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MARINE VOYAGE SAFETY SYSTEM (MARVSS): A STUDY CONCERNING THE FE--ETC(U)

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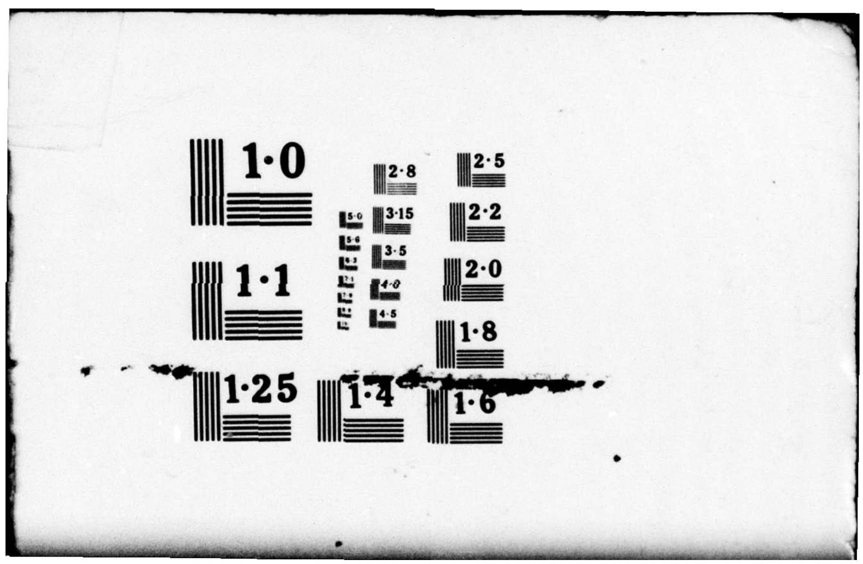
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Report No. CG-CAA-3-75

MARINE VOYAGE SAFETY SYSTEM

(MARVSS)

A Study Concerning the Feasibility of

Computerizing MARVSS

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

COMMANDER, ATLANTIC AREA
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16. Abstract

The Marine Voyage Safety System (MARVSS) was conceived and proposed by Commander, Coast Guard Pacific Area. The Operations Analysis Branch, Commander, Atlantic Area was directed to conduct a technical analysis and feasibility study of the proposed float plan system. To determine the estimated costs of implementing MARVSS, a model was developed and evaluated for one, two and three regional data collection points. The study shows that the cost of such a float plan system cannot be justified by the limited benefits that such a system can provide.

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I. OBJECT OF REPORT

The Marine Voyage Safety System (MARVSS) was conceived and proposed by Commander, Coast Guard Pacific Area. The concept of small vessel float plans had been previously considered by the Coast Guard as a method of improving small boat safety. There appears now to be enough interest generated by the inherent value in the system to warrant further consideration.

The Operations Analysis Branch, Commander, Coast Guard Atlantic Area was directed to conduct a technical analysis and feasibility study of the proposed float plan system. The Coast Guard has a moral responsibility to do all within its resources to improve small boat safety. The adoption of a small boat float plan system would be a step forward in providing service to the boating public. However, if such a system were developed, the Coast Guard would have assumed a degree of legal responsibility for the safety of the boater. The degree of this legal responsibility is unknown and was not considered in the course of this study. The object of this report was only to determine the possibility and feasibility of adapting the Marine Voyage Safety System (MARVSS) to a computer system.

II. BACKGROUND INFORMATION

During the summer months of 1973, there were several SAR cases involving small vessels that required the expenditure of considerable effort with little results in return. The typical problems were the lack of a satisfactory description of the vessel in question, how it was equipped, time frame of planned voyage and general information of the planned track. Due to the fact that there is no existing system of followup subsequent to departing and often tardy notification of a possible overdue situation, a search was not begun until a much later time and the chance of success was substantially lessened. It appeared that the time was now right for the Coast Guard to develop and promote an active program of float plans.

The topic of small vessel float plans had been previously addressed by the Commandant's Science Advisory Committee and recommendations were made that the Coast Guard consider such a program to improve small vessel safety. By coincidence, Commander, Pacific Area had his staff devoting some efforts in this same area with a view toward optimizing benefits from search and rescue resources available to the Coast Guard. The result was a formal proposal by Commander, Pacific Area that the Coast Guard's passive stance in the field of "Float Plans" be changed and that a more active posture be assumed in the area of small boat voyage following.

III. PARTICIPATION

An important task envisioned within this study is to determine the predicted levels of participation for various modes of operation of a Float Plan system. To effectively carry out this function, we must have current, accurate information to support an informed decision-making process.

At the present time, information is available on the number of recreational boats by states. The chief source of this information is from the 47 individual federally approved state numbering systems and from the Coast Guard numbering records for other jurisdictions which do not yet have federally approved systems; namely Washington, New Hampshire, Alaska and the District of Columbia. In order to accurately predict levels of participation in MARVSS, in addition to the number of boats, we must also know the total number of boat trips per year and the average number of days per trip.

The number of recreational boats in the United States have been increasing at an annual rate of approximately 7.4 percent in recent years. According to a recent survey[1], the total number of private recreational boats was estimated

1. *Kenneth M. Bromberg, Determination of the Number of Commercial and Non-commercial Recreational Boats in the U. S., their use, and Selected Characteristics, Information Concepts Incorporated, Final Report prepared for: National Marine Fisheries Service, U. S. Department of Commerce - NOAA, Washington, D.C.*

to be 8,007,717 as of 31 December 1973. A breakdown of this total by class size and region is shown in Table 1.

The estimated number of recreational boats by size and location shown represent boats owned by residents of the particular regions, and do not represent boats used in that area. For example, there is the possibility that inland state boaters either transport their boats to salt water areas or keep them permanently docked for use in salt water. For the purpose of this study, this possibility was assumed to be too low to be significant. The rationale for this decision was the belief that "salt water states" would have a greater proportion of their recreational boats used for salt water use than would the inland states. Also, since we will be varying the levels of participation, this was not considered to be a critical factor. The decision to be concerned only with salt water boats was based primarily on the concept that MARVSS would be used primarily for off-shore voyages. If the system proves beneficial, it can easily be adopted for inland rivers and lakes.

The total number of salt water boats was estimated to be 4,573,193 or 57.1 percent of the total recreational boats in the continental United States. Of this figure, 2,919,327 or 63.8 percent are less than 16 feet; 1,467,487 or 32.1 percent are 16 feet in length but less 26 feet; and 187,379 or 4.1 percent are 26 feet or greater.

REGION	Total Private Recreational Boats	Less Than 16 Feet	16 Feet But Less Than 26 Feet	26 Feet Or Greater
New England -I	409,140	222,981	157,110	29,049
Mid Atlantic - II	998,313	586,010	366,381	45,922
South Atlantic - III	750,760	518,775	207,961	24,024
Gulf - IV	1,407,727	988,224	388,533	30,970
Pacific - V	1,007,253	602,337	347,502	57,414
Inland - VI	3,434,524	2,431,643	951,363	51,518
TOTAL	8,007,717	5,349,970	2,418,850	238,897

TABLE 1: Estimated Number of Recreational Boats By Length and Region.

The study prepared for the National Marine Fisheries Service also gives an estimation for the total number of boat trips per year and the average number of days per trip. Based on a sample of 587,929 boats, the following table was extracted from information provided in the study.

SIZE/CLASS	TRIPS PER YEAR	AVERAGE TRIP LENGTH (days)
Less than 16 feet	11.6	1.0
16 feet but less than 26 feet	17.6	1.15
Greater than 26 feet	9.9	1.34

TABLE 2: Estimated number of trips and average trip length for recreational boats.

A maximum level of participation, if all recreational boaters participated in the system, would be in the vicinity of 60 million float plans per year. However, it is anticipated that if such a system were available to the marine community, only a small percentage of the boating population would use it. Therefore, a more realistic estimate on the number of float plans that might be submitted during the course of a year would be in the range of 1 to 10 million.

IV. FORMULATING THE PROBLEM

Several thousand vessels that are not participants in the Automated Mutual-assistance Vessel Rescue System (AMVER) sail the waters of the United States or make extended voyages between ports of the United States or sail to nearby countries. Any of these vessels are subject to difficulties that are beyond their capability to resolve, and may require assistance. The Marine Voyage Safety System as conceived by Commander, Pacific Area is intended to provide information to the cognizant SAR Coordinator in a timely manner in order that the vessel may be located and assistance can be rendered.

A vessel would be deemed a participant in MARVSS when vessel characteristics have been submitted to the Coast Guard and a vessel Float Plan(FP) is sent to the Coast Guard upon departure. This system would use the volunteer feature that is employed by the Federal Aviation Administration in its flight plan system serving the general aviation community. According to the plan submitted by COMPACAREA, voyages would be divided into two categories:

(1) A vessel departing and returning to the same port within 24 hours may file a float plan with the nearest Coast Guard activity. These voyages shall be considered local operations and will be followed by the appropriate Coast Guard group commander. No further communications would be

anticipated except in the event of an emergency or when terminating the float plan upon safe arrival in port.

