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OPTIMIZATION OF SERVICE — EQUIPMENT FLEET BY SIMULATION

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Abstract:

The optimization of service — equipment fleet involves multiple variables, many of which are non-deterministic in nature. The demand for fleet services is normally time and zone dependent and follows certain random distributions. The type and size of the fleet affect the level of the services rendered and is a function of the initial investment, the operational costs and the desired service quality. This paper gives an application of a simulation approach for planning the optimal fleet of fire-fighting equipment for a given municipality. The area under study is divided into a commercial/industrial zone and a residential zone. Possible fires and their intensities are described by stochastic variables that are time, zone and service dependent. In addition to the local equipment that is made available, possible assistance from neighbouring localities may be rendered subject to given priorities, constraints, costs and penalties. A simulation model using GUSS (General Utility Simulation System) is used to determine the optimal fleet.

I. INTRODUCTION

Equipment planning, be it the type, number or replacement schedules, is a major preoccupation for scientists and engineers. It normally involves major decisions that, once made, not only commit a major capital allocation, but also a given capacity and quality of service and an impact on the environment. Careful studies are therefore justified to ensure the selection of an optimum decision.

Analytical optimization models, even when they are simple in structure, become difficult to solve as a result of the interaction of the different problem variables and their stochastic nature. This is rather evident in models of service equipment such as trucks, autos, fork lift trucks, etc., where the demand is stochastic in nature. In such a case, the simulation provides an efficient tool for determining an optimal solution. This paper presents a simulation application for the determination of the optimal number of fire trucks for a fire-fighting centre.

II. PROBLEM FORMULATION

The objective is set to determine the optimum number of fire-fighting equipment for a fire-fighting centre to meet the needs of a given region. The type of equipment is selected in advance based on the available technology. It is clear that the services offered by the centre correspond, for a given type, to the number of pieces of equipment available. Figure 1 shows an example of such a relationship.

For this problem, the region where this service is planned is divided into different districts, each characterized by its distinct parameters such as its distance from the centre, its nature w.r.t. its service needs, etc. For example, the distance between the centre and a given district influences the delay before the arrival of the equipment and is stochastic in nature with a given probability distribution. The district's nature reflects the probability of a service call and the intensity of the demand. Following is a list of the variables and hypotheses assumed in this study:

II.1 - Nature of demand

The possibility of a fire depends on the nature of the district as follows:

a) Fire occurrence

Figure 2 shows a distribution of fire occurrence in two districts, one residential and the other commercial, each with its probability distribution of demand given by:

NAT(i,j) = probability for a service need, i.e. a fire break, in district i during the interval j; a stochastic variable.

b) Demand intensity

The intensity of the demand, fire in this case, depends on different factors. Such factors are classified in two major categories:

i. Linear factors : those that increase the fire such as the type of building, its age, etc.

ii. Exponential factors : those that exponentially increase the fire such as the contents of the building of chemical materials, etc.

At the end of each period, the intensity of the demand is changed as follows:

$$GRAN(i) = f(X_{ij}, Y_{ik}) \; \forall_{i,j,k} \qquad (1)$$

where:

X_{ij} = effect of linear factor #j on demand #i; j = 1, ..., m

Y_{ik} = effect of exponential factor #k on demand #i; k = 1, ..., n

The following function is adopted in this study:

$$GRAN(i) = \frac{1}{2}\left[\frac{1}{m}\sum_{j=1}^{m} x_{ij} + e^{-n}\sum_{k=1}^{n} y_{ik}\right] \forall i \qquad (2)$$

where with

m = # of linear factors
n = # of exponential factors

and $0 \leqslant GRAN(i) \leqslant 1$

II.2 Delay

The arrival time of a piece of equipment to its destination where a demand has originated is a function of both deterministic variables, such as the distance between the service centre and the demand origin, as well as stochastic ones such as congestions and route conditions at the time of the demand. A delay in equipment arrival may result in increasing the intensity of the demand. Supposing therefore:

DELMAX(i) = maximum delay possible normally between the need i and the arrival of equipment.

DELAI = a random factor with $0 \leqslant DELAI \leqslant 1$

$$DEL(i) = DELAI * DELMAX(i) \qquad (3)$$

where

DEL(i) = possible delay before the arrival of equipment to demand #i.

The effect of the delay on the demand intensity can then be expressed as follows:

$$GRAND(i) = GRAN(i) * \left[1 + DEL(i)\right] \qquad (4)$$

where

GRAND(i) = the demand intensity at the arrival of equipment, with $0 \leqslant GRAND(i) \leqslant 1$

II.3 - Assignment of Equipment

After a call for equipment services arrives to the centre, the demand is expressed in terms of its intensity and the efficiency of equipment into a number of units (equipment) for a certain service time. In addition to equipment locally available to a centre, additional help can normally be called upon from neighbouring centres for some costs, normally higher than those for local equipment. An operational policy is normally established at a centre such as:

a) A piece of equipment that is serving at a given location at present period will remain there for the next one unless the demand is totally met or priorities have changed.

b) A priority system is established among requests for the service.

c) A higher priority is given to a demand with higher intensity.

d) The call for outside assistance is called upon only after all local equipment has been assigned.

e) Other policies.

