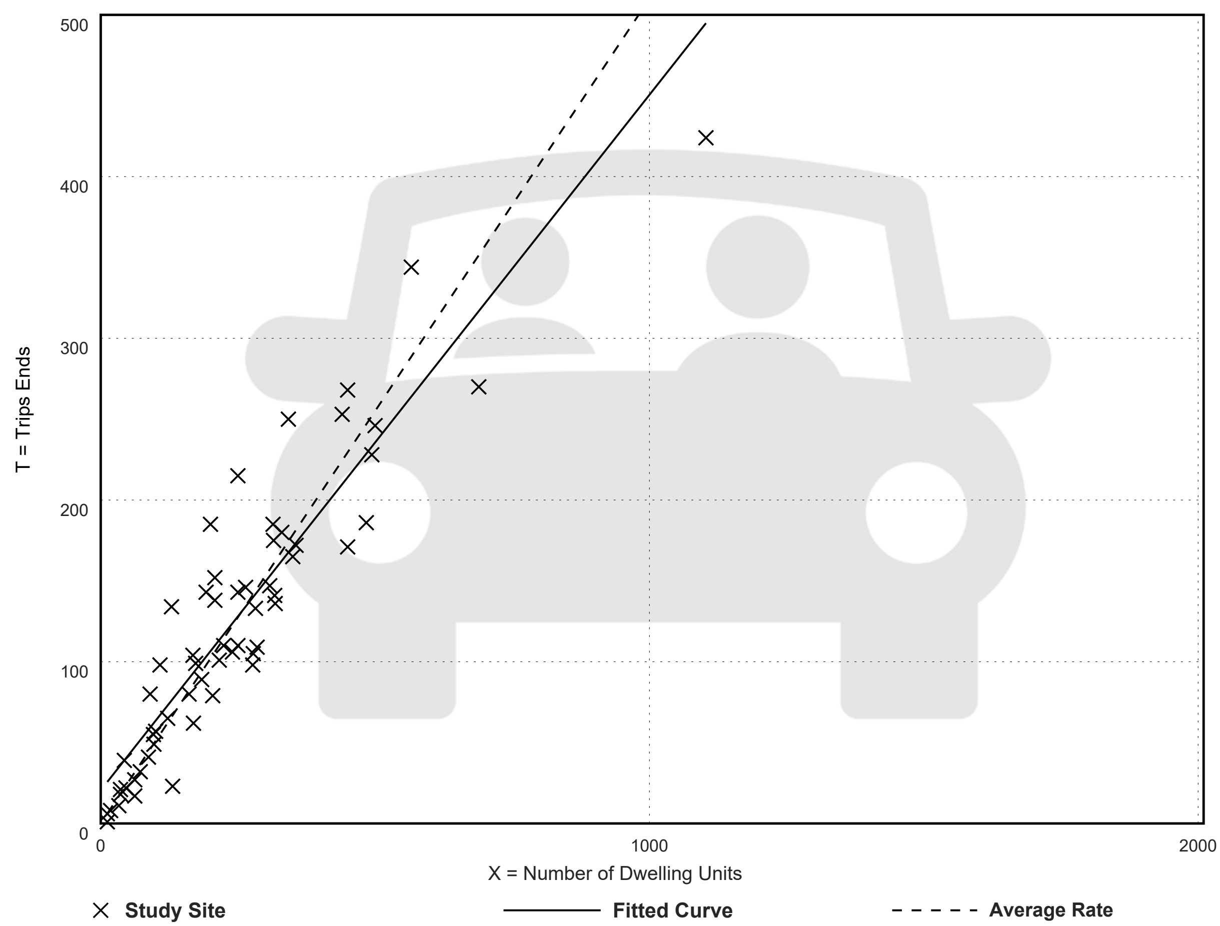
Multifamily Housing (Low-Rise)
Not Close to Rail Transit (220)

Vehicle Trip Ends vs: Dwelling Units
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.
Setting/Location: General Urban/Suburban
Number of Studies: 59
Avg. Num. of Dwelling Units: 241
Directional Distribution: 63% entering, 37% exiting

Vehicle Trip Generation per Dwelling Unit

Average Rate	Range of Rates	Standard Deviation
0.51	0.08 - 1.04	0.15

Data Plot and Equation

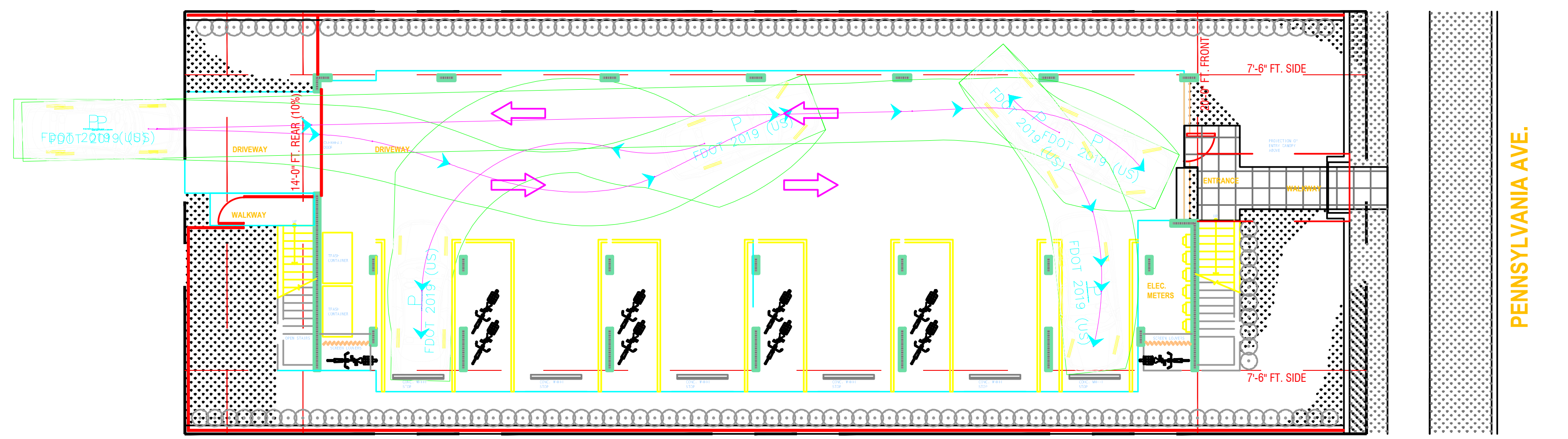


Fitted Curve Equation: $T = 0.43(X) + 20.55$

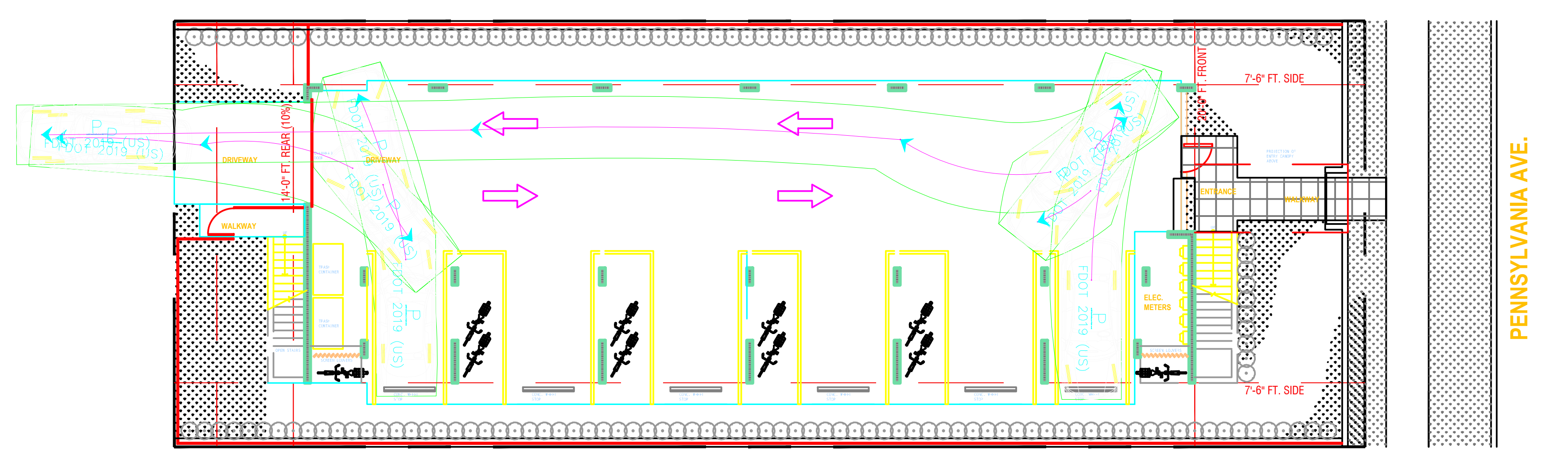
$R^2 = 0.84$

Appendix C

AutoTurn Analysis



DRIVEWAY
WALKWAY
14'-0" FT. REAR (10%)
7'-6" FT. SIDE
7'-6" FT. SIDE
ENTRANCE
ELEC. METERS
PENNSYLVANIA AVE.



DRIVEWAY
WALKWAY
14'-0" FT. REAR (10%)
7'-6" FT. SIDE
7'-6" FT. SIDE
ENTRANCE
ELEC. METERS
PENNSYLVANIA AVE.

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Appendix D

Access Gate Queue Analysis

Required Storage:

$$M = \frac{[\ln P(x > M) - \ln QM]}{\ln \rho} - 1$$

coefficient of utilization:

$\rho = q/NQ$

$$\rho = \frac{14}{(1)\ 60} = \mathbf{0.2333}$$

Required Storage with 95% confidence level [P(x >M)]:

$$\mathbf{M =} \frac{\ln(.05) - \ln\ (0.2333)}{\ln(\ 0.2333)} = \boxed{\mathbf{0.06\ \text{vehicles}}}$$

q is the demand rate. For this analysis,

q = 14 veh/hr.

N is the number of gates. For this analysis,

N = 1 Gate

Q is the processing rate for the gate. For this analysis,

Processing Time: 60 sec * 1 min/60 sec = 1 min

Total Time: **1.00 min**

$$Q = \frac{1\ \text{proccess}}{\text{process time}} * \frac{60\ \text{min}}{1\ \text{hr}} \Rightarrow \frac{1\ \text{process}*60\ \text{min}}{1.00} \Rightarrow \mathbf{60\ \text{proccesses/hr}}$$

Q_M is a table value obtained from Table 8-11 based on ρ and N.

Table 8-11 (page 6 of pdf)

From Table:	N =	1	and	ρ =	0.2000	=>	0.2000
From Table:	N =	1	and	ρ =	0.3000	=>	0.3000

$$Q_M = 0.2000 + \frac{(0.3000 - 0.2000) * (0.2333 - 0.2000)}{(0.3000 - 0.2000)} = \mathbf{0.2333}$$

Transportation and Land Development

Vergil G. Stover / Frank J. Koepke

Institute of Transportation Engineers

TABLE 8-1
Design-Hour Lobby Traffic Generation for Banks with Drive-In Windows

Gross Floor Area Used by Bank	*Hourly One-Way Traffic Generation (per 1,000 sq. ft.)*
5,000 to 20,000 sq. ft.	15 to 20 vehicles
20,000 to 40,000 sq. ft.	10 to 15 vehicles
Over 40,000 sq. ft.	5 to 10 vehicles

SOURCE: Peter N. Scifres [8].

Parking. It is desirable to have as much traffic as possible use the drive-in windows. Petersen [7] reported a 50–50 split between lobby and drive-thru customers when the drive-thru facilities are not unduly congested. Customer parking duration averages about 15 to 20 minutes. During the peak period, parking demand should not exceed 90% of the parking capacity if customers are to be able to find a parking space without excessive delay. Scifres [8] reported customer parking requirements as given in Table 8-2.

TABLE 8-2
Design-Hour Lobby Customer Parking Requirements for Banks with Drive-In Windows

Gross Floor Area Used by Bank	*Customer Parking Requirements (per 1,000 sq. ft.)*
5,000 to 20,000 sq. ft.	2.0 to 2.5 Spaces
20,000 to 40,000 sq. ft.	1.5 to 2.0 Spaces
Over 40,000 sq. ft.	1.0 to 1.5 Spaces

SOURCE: Peter N. Scifres [8].

Drive-In Window Requirements. The number of service positions required is a function of the average service time and the demand. The technique contained in the section "Analysis of Service Times," presented later in this chapter, can be used to calculate the average time in the system and the average time in the queue for different operating conditions (number of service positions, number of tellers, average service time, and demand) in order to help evaluate proposed designs.

Bank officials commonly underestimate service and waiting time; therefore the average service time should be obtained through observation of similar facilities in the local area, since wait time and, theoretically, storage requirements are fairly sensitive to the parameter.

Table 8-3 gives guidelines for the number of drive-in windows as a function of lobby size. These guidelines assume an average service time of approximately 2 minutes and that 50% of the bank customers will use the drive-in windows. These typical values might be used where a more detailed (and expensive) analysis is not warranted.

TABLE 8-3
Lobby Size Versus Drive-In Window Requirements

Lobby Sizes (sq. ft.)	*Number of Drive-In Windows*
5,000 to 10,000	2 to 3
10,000 to 20,000	3 to 4
20,000 to 30,000	4 to 5
30,000 to 40,000	6 to 8
40,000 to 50,000	8 to 10

SOURCE: Peter N. Scifres [8].

APPLICATIONS OF QUEUEING ANALYSIS

Providing an adequate and well-defined storage area for drive-thru traffic is particularly critical, especially at fast-food restaurants and drive-thru bank facilities where queues can, and do, become quite long. Waiting vehicles should be stored on private property clear of driveways so that traffic back-up does not interfere with movement on the arterial street. At fast-food restaurants, the menu board should be installed upstream of the service window to permit drive-thru customers to place their orders prior to their arrival at the service window. Preparation of their order can then begin before they reach the service window, thus minimizing their time at the service window. A well-defined storage area for the waiting traffic should be located so that the waiting vehicles do not block or impede the movement of driveway traffic.

Where a single service position is involved, the situation is referred to as a *single-channel problem*. *Multiple-channel problems* arise when two or more service positions are available. Such problems commonly arise with bank tellers (indoor as well as drive-in windows), entrances and exits at large parking lots and garages, at passenger pick-up areas at transit stations and taxi stands, truck terminals or loading/unloading areas, supermarket checkout counters, telephone calls, building entrances, and transit-station turnstiles. The assumptions of Poisson arrivals and negative exponential service time are commonly acceptable and used for both single- and multiple-channel problems. Thurgood [11] found these assumptions to be representative of drive-in facilities.

Customers arriving randomly at a drive-in facility may enter into service immediately or may have to enter the queue until they can be served. Waiting lines occur whenever the immediate demand for service exceeds the current capacity of the facility providing that service.

Basic Notation and Terminology

The following notation is employed throughout this section:

n = number of customers in the drive-in system

M = number of customers in the queue waiting to be served (number of customers in the system minus the number being served)

$P(n)$ = steady-state probability that exactly n customers are in the queueing system

$P(0)$ = probability that zero vehicles are in the queueing system

N = number of parallel service positions

q = mean average arrival rate of vehicles into the system (vehicles/hour)

Q = mean average service rate per service position (vehicles/hour/position)

Avg (t) = $^{60}/_{Q}$ = mean service time expressed in minutes per vehicle

ρ = $^{q}/_{NQ}$ = coefficient of utilization

$E(m)$ = expected (average) number of customers in the system

$E(n)$ = expected (average) number of customers waiting in the queue

$E(t)$ = expected (average) waiting time in system (includes service time)

$E(w)$ = expected (average) waiting time in queue (excludes service time)

The equations employed in the analysis of queueing problems are given in Table 8-10.

Jones, Woods, and Thurgood [4] have developed a graph (Figure 8-6) for determining the probability that there will be no customers in the system—values for $P(0)$. They also developed graphs for determining the average number of waiting customers (Figure 8-7), the average waiting time (Figure 8-8), and average queue length (Figure 8-9). These figures avoid the necessity to perform the time-consuming, although simple, queueing-analysis calculations. See pp. 228–30.

TABLE 8-10
Queueing System Equations

Equation Number	Variable	Equation
(8-1)	Coefficient of utilization	$\rho = \dfrac{q}{NQ}$
(8-2)	Probability of no customers in the system	$P(0) = \left[\sum_{n=0}^{N-1} \dfrac{\left(\frac{q}{Q}\right)^n}{n!} + \dfrac{\left(\frac{q}{Q}\right)^N}{N!(1-\rho)}\right]^{-1}$
(8-3)	Mean number in the queue	$E(m) = \left[\dfrac{\rho\left(\frac{q}{Q}\right)^N}{N!(1-\rho)^2}\right] P(0)$
(8-4)	Mean number in the system	$E(n) = E(m) + \dfrac{q}{Q}$
(8-5)	Mean wait time in queue (hours)	$E(w) = \dfrac{E(m)}{q}$
(8-6)	Mean time in the system (hours)	$E(t) = E(w) + \dfrac{1}{Q}$ $= E(w) + \text{Avg}(t)$
(8-7)	Proportion of customers who wait	$P[E(w) > 0] = \left[\dfrac{\left(\frac{q}{Q}\right)^N}{N!(1-\rho)}\right] P(0)$
(8-8)	Probability of a queue exceeding a length M	$P(x > M) = (\rho^{N+1}) P[E(w) > 0]$
(8-9a)	Queue storage required	$M = \left[\dfrac{\ln P(x > M) - \ln E(w) > 0}{\ln \rho}\right] - 1$
(8-9b)*	Queue storage required	$M = \left[\dfrac{\ln P(x > M) - \ln Q_M}{\ln \rho}\right] - 1$

*Q_M is a statistic which is a function of the utilization rate and the number of service channels (service positions); see Table 8-11. The table of Q_M values and use of Equation (8-9b) greatly simplifies the calculations compared to those using Equations (8-9a).

Use of the equations and the graphs may be illustrated by the following example of a drive-in bank.

Conditions:

Number of drive-in windows, $N = 3$
Demand on the system, $q = 70$
Service capacity per channel, $Q = 28.6$ for an average service time, Avg (t) = 2.1 minutes

Solution Using Graphs:

- Coefficient of utilization = 70/(3)(28.6) = 0.816
- Probability that there are customers waiting in the system, Figure 8-6: $P(0) = 0.05$
- Expected average number of customers waiting in the queue, Figure 8-7: $E(m)/N = 1.0$; and the average number $E(m) = (3)(1.0) = 3$

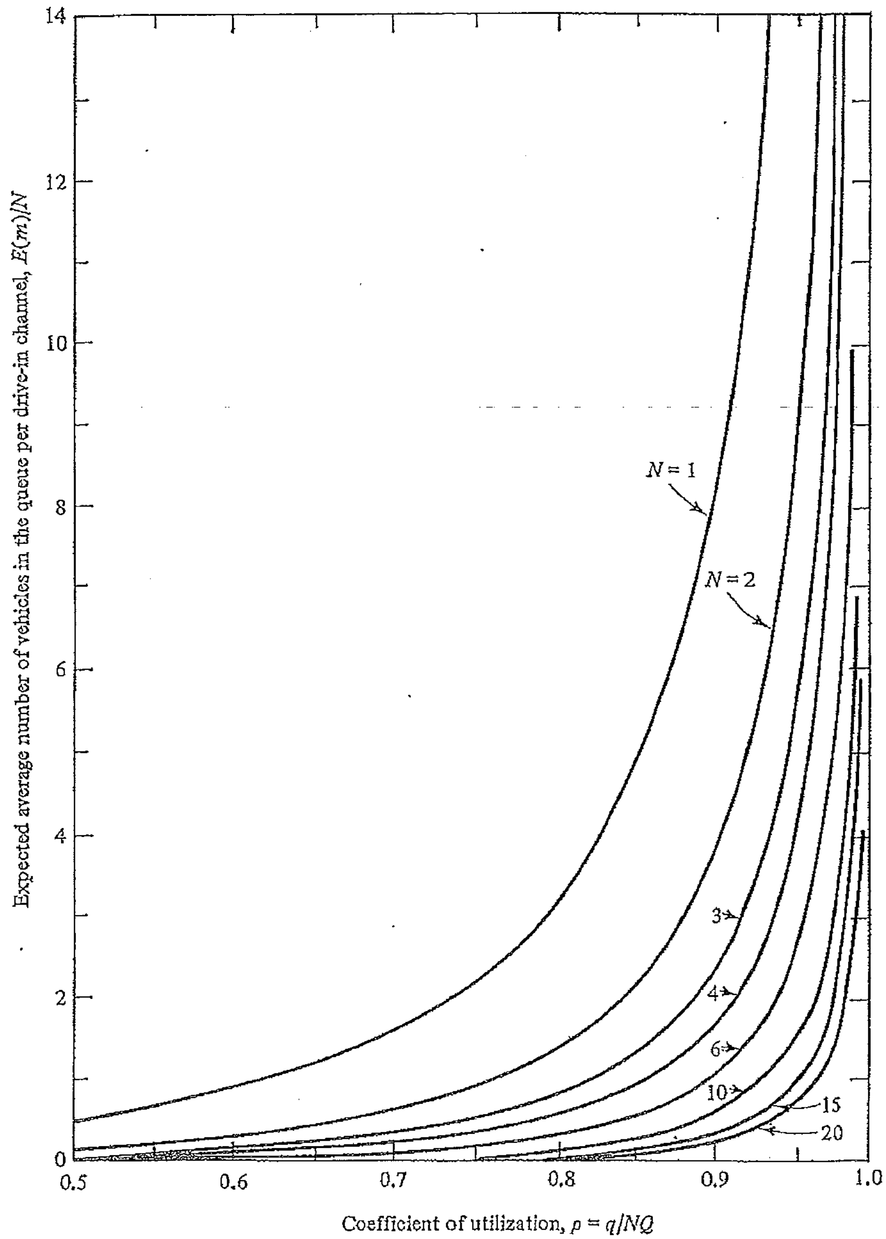

Figure 8-9 Average queue length per service position [$E(m)/N$ values]. SOURCE: Jones, Woods, and Thurgood [4].

Comparison:

Variable	Graphs	Equations
$P(0)$	0.05	0.0505
$E(m)$	3	2.97
$E(w)$	2.5	2.55

Example and Case Studies of Required Storage at a Drive-In Bank

Consider the following example of a drive-in bank facility as a demonstration of the use of queueing analysis. Review of a site plan for a proposed bank shows there are six drive-in window positions plus space to store 18 vehicles waiting to be served. In view of its location, a 5% probability of back-up onto the adjacent street is judged to be acceptable. Demand on the system for design is expected to be 110 vehicles in a 45-minute period. Average service time was expected to be 2.2 minutes. Is the queue storage adequate?

Such problems can be quickly solved using Equation (8–9b) given in Table 8-10 and repeated below for convenience.

$$M = \left[\frac{\ln P(x > M) - \ln Q_M}{\ln \rho}\right] - 1$$

where:

M = queue length which is exceeded p percent of the time
N = number of service channels (drive-in positions)
Q = service rate per channel (vehicles per hour)
$\rho = \dfrac{\text{demand rate}}{\text{service rate}} = \dfrac{q}{NQ}$ = utilization factor
q = demand rate on the system (vehicles per hour)
Q_M = tabled values of the relationship between queue length, number of channels, and utilization factor (see Table 8.11)

TABLE 8-11
Table of Q_M Values

	N = 1	2	3	4	6	8	10
0.0	0.0000	0.0000	0.0000	0.0000			
0.1	.1000	.0182	.0037	.0008	.0000	0.0000	0.0000
.2	.2000	.0666	.0247	.0096	.0015	.0002	.0000
.3	.3000	.1385	.0700	.0370	.0111	.0036	.0011
.4	.4000	.2286	.1411	.0907	.0400	.0185	.0088
.5	.5000	.3333	.2368	.1739	.0991	.0591	.0360
.6	.6000	.4501	.3548	.2870	.1965	.1395	.1013
.7	.7000	.5766	.4923	.4286	.3359	.2706	.2218
.8	.8000	.7111	.6472	.5964	.5178	.4576	.4093
.9	.9000	.8526	.8172	.7878	.7401	.7014	.6687
1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

$\rho = \dfrac{q}{NQ} = \dfrac{\text{arrival rate, total}}{\text{(number of channels)(service rate per channel)}}$

N = number of channels (service positions)

Solution

Step 1: $Q = \dfrac{60\ \text{min/hr}}{2.2\ \text{min/service}} = 27.3$ services per hour

Step 2: $q = (110\ \text{veh}/45\ \text{min}) \times (60\ \text{min/hr}) = 146.7$ vehicles per hour

Step 3: $\rho = \dfrac{q}{NQ} = \dfrac{146.7}{(6)(27.3)} = 0.8956$

Step 4: $Q_M = 0.7303$ by interpolation between 0.8 and 0.9 for $N = 6$ from the table of Q_M values (see Table 8-11).

Step 5: The acceptable probability of the queue, M, being longer than the storage, 18 spaces in this example, was stated to be 5%. $P(x > M) = 0.05$, and:

$$M = \left[\frac{\ln 0.05 - \ln 0.7303}{\ln 0.8956}\right] - 1 = \left[\frac{-2.996 - (-0.314)}{-0.110}\right] - 1$$

$$= 24.38 - 1 = 23.38, \text{ say 23 vehicles.}$$

The number of vehicles in the queue would be expected to exceed 23 more than 5% of the time. Since the site plan will accommodate a queue of 18 vehicles, the storage is not sufficient for the conditions stated.

It is important to realize that, for any $P\ (x > M)$ value, the queue length required increases very rapidly for values of $\rho > 0.85$ (see Figure 8-9). When $\rho > 1.0$, the solution is indeterminate and the queue length theoretically becomes infinite.

Analysis of Service Times. In many instances it is effective to demonstrate that a proposed design not only is inadequate to store vehicles waiting for service but will result in unacceptable wait times as well. The necessary equations are given in Table 8-10.

For purposes of checking computations it is convenient to know that the limit of $P(0)$, as the number of channels approaches infinity (in practical terms when $N > 10$), is;

$$\lim_{N \to \infty} P(0) = e^{-\lambda} \qquad \text{where } \lambda = q/Q$$

Drive-In Bank Example; Under the site-development approval requirements, representatives of a bank presented a site plan for the construction of a new bank having three service positions. Information provided by bank officials and observations at other local banks provided the following data:

- Expected average arrival rate during the design hour (4:30–5:30 p.m. on Fridays) = 70 vehicles per hour (vph)
- Average service time per customer = 2.1 minutes

Does the site plan provide for sufficient storage to accommodate all vehicles arriving 95% of the time?

$$q = 70 \text{ vph arrival rate}$$

$$Q = \frac{60 \text{ minutes per hour}}{2.1 \text{ minutes per service}} = 28.6 \text{ vph service rate}$$

$$\rho = \frac{70}{(3)(28.6)} = 0.816$$

$$\frac{q}{Q} = \frac{70}{28.6} = 2.45$$

$$Q_M = 0.674 \text{ by interpolation from Table 8-11}$$

$$P(x > M) = 1.00 - 0.95 = 0.05$$

By Equation (8-9b)

$$M = \left[\frac{\ln 0.05 - \ln 0.674}{\ln 0.816}\right] - 1 = \left[\frac{-2.996 - (-0.396)}{-0.203}\right] - 1 = 11.8, \text{ say } 12$$

Thus, it would be necessary to store 12 vehicles, exclusive of the three service positions, in order to accommodate the arriving vehicles 95% of the time; or alternatively, to have waiting vehicles extending back into the adjacent street no more than 5% of the time between 4:30 and 5:30 p.m. on Fridays. Since the site plan provides for six spaces, the site plan as submitted is inadequate and should be disapproved.

A solution to the problem would be to increase the storage, or if this is not possible add a service position in order to reduce the average service time.

Addition of a service position would reduce the number of storage spaces needed to three (three storage plus four service positions)—assuming the same arrival rate and service time:

$$M = \left[\frac{\ln 0.05 - \ln 0.301}{\ln 0.612}\right] - 1 = 2.7, \text{ say } 3$$

A redesign to provide four service positions would have the additional benefit of substantially reducing the expected waiting time (from over 4 minutes to less than $\frac{1}{2}$ minute) for the bank customers using the drive-in windows:

With Three Service Positions:

$$q = 70 \text{ vph}$$
$$Q = 28.6 \text{ vph}$$
$$\frac{q}{Q} = 2.45$$
$$\rho = \frac{70}{(3)(28.6)} = 0.816$$
$$P(0) = \left[\frac{(2.45)^0}{0!} + \frac{(2.45)^1}{1!} + \frac{(2.45)^2}{2!} + \frac{(2.45)^3}{3!\left[1 - \left(\frac{2.45}{3}\right)\right]}\right]^{-1}$$
$$= [1 + 2.45 + 3.00 + 13.37]^{-1} = 0.0505$$
$$E(m) = \left[\frac{(0.816)\left(\frac{70}{28.6}\right)^3}{3!(1 - 0.816)^2}\right] 0.0505 \doteq 2.97$$
$$E(n) = 2.97 + 70/28.6 = 5.42$$
$$E(t) \doteq \frac{2.97}{70} = 0.0424 \text{ hours or } 2.55 \text{ minutes}$$
$$E(w) = 0.0424 + \frac{1}{28.6} = 0.0774 \text{ hours or } 4.64 \text{ minutes}$$

With Four Service Positions:

$$q = 70 \text{ vph}$$
$$Q = 28.6 \text{ vph}$$
$$\frac{q}{Q} = 2.45$$
$$\rho = \frac{70}{(4)(28.6)} = 0.612$$
$$P(0) = \left[\frac{(2.45)^0}{0!} + \frac{(2.45)^1}{1!} + \frac{(2.45)^2}{2!} + \frac{(2.45)^3}{3!} + \frac{(2.45)^4}{4!\left[1 - \left(\frac{2.45}{4}\right)\right]}\right]^{-1}$$
$$= 0.0783$$
$$E(m) = \left[\frac{(0.612)(2.45)^4}{4!(1 - 0.612)^2}\right] 0.0783 = 0.48$$
$$E(n) = 0.48 + 2.45 = 2.93$$
$$E(t) = 0.007 + \frac{1}{28.6} = 0.042 \text{ hours or } 2.51 \text{ minutes}$$
$$E(w) = \frac{0.48}{70} = 0.007 \text{ hours or } 0.41 \text{ minutes}$$

However, the service time would increase somewhat unless an additional teller were also added. Nevertheless, an increase to 2.5 minutes, or more, would still reduce the storage space required and result in better service (less time in the system). Besides, time spent being served is less irritating to the customer than an equal time spent waiting.