(2) A vessel departing on a voyage of 24 hours or more duration or more than 100 miles may file a float plan with the nearest Coast Guard activity for further transmission to the MARVSS Center. Daily position information will be accepted by any radio-equipped Coast Guard activity and forwarded to the MARVSS Center. The float plan shall be terminated by the boat operator by notifying the nearest Coast Guard activity to the destination. Voyages terminating in a foreign port may be closed by radio if Coast Guard communications are available, or by the fastest telephonic means on a collect basis to the nearest Coast Guard activity.

Although not a requirement for participation, it would be advantageous to the participants that their vessel be radio-equipped for the type of voyage planned. The ability to communicate would permit the submission of daily position information to the Coast Guard as well as the determination of SAR assistance need in times of emergencies.

To determine the possible alternatives, we must first look at the system as proposed by COMPACAREA. The vast majority the boating population that would use a float plan system would be in the first category, or vessels engaged in local operations. The amount of additional work at the local unit and/or group command which would be generated by the implementation of a float plan system would be difficult to forecast, but is presumed to be considerably large. In most areas of the continental United States, boating activity is heavily influenced by the season of the year. The amount of work at the local unit and group command is already directly affected by the amount of boating activity in that area. A float plan system will in itself generate more work for the local commands.

According to the proposal, vessels departing on voyages of more than 24 hours or more than 100 miles would file a float plan that would be transmitted to a central MARVSS Center. This concept would be similar to and complement the AMVER system. Whether it be for local or coastwise voyages, the concept of a centralized float plan file lends itself to automation thru computerization.

The initial step in establishing a Marine Voyage Safety System would be the development of a computerized recreational boat file. Whether the participant intended to use the float plan system on local or coastwise basis, a centrally located boat file that can be accessed by various Coast Guard activities via telephone or teletype would be necessary. All prospective participants would be required to submit vessel description and characteristics, including the type of communications, propulsion, navigation and survival equipment on board.

To develop such a file, it would be necessary to sell the idea of float plans to the boating public. Although the majority would agree that the concept of float plans would be a benefit to small vessel safety, many boaters may fear that the computerized boat file would infringe on their individual rights as citizens. The public reaction to the float plan system would become evident while establishing the computerized boat file. Since boaters would be required to have pertinent data on file before they were allowed to participate in the float plan system, the file would give a good indication of possible levels of participation. Once the system was established, an important point would be the ease in which boaters could put information on file, or change boat data already on file.

One method of actually completing the boat file would be the wide distribution of vessel information forms to be filled out by the boat owners and then returned to a centralized center. Here they would be coded and placed on computer cards as input to the computer. A second method would be the use of "800" WATS telephone numbers where the boat owner may call the Coast Guard central MARVSS Center. The operator working at a terminal would input the boat information directly to the computer. Another possibility would be the use of local telephone numbers manned by a special staff set up as a data collection point. The telephone costs for the regional collection points would be less than those for a centralized collection point.

There are two methods by which the small boat owner or operator can file a float plan. The two means of communications readily available to the boating public are radiotelephone and public telephones. Using the radiotelephone, the boat operator would file his float plan with the nearest Coast Guard activity for further transmission to the MARVSS Center. This method would place a heavy burden on the local commands if all boats were radio-equipped. However, according to a recent survey[2], only 6.2% of the recreational boats registered in the continental United States are radio-equipped. Therefore, this method of filing float plans would eliminate the vast majority of boat operator from participating in the system.

A second method would be the use of toll free "800" WATS telephone numbers. The boat operator would call the MARVSS Center and file his float plan prior to departure.

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2. *Recreational Boating in the Continental United States in 1973; The Nationwide Boating Survey, prepared for the U. S. Coast Guard, Office of Boating Safety.*

The operator at the MARVSS Center would input the float plan directly into the computer via a CRT terminal. The boat operator would terminate his float plan upon his safe arrival in port by recalling the MARVSS Center. This method of communications with the MARVSS Center would be readily available to all boat operators in almost every location in the continental United States. This configuration is the one considered to be most practical.

The computerized small boat float plan data entry system will require a dedicated computer system capable of processing simple computer programs. The system must have a large amount of online storage which can be easily expanded. For a centralized center, the computer must have the capability to be interfaced with many CRT terminals. If more than one data collection point is utilized, the computer must have the capability to batch process the float plans from the regional collection points. The computer should also have the capability to process float plans and additions or changes to the boat data file simultaneously.

Four computer system options would be available if the float plan concept is adopted. The first option would be utilization of the Coast Guard computer system. Because the MARVSS data entry would require a full time system, the present Coast Guard computer could not provide all the necessary service required to maintain a float plan system.

A second option would be to procure a small duplex computer to provide 100% availability for data entry, and to interface with the Coast Guard computer for processing of the MARVSS data. A third option would be the purchase or lease of a completely independent computer system. The fourth option would be the purchase of computer time from a computer software firm. However, most computer services firms are not capable of providing round the clock service every day.

A very important part of the MARVSS computer system would be the type of computer backup provided. If the computer system does not operate during a period of high boating activity, the central site must have immediate access to a backup system.

If a small vessel float plan system is implemented, the overall responsibility for the small boat safety will remain with the cognizant district Rescue Coordination Center. The MARVSS Center would periodically pass overdue information to the RCCs. This information would then be relayed to the local group commands for evaluation. The final disposition of the case would then be reported back to the MARVSS Center by the RCCs. In cases initiated at the local level, the group or station could request information on file for a specific boat. This request would go to the RCC, where it would be forwarded to the MARVSS Center. When a request for information about a specific boat is received at the MARVSS Center, both the float plan and boat information data would be provided.

Two methods of storing float plan information are envisioned:

(1) Voice tape recordings of conversations between operators and boaters, keyed on clock time and operator number.

(2) Computer data files containing boat identification, estimated time of arrival, time of initializing float plan and operator number to allow access to voice tape.

There are two options available for passing information between the MARVSS Center and the RCC. They are the SARLANT/SARPAC teletype network or CRT terminals installed in each RCC which have direct interface with the computer. The SARLANT/SARPAC teletype network is already being used for access between the RCC and the Coast Guard computer for AMVER/SARP/CASP messages. Although this method has worked satisfactorily, there are definite time delays that would be eliminated with the terminals in the RCCs.

The total system considered in this study is shown in Figure 1.

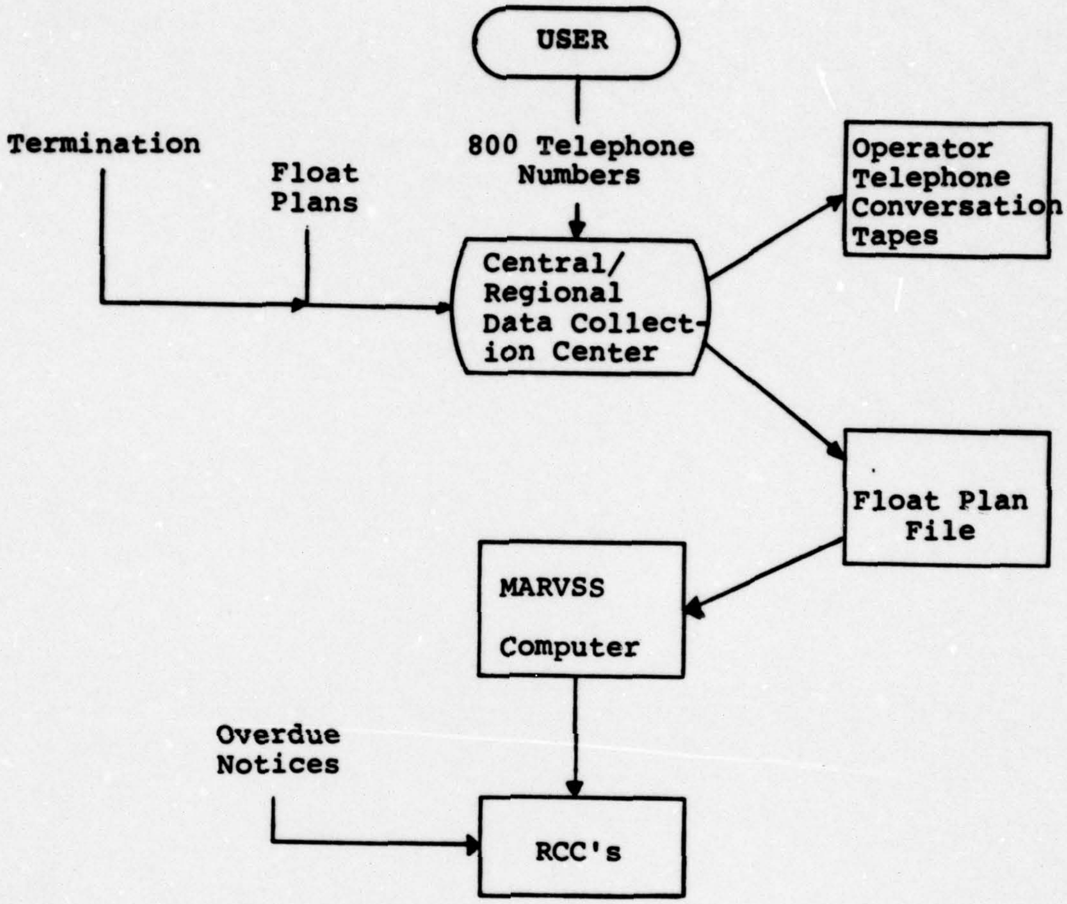


Figure 1: MARVSS Data Collection and Processing System.