After a call for service is received, the demand is translated, e.g. Figure 1, into a given number of equipment NCN(i), necessary to meet the demand. A decision for equipment assignment is then made.

II.4 - Cost

In this study, two types of costs are included:

a) Operational Cost

This includes both direct and indirect costs incurred for the service and could be expressed per unit of equipment dispatched. The operational cost of a certain demand can therefore be calculated based on the number of units assigned and the service duration as follows:

$$COP(i) = CU * NCS(i) \qquad (5)$$

where

COP(i) = operational cost for demand i per period

CU = operational cost, direct and indirect, for a piece of equipment.

NCS(i) = # of pieces of equipment assigned to demand #i.

b) Damage Cost

The number of equipment assigned to a demand affects the quality of the service, e.g., the ability to control fires. The amount of damage incurred is a function of the equipment shortage and the demand intensity. The following function is assumed in this study:

$$CDG(i) = CDVAR * GRAND(i) * \left[\frac{NCN(i)}{NCS(i)}\right] \qquad (6)$$

where

CDG(i) = anticipated damage cost for the i th demand

CDVAR = possible damage cost, a random variable.

II.5 - The Simulation

In order to determine the optimum number of pieces of equipment, n, to have at the centre, the call for services and the effected response are simulated for different values of n = 1, 2, ... In this study, the simulation is effected using GUSS, "General Utility Simulation System", [1]. The choice of GUSS was made based on its flexibility and advantages for such a study. The equipment-planning model is written in FORTRAN and is submitted as a sub-routine to GUSS. The results of the analysis are presented in tables 1, 2 and 3 and figures 1, 2 and 3.

III. CONCLUSION

This application shows how simulation can aid in studying complex and stochastic models. It can be applicable to different cases where the demand on equipment services assumes a stochastic nature.

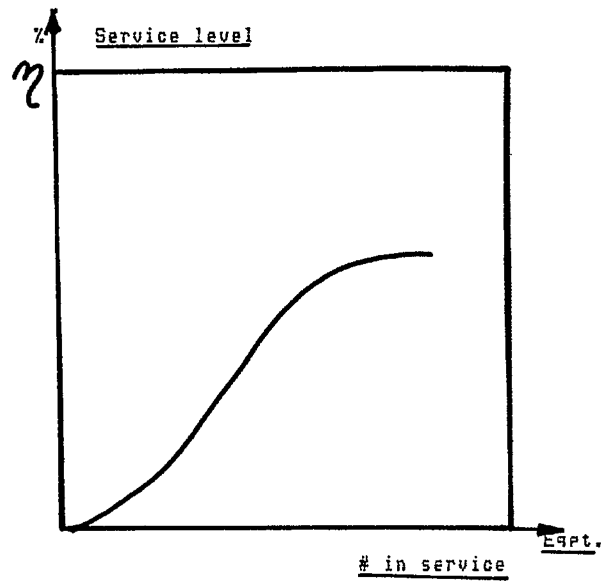

Fig. 1: SERVICE LEVEL

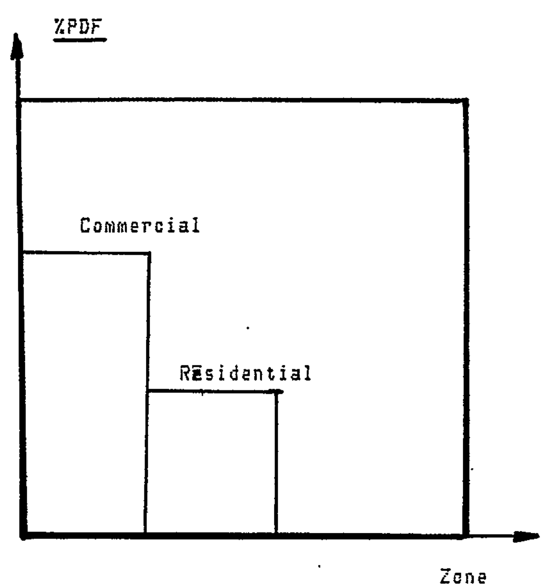

Fig. 2: Probability of service need by zone.

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*                                  FIRE STATION  X-TRA                                  *
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INTEGER CONSTANTS & INDEXES

NUMBER OF AVAILABLE LOCAL EQUIPMENT AT THE STATION	=	10
MAX. NUMBER OF AVAILABLE LOCAL EQUIPMENT AT THE OUTSIDE	=	3
MAX. NUMBER OF EQUIPMENT AT THE COMMERCIAL SERVICE	=	6
MAX. NUMBER OF EQUIPMENT AT THE RESIDENTIAL SERVICE	=	2
NUMBER OF LINEAR FACTORS -------- COMMERCIAL	=	1
NUMBER OF EXPONENTIAL FACTORS -- COMMERCIAL	=	1
NUMBER OF LINEAR FACTORS -------- RESIDENTIAL	=	1
NUMBER OF EXPONENTIAL FACTORS --- RