Design of Rest Area Comfort Facilities by Systems Analysis

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This report describes a computer simulation model used to determine the number of comfort station facilities needed within rest areas. Systems analysis techniques are used to simulate the operation of a comfort station. The model determines the number of facilities—including toilets, urinals, wash basins, and dryers—necessary to satisfy certain levels of service for specified volumes.

The model is based on a limited sample of data and assumed design criteria, and therefore is presented primarily as a demonstration of technique. It is hoped that this report will stimulate further research in this area.

•SAFETY rest areas are designed to serve the needs of motorists. As a result of public demand, comfort stations are now included in rest areas on the Interstate System and on other major highways.

This report describes a computer simulation model for determining the number of facilities—toilets, urinals, wash basins, and hand dryers—necessary in the comfort stations. The research was undertaken in an attempt to satisfy a commonly recognized need for uniform standards in comfort station design. Systems analysis techniques were used to determine the optimum number of service facilities using assumed criteria for optimization.

The systems analysis approach in this case is based on the collection of data regarding individual service times at the facilities. To avoid infringing on personal privacy, the comfort station service times were not collected through a survey of the general public. Instead, service times were reported by volunteers from the Office of Planning of the Bureau of Public Roads. Considering this limitation, tests were made to measure the effects of possible errors in the reported service times. The results were found to be relatively insensitive to minor changes in the service times.

The model results were sensitive to changes in the proportion of persons using the toilets and urinals. However, little information was available concerning the division between toilet use and urinal use in rest areas. For this analysis, a proportion of 80 percent for urinals and 20 percent for toilets was used. This proportion was based on a review of limited data reported by North Dakota and South Dakota in 1968.

THE SYSTEMS APPROACH

The systems approach consists of four distinct phases: (a) orientation phase, including definition of the problem; (b) analytical phase, where the problem is represented mathematically; (c) evaluation phase, where the problem is solved; and (d) verification phase, where the model results are tested against the real operation. The application of these four phases to the comfort station problem is described in the following.

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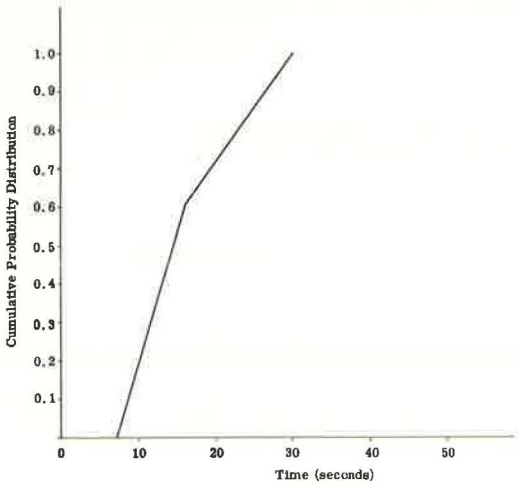

Figure 1. Cumulative distribution of times men spent washing their hands.

Orientation Phase

The comfort station operation may be described as a waiting-time problem, where the arrivals are randomly spaced and the service time is of random duration, within the limits of distribution functions. Problems arise when there is either too much demand or too little demand on the service facilities. The situation requires the determination of the optimum number of service facilities under known or assumed criteria for optimization.

Analytical Phase

Complex mathematical models are usually required to solve waiting-time problems. However, Monte Carlo procedures may be used to approximate, in relatively simple fashion, the solution of waiting-time problems. The Monte Carlo technique is a means of introducing probability in the description of an operation. The process is so named because it is necessary to generate a random number, in a manner similar to spinning a roulette wheel, to decide an action at a probability step. Random number generation is readily accomplished in computer programming.

In this model, the Monte Carlo technique was used to determine the arrival times and service times of each person using the comfort station facilities. Probability distributions were established for arrival times and service times. Generated random numbers determined individual arrival times and service times on the basis of the probability distributions. [1]

The following example illustrates the use of a probability distribution in determining service time. Figure 1 shows a cumulative array of the times men spend washing their hands. A random number is generated to represent the time that one sampled male will spend washing his hands. Assume that the number 0.29428 is generated. This produces a wash time of 11 seconds.

Arrival gap data were collected during a few hours of observation at three rest areas on Interstate 95 and Interstate 66 south of Washington, D. C. The service time data represent 74 observations reported by seven volunteers within the office.

The simulation model was designed for optimum use to be made of the facilities. If a user encountered a queue at multiple facilities, the user was assigned to the facility where the ultimate wait would be less. The model also made multiple use of the toilets in allowing use for urinal purposes.

In addition to simulating the arrival times and service times of rest area users, the computer tallied the number of persons that had to wait at each facility, their waiting times, and the total time each person spent within the comfort station. This information was used in the evaluation phase of the project.

Evaluation Phase

Once a model is formulated, it may be used in evaluation. In this case, the level of service criteria relating to the waiting times of persons were input to the model. The model determined the number of service facilities necessary to satisfy the criteria.

[1] The original manuscript of this paper included Appendix A, containing probability distribution used for arrival gaps and service times, and Appendix B, containing a flow chart and a program listing of the simulation model. The two Appendixes are available in Xerox form at cost of reproduction and handling from the Highway Research Board. When ordering, refer to XS-25, Highway Research Record 280.

TABLE 1

DESIGN CRITERIA FOR COMFORT STATION FACILITIES

Facility	Number of Persons[a] Who Had to Wait at Facility	
	Minimum	Maximum
Men's Room		
Urinal	2	20 percent of users
Toilet	1	(no wait over 5 minutes)
Wash basin	2	20 percent of users
Hand dryer	2	20 percent of users
Women's Room		
Toilet	1	20 percent of users (also no wait over 5 minutes)
Wash basin	2	20 percent of users
Hand dryer	2	20 percent of users

[a]Based on simulation of 60 users.

TABLE 2

REQUIRED NUMBER OF MEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Urinals	Toilets	Wash Basins	Dryers (air)
30	1	2	2	2
60	1	2	2	2
90	2	2	3	3
120	2	2	3	3
150	3	2	3	4
180	4	3	4	5
210	4	3	4	5
240	4	3	4	5
270	5	4	4	6
300	6	4	5	7
330	6	4	5	7
360	6	4	6	7
390	7	4	6	8
420	8	4	6	8
450	7	4	6	8
480	7	4	6	8
510	8	5	6	8

In these tests, 60 persons and 120 persons respectively were simulated through the women's and men's comfort stations. These volumes were found to be necessary to stabilize the model results. If the criteria (Table 1) were not satisfied, the number of facilities was adjusted and the simulation repeated. When all criteria were satisfied, the computer results were printed.

The tests were run for volumes of 30 to 510 persons per hour in increments of 30 persons per hour. The same number of persons was simulated in the model for all volume levels. Volume increases were accomplished by shortening the arrival gaps.

Tables 2 through 5 give the facilities required for volumes of 30 to 510 persons per hour, in increments of 30 persons per hour. The four tables show the number of facilities required for men and women, with two types of hand dryers. Table 2 and 4 give results for air dryers, and Table 3 and 5 give the results for paper towels. The dryers were analyzed separately owing to the longer drying time required with the air dryers.

Verification Phase

Model results should be verified by comparisons with actual comfort station operation. To avoid infringing on personal privacy, surveys were not conducted within comfort stations. Limited tests were made of the total time persons spend within comfort

TABLE 3

REQUIRED NUMBER OF MEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Urinals	Toilets	Wash Basins	Dryers (paper towels)
30	1	1	2	2
60	2	2	2	2
90	2	2	3	2
120	3	2	3	3
150	3	3	4	3
180	3	3	4	3
210	3	3	4	3
240	4	4	4	4
270	4	4	5	4
300	4	4	5	4
330	5	4	5	5
360	5	4	5	5
390	6	4	5	5
420	7	4	5	5
450	8	5	6	5
480	9	5	7	6
510	9	5	7	6

TABLE 4

REQUIRED NUMBER OF WOMEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Toilets	Wash Basins	Dryers (air)
30	2	2	2
60	3	2	2
90	4	3	3
120	4	3	3
150	4	3	3
180	6	4	4
210	8	5	5
240	8	5	5
270	8	5	5
300	11	6	7
330	11	6	7
360	10	6	6
390	11	7	7
420	12	8	7
450	12	8	8
480	13	8	8
510	13	8	8

TABLE 5

REQUIRED NUMBER OF WOMEN'S COMFORT STATION FACILITIES

Volume (persons/hour)	Toilets	Wash Basins	Dryers (paper towels)
30	2	2	1
60	4	3	2
90	5	3	2
120	5	3	2
150	6	4	3
180	7	4	3
210	7	5	3
240	9	6	4
270	8	5	4
300	10	6	4
330	10	6	4
360	10	6	4
390	11	8	5
420	12	8	5
450	14	8	5
480	12	8	5
510	13	8	5

TABLE 6

COMPARISON OF MODEL RESULTS WITH ACTUAL REST AREA OPERATION – MEN'S COMFORT STATION
(Rest Area on I-95 South of Washington, D.C.)

Time in Comfort Station (seconds)	Volume = 30 Persons/Hour		Volume = 57 Persons/Hour	
	Observed Values (percent of users)	Simulated Values (percent of users)	Observed Values (percent of users)	Simulated Values (percent of users)
0-29	–	–	–	–
30-59	15.6	0.8	7.7	–
60-89	9.4	21.7	30.8	24.2
90-119	31.2	40.0	23.1	27.5
120-149	18.8	20.0	15.4	20.0
150-179	9.4	2.5	3.8	4.2
180-209	9.4	4.2	–	5.8
210-239	3.1	5.8	3.8	7.5
240 and over	3.1	5.0	15.4	10.8
Total	100.0	100.0	100.0	100.0

TABLE 7

COMPARISON OF MODEL RESULTS WITH ACTUAL REST AREA OPERATION – WOMEN'S COMFORT STATION
(Rest Area on I-95 South of Washington, D.C.)

Time in Comfort Station (seconds)	Volume = 30 Persons/Hour		Volume = 47 Persons/Hour	
	Observed Values (percent of users)	Simulated Values (percent of users)	Observed Values (percent of users)	Simulated Values (percent of users)
0-29	–	–	–	–
30-59	–	–	–	–
60-89	6.9	12.5	2.7	10.0
90-119	10.4	34.2	10.6	26.7
120-149	10.4	32.5	10.6	30.0
150-179	20.7	3.3	21.0	10.9
180-209	3.4	3.3	21.0	8.3
210-239	20.7	1.7	13.0	6.7
240-269	6.9	7.5	10.5	1.7
270-299	6.9	3.3	7.9	5.0
300-329	3.4	1.7	2.6	0.8
330-359	6.9	–	–	–
360 and over	3.4	–	–	–
Total	100.0	100.0	100.0	100.0

stations. These tests were made at two rest areas on Interstate 95 south of Washington, D. C. The results (Tables 6 and 7) indicate that the model offers a fair approximation of actual rest area operation for the men's comfort stations. The model tends to show a higher percentage staying for shorter lengths of time in the women's comfort stations.

Sensitivity tests for the model were run to evaluate the results with varying input data. Service times were appreciably altered, as was the division between toilet use and urinal use. As mentioned, the model results were shown to be relatively insensitive to changes in service time. The "toilet-urinal" use division had more effect on the results.

DISCUSSION OF RESULTS

Tables 2 through 5 give the results of the simulation. The number of facilities increases as the volume increases, although not in a direct proportion. Occasionally the number of facilities is reduced with an increase in the volume of users. This occurs owing to the randomness feature of the model. Engineering judgment must be used in evaluating the model results, and in establishing design criteria.

To be effective in highway design, the criteria must be related to ADT. Table 8 gives the number of facilities required by volumes of users per hour and by ADT groups. The following equation was used to relate persons per hour with ADT (the values for the variables represent average conditions in rest areas on rural interstate highways):

$$\text{Persons/hour} = \text{ADT}\ K \cdot D \cdot N \cdot V \cdot R$$

where

ADT = Average daily traffic,
K = Ratio of design hour volume to ADT (13.5 percent),
D = Directional distribution (60 percent),
N = Percentage of vehicles that stop at rest areas during peak hours (10 percent),
V = Vehicle occupancy (3.5), and
R = Percentage of persons stopping at rest areas who use comfort stations (75 percent).

TABLE 8

DESIGN GUIDE FOR COMFORT STATIONS ON RURAL INTERSTATE REST AREAS

ADT	Persons per Hour Using Rest Rooms During Design Hours	Number of Facilities				
		Urinals	Toilets	Wash Basins	Hand Dryers	
					Paper Towels	Air Dryers
Men's Room						
0-10, 000	0-105	2	2	2	2	2
10, 000-21, 000	105-225	3	3	4	3	4
21, 000-30, 000	225-315	4	4	5	4	6
30, 000-35, 000	315-375	5	4	5	4	7
35, 000-41, 000	375-435	7	4	5	5	7
41, 000-47, 000	435-500	9	5	7	5	8
Women's Room						
0-10, 000	0-105		4	3	2	2
10, 000-21, 000	105-225		6	4	3	4
21, 000-30, 000	225-315		9	6	4	6
30, 000-35, 000	315-375		10	6	4	7
35, 000-41, 000	375-435		12	8	5	7
41, 000-47, 000	435-500		14	8	5	8

The values of N, V, and R were obtained from a preliminary analysis of the 1968 national rest area survey. The persons per hour entering the men's and women's facilities was set at half the total persons per hour.

Table 8 is applicable only to rest areas with values of K, D, N, V, and R similar to those given. Where these values are different, the designer should compute the persons per hour figure. Tables 2 through 5 would then be used for determining the number of facilities.

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