V. A MATHEMATICAL MODEL TO REPRESENT MARVSS

The priliminary selection of a feasible Marine Voyage Safety System was made after a review of the communications methods, information and collection methods, notification methods, response criteria, degree of centralization and criteria for participation of the boating public was completed. The designed system would consist of a centralized computer center with a dedicated computer used to maintain the boat data file and the individual float plan file, along with the voice tape conversations. The boat operator would initiate and terminate his or her float plan via toll free WATS telephone services.

The collection and processing of float plan data by local commands, such as groups or stations, was discarded as impractical for the following reasons:

(1) Boating activity is seasonal, therefore local staffs would have to be supplemented on a seasonal basis even more so then is done now.

(2) In order to prevent saturation of communication lines on weekends, separate telephone numbers at each group or station would have to be installed, and even then there would be no way to prevent spillovers to the regular command phone numbers.

The formation of waiting lines will be a common phenomenon whenever the arrival rate of float plans exceeds the MARVSS Center capacity to serve the boating public. The decisions regarding the amount of capacity to provide must be made. Since it will be difficult to accurately predict when boat operators will elect to use the system, the decisions will be difficult ones. Providing too much service would involve excessive costs. On the other hand, not providing enough service capacity would cause the waiting lines to become excessively long at times. Excessive waiting lines also are costly in some sense, whether it be a social cost, or the cost of lost "customer". Therefore, the ultimate goal would be to achieve an economic balance between the cost of service and the cost associated with waiting for that service.

With the selection of a feasible system, it was then possible to develop and test a model of the system. Through simulation of user activity, the model calculates costs associated with various MARVSS data collection configurations. The model consists of a main program and five subroutines. Input values concerning desired performance characteristics of the system being modeled act as constraints, forcing the model to calculate resources and their associated costs to satisfy the constraints.

The following input variables act as designed constraints:

(1) Maximum probability of waiting

(2) Expected wait time for customer who waits

(3) Expected overall wait time

(4) Probability of a busy signal

(5) Maximum allowable wait time

(6) Probability of occurrence of maximum wait time

(7) Service time

The main program of the model accepts and interprets information concerning unit costs for services, system capability constraints, system configuration and an estimated workload distribution. The yearly distribution of expected call arrival rates is calculated based on a sample of 44,238 SAR cases involving recreational boats during FY 1973. For each level of predicted yearly participation, the main program calculates 24 call arrival rates, one for weekdays and weekends for each month. System configuration, constraints and expected call arrival rates are passed to Subroutine COSTIT.

Subroutine COSTIT accepts the information from the main program and passes it to Subroutine SERVCOST for processing. System constraints are printed prior to returning to the main program.

Subroutine SERVCOST monitors the processing in Subroutines WATSCOST and SERVER. Output information computed by each subroutine is printed prior to calling the next subroutine. The total cost for each collection point is computed in Subroutine SERVCOST prior to returning control to Subroutine COSTIT.

Subroutine WATSCOST calculates the number of telephone lines required to meet the constraint on the maximum probability of a busy signal by repeated calls to Subroutine QUEUE for each time period. This value is returned to Subroutine SERVCOST. Utilizing the WCOST entrypoint, Subroutine WATSCOST is passed the number of lines and operators, then the cost for each time period is minimized subject to the performance requirements by establishing a mix of full time and measured time lines.

Subroutine SERVER calculates the number of operators required to meet constraints on probability of waiting and waiting time by repeated calls to Subroutine QUEUE for each time period. This value is returned to Subroutine SERVCOST.

Subroutine QUEUE is called by Subroutines WATSCOST and SERVER. Statistical values derived from queuing theory are calculated for comparison with constraints in the calling subroutines. These values are statistics of waiting times or busy signals which result from a particular number of telephone lines or operators which act as servers in queuing mathematics in relation to the workload distribution representing "call arrivals". Both services times and interarrival times are assumed to have a negative exponential distribution. References used for the formulas used in this subroutine are Bhat (1972)[3] and Martin (1972)[4].

---

3. *Bhat, U. Narayan, Elements of Applied Stochastics Processes, John Wiley & Sons, New York, 1972*

4. *Martin, James, Systems Analysis for Data Transmission, Prentice-Hall, Englewood Cliffs, New Jersey, 1972*

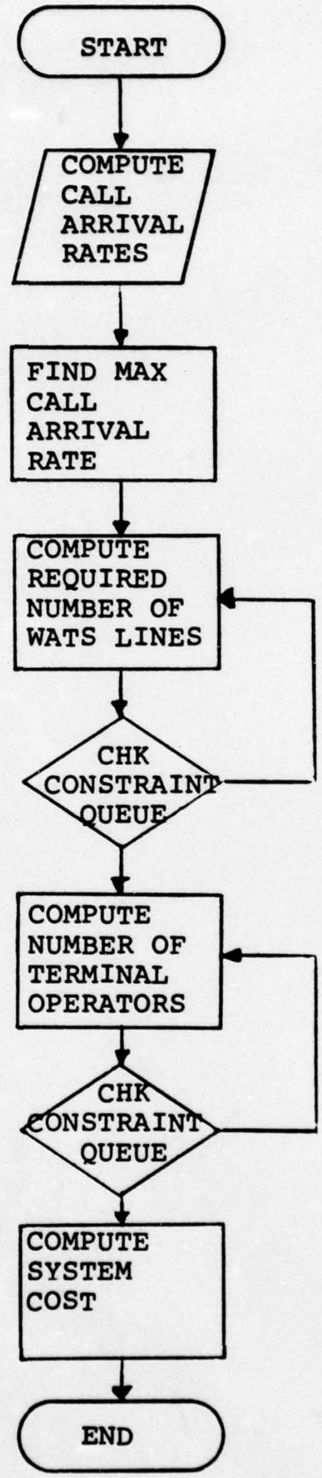


Figure 2: Model of MARVSS System

```
      DIMENSION JCONF(10)
      DIMENSION ISEAS(20)
      DIMENSION TIME(24),EN(24),COSTOT(10),PART(5),XMO(10,12),FRAC(20)
      DIMENSION ETS(24),T1(20),T2(20),T3(20)
      DIMENSION DAYWEEK(7),HOUR(24),XMONTH(12),CALLPRMO(12),CALLRATE(12,
     -7),JMONTH(12),IDAY(7)
      DATA (DAYWEEK(I),I=1,7)/0.11329158,0.09859601,0.08885171,
     -0.08611607,0.09486559,0.25206303,0.2662160/
      DATA (IDAY(I),I=1,7)/3HMON,3HTUE,3HWED,3HTHU,3HFRI,3HSAT,3HSUN/
      DATA ((JMONTH(I),I=1,12)/3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,3HJUL
     -,3HAUG,3HSEP,3HOCT,3HNOV,3HDEC/
      DATA (XMONTH(J),J=1,12)/0.027582,0.023581,0.033664,0.061834,
     -0.092989,0.134001,0.203771,0.173521,0.114467,0.066831,0.037304,
     -0.030454/
      DATA(HOUR(J),J=1,24)/0.014197,0.011688,0.009088,0.007890,0.005833,
     -0.007280,0.015577,0.026293,0.036760,0.045826,0.055954,0.061764,
     -0.068184,0.078855,0.084756,0.088463,0.084010,0.072796,0.060836,
     -0.052653,0.041281,0.030000,0.022495,0.017521/
      DATA TIME/521.8,208.7,521.8,208.7,521.8,208.7,521.8,208.7,521.8,
     -208.7,521.8,208.7,521.8,208.7,521.8,208.7,521.8,208.7,521.8,208.7,
     -521.8,208.7,521.8,208.7/
      DATA PART/1E6,2E6,3E6,4E6,5E6/
      DATA ETS/24*2.0       /
      READ 11,TRIPPRYR,ITIME
   11 FORMAT(F10.0,I4)
      NPART=4
      NPART=1
      NPART=2
      NPART=5
      DO 9 I=1,12
    9 XMO(1,I)=1./12.
      READ 100,SERVRATE,TERMRATE,SPACE,SPRATE
  100 FORMAT(8F10.0)
      PRINT 101,SERVRATE,TERMRATE,SPACE,SPRATE
  101 FORMAT(
     -≠1HOURLY WAGE PER OPERATOR                          ≠,F10.4//
     -≠0MONTHLY RATE PER TERMINAL                         ≠,F10.4//
     -≠0FLOOR SPACE IN SQ FT PER OPERATOR                 ≠,F10.4//
     -≠0CONSTRUCTION COST PER SQ FT                       ≠,F10.4//
     -)
          RATE=SERVRATE/60.
      SPRATE=SPACE*SPRATE/2629800.
      TERMRATE=TERMRATE/43830
      READ 100,BMAX,ETDMAX,ETWMAX,PLOST,DMAX,P
      PRINT 102,BMAX,ETDMAX,ETWMAX,PLOST,DMAX,P
  102 FORMAT(
     - ≠0MAX PROBABILITY OF WAITING                       ≠,F10.4//
     - ≠EXPECTED DELAY TIME FOR CUSTOMERWHO WAITS ≠,F10.4//
     - ≠EXPECTED OVERALL WAIT TIME                        ≠,F10.4//
     - ≠PROBABILITY OF BUSY SIGNAL                        ≠,F10.4//
     - ≠MAX ALLOWABLE WAIT TIME                           ≠,F10.4//
     - ≠PROBABILITY OF OCCURRENCE                         ≠,F10.4//
     -)
      X=PLOST
```

```
      T=DMAX
   10 READ 200,ICONF,JCONF,NCOLPT
      IF(IFEOF(60).EQ.-1) STOP
      READ 202,(FRAC(I),I=1,NCOLPT)
  203 FORMAT(10I8)
      READ 203,(ISEAS(I),I=1,NCOLPT)
      READ 204,(T1(I),T2(I),T3(I),I=1,NCOLPT)
  204 FORMAT(3F10.0)
  200 FORMAT(I8,10A4,I8)
  202 FORMAT(10F8.5)
      PRINT 201,ICONF,JCONF,NCOLPT,(I,FRAC(I),ISEAS(I),T1(I),T2(I),T3(I)
     -,I=1,NCOLPT)
  201 FORMAT(
     -≠1CONFIGURATION≠,I10//1X,10A4//
     -I6,≠ COLLECTION POINTS≠//
     -≠ COLLECTION PT   FRACTION   SEASON TYPE   TELEPHONE TARIFFS≠//
     -20(I9,F14.3,I15,3F10.4//))
      DO 3 KKK=1,NPART
      DO 4 III=1,NCOLPT
      XPROB=0.
      L=ISEAS(III)
      TRIPPRYR=PART(KKK)
      CALLPRYR=TRIPPRYR*2.
      DO 1 I=1,12
    1 CALLPRMO(I)=CALLPRYR*XMONTH(I)
      IFIRSTHR=ITIME/100+1
      IDUM=ITIME/100
      ILASTHR=((ITIME/100.-IDUM)*100)+1
      K=IFIRSTHR
      L=ILASTHR
      M=K-1
      N=L
      DO 12 I=K,L
   12 XPROB=XPROB+HOUR(I)
      XMIN=(L-K)*60.
      DO 13 I=1,12
      DO 13 J=1,7
   13 CALLRATE(I,J)=(CALLPRMO(I)*DAYWEEK(J)*XPROB)/(4.345238*XMIN)
  999 FORMAT(*          *)
      PRINT 210,CALLPRYR
  210 FORMAT(* ESTIMATED NUMBER OF CALLS PER YEAR EQUALS  *,F10.1)
      PRINT 999
      PRINT 999
      K=0
      DO 6 I=1,12
      K=K+1
      EN(K)=0.
      DO 2 J=1,5
    2 EN(K)=EN(K)+CALLRATE(I,J)
      EN(K)=EN(K)/5.*FRAC(III)
      K=K+1
      EN(K)=0.
      DO 5 J=6,7
    5 EN(K)=EN(K)+CALLRATE(I,J)
```

RAN(2.3)/MASTER   INTEGER WORD SIZE = 1 . * OPTION IS OFF . 0 OPTION IS

```
      EN(K)=EN(K)/2.*FRAC(III)
    6 CONTINUE
      CALL COSTIT(24,TIME,EN,ETS,RATE,BMAX,ETDMAX,ETWMAX,X,T,P,TERMRATE,
     -SPRATE,TOTAL,T1(III),T2(III),T3(III))
    4 XTOT=XTOT+TOTAL
      COSTOT(KKK)=XTOT
    3 XTOT=0.
       GO TO 10
      END
```

ASI FORTRAN DIAGNOSTIC RESULTS FOR FTN.MAIN

NO ERRORS

```
'AN(2,3)/MASTER       INTEGER WORD SIZE = 1 , * OPTION IS  OFF . O OPTION IS

      SUBROUTINE COSTIT(NT,TIME,EN,ETS,RATE,BM,ETDMAX,ETWMAX,X,T,P,TERM,
     -SP,TOTAL,T1,T2,T3)
      DIMENSION TIME(12),EN(12),ETS(12)
      CALL SERVCOST(NT,TIME,EN,ETS,RATE,BM,X,ETDMAX,FTWMAX,TOTAL,T,P,
     -TERM,SP,T1,T2,T3)
   10 FORMAT(I2/100(3F8.0/))
      PRINT 30,RATE,BM,X,ETDMAX,ETWMAX,TOTAL
   30 FORMAT(≠0RATE=                              ≠,F20.5/
     -          ≠0MAX PROBABILITY=                ≠,F20.5/
     -          ≠0PROB OF LOST CUSTOMER           ≠,F20.5/
     -          ≠0DELAY TIME=                     ≠,F20.5/
     -          ≠0TOTAL WAIT TIME=                ≠,F20.5/
     -          ≠0TOTAL COST=                     ≠,F20.5/       )
      RETURN
      END

;ASI FORTRAN DIAGNOSTIC RESULTS FOR COSTIT

    NO ERRORS

'ENCED STATEMENT LABELS
```

```
RAN(2,3)/MASTER       INTEGER WORD SIZE = 1 , * OPTION IS  OFF , O OPTION IS
      SUBROUTINE SERVCOST(NT,TIME,EN,ETS,RATE,BM,X,ETDMAX,ETWMAX,TOTAL,
     -T,P,TERM,SP,T1,T2,T3)
      DIMENSION TIME(1),EN(1),ETS(1)
      HIGH=0.
      DO 9 I=1,NT
      IF(EN(I)*ETS(I).LT.HIGH) GO TO 9
      HIGH=EN(I)*ETS(I)
      NH=I
    9 CONTINUE
      I=1
      CALL WATSCOST(EN(I),ETS(I),X,EN(NH),ETS(NH),COST,L,T1,T2,T3,M,
     -ETWMAX,NFTL)
      PRINT 10,I,L,RATE
   10 FORMAT(≠0SUBROUTINE SERVCOST≠,3X,≠TIME PERIOD≠,I10,≠  PEAK, REQUIR
     -ING≠,I10,≠ WATS LINES≠//≠ OPERATOR RATE≠,F10.4//)
      JTERM=0
      TOTAL =0.
      DO 1 I=1,NT
      CALL SERVER(BM  ,ETDMAX,ETWMAX,EN(I),ETS(I),T,P,M)
      CALL WCOST(EN(I),ETS(I),X,EN(NH),ETS(NH),COST,L,T1,T2,T3,M,ETWMAX,
     -NFTL)
      PRINT 11,T1,T2,T3,EN(I),ETS(I),I,M,L,NFTL,COST
   11 FORMAT(≠   ≠,5F10.3,4I5,F12.2)
      COSTOPER=TIME(I)*60.*RATE*M
      TOTAL=TOTAL+COSTOPER
      IF(M.GT.JTERM) JTERM=M
      N=I/2
      N=I*2
      IF(N.LT.I) GO TO 1
      TOTAL=TOTAL+COST
    1 CONTINUE
      TOTAL=TOTAL+JTERM*525960.*(TERM*1.1+SP)
      RETURN
      END

SASI FORTRAN DIAGNOSTIC RESULTS FOR SERVCOST

    NO ERRORS
```

```
'AN(2.3)/MASTER      INTEGER WORD SIZE = 1 , * OPTION IS  OFF , O OPTION IS

      SUBROUTINE WATSCOST(ETN,ETS,P,ETNMAX,ETSMAX,COST,L,T1,T2,T3,M,
     -ETWMAX,N)
      L=ETNMAX*ETSMAX
    1 L=L+1
      CALL QUEUE(ETNMAX,ETSMAX,L,T,K,B,EW,EQ,ETW,ETQ,PTWGT,
     -ETD,POGEK,SDW,SDTW,SDTQ,PLOST)
      IF(PLOST.GE.P) GO TO 1
      RETURN
      ENTRY WCOST
      TIME=ETN*ETS
      COST=T1*L+(ETN*(ETS+ETWMAX)*43830-T2*L)*T3
      COST=AMAX1(COST,T1   *L)
      BCOST=1000000.
      DO 2 N=1,L
      LM=L-N
      XCOST=1940.*N+(T1*LM)+((ETN*(ETS+ETWMAX)-N)*43830-T2*LM)*T3
      XCOST=AMAX1(XCOST,1940.*N+T1*LM)
      IF(LM.EQ.0) XCOST=1940.*N
      IF(XCOST.GT.BCOST) GO TO 2
      BCOST=XCOST
      MM=N
    2 CONTINUE
      XCOST=BCOST
      N=MM
      IF(XCOST.GT.COST) RETURN
      COST=XCOST
      LN=L-N
      RETURN
      END

SASI FORTRAN DIAGNOSTIC RESULTS FOR WATSCOST

   NO ERRORS
```

RAN(2.3)/MASTER INTEGER WORD SIZE = 1 , * OPTION IS OFF . O OPTION IS

```
      SUBROUTINE SERVER(BMAX,ETDMAX,ETWMAX,EN,ETS,T,P,M)
      M=EN*ETS+1.
    1 CALL QUEUE(EN,ETS,M,T,K,B,EW,EQ,ETW,ETQ,PTWGT,ETD,POGEK,SDW,SDTW,S
     -DTQ)
      IF(B.LE.BMAX.AND.ETD.LE.ETDMAX.AND.ETW.LE.ETWMAX.AND.(PTWGT.LT.P
     - .OR.P.EQ.0.)) GO TO 2
      M=M+1
      GO TO 1
    2 CONTINUE
C     >RINT 20,EN,ETS,M,T,K,B,EW,>Q,ET=,E.Q,PTWG.,ETD,POGEK,SDW,SDTW,
C    -SDTQ
   20 FORMAT(≠0EN                                     ≠,F20,5//
     -          ≠ ETS                                 ≠,F20.5//
     -          ≠ M                                   ≠,I20  //
     -          ≠ T                                   ≠,F20.5//
     -          ≠ K                                   ≠,I20  //
     -          ≠ B                                   ≠,F20.5//
     -          ≠ EW                                  ≠,F20,5//
     -          ≠ EQ                                  ≠,F20,5//
     -          ≠ ETW                                 ≠,F20,5//
     -          ≠ ETQ                                 ≠,F20,5//
     -          ≠ PTWGT                               ≠,F20,5//
     -          ≠ ETD                                 ≠,F20,5//
     -          ≠ POGEK                               ≠,F20,5//
     -          ≠ SDW                                 ≠,F20,5//
     -          ≠ SDTW                                ≠,F20,5//
     -          ≠ SDTQ                                ≠,F20.5//        )
      RETURN
      END
```

;ASI FORTRAN DIAGNOSTIC RESULTS FOR SERVER

NO ERRORS

?ENCED STATEMENT LABELS

'AN(2.3)/MASTER   INTEGER WORD SIZE = 1 . * OPTION IS OFF . O OPTION IS

```
      SUBROUTINE QUEUE      (EN,ETS,M,T,K,R,EW,EQ,ETW,
     -ETQ,PTWGT,ETD,POGEK,SDW,SDTW,SDTQ,PLOST)
      IF(M.LT.1.OR.ETS.LE.0..OR.EN.LE.0..OR.T.LT.0..OR.K.LT.0)GO TO 90
      R=EN*ETS/M
      IF(R.GT.1.) GO TO 82
      X=1.
      N=M-1
      F=1.
      X=0.
      DO 1 I=1,N
      F=F*I
    1 X=X+((M*R)**I)/F
      F=F*M
      Z=X+(M*R)**M/F
      Y=X/Z
      B=(1.-Y)/(1.-R*Y)
      EW=B*R/(1.-R)
      EQ=EW+M*R
      ETW=(B/M)*ETS/(1.-R)
      ETQ=ETW+ETS
      PTWGT=B*EXP(M*(R-1.)*T/ETS)
      SDW=(1./(1.-R))*SQRT(B*R*(1.+R-B*R))
      ETD=ETS/(M*(1.-R))
      SDTW=ETD*SQRT(B*(2.-B))
      SDTQ=ETD*SQRT(B*(2.-B)+(M**2)*(1.-R)**2)
      PLOST=(((M*R)**M)/F)/Z
      W=((M*R)**M)/((1.-R)*F)
      FN=1.
      DO 2 I=1,K
      IF(N.GE.M) GO TO 3
      FN=FN*I
      POGEK=POGEK+(((M*R)**I)/FN)/(X+((M*R)**I)/((1.-R)*F))
      GO TO 2
    3 POGEK=POGEK+(((M*R)**I)/(F*M**(I-M)))/(X+W)
    2 CONTINUE
      RETURN
 90   PRINT 91
   91 FORMAT(≠ ****SUBROUTINE QUEUE CALLED WITH INVALID DATA≠)
      RETURN
   82 PRINT 83,R
      RETURN
   83 FORMAT(≠ ******SUBROUTINE QUEUE FOUND UNSTABLE CONDITION. R=≠,F9.2
     -)
      END
```

EASI FORTRAN DIAGNOSTIC RESULTS FOR QUEUE

NO ERRORS
.LGO)

VI. DERIVING A SOLUTION FROM THE MODEL

To determine the estimated costs of implementing MARVSS, the model was evaluated for one, two and three regional data collection points. The selection of location sites for these collection centers is an important decision in controlling total system costs. Because WATS telephone service charges will be an overwhelming consideration in any system in which they are used, the following items should be considerd:

(1) The regional collection point site(s) should not be located in any state where a large number of calls will originate. Calls originating within the same state as the collection center are not covered by the WATS service charges. This, therefore, eliminates all coastal states as possible locations for the collection centers.

(2) It would be desirable to locate away from any metropolitan center but within reasonable distance of equipment service personnel.

The WATS service charges used in this study were the rates that were in effect during November 1974. The model employed the concept of both full time lines and measured time lines. During January 1975, the telephone company requested a rate increase. If this request is approved, all WATS lines will become measured time lines.

The fixed cost of these measured time lines will be approximately the same as the former cost of a full time line, however, the number of hours covered by the fixed cost will be increased from 10 to 240 hours.

For the above reasons, the site selection and associated telephone services as shown in Table 3 were used in the evaluation of the model.

Number of collection points	Site locations	Monthly charge for full time line	Monthly charge for measured time line
1	Oklahoma City	$1940.00	
2	West Virginia Nevada	$1600.00	$320.00 for first 10 hours $24.10 for each additional hour
3	Pennsylvania Tennessee Nevada	$1300.00	

TABLE 3: WATS Telephone Service Charges

The number of float plans received at each collection point was based on the percent of the estimated total recreational boats in the area covered by the collection point. The area covered and the percent of float plan received at each collection point are shown in Table 4.

Number of collection points	Site locations	Regional area	Percent of float plans received
1	Oklahoma City	Continental US	100
2	West Virginia	Atlantic and Gulf Coasts	78
	Nevada	Pacific Coast	22
3	Pennslyvania	North Atlantic Coast	37
	Tennessee	South Atlantic Coast	41
	Nevada	Pacific Coast	22

TABLE 4: Expected distribution of calls at each collection point.

The number of terminal operators required to maintain MARVSS varied throughout the year as the amount of expected boating activity varied. The model determined the personnel cost by employing only the required number of operators necessary for each time period. The wage rate for these operators was set at $4.00 per hour. This rate was the estimated rate to cover both hourly wages and employment benefits.

The monthly rental charge for the CRT terminals was set at $175.00. Like the monthly charge for the total number of WATS lines, this charge must be applied during each time period regardless of the amount of activity.

The cost of computer services vary according to the type of services required. To maintain MARVSS, the computer must be capable of processing file inputs from many CRT terminals simultaneously. The system must have a large amount of on-line storage, which can be easily expanded. If data collection points are separated, mini-computers may be used for terminal control and/or control of transmitting records to the central site for processing. The estimated cost for a dedicated computer system for maintaining MARVSS would be in the range of $1.2 to $1.5 million dollars. This range allows for differences in system configurations. To lease a comparable system would cost between $28,000 and $35,000 per month.

The total cost for a system such as this for the first five years would be approximately 7 million dollars for an anticipated participation level of 1 million float plans per year. If five million float plans were submitted each year, the estimate total cost for the required system would be approximately 25 million dollars. A breakdown of the total costs for the initial five year period is shown in Table 5.

Costs ($000's) for 1 million participants per year

FY	77	78	79	80	81	Total
Central Site - Personnel Construction Costs - CRT rentals - Telephone	1,100	1,100	1,100	1,100	1,100	5,500
Software	75					75
Computer services	1,200					1,200
RCC terminals	45	45	45	45	45	225
RCC comms equipment	20	20	20	20	20	100
						7,100

Costs ($000's) for 5 million participants per year

FY	77	78	79	80	81	Total
Central Site - Personnel Construction Costs-CRT rentals - Telephone	4,550	4,550	4,550	4,550	4,550	22,750
Software	75					75
Computer services	1,500					1,500
RCC terminals	45	45	45	45	45	225
RCC comms equipment	20	20	20	20	20	100
						24,650

TABLE 5: Initial costs for five year period

VII. TESTING THE MODEL

The model was subjected to a technique known as sensitivity analysis, which is quite literally an analysis of the sensitivity of the model to changes in its assumptions or in the levels of its parameters. What we hoped to learn through sensitivity analysis was whether a particular assumption really makes any difference with respect to the results yielded by the model, or the solutions and inferences drawn from it, or whether the results, solutions, and inferences obtained from the model were highly dependent upon the specific values assigned to the model parameters.

The following inputs were considered to be desired constraint parameters of the model and were used as base data for cost comparisons:

(a)	Estimated service time	1.5
(b)	Expected wait time	1.5
(c)	Expected overall wait time	0.5
(d)	Maximum allowable wait time	3.0
(e)	Maximum probability of waiting	0.1
(f)	Probability of bust signal	0.01
(g)	Service time	1.5

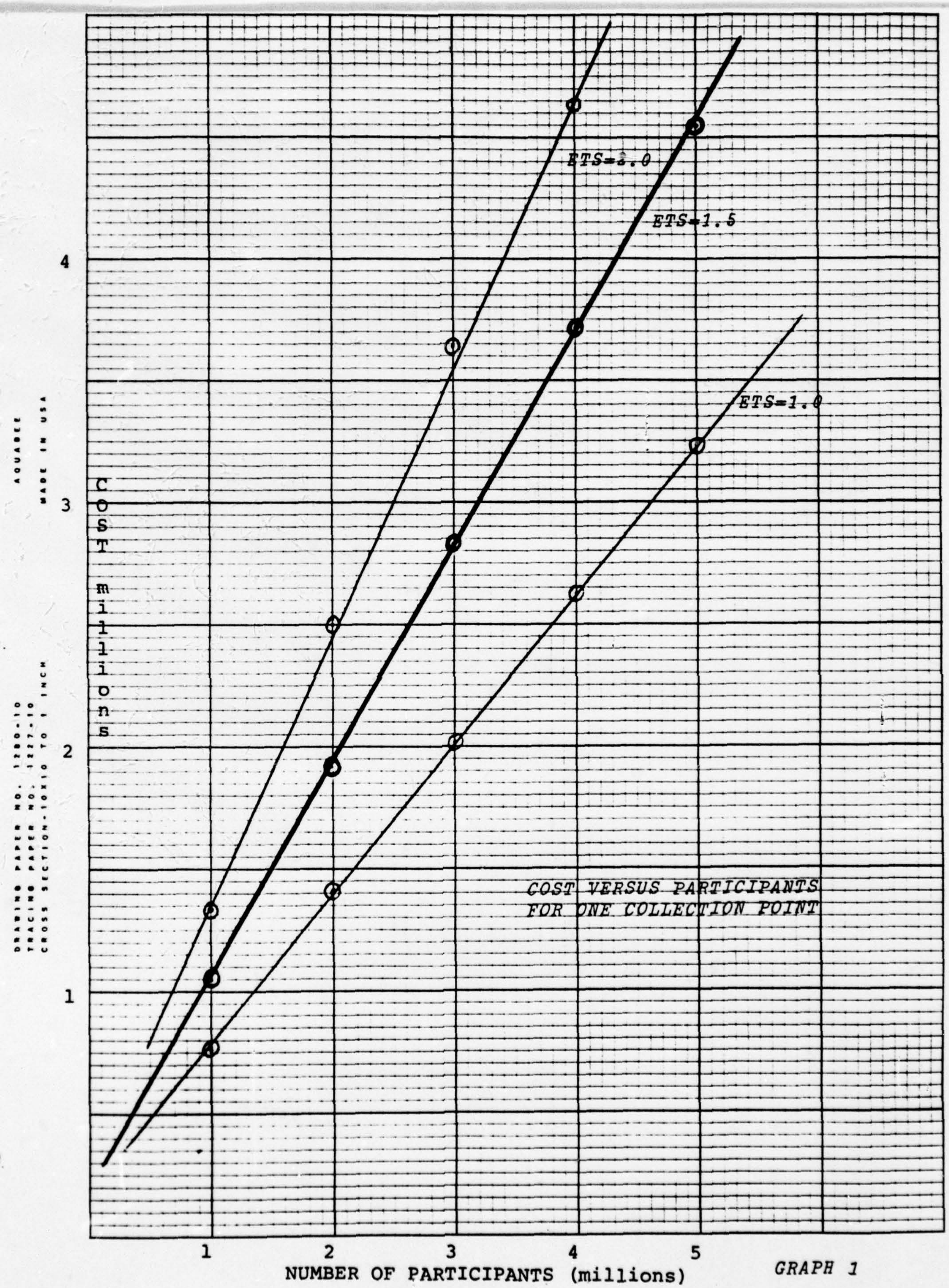
This analysis showed that the estimated costs of implementing MARVSS were mostly affected by the number of participants, estimated service time and the probability of a busy signal. Of these, the number of participants and estimated service time are the critical factors. The number of participants must be controlled before any decision to implement can be made. Without this control, any designed system could easily become unmanageable.

The method by which the MARVSS operator records the float plan information would directly affect the service time. For this reason, the concept of tape recording all information as received was adopted. This method would also play a vital role in the evaluation of the float plan information for search planning purposes.

The yearly costs for the initial five year period, as affected by the number of participants and estimated service times, are shown in GRAPHs 1 thru 3.

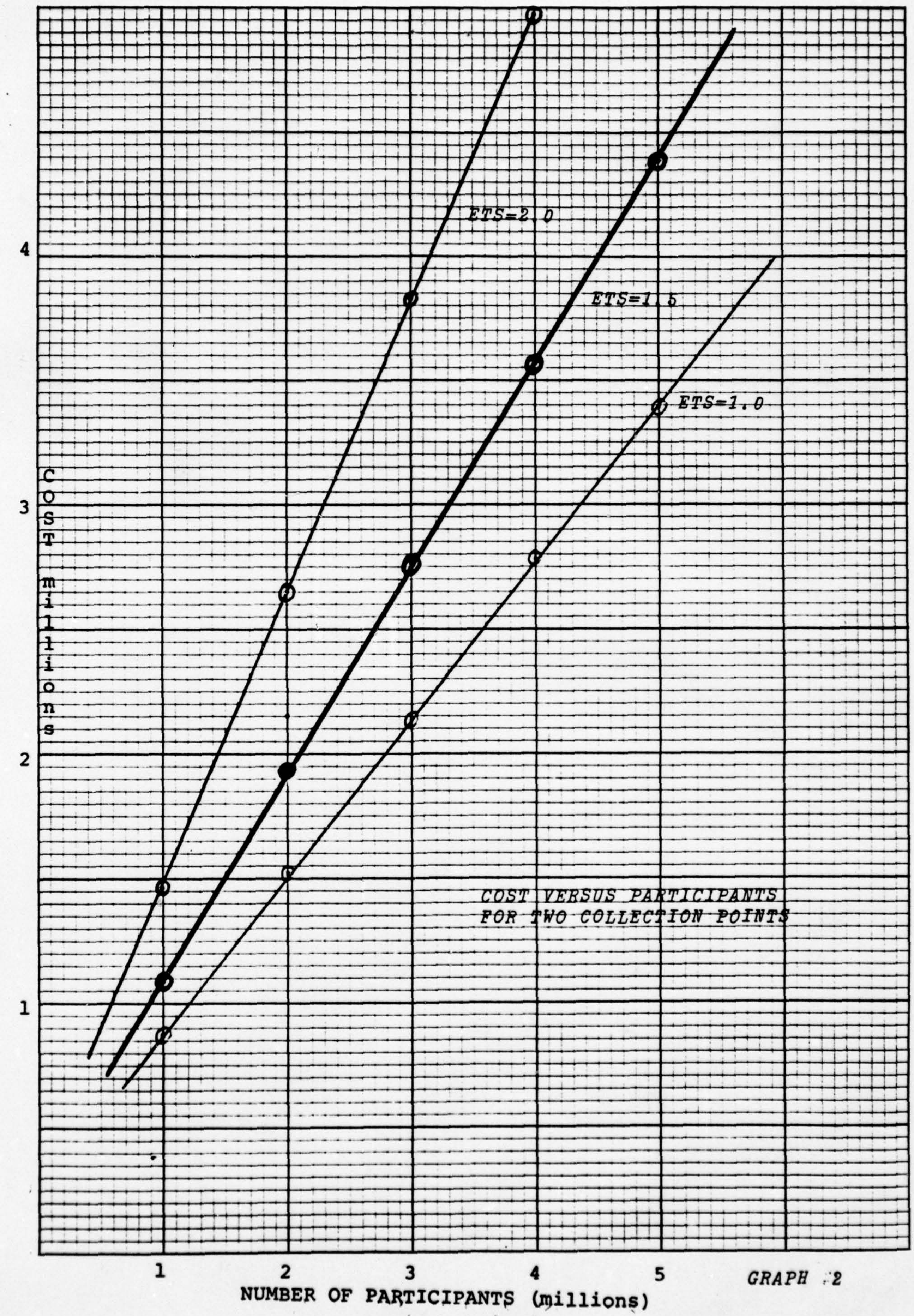
The other constraint parameters, when varied, caused only moderate changes in system costs. Only when the probability of a busv signal was increased, did the model change the system structure, i.e. reduction in the required number of WATS lines.

Therefore, the number of participants, estimated service time and probability of a busy signal play a crucial role in the results yielded by the model. For this reason, before MARVSS can be implemented, the values for these parameters must be properly identified.

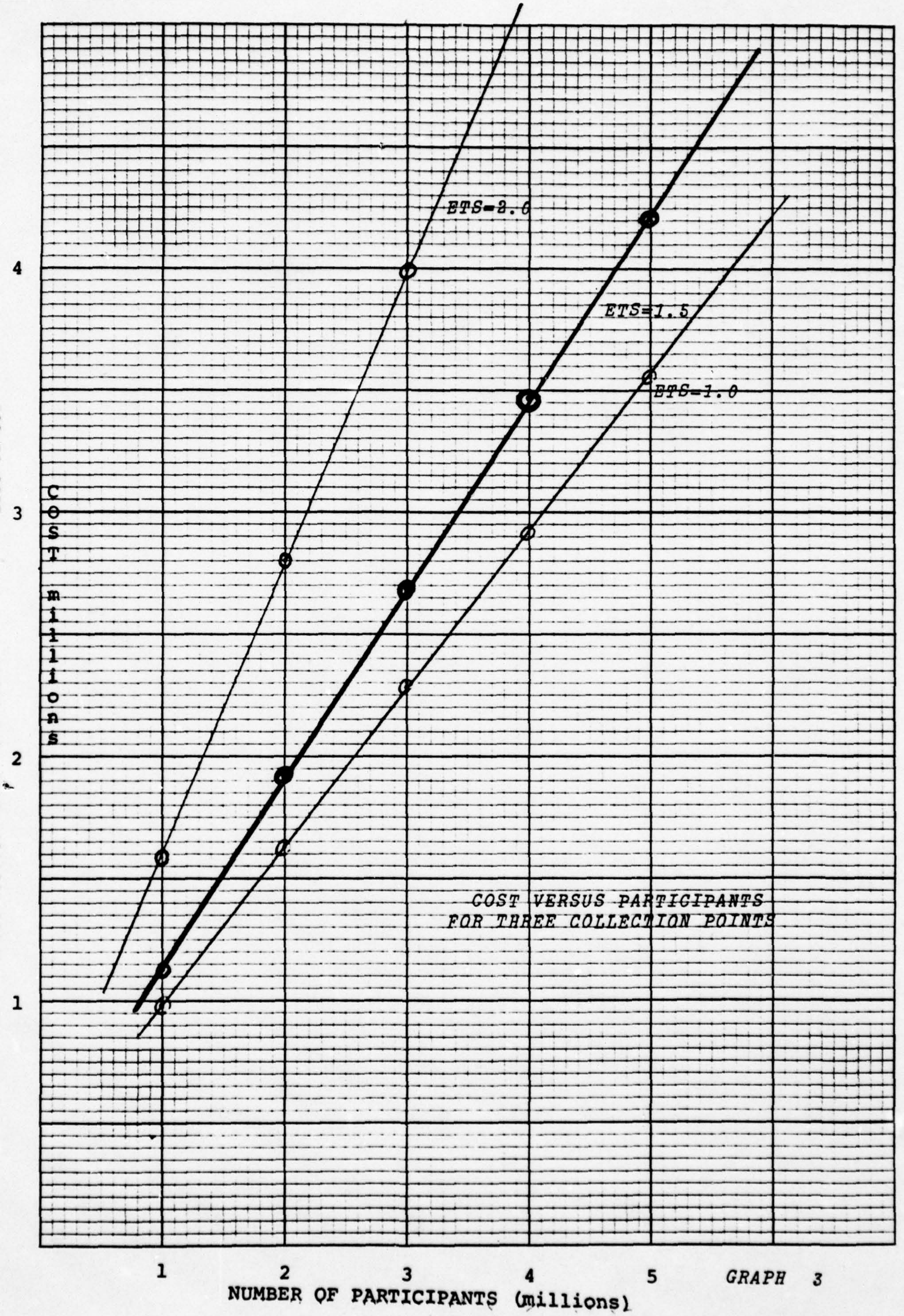


ETS=2.0
ETS=1.5
ETS=1.0
COST VERSUS PARTICIPANTS
FOR ONE COLLECTION POINT
COST millions
NUMBER OF PARTICIPANTS (millions)
1
2
3
4
5

GRAPH 1


ETS=2.0
ETS=1.5
ETS=1.0
COST millions
1
2
3
4
1
2
3
4
5
COST VERSUS PARTICIPANTS
FOR TWO COLLECTION POINTS
NUMBER OF PARTICIPANTS (millions)

GRAPH 2



ETS=2.0
ETS=1.5
ETS=1.0
COST VERSUS PARTICIPANTS
FOR THREE COLLECTION POINTS
COST millions
1
2
3
4
1
2
3
4
5
NUMBER OF PARTICIPANTS (millions)

GRAPH 3

VIII. SUMMARIZATION

Following the recommendation of Commander, Pacific Area for the Coast Guard to implement the Marine Voyage Safety System, the Operations Analysis Branch of Commander, Atlantic Area was directed to conduct a feasibility study and technical analysis of the proposed float plan system.

Summarizing the phases of this operations research study, we have thus far

(1) Formulated the problem

(2) Constructed a mathematical model to represent the system

(3) Derived a solution from the model

(4) Tested the model and the solution derived from it and identified the critical input parameters

The final phase of the study would be the implementation of a system based on the results of the study as approved by the decision-makers. This phase is a critical one since it is here, and only here, that the benefits of the study are reaped. However, the purpose of this study was only to determine the possibility and feasibility of adapting MARVSS to a computer system. Therefore, before implementation can be considered, a careful explanation of the results of the study and how they relate to operating realities is necessary.

The designed system would consist of a centralized computer center with a dedicated computer used to maintain boat data file and the individual float plan file. In keeping with the definition of a real-time system (each transaction processed as it occurs), the boat operator would initiate and terminate his or her float plan via toll free WATS telephone services. Each RCC would be outfitted with a CRT terminal and printer. Upon notification to the RCC of an overdue, the rescue center would call the appropriate MARVSS data collection center and get a replay of the entire voice conversation between the boater and the MARVSS operator, allowing the controller to evaluate the accuracy of the float plan on file and the degree of urgency in the particular situation.

As previously shown, the cost for such a system, based on 1974 prices, for the initial five year period would range from approximately seven million dollars for one million participants per year to twenty-five million dollars for five million participants per year.

The idea of a small vessel float plan system as conceived by Commander, Pacific Area, if implemented should be automated thru computerization. The task of trying to maintain accurate records at either a local, district or national level without the aid of computers would be completely unmanageable. There are and will be considerations to be made, however, before final authority to computerize MARVSS can be justified.

The adoption of a small vessel float plan system would be a step forward in providing service to the boating population. With the adoption of such a system, the Coast Guard would assume a degree of legal responsibility for the safety of the boater. Therefore, before the system can be implemented, the question of legal responsibility should be resolved.

The levels of participation of the boating public will be dependent upon the size and classes of vessels allowed to participate and/or the type of voyage for which a particular boat would be allowed to submit a float plan. Because the level of participation is critical to the operation of the system, controls over who will be allowed to participate in MARVSS must be established and justified before implementation.

The variation in the amount of boating activity, and likewise the expected level of participation in MARVSS, will be an important factor in determining personnel requirements for manning central site terminals. The required number of personnel at the MARVSS Center will vary during the course of the year. Although it would be desired that the number of Coast Guard personnel at the center be minimal, there will definitely be personnel management problems encountered when trying to maintain a variable civilian work force that will be required to work nights and weekends.

A high level of participation will also result in a large number of false overdues or boaters, who safely reach port and fail to call the MARVSS Center and terminate their float plan.

The most important consideration as to whether or not MARVSS should be implemented is the cost versus derived benefit from such a system. The system designed by this study was not based strictly on minimun cost figures. Some alternatives were chosen because it was felt that operationally they provided a more reliable real-time system. To determine the possible derived benefit from such a system, a review of Coast Guard Assistance Reports for FY 1973 was undertaken. During this period there were 1724 cases where the time between the time of the distress incident and the time of Coast Guard notification of the distress was greater than 9 hours. Of these cases, 774 or 45 % were overdues or missing vessels. To what extent a system such as MARVSS could have benefitted the persons in distress in any of these cases is nearly impossible to determine.

As is the case with most users of data processing equipment, once their original applications are functioning well, they usually find other applications that they want automated. For this reason, it will be necessary to determine if all operational computer programs, such as AMVER, SARP and CASP, could all be centralized into one operational computer center with dedicated equipment. If the decision was made to implement a small vessel float plan system, it should be approached with the idea of centralizing all operational computer programs on one dedicated computer system. The computer terminals for the Rescue Coordination Centers as outlined in this study have already been proposed[5] by Commander, Atlantic Area for the present day operational computer SAR programs.

5. *Planning Proposal CAA-01-73, Computer Terminals for Rescue Coordination Centers (RCS GCPE-1100) dated 18 July 1973.*

CONCLUSIONS

The basic question dealt with in this study has been -- Can a Marine Voyage Safety System be adapted to automation thru computerization? The answer to this question is Yes. However, it is the opinion of this study that if the svstem were implemented for all recreational boats, the result would be an unmanageable management information system. The primary reasons for this unmanageability would be:

(1) The lack of control over false alarm overdues, that is, those boaters who safely complete their voyage but fail to terminate their float plan. Only after such a system were implemented could personnel requirements be determined for manning rescue coordination centers to provide follow ups to computer generated overdues. Most recreational boaters have a very flexible time schedule, therefore many of the schedule trips are subject to change without notice. Failure to notify the MARVSS Center of these changes would probably be a common occurrence, since the boater would consider himself safe and in no difficulty. As a practical matter, some kind of penalty would have to be assessed to a boater who repeatedly fails to terminate his float plan in a proper manner.

(2) For many local voyages, the concept of a real-time system would be impossible to maintain. Although in theory the ideas sounds good, in actual practice many

real-time computer systems have definite problems in providing up to date information due to communication delays.

(3) It does not appear that the cost of a system for all recreational boats can be justified by the limited benefits that such a system can provide. At present, there is no evidence to show that if such a system had been in effect during the last few years, that it would have had any major effect on the outcome of Coast Guard search and rescue operations.

TEST 1

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437,626	1,132,781
2	1	67	1,947,798	1,947,798
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

Service Time	1.5
Maximum probability of waiting	0.05
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437,626	1,132,781
2	1	67	1,947,798	1,947,798
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

TEST 2

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	1,054,970	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

Service Time	1.5
Maximum probability of waiting	0.15
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437.626	1,132,781
2	1	67	1,947,798	
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

TEST 4

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.0
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,056,331	1,056,331
1	1	12	312,413	
	2	31	792,348	1,104,761
1	1	12	294,263	
	2	18	420,510	
	3	19	450,566	1,165,339
2	1	67	1,951,973	1,951,973
2	1	20	508,554	
	2	54	1,439,885	1,948,439
2	1	20	475,990	
	2	30	708,170	
	3	32	760,204	1,944,364

TEST 4

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	694,453	
	2	77	2,076,022	2,770,475
3	1	27	645,866	
	2	41	992.623	
	3	44	1,073,901	2,712,390
4	1	123	3,717,531	3,717,531
4	1	34	882,859	
	2	99	2,702,964	3,585,823
4	1	34	818,814	
	2	52	1,278,344	
	3	56	1,378,583	3,475,741
5	1	146	4,552,763	4,552,763
5	1	41	1,059,145	
	2	121	3,336.715	4,395,860
5	1	41	985,763	
	2	63	1,554,627	
	3	68	1,680,974	4,221,364

TEST 5

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	2.0
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,332	1,051,332
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437,626	1,132,781
2	1	67	1,947,798	1,947,798
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.25
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,032,208	1,032,208
1	1	12	305,131	
	2	31	779,370	1,084,501
1	1	12	289,308	
	2	18	423,159	
	3	19	447,452	1,159,919
2	1	67	1,897,408	1,897,408
2	1	20	505,433	
	2	54	1,402,138	1,907,571
2	1	20	476,450	
	2	30	705,387	
	3	32	755,559	1,937,396

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,743,099	2,743,099
3	1	27	680,918	
	2	77	2,023,301	2,704,219
3	1	27	639,311	
	2	41	982,041	
	3	44	1,052,463	2,673,815
4	1	123	3,587,144	3,587,144
4	1	34	858,710	
	2	99	2,632,657	3,491,367
4	1	34	804,067	
	2	52	1,250,708	
	3	56	1,357,788	3,412,563
5	1	146	4,385,960	4,385,960
5	1	41	1,044,608	
	2	121	3,247,720	4,292,328
5	1	41	976,272	
	2	63	1,528,742	
	3	68	1,658,615	4,163,629

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.75
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,089,845	1,089,845
1	1	12	307,925	
	2	31	807,531	1,115,456
1	1	12	288,153	
	2	18	418,232	
	3	19	444,358	1,150,743
2	1	67	2,025,553	2,025,553
2	1	20	501,008	
	2	54	1,469,774	1,970,782
2	1	20	464,510	
	2	30	724,588	
	3	32	773.341	1,962,439

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,931,665	2,931,665
3	1	27	705,141	
	2	77	2,130,737	2,835,878
3	1	27	651,029	
	2	41	1,005,805	
	3	44	1,087,561	2,744,395
4	1	123	3,849,144	3,849,144
4	1	34	891,807	
	2	99	2,784,866	3,676,673
4	1	34	822,331	
	2	52	1,292,376	
	3	56	1,406,688	3,521,395
5	1	146	4,707,546	4,707,546
5	1	41	1,088,009	
	2	121	3,426,131	4,514,140
5	1	41	1,001,011	
	2	63	1,584,354	
	3	68	1,720,643	4,306,008

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.05
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	32	1,002,610	1,002,610
1	1	10	290,504	
	2	26	751,519	1,042,023
1	1	10	272,354	
	2	15	386,925	
	3	16	414,586	1,073,865
2	1	59	1,875,998	1,875,998
2	1	17	473,655	
	2	47	1,375,447	1,849,102
2	1	17	440,733	
	2	25	667,841	
	3	27	715,476	1,824,050

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	85	2,739.022	2.739,022
3	1	23	655.369	
	2	68	1,991,208	2,646,577
3	1	23	607,099	
	2	35	938,441	
	3	38	1,018,471	2,564,011
4	1	111	3,592,099	3,592,099
4	1	29	837,045	
	2	88	2,597,562	3,434,607
4	1	29	773,445	
	2	45	1,213,441	
	3	49	1,317,005	3,303,891
5	1	136	4,447,169	4,447,169
5	1	35	1,006,203	
	2	108	3,215,499	4,221,702
5	1	35	933,152	
	2	55	1,484,842	
	3	60	1,609,247	4,027,241

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	2.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,062,593	1,062,593
1	1	12	312,413	
	2	31	793,183	1,105,596
1	1	12	294,263	
	2	18	418,840	
	3	19	446,392	1,159,495
2	1	67	1,954,060	1,954,060
2	1	20	503,545	
	2	54	1,440,720	1,944,265
2	1	20	470,981	
	2	30	709,005	
	3	32	762,291	1,942,277

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,839,039	2,839,039
3	1	27	696,540	
	2	77	2,077,692	2,774,232
3	1	27	647,953	
	2	41	995,545	
	3	44	1,075,988	2,719,486
4	1	123	3,719,618	3,719,618
4	1	34	882,859	
	2	99	2,710,061	3,592,920
4	1	34	821,736	
	2	52	1,280,431	
	3	56	1,379,418	3,481,585
5	1	146	4,554,850	4,554,850
5	1	41	1,059,979	
	2	121	3,338,802	4,398,781
5	1	41	986,597	
	2	63	1,559,637	
	3	68	1,680,974	4,227,205

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	4.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437,626	1,132,781
2	1	67	1,947,798	1,947,798
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.025

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	309,491	
	2	31	790,261	1,099,752
1	1	12	291,341	
	2	18	412,579	
	3	19	442,635	1,146,555
2	1	67	1,951,973	1,951,973
2	1	20	500,623	
	2	54	1,437,798	1,938,421
2	1	20	468,059	
	2	30	708,170	
	3	32	757,282	1,933,511

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	691,531	
	2	77	2,076,022	2,767,553
3	1	27	642,944	
	2	41	990,536	
	3	44	1,071,814	2,705,294
4	1	123	3,715,443	3,715,443
4	1	34	878,684	
	2	99	2,700,877	3,579,561
4	1	34	814,640	
	2	52	1,276,674	
	3	56	1,378,583	3,469,897
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,554,627	
	3	68	1,680,974	4,217,189

Service Time	1.5
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.075

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	38	1,051,322	1,051,322
1	1	12	304,900	
	2	31	790,261	1,095,161
1	1	12	286,750	
	2	18	408,405	
	3	19	437,626	1,132,781
2	1	67	1,947,798	1,947,798
2	1	20	495,614	
	2	54	1,435,710	1,931,324
2	1	20	463,050	
	2	30	706,500	
	3	32	755,195	1,924,745

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	95	2,836,951	2,836,951
3	1	27	687,357	
	2	77	2,073,935	2,761,292
3	1	27	638,769	
	2	41	988,449	
	3	44	1,069,726	2,696,944
4	1	123	3,715,443	3,715,443
4	1	34	877,849	
	2	99	2,698,790	3,576,639
4	1	34	813,805	
	2	52	1,272,500	
	3	56	1,376,496	3,462,801
5	1	146	4,552,763	4,552,763
5	1	41	1,054,970	
	2	121	3,336,715	4,391,685
5	1	41	981,588	
	2	63	1,552,540	
	3	68	1,676,800	4,210,928

TEST 13

Service Time	1.6
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	27	764,231	764,231
1	1	10	256,523	
	2	23	628,147	884,670
1	1	10	256,599	
	2	13	354,846	
	3	14	380,964	992,409
2	1	48	1,402,466	1,402,466
2	1	15	400,016	
	2	39	1,122,509	
2	1	15	400,016	
	2	22	596,977	
	3	23	639,270	1,636,263

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	67	2,023,466	2,023,466
3	1	20	539,453	
	2	30	1,606,979	2,146,432
3	1	20	539,668	
	2	30	850,074	
	3	32	908,780	2,298,522
4	1	86	2,633,282	2,633,282
4	1	25	687,339	
	2	69	2,091,283	2,778,622
4	1	25	687,339	
	2	37	1,073,644	
	3	40	1,165,164	2,926,147
5	1	105	3,242,469	3,242,469
5	1	29	827,858	
	2	84	2,567,787	3,395,645
5	1	29	828,397	
	2	45	1,317,996	
	3	48	1,417,427	3,563,820

Service Time	2.0
Maximum probability of waiting	0.1
Expected delay time for customer who waits	1.5
Expected overall wait time	0.5
Probability of a busy signal	0.01
Maximum allowable wait time	3.0
Probability of maximum wait time	0.05

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
1	1	48	1,334,569	1,334,569
1	1	15	392,758	
	2	39	1,074,032	1,466,790
1	1	15	392,834	
	2	22	581,566	
	3	23	622,674	1,597,074
2	1	86	2,500,551	2,500,551
2	1	25	668,548	
	2	69	1,989,591	2,658,139
2	1	25	668,605	
	2	37	1,028,457	
	3	40	1,105,948	2,803,010

TEST 14

Participants (Millions)	Collection Point	# WATS lines	Cost	Total Cost Per Year
3	1	123	3,649,285	3,649,285
3	1	34	927,388	
	2	99	2,901,823	3,829,211
3	1	34	929,058	
	2	52	1,472,632	
	3	56	1,595,769	3,997,459
4	1	144	4,641,406	4,641,406
4	1	43	1,195,050	
	2	128	3,792,640	4,987,690
4	1	43	1,195,845	
	2	67	1,913,371	
	3	72	2,069,644	5,178,860
5	1	177	5,741,494	5,741,494
5	1	51	1,449,618	
	2	145	4,574,936	6,024,554
5	1	51	1,449,683	
	2	81	2,349,639	
	3	87	2,538,603	6,337,925