Rest Area Usage Design Criteria Update

WA-RD 173.1

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Washington State Department of Transportation
Planning, Research and Public Transportation Division

in cooperation with the
United States Department of Transportation
Federal Highway Administration

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16. ABSTRACT

A data survey was conducted at eight rest area sites in Washington to reevaluate the rest area design guidelines for the number of parking stalls, the water/sewage volume, and the number and ratio of women's to men's restroom stalls. The criteria for the number of parking stalls and water/sewage volume are affected by the increased highway traffic volume and a lower average vehicle occupancy. A fifty/fifty ratio of women's to men's stalls was the standard, but the results of the data analysis show that a sixty/forty ratio is more appropriate. A simulation program, written in Lightspeed Pascal, is available to assist in determining the respective number of stalls based on vehicle arrival rate.

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REST AREA USAGE DESIGN CRITERIA UPDATE

by

William Melton
Roadside Specialist

Anh Tran
Transportation Technician

and

Julie Leverson
Transportation Planning Specialist

Washington State Department of Transportation
Technical Monitor
Jay Burgin
Travel Analyses Section Specialist

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SUMMARY

Rest areas have become an increasingly important feature in highway travel. The addition of commercial advertising, information displays, weather updates, free coffee, vending machines, and recreational vehicle dump stations to highway rest areas, coupled with tension from driving in higher traffic volumes, have attracted more motorists to rest areas. So that the limited available funds are utilized most efficiently, the existing rest area design criteria need to be updated to reflect the new conditions.

A data survey was conducted at eight rest area sites to reevaluate the rest area design guidelines for the number of parking stalls, water/sewage volume, and the number and ratio of women's to men's restroom stalls. The criteria for the number of parking stalls and water/sewage volume are affected by the increased highway traffic volume and a lower average vehicle occupancy. A fifty/fifty ratio of women's to men's stalls is the standard, but crowded conditions around the women's facilities led WSDOT to believe that the fifty/fifty stall ratio is not adequate.

Data analysis indicated that the formulas for determining the number of parking stalls and the water/sewage volume required modifications. Parking specifications were altered to better serve the demands of the different rest areas. Rest areas near towns have a lower parking demand than rest areas in remote locations, so the parking demand was changed to a variable 2 to 4 percent instead of the previous 4 percent.

The percentage of traffic entering the rest areas has increased at all rest areas since 1967, but this was countered by decreased vehicle occupancy and a decreased percentage of people who use the restrooms. The decreased vehicle occupancy and decrease in restroom use outweighed the increased traffic, so it was

necessary to lower the water/sewage specifications. The results of the data analysis also showed that a sixty/forty ratio of women's to men's stalls was more appropriate for restroom stall design.

INTRODUCTION

Project Overview

The Washington State Department of Transportation is reevaluating the rest area design criteria it has used since 1968. In 1968, WSDOT conducted a study of seven Washington rest areas, collecting information on average daily traffic (ADT), percentage of highway vehicles entering the rest area, vehicle occupancy, and peak conditions demand for parking and restroom usage. Data analysis resulted in the formulation of parking stalls, water/sewage volume, and restroom stalls guidelines.

Since the Rest Area Design Criteria study in 1968, changes have influenced the volume of rest area use, the nature of that use, and the length of time spent in rest areas. A few of these changes include the following:

1. decreased speed limit in most areas,
2. shorter travelling distances between rest areas,
3. higher traffic volumes, resulting in increased tension and a more frequent need to stop, and
4. the addition of attractive rest area features such as commercial advertising, information displays, weather information, free coffee, vending machines, and recreational vehicle dump stations.

There are 27 Interstate rest areas in Washington, many of which need rehabilitation at the average cost of $500,000 to $1,000,000 per rest area. WSDOT currently has a budget of $1 million per year to rehabilitate and, in some cases, expand existing rest area facilities. Thus, accurate, current design criteria are needed to maximize the use of these limited funds.

One concern in evaluating the design criteria was the ratio of female/male restroom stalls. Currently a fifty/fifty ratio is the standard implemented nationwide at rest areas. However, at many rest stations queues develop outside the women's facilities more often than the men's. WSDOT has received requests from female travellers to expand the women's facilities. Informal observations at several heavily used rest areas led to the conclusion that a sixty/forty, female/male ratio was more appropriate, but a definitive analysis was needed to verify these observations.

During the summer of 1987, a survey of current rest area usage was conducted at eight sites, three of which were control sites previously surveyed in WSDOT's 1968 study. At each survey site, the following data was collected: the number of occupants per vehicle, the number of men and women using the restrooms, and the duration a vehicle spent at the rest area. Mainline traffic counts and the number and type of vehicles entering the rest areas were taken at all Washington rest areas during the week of Labor Day 1987. Analysis of the data led to several recommendations for changes to the existing design criteria.

Project Objectives

The current rest area design criteria were established in 1968. The objectives of the 1987 study were to reevaluate the 1968 rest area design criteria and to investigate the sex ratio of restroom stall use.

One of the primary benefits of accurate design criteria is the efficient utilization of limited funds. An annual budget of $1 million will pay for rehabilitation and expansion of one to three of the 27 Interstate rest areas throughout the state. A major portion of this money is spent on building more restroom stalls to accommodate the increasing demand. Thus, it is beneficial to implement the correct ratio of female/male restroom stalls in the design criteria used for these expansion projects. State funds are inefficiently used to build, maintain, and operate excess facilities, while a rest area with too few facilities results in overcrowded, unsanitary conditions. Inadequate facilities also result in long waiting periods for restroom use, causing public dissatisfaction. For these reasons, it is important that current and accurate design criteria are used.

REVIEW OF PREVIOUS WORK

Literature Review

A research project conducted by the Civil and Environmental Engineering Department at the University of Texas at Austin was reviewed (Straughan, Rock, et al, 1986). The project is a two-year effort currently in its completion phase. Although the report did provide rest area design criteria, the guidelines were too general to be of use in Washington. The report made no reference to the inadequacies of a fifty/fifty, female/male ratio for restroom stalls and no recommedations for change.

In addition, fifty other publications were reviewed. Some publications were obsolete, some were relevant, and others did state a need for establishing accurate design criteria but did not address the area of interest to WSDOT, ratios for restroom stall use by sex. One publication, Rest Areas (NCHRP, 1973), stated that "additional information was needed in the area of an operations and design manual," reaffirming WSDOT's research effort.

Review of the 1968 Study Findings

In 1968 data was collected at the following seven rest areas. (See Appendix for location of the rest areas.) The data was collected in the late summer to capture peak traffic that included vacationers:

Rest Area	Date
1. Hatton Coulee	August 11-12, 1968
2. Nason Creek	August 10-11, 1968
3. Horn School	August 3-4, 1968
4. Vernita	August 10, 1968
5. Blue Lake	August 3-4, 1968
6. Indian John Hill Eastbound	August 16-17, 1968
7. Indian John Hill Westbound	August 18-19, 1968

The following formulas were determined on the basis of data collected in 1968:

Parking Stall Demand

Total Parking Stalls Required = Seasonal ADT X Total Vehicles Entering (5-12%) X Parking Demand (4%)

Water Usage

Gallons Used During Peak Hour = Seasonal ADT X Total Vehicles Entering (5-12%) X Average Vehicle Occupancy (3) X Percentage of People Using the Restrooms (80%) X Gallons Used per Person (3.5)

The percentage of vehicles entering rest areas located near parks, resorts, or cities is lower than that for rest areas in remote locations. Consequently, a flexible range of 5 to 12 percent was used to calculate the total number of vehicles entering to allow for this variation in rest area usage. The total number of persons using the restrooms was 80 percent, indicating that 80 percent of the people entering the rest areas used the restroom facilities. Also, data analysis showed that each person used 3.5 gallons of water.

PROCEDURES -- 1987 DESIGN CRITERIA UPDATE

Detailed data was collected at the following eight rest areas. Traffic counts were obtained from all other sites. (See Appendix A for location of rest areas.)

	Rest Area	Date	Time
1.	Maytown	July 17, 1987	1400-2000
2.	Scatter Creek	July 19, 1987	1400-2000
3.	Smokey Point Northbound	July 24, 1987	1400-2000
4.	Custer NB & SB	July 25, 1987	1100-1500
5.	Smokey Point Southbound	July 26, 1987	1200-1800

	Rest Area	Date	Time
6.	Indian John Hill Westbound*	July 31, 1987 August 1, 1987	1500-2100 1030-1830
7.	Indian John Hill Eastbound*	August 2, 1987 August 2, 1987	1500-2100 1030-1830
8.	Nason Creek*	July 31, 1987 August 2, 1987	1500-2100 1400-2000

Data Collection Procedures

At all the surveyed sites, except Custer, the following information was recorded during 15-minute periods:

1. number of vehicles entering,
2. type of vehicles entering,
3. number of passengers in each vehicle,
4. number of females/males entering the restrooms, and
5. random recording of vehicle length of stay.

On separate occasions, the length of stay in the restrooms was recorded at Maytown, Indian John Hill westbound, and Indian John Hill eastbound.

Data was recorded on forms (see Appendix B), sorted, and stored in a database developed in the software package *R:Base System V.* The peak hour was the chronological hour in the survey with the highest number of persons entering the rest area. The peak period in the survey was the 15 minutes of data collection with the highest number of persons entering the rest area.

Data Collection Design

The following factors were considered for data collection (Ulberg, 1987):

1. **Outside effects:** The survey was conducted on weekends and holidays to capture the higher traffic volumes. Poor weather conditions may

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*Control Sites

cause fewer people to travel, but on a weekend or holiday this effect is lessened.

2. **Time effects:** The times of the survey were altered slightly for each individual rest area in order to capture peak traffic. For instance, at Maytown, data was collected from 2 p.m. until 8 p.m. on Friday and Sunday -- anticipated times during which travellers leave and return from vacations and commuters seek respite from the heavily congested Friday afternoon traffic.

3. **Testing:** Data collection was not affected by people's attitudes, motivations, performance, or behavior for the majority of the study. Most people were unaware of the survey due to the location of the data collection team. Moreover, the data recorded was quantitative: the number of vehicles, the number of passengers, the number of people using the restrooms. The only exception was the timing of restroom use. To achieve greater accuracy, the researchers were in the restrooms when timing the subjects. The presence of a surveyor may have altered the subjects' behavior, but this effect was overlooked for lack of a discreet timing method.

4. **Instrumentation:** Measurement errors may have occurred during the survey but these were treated as random errors in the statistical analysis.

5. **Central Tendency:** Data analysis showed some extreme statistics. At times, the vehicle arrival rate and the percentage of restroom use were low, causing a large deviation in overall interpretation. However, this source of data invalidity was negligible, since the main focus of the data was peak conditions.

6. **Selection:** The chosen rest areas are representative samples of all rest areas by type. Maytown and Scatter Creek have a high vehicle arrival

rate and serve many commuters. Smokey Point is located in the northern part of western Washington. This rest area is frequented by vacationers, Canadians, and some commuters. Indian John Hill is the main rest stop for east-west Washington travellers. Nason Creek was chosen because it will soon be expanded.

7. **Sample Size:** Detailed data was collected at eight sites, but to ensure research results, mainline traffic count and distribution of vehicle types were recorded at all other rest areas in Washington.

DISCUSSION

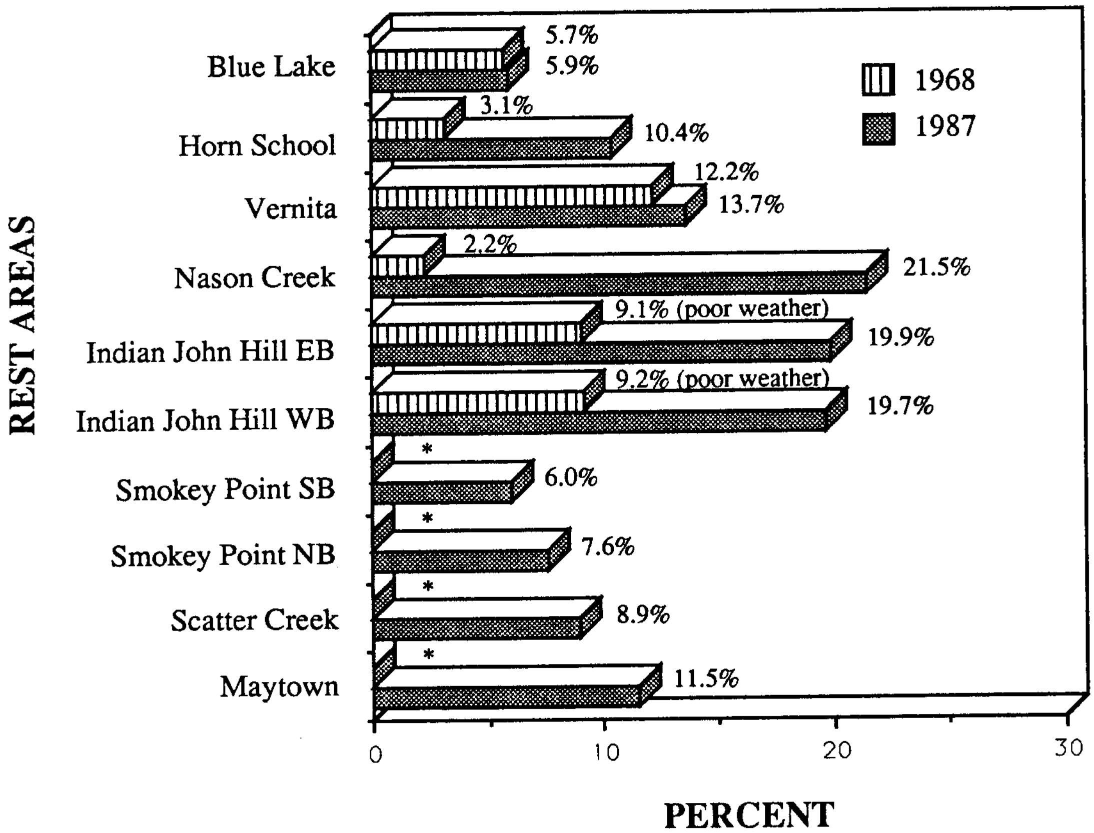
Data Summary

At all of the surveyed rest areas the percentage of highway traffic entering the rest areas on an average day has increased since 1968 (Figure 1). The percentage doubled at the Indian John Hill rest areas and tripled at the Horn School rest area. The greatest increase from 1968 to 1987 was noted at the Nason Creek rest area where the percentage of highway traffic entering increased almost 10 times.

Figure 2 compares the peak hour data of 1968 with the 1987 peak hour and peak day information. The information is shown as a percentage of highway traffic entering the rest area during peak periods. For the design of new rest areas or for expansion and rehabilitation projects, this data is used in determining the number of parking stalls, the number of restroom stalls, and the sewage system to meet the expected demand.

The distribution of vehicle types entering the surveyed rest areas is displayed in Table 1. The percentages obtained for the peak hour, as well as the surveyed time, are compared for each vehicle type. The percentage of cars entering the rest areas increased during the peak time for all rest areas except Indian John Hill

Figure 1: Highway Traffic Entering Rest Areas on Average Days (%)



* Rest Area not surveyed in 1968

Figure 2:
Highway Traffic Entering Rest Areas During Peak Hour and Day (%).

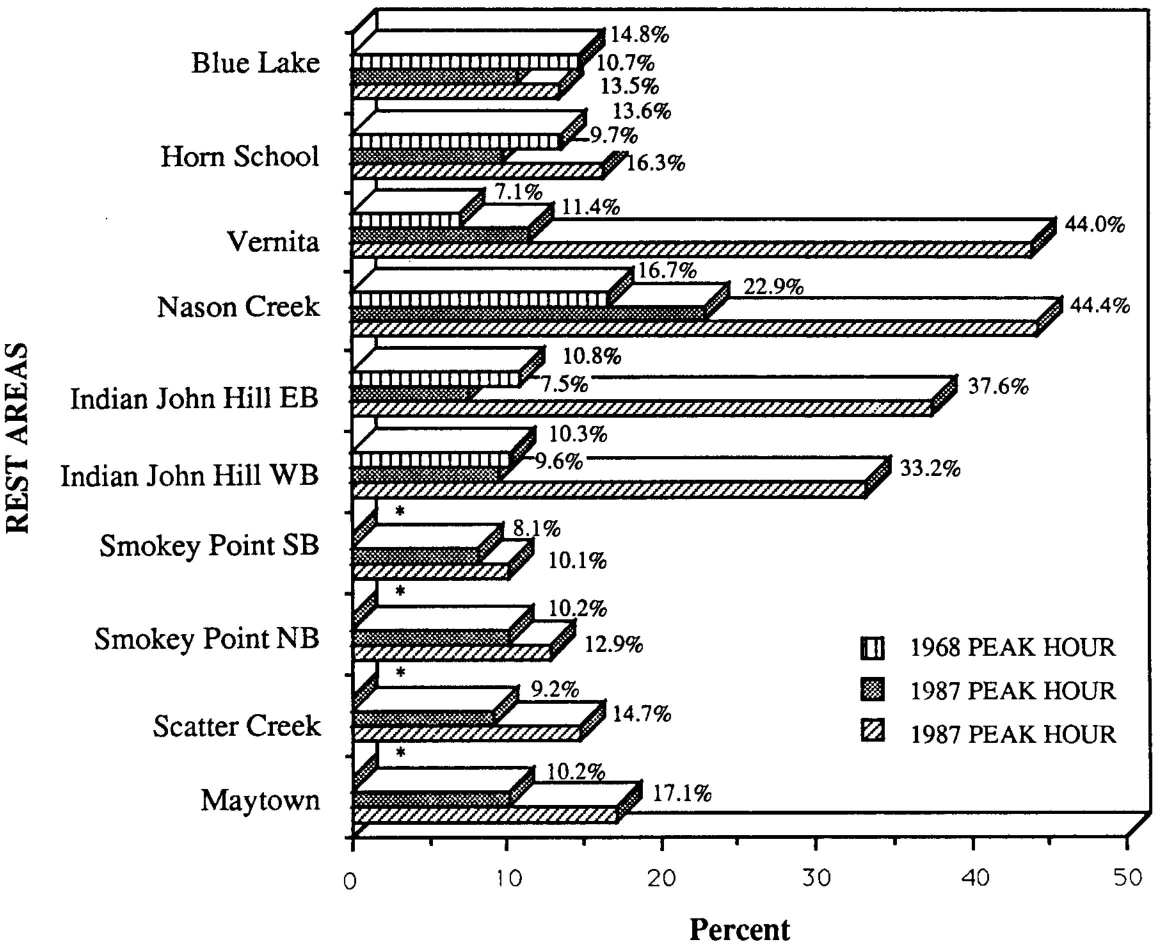


TABLE 1. DISTRIBUTION OF VEHICLE TYPES

	Car (%)		Truck (%)		Vehicle w/ Trailer (%)		RV's (%)	
Rest Area	Surveyed Time	Peak Hour	Ave.	Peak	Ave.	Peak	Ave.	Peak
Maytown	83.0	91.6	8.5	2.9	5.6	1.9	2.9	3.6
Scatter Creek	86.2	90.7	5.4	2.3	5.4	2.3	3.0	4.7
Smokey Point NB	82.0	94.1	5.1	2.2	8.3	2.9	4.6	0.8
Smokey Point SB	86.0	95.3	1.0	0.6	8.2	2.3	4.8	1.8
Indian John EB	90.0	85.6	3.3	8.8	5.2	5.6	1.5	0.0
Indian John WB	89.0	91.4	4.4	0.5	4.2	6.6	2.4	1.5
Nason Creek	87.0	86.7	1.2	0.0	7.2	9.1	4.6	4.2

TABLE 2. NUMBER OF PERSONS PER VEHICLE

Vehicle Type	1987 Average	1968 Average
Passenger Car	2.2	3.1
Vehicle w/trailer	2.5	3.8
Truck (1987 estimated)	2.0	2.2
R.V.	2.4	**
Weighted Average	2.2	3.2
**1968 Data not available		

TABLE 3. RESTROOM USE -- INTERSTATE/NON-INTERSTATE

	1987 Peak (%)	1987 (%)	1968 (%)
Non-Interstate	45.2	64.5	77.5
Interstate	65.9	69.6	80.2
Combined	64.1	69.3	79.1

TABLE 4. RESTROOM USE BY SITE

Rest Area	1987 Peak (%)	1987 Ave. (%)	1968 Ave. (%)
Maytown	62.2	59.9	*
Scatter Creek	68.8	69.5	*
Smokey Point NB	68.0	65.5	*
Smokey Point SB	54.0	63.3	*
Indian John Hill WB	73.6	77.0	79.0
Indian John Hill EB	76.2	76.4	74.0
Nason Creek	46.4	64.6	49.0

*Rest area not surveyed in 1968.

eastbound. The greatest increases were seen at Maytown and Smokey Point north and soundbound.

The weighted average vehicle occupancy is currently 2.2, down from 3.2 in 1968 (Table 2). The reduction in vehicle occupancy can be attributed to the addition of the R.V. category and an increased percentage of single individuals, personal affluence, and number of vehicles per household.

The percentage of persons using the restrooms is down to a variable 65 to 70 percent, depending on the location of the rest area (Table 3). In 1968, 80 percent of the travellers used the restroom facilities when stopping at rest areas. Today, with facilities and services like vending machines, travel and weather information, picnic areas, telephones, RV dump stations, and free coffee, rest areas offer motorists more than just restroom use.

Table 4 shows the percentage of restroom use by rest area. At the Nason Creek rest area there was a 15 percent increase in restroom use since 1968. This rest area is scheduled to be expanded due to the increase in demand. The percentage of restroom usage is lower during the peak period because travellers often avoid the congestion of a busy restroom facility.

Parking Demand

The percent of parking demand based on the 1987 information was computed as follows:

1. The average length of vehicle stay in the rest area (Table 5) was divided into 60 minutes. This number represents the vehicle turnover per hour.
2. The number of vehicles entering the rest area during a peak day was determined. This was equal to the average daily traffic (ADT) multiplied by the peak percent of vehicles entering the rest area.
3. The number of vehicles entering during the peak day was multiplied by 85 percent. Due to space limitations, each rest area is designed to service only 85 percent of the vehicles during peak conditions.
4. The value from Step 2 was divided by the turnover rate.
5. The percentage of parking demand was determined by dividing the parking demand by the seasonal average daily traffic.

Water Usage

The factors affecting the guideline for water usage are seasonal average daily traffic (ADT), percent of total vehicles entering, average vehicle occupancy, percentage of travellers using the restrooms, and gallons of water used per person. Since 1968, the percent of total vehicles entering a rest area has changed (see Figure 1) and there has been a reduction in average vehicle occupancy and in the percentage of travellers using the restrooms. Consequently, the formula for water usage was revised to include these changes.

Restroom Equity

The design guidelines for the number of toilet fixtures also requires reevaluation. Ensuring an adequate number of toilet fixtures for each rest area is an important consideration in rest area design. Most of the budget for upgrading a rest area is spent on renovating the restrooms. 65 to 70 percent of the motorists

TABLE 5. VEHICLE LENGTH OF STAY

Vehicle Type	Minutes	Turnover Rate/Hour
Passenger/Pick-up	7.25	8.28
Trucks	8.4	7.14
Vehicles w/ Trailers	11.8	5.08
RV's	9.7	6.19
Combined (weighted)	8.34	7.19

TABLE 6. PARKING DEMAND

Rest Area	Peak Use (# of vehicles)	85% Parking Demand	% of Ave. Daily Traffic
Maytown	3010	36	2.02
Scatter Creek	2793	30	1.73
Smokey Point NB	2683	37	1.53
Smokey Point SB	2101	26	1.19
Indian John EB	2572	23	4.45
Indian John WB	2362	27	3.92
Nason Creek	1226	33	5.25
Custer	1021	12	1.45

stopping at these rest areas require the use of the restroom facilities. The state needs to fulfill this demand sufficiently.

Currently, the ratio of female-to-male stalls is fifty/fifty in most Washington rest areas.[1] However, the fifty/fifty stall ratio was inadequate. Long queues frequently accumulate outside the women's facilities but rarely outside the men's. The results of the data collection show that a sixty/forty, female/male stall ratio is effective in alleviating the problem.

Two hypotheses are involved in the proposal to implement a sixty/forty, female/male ratio for restroom stalls: (1) The demand for use is equal, but (2) women require more time than men. Consequently, the women's queue time is longer. The data for the proportion of female to male users and the restroom

[1]A sixty/forty ratio is being used for the rehabilitation project at the Gee Creek Rest Area near Vancouver.

service times must be statistically sound. (The statistical formulas used are contained in Appendix C.)

Hypothesis I -- Proportion of Female-to-Male Restroom Users. The proportion of female to male restroom users during the peak period at all test sites was as follows:

Number of females:	269
Number of males:	285
Percent of females:	48.6%
Percent of males:	51.4%
Standard error of proportion:	.02
Null hypothesis:	percent female equal to percent male
Alternative:	percent female not equal to percent male

Under the null hypothesis, the expected number of females sampled is the same as the expected number of males sampled: 277. The observed number of females sampled is 269; the observed number of males sampled is 285. The Chi-Square statistic is used to test whether the difference in proportions is significant or whether it is due to chance and negligible.

Chi-Square Statistic Test

1. Subtract each expected value from each observed value.
2. Square the difference.
3. Divide each quantity by the respective expected value.
4. Sum all the quantities obtained from Steps 1 to 3.
5. Determine the degrees of freedom. This is equal to *k-1* where k is the number of proportions in the sample. The degree of freedom is one.
6. Test the hypothesis at a significance level of .01: the probability of the hypothesis being rejected if it is true is one percent.

7. Under the probability distribution table, the value of Chi-Square at a significance level of .01 for one degree of freedom is 6.635.

8. If the Chi-Square statistic value obtained in Step 3 is larger than 6.635, then the observed difference in the proportions cannot be attributed to chance.

9. The Chi-Square statistic value of .462 [from Step 3] does not exceed 6.635. We accept the null hypothesis. The proportions of female and male users are the same. There is equal demand.

<u>Hypothesis II -- Service Times</u>

<u>Women</u>

Number of observations:	71
Mean service time:	79 seconds
Standard deviation:	37.65 seconds
Standard error:	4.47 seconds

<u>Men</u>

Number of observations:	106
Mean service time:	47 seconds
Standard deviation:	40.15 seconds
Standard error:	3.90 seconds
Null hypothesis:	women and men's average restroom use times are the same
Alternative:	women's restroom use times are longer than men's

Procedure for hypothesis testing:

1. Find the difference in the means.

2. Divide by the square root of the sum of the standard errors. Call this quantity Z

3. Set the significance level at .01. If the null hypothesis were true, then there would be a one percent probability that it would be mistakenly rejected.

4. Under the normal probability distribution table, the z value for a significance level of .01 is 2.33.

5. If the calculated Z value from Step 2 is larger than 2.33, then the difference in the means is too large to be attributed to chance.

6. Z calculated is 5.49, which does exceed 2.33. The null hypothesis is rejected; the alternative is accepted. Women's restroom use times are longer than men's.

Simulation Modeling. Although the number of male and female users is nearly equal, women require more time to use the restroom. Consequently, queues form around the ladies' room and the demand for use increases. Maintaining the fifty/fifty toilet fixture ratio in the design criteria will result in excess male restroom facilities and/or inadequate female facilities.

A simple queueing formula shows that a sixty/forty, female/male toilet facility ratio is indeed more accurate than a fifty/fifty ratio. However, there are many disadvantages to using a queueing formula. Queueing formulae assume constant demand and usage rates, conditions that are not real-to-life. A better method for developing design guidelines is a simulation model.

A simulation model has many advantages. A simulation model is easily expandable and user-friendly. It is also possible to experiment with inter-related elements of the system and to study the effects of certain changes in the operation. The model can be used to test new policies for operating the rest area system, reducing the risk of experimentation on the real system. It enables detailed observations of activities in the system in reduced time.

Simulation does not assume static operating conditions, with constant arrival and usage rates, as a queueing formula does. Instead, a simulation model uses distribution rates. Vehicles arrive at the rest area with a Poisson distribution: "Poisson distributed events frequently occur in the real world . . . [It] is particularly useful in dealing with the occurrence of isolated events over a continuation of time . . . ."(Naylor, p. 112). The histogram of the restroom usage times resemble a bell-shaped curve. A bell-shaped curve represents a normal distribution, a range in which many random, real-to-life events fall.

A simulation model was developed in *Lightspeed Pascal* to represent the operation of a rest area, with focus on the restroom usage. The coding for this program is contained in Appendix D. The program prompts the user for the following information, most of which may remain constant for any rest area (constant rates are denoted by an asterisk):

1.	The number of male and female stalls	Example: 4,4
2.	The vehicle arrival rate per hour at the rest area	Example: 300
3.	The length of peak time in minutes	Example: 15
4.	The average number of passengers per car	Example: 2.2 *
5.	The percentage of women	Example: 48% * (.48)
6.	The percentage of men	Example: 52% * (.52)
7.	The percentage of people who will use restrooms	Example: 70% (.70)
8.	Average service rate for women, in seconds	Example: 79 *
9.	Average service rate for men, in seconds	Example: 45 *

The program will run after the last input and will output the number of men and women who waited in line during the peak period with their average wait time. To reduce the women's wait time, the program is run again, keeping every value the same except the number of stalls. When inputting the values for the number of stalls representing the sixty/forty, female/male ratio, the output will show a decreased waiting time for both sexes. The process is repeated until a satisfactory number of stalls and waiting time has been determined.

APPLICATION AND IMPLEMENTATION -- THE DESIGN CRITERIA

The design criteria consist of guidelines for the optimal number of restroom stalls, the number of parking stalls, and water/sewage usage. The simulation program can be used to determine the number of restroom stalls. Formulae established in the 1968 study were modified on the basis of the new data results from this current study to determine the number of parking stalls and water volume.

Parking Stalls

Most rest areas in Washington are designed to accommodate the parking demand 85 percent of the time during the peak hour. To determine the number of parking stalls, the procedures below should be followed:

1. Determine a projection of the seasonal average daily highway traffic (ADT) from counter readings.
2. Multiply the ADT by the percentage of vehicles entering the rest area. Percentages range from 5-12 percent of the ADT, depending on the location of the rest area.
3. The product from Step 2 is the average daily number of vehicles that go through a rest area, or the average daily usage. Depending on the location and type of rest area, parking demand is equal to 2 to 4 percent of so the average daily usage. A rest area near a town serves more commuters, the length of stay at the rest area is approximately 5 minutes. The parking turnover rate for that rest area is high; the parking demand is closer to 2 percent. A remote rest area with recreational features serves more vacationers, whose length of stay is much longer than that of commuters. The parking turnover rate for

that rest area is low; the parking demand is closer to 4 percent. For greater accuracy in determining the required number of parking stalls, a parking survey of the individual rest area should be conducted.

4. Thus, for the number of stalls that will satisfy the parking demand eighty-five percent of the time, multiply the average daily usage (product from Step 2) by .02 to .04.

Water Usage

The following formula is used in determining the water demand during peak time:

Gallons Used During Peak Hour = Seasonal ADT X Total Vehicles Entering (5-12%) X Average Vehicle Occupancy (2) X Percentage of People Using the Restrooms (70%) X Gallons Used per Person (3.5)

Restroom Stalls

WSDOT has a list of the level of traffic for each hour of the year. Most rest areas in Washington are designed to accommodate the 30th busiest traffic hour of the year. An important decision factor in the design criteria is the determination of a tolerable waiting time during the other 29 hours of traffic. The simulation program can be used to test several sample numbers for restroom stalls, demand of use, and vehicle arrival rates that will result in a satisfactory waiting time.

Traffic volume and rest area use are lower during the winter months. To reduce maintenance and operations costs, the men and women's restrooms should be constructed with a divider in each to allow the toilet fixtures that are not needed during the slow periods to be shut down.

REFERENCES

1. Evaluation of Rest Area Design Criteria Used by the State of Washington. Washington State Highway Commission, Department of Highways, Advance Planning Division, Olympia, Washington, 1968.

2. Freund, John E., Modern Elementary Statistics, Prentice-Hall, Inc., New Jersey, 1979.

3. Naylor, Thomas H., Balintfy, Joseph L., Burdick, Donald S., Chu, Kong. Computer Simulation Techniques. John Wiley & Son, Inc., New York. 1966.

4. Rest Areas, National Cooperative Highway Research Program, Synthesis of Highway Practice, Highway Research Board, 1973.

5. Straughan, W.T., Rock, Brian, Scharfe, Carl, Fowler, David W., Malina, Joseph F., Perry, Kirby, Vliet, Gary. Design Recommendations For Rest Areas, Center For Transportation Research, University of Texas at Austin, Austin, Texas, 1986.

4\. Ulberg, Cy. Highway Research Design Manual. Washington State Department of Transporation, Olympia, Washington, 1987.

APPENDIX A
LOCATION OF SURVEYED REST AREAS

APPENDIX A
LOCATION OF SURVEYED REST AREAS

Rest Area	Location
Blue Lake	Southwest of Coulee City on SR-17
Custer	North of Bellingham on I-5
Hatton-Coulee	SR-26 & SR-395, Southwest of Ritzville
Horn School	South of Rosalia on SR-195
Indian John Hill (East & Westbound)	Northwest of Ellensburg on I-90
Maytown	South of Olympia on I-5 SB
Nason Creek	West of Coles Corner on SR-2
Scatter Creek	South of Olympia on I-5 NB
Smokey Point	North of Mount Vernon on I-5
Vernita	Northwest of Pasco on SR-240

APPENDIX B
SURVEY FORM

APPENDIX B

clouds w/clearing 70's

STATION: Scatter Creek Rest Area DATE: 7/19/87 TIME(S): 1400 to 2000

p. 1 of 4

	1	2	3	4	5	6	1400
CARS, VANS, PICK-UPS	10	20	3	4	1	1	
VEHICLES WITH TRAILERS		2	2				
RV'S			2				
SINGLE UNITS	1						pass 4'
DOUBLE UNITS							pass. 6'
TRIPLE UNITS							pass. 3'
BUSES							truck 3' 24"
MALE RESTROOM USE	41						
FEMALE RESTROOM USE	39						
TOTALS							

	1	2	3	4	5	6	1415
CARS, VANS, PICK-UPS	count interrupted						
VEHICLES WITH TRAILERS	due to assistance						
RV'S	for person w/locked car						
SINGLE UNITS	2						
DOUBLE UNITS							
TRIPLE UNITS							
BUSES							
MALE RESTROOM USE	27						
FEMALE RESTROOM USE	~~8~~						
TOTALS							

	1	2	3	4	5	6	1430
CARS, VANS, PICK-UPS	11	9	1	3	1		
VEHICLES WITH TRAILERS		4	1				
RV'S		1					
SINGLE UNITS	4						pass. 8'
DOUBLE UNITS							pass. 11'
TRIPLE UNITS							pass. 4'
BUSES							pass. 10'
MALE RESTROOM USE	23						RV 26'
FEMALE RESTROOM USE	28						trailer 6'21"
TOTALS							

	1	2	3	4	5	6	1445
CARS, VANS, PICK-UPS	10	14	2	5		1	
VEHICLES WITH TRAILERS		2					
RV'S	2	1					
SINGLE UNITS							pass. 11'
DOUBLE UNITS							pass. 7'
TRIPLE UNITS							pass. 5'
BUSES							pass. 6'
MALE RESTROOM USE	31						
FEMALE RESTROOM USE	31						
TOTALS							

	1	2	3	4	5	6	1500
CARS, VANS, PICK-UPS	14	26	6	5			
VEHICLES WITH TRAILERS		4	1				
RV'S		2					
SINGLE UNITS	4						pass. 5'
DOUBLE UNITS							pass. 7'
TRIPLE UNITS							pass. 6'
BUSES	13 pass. 7'06' stay						pass. 4'
MALE RESTROOM USE	46						trailer 3'
FEMALE RESTROOM USE	53						
TOTALS							

	1	2	3	4	5	6	1515
CARS, VANS, PICK-UPS	8	14	4	7	2		
VEHICLES WITH TRAILERS		3	1				
RV'S							
SINGLE UNITS	3						pass 6'
DOUBLE UNITS							pass 20'
TRIPLE UNITS							pass 4'
BUSES	22 pass. picnicking						
MALE RESTROOM USE	43						
FEMALE RESTROOM USE	34						
TOTALS							

APPENDIX C
STATISTICAL FORMULAE USED

APPENDIX C

Formulae used in statistical analysis:

x_1	=	observation
n_1	=	total number of female observations
n_2	=	total number of male observations
N	=	total observations
$\sum$	=	summation of
X	=	mean
P_1	=	1st proportion
P_2	=	2nd proportion
P_c	=	combined proportion
σ	=	standard deviation
σ_e	=	standard error
σ_p	=	standard error in proportions
α_e	=	standard error in difference between two means
α_p	=	standard error in difference between two proportions

$$\bar{x} = \frac{\sum x_n}{N}$$

$$\alpha_e = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

$$\sigma = \sqrt{\frac{\sum (x_n - \bar{x})^2}{N}}$$

$$\alpha_p = \sqrt{p_c(1 - p_c)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

$$\sigma_e = \frac{\sigma}{\sqrt{N}}$$

$$\sigma_p = \sqrt{\frac{p_1(1 - p_1)}{N}}$$

$$p_c = \frac{n_1 p_1 + n_2 p_2}{N}$$

APPENDIX D
COMPUTER SIMULATION MODEL CODING

APPENDIX D
COMPUTER SIMULATION MODEL CODING

```
{REST AREA SIMULATION SYSTEM}
{This program will simulate the operation of a rest area to aid the program user in determining}
{ the number of stalls needed to accomodate any rate of user arrival. The program user needs}
{to input the vehicle arrival rate, the average use time or service rate, the male/female ratio,}
{ the average passenger count, and the duration of the simulation.}


PROGRAM RestArea;

        CONST
                Maxstall = 25;          {an arbritrary number for the maximum number of stalls for syntax}
                MaxQueue = 250;          {an arbritrary number for the number of people in line}

        VAR
                QueueM : ARRAY[0..MaxQueue] OF integer;
                StallsM : ARRAY[0..Maxstall] OF integer;
                QueueF : ARRAY[0..MaxQueue] OF integer;
                StallsF : ARRAY[0..Maxstall] OF integer;
                numberstallsM, numberstallsF : integer;
                headM, headF : integer;
                tailM, tailF : integer;
                clock : integer;
                endtime : integer;
                TotalBTimeM, TotalBTimeF : integer;
                TotalQTimeM, TotalQTimeF : integer;
                TotalBM, TotalBF : integer;
                TotalQM, TotalQF : integer;
                SizeQM, SizeQF : integer;
                WomenInCar : integer;
                MenInCar : integer;
                arriverate : integer;
                passengers : integer;
                useratef : integer;
                useratem : integer;
                stdM, stdW, stdP : real;
                duration : integer;
                PlaceQM, PlaceQF : integer;
                Passenger : integer;
                i, j : integer;
                PercentWomen : real;
                PercentMen : real;
                PercentIn : real;
                AveCount : real;
                QTimeF, QTimeM : real;
                cararrives : boolean;


{Produces a variable amount of restroom time that  male user requires, based on experimental standard}
{deviation of 38 seconds and mean of 47 seconds}

        FUNCTION UseTimeM (avetimeM : integer) : integer;

                VAR
                        a, b, c, x, y, z : real;

        BEGIN
                REPEAT

                        x := ((abs(random MOD 100) + 1) / 100);
```

```
                y := ((abs(random MOD 100) + 1) / 100);
                b := 360 * y;
                c := (sin(b));
                z := ((-2) * (ln(x)) * (c));
                a := (stdM * z) + avetimeM
        UNTIL a > 0;

        UseTimeM := trunc(a + x);


    END;
```

```
{Produces a variable amount of restroom time that female user requires}

    FUNCTION UseTimeF (avetimeF : integer) : integer;
        VAR
                a, b, c, x, y, z : real;
    BEGIN
        REPEAT

                x := ((abs(random MOD 100) + 1) / 100);
                y := ((abs(random MOD 100) + 1) / 100);
                b := 360 * y;
                c := (sin(b));
                z := ((-2) * (ln(x)) * (c));
                a := (stdW * z) + avetimeF
        UNTIL a > 0;
        UseTimeF := trunc(a + x);

    END;


{Converts duration of peak time into seconds}

    FUNCTION Convert (Finishtime : integer) : integer;

    BEGIN

        Convert := Finishtime * 60;
    END;


{Generates vehicle arrival based on the given rate}

    PROCEDURE GetCar (arrivalrate, finishtime : integer);

        VAR
                y, carrate : real;
                w, z, newrate : integer;

    BEGIN

        carrate := (arrivalrate * (finishtime / 60));
        y := ln((abs(random MOD 11) + 22) / 10);
        newrate := trunc(carrate * y);
        w := Convert(endtime);
        z := abs(random MOD w) + 1;
        IF z <= newrate THEN
                cararrives := true
```

```
                ELSE
                        cararrives := false;
                IF cararrives THEN
                        newrate := newrate - 1;
                w := w - 1;
        END;


{Output is the number of women and men requiring use of restroom}

        PROCEDURE PassCount (AvePass : real);

                VAR
                        a, b, c, x, y, z : real;

        BEGIN
                REPEAT

                        x := ((abs(random MOD 100) + 1) / 100);
                        y := ((abs(random MOD 100) + 1) / 100);
                        b := 360 * y;
                        c := (sin(b));
                        z := ((-2) * (ln(x)) * (c));
                        a := (stdP * z) + AvePass
                UNTIL a > 0.5;
                Passenger := trunc(a + x);

                WomenInCar := trunc(Passenger * PercentWomen * PercentIn);
                MenInCar := trunc(Passenger * PercentMen * PercentIn);



        END;


{Asks program user to input necessary data}
        PROCEDURE Prompt;

        BEGIN

                writeln('Enter the number of stalls in facilities for women: ');
                readln(numberstallsF);
                writeln('Enter the number of stalls and urinals in facilities for men:  ');
                readln(numberstallsM);
                writeln('Enter vehicle arrival rate per hour: ');
                readln(arriverate);
                writeln('How long do you want to run the simulation (in simulated run time)?');
                readln(endtime);
                writeln('What is the average number of occupants per car? ');
                readln(AveCount);
                writeln('Standard deviation for the average number of vehicle occupancy:  ');
                readln(stdP);
                writeln('What is the proportion of women (enter as two place decimals)? ');
                readln(PercentWomen);
                IF (PercentWomen < 0) OR (PercentWomen > 1) THEN
                        writeln('The proportion of women who use the bathroom must be a proportion between zero and
one.  Restart the program and try again.');
                writeln('What is the percent of people who will use restroom (enter as two place decimals)?');
                readln(PercentIn);
                IF (PercentIn < 0) OR (PercentIn > 1) THEN
                        writeln('The proportion of users must be a decimal fraction between zero and one.  Reset
program and try again.');
```

```
        writeln('Average service time for men, round off in seconds: ');
        readln(useratem);
        writeln('Average service time for women, round off in seconds: ');
        readln(useratef);
        writeln('Standard deviation for men''s use time , round of in seconds : ');
        readln(stdM);
        writeln('Standard deviation for women'' s use time , round of in seconds : ');
        readln(stdW);

END;


PROCEDURE Initialize;

        VAR
                a, b : integer;

BEGIN

        clock := 0;
        headM := 0;
        headF := 0;
        tailM := 0;
        tailF := 0;
        TotalBTimeM := 0;
        TotalBTimeF := 0;
        TotalQTimeM := 0;
        TotalQTimeF := 0;
        TotalBM := 0;
        TotalBF := 0;
        TotalQM := 0;
        TotalQF := 0;
        SizeQM := 0;
        SizeQF := 0;
        WomenInCar := 0;
        MenInCar := 0;
        Passenger := 0;
        QTimeF := 0;
        QTimeM := 0;
        cararrives := false;
        PercentMen := 1 - PercentWomen;

        FOR a := 0 TO MaxQueue DO
                BEGIN
                        QueueM[a] := 0;
                        QueueF[a] := 0
                END;

        FOR b := 0 TO Maxstall DO
                BEGIN
                        StallsM[b] := 0;
                        StallsF[b] := 0;
                END

END;

{Places men in line for restroom}

        PROCEDURE InQueueM (PlaceQM : integer);
```

```
      BEGIN
           QueueM[tailM] := PlaceQM;
           IF tailM = MaxQueue THEN
                tailM := 0
           ELSE
                BEGIN
                     tailM := tailM + 1;
                     SizeQM := SizeQM + 1;
                END
      END;

{Places women in line for restroom}
      PROCEDURE InQueueF (PlaceQF : integer);
      BEGIN
           QueueF[tailF] := PlaceQF;
           IF tailF = MaxQueue THEN
                tailF := 0
           ELSE
                BEGIN
                     tailF := tailF + 1;
                     SizeQF := SizeQF + 1;
                END
      END;

{Takes women out of bathroom line}
      PROCEDURE OutQueueF;
      BEGIN
           IF headF = MaxQueue THEN
                headF := 0
           ELSE
                BEGIN
                     headF := headF + 1;
                     SizeQF := SizeQF - 1;
                END;
      END;
```

```
{Takes men out of bathroom line}

        PROCEDURE OutQueueM;

        BEGIN

                IF headM = MaxQueue THEN

                        headM := 0

                ELSE

                        BEGIN

                                headM := headM + 1;
                                SizeQM := SizeQM - 1;

                        END;
        END;

{Adds "time" to duration in queue for men}

        PROCEDURE IncrementQM;

                VAR
                        c : integer;

        BEGIN

                c := headM;

                WHILE c <> tailM DO

                        BEGIN
                                QueueM[c] := QueueM[c] + 1;
                                IF c = MaxQueue THEN
                                        c := 0
                                ELSE
                                        c := c + 1
                        END;
        END;

{Adds "time" to duration in queue for women}

        PROCEDURE IncrementQF;

                VAR
                        c : integer;

        BEGIN

                c := headF;

                WHILE c <> tailF DO

                        BEGIN
                                QueueF[c] := QueueF[c] + 1;
                                IF c = MaxQueue THEN
                                        c := 0
                                ELSE
```

```
                                        c := c + 1
                        END;
        END;


{Subtracts "time" men will spend in facilities}
        PROCEDURE DecrementBM;
                VAR
                        c : integer;

        BEGIN

                FOR c := 1 TO numberstallsM DO

                        IF StallsM[c] <> 0 THEN
                                StallsM[c] := StallsM[c] - 1;
        END;



{Subtracts "time" women will spend in facilities}
        PROCEDURE DecrementBF;
                VAR
                        c : integer;

        BEGIN

                FOR c := 1 TO numberstallsF DO

                        IF StallsF[c] <> 0 THEN
                                StallsF[c] := StallsF[c] - 1;
        END;



BEGIN

        Prompt;
        Initialize;
        ShowText;
        duration := Convert(endtime);

        WHILE clock <= duration DO

                BEGIN

                        clock := clock + 1;
                        GetCar(arriverate, endtime);

                        IF cararrives = true THEN
                                BEGIN
                                        PassCount(AveCount);
                                        writeln('Car came at  ', clock, 'with ', Passenger, 'people.');
                                        writeln(WomenInCar, 'were female ', MenInCar, ' were male.');
                                        IF WomenInCar <> 0 THEN
                                                FOR i := 1 TO WomenInCar DO

                                                        InQueueF(0);


                                        IF MenInCar <> 0 THEN
                                                BEGIN
                                                        FOR j := 1 TO MenInCar DO
```

```
                                        InQueueM(0);

                              END;
                    END;

          FOR i := 1 TO numberstallsF DO
                    IF SizeQF <> 0 THEN
                              IF StallsF[i] = 0 THEN
                                        BEGIN

                                                  StallsF[i] := UseTimeF(useratef);
                                                  writeln('Woman came in at ', clock);
                                                  writeln('Woman in Stall# ', i, ' takes ', StallsF[i], '
seconds');
                                                  TotalBF := TotalBF + 1;
                                                  TotalBTimeF := TotalBTimeF + UseTimeF(useratef);
                                                  TotalQTimeF := TotalQtimeF + QueueF[headF];
                                                  writeln('Woman spent ', QueueF[headF], ' seconds in line.');
                                                  IF QueueF[headF] > 0 THEN
                                                            TotalQF := TotalQF + 1;
                                                  OutQueueF;
                                        END;
          IncrementQF;
          DecrementBF;

          FOR j := 1 TO numberstallsM DO
                    IF SizeQM <> 0 THEN
                              IF StallsM[j] = 0 THEN
                                        BEGIN

                                                  StallsM[j] := UseTimeM(useratem);
                                                  writeln('Man came in at ', clock);
                                                  writeln('Man in Stall# ', j, ' takes', StallsM[j], ' seconds');
                                                  TotalBM := TotalBM + 1;
                                                  TotalBTimeM := TotalBTimeM + UseTimeM(useratem);
                                                  TotalQTimeM := TotalQtimeM + QueueM[headM];
                                                  writeln('Man spent ', QueueM[headM], ' seconds in line.');
                                                  IF QueueM[headM] > 0 THEN
                                                            TotalQM := TotalQM + 1;
                                                  OutQueueM;
                                        END;
          IncrementQM;
          DecrementBM;

     END;

  QTimeF := TotalQTimeF / TotalQF;

  QTimeM := TotalQTimeM / TotalQM;

  writeln('The total number of women in line during simulation is   ', TotalQF);
  writeln('The total number of men in line during simulation is   ', TotalQM);
  writeln('The average time women spent in line is   ', QTimeF);
  writeln('The average time men spent in line is  ', QTimeM);

END.
```

APPENDIX E
WOMEN'S RESTROOM TIMES

APPENDIX E
WOMEN'S RESTROOM TIMES

Taken during peak period at Maytown, listed in ascending order

Mean: 79 seconds

Obs.	[Obs - Mean]	[Obs. - Mean]^2	Obs.	[Obs - Mean]	[Obs. - Mean]^2
30	49	2401	73	6	36
31	48	2304	74	5	25
35	44	1936	75	4	16
38	41	1681	78	1	1
38	41	1681	78	1	1
39	40	1600	79	0	0
40	39	1521	79	0	0
40	39	1521	79	0	0
41	38	1444	80	1	1
42	37	1369	81	2	4
44	35	1225	81	2	4
45	34	1156	84	5	25
46	33	1089	91	12	144
50	29	841	93	14	196
51	28	784	93	14	196
51	28	784	95	16	256
51	28	784	95	16	256
52	27	729	96	17	289
52	27	729	98	19	361
53	26	676	99	20	400
54	25	625	99	20	400
55	24	576	100	21	441
55	24	576	105	26	676
58	21	441	105	26	676
61	18	324	105	26	676
64	15	225	109	30	900
64	15	225	110	31	961
64	15	225	114	35	1225
66	13	169	135	56	3136
66	13	169	139	60	3600
67	12	144	142	63	3969
68	11	121	152	73	5329
70	9	81	153	74	5476
70	9	81	195	116	13456
72	7	49	244	165	27225
72	7	49			

APPENDIX F
MEN'S RESTROOM TIMES

APPENDIX F
MEN'S RESTROOM TIMES

Mean: 47 seconds

Taken during peak period at Maytown, listed in ascending order

Obs.	[Obs - Mean]	[Obs. - Mean]^2	Obs.	[Obs - Mean]	[Obs. - Mean]^2
13	34	1156	34	13	169
16	31	961	34	13	169
17	30	900	35	12	144
17	30	900	35	12	144
18	29	841	35	12	144
20	27	729	35	12	144
21	26	676	35	12	144
23	24	576	36	11	121
23	24	576	36	11	121
25	22	484	36	11	121
26	21	441	37	10	100
26	21	441	37	10	100
26	21	441	37	10	100
27	20	400	37	10	100
27	20	400	38	9	81
27	20	400	38	9	81
27	20	400	40	7	49
28	19	361	40	7	49
28	19	361	41	6	36
29	18	324	44	3	9
29	18	324	44	3	9
29	18	324	45	2	4
30	17	289	45	2	4
30	17	289	45	2	4
31	16	256	45	2	4
31	16	256	46	1	1
31	16	256	46	1	1
31	16	256	48	1	1
31	16	256	48	1	1
31	16	256	48	1	1
31	16	256	48	1	1
32	15	225	49	2	4
32	15	225	50	3	9
32	15	225	51	4	16
32	15	225	51	4	16
33	14	196	51	4	16
33	14	196	52	5	25
33	14	196	52	5	25
33	14	196	54	7	49
34	13	169	56	9	81
34	13	169	57	10	100
34	13	169	57	10	100

APPENDIX F
MEN'S RESTROOM TIMES (Continued)

Obs.	[Obs - Mean]	[Obs. - Mean]^2	Obs.	[Obs - Mean]	[Obs. - Mean]^2
58	11	121	70	23	529
59	12	144	72	25	625
59	12	144	73	26	676
59	12	144	74	27	729
59	12	144	76	29	841
61	14	196	76	29	841
62	15	225	92	45	2025
62	15	225	115	68	4624
63	16	256	146	99	9801
64	17	289	166	119	14161
65	18	324	385	338	114244

APPENDIX G
REST AREA TRAFFIC DATA

APPENDIX G
REST AREA TRAFFIC DATA

Rest Area	ADT	% Entering on Average Day	% Entering on Peak Day	% Entering During Peak Hour
Bow Hill NB	12100	6.96	10.8	9.5
Bow Hill SB	12100	6.5	8.4	10.97
Chamberlain Lake EB	1745	7.2	*7.8	12.5
Custer NB	8300	7.2	12.3	9.7
Custer SB	8300	7.6	12.5	10.3
Elma EB	5600	12.3	*38.9	12.7
Gee Creek NB	18300	8.1	*13.2	9.5
Gee Creek SB	18400	8.5	12.8	9.3
Hatton Coulee NB	1883	22.5	--	--
Hatton Coulee SB	1714	12.7	--	--
Horn School NB	3905	10.4	*16.3	9.7
Horn School SB	3905	10.4	*16.3	9.7
Indian John Hill EB	6841	19.9	37.6	7.5
Indian John Hill WB	7114	19.7	33.2	9.6
Maytown SB	17600	11.5	17.1	10.2
Megler EB	1472	21.0	*29.1	11.7
Megler WB	1472	21.0	*29.1	11.7
Nason Creek EB	2761	21.5	44.4	22.9
Nason Creek WB	2761	--	--	--
Quincy Valley EB	4513	10.2	*15.8	10.4
Quincy Valley WB	4513	10.2	*15.8	10.4
Ryegrass EB	5054	10	*15.6	10.4
Ryegrass WB	5232	10.2	25.7	10.5
Scatter Creek NB	19000	8.9	14.7	9.2
Schrag EB	3296	15.4	*27.3	10.1
Schrag WB	3293	17.0	*39.3	9.7
Sea-Tac NB	47500	3.2	*6.2	9.2
Selah Creek NB	4286	9.7	19.9	10.8
Selah Creek SB	4158	8.3	*12.3	11.8
Silver Lake SB	47000	1.8	*3.0	9.4
Smokey Point NB	20800	7.6	12.9	10.2
Smokey Point SB	20800	6.0	10.1	8.1
Spokane River WB	12000	6.3	6.4	--
Sprague Lake EB	6029	13.3	*25.3	10.5
Sprague Lake WB	6055	13.5	*20.0	9.7
Telford EB	2150	6.9	*10.9	6.6
Telford WB	2150	6.9	*10.9	6.6
Toutle NB	16800	10.6	*16.0	9.1
Toutle SB	17000	11.0	15.0	9.4
Vernita NB	2224	--	*44.0	11.4
Vernita SB	2224	13.7		
Winchester EB	3555	11.8	14.5	9.7
Winchester WB	3845	11.1	*27.0	9.6

*Data collected on Labor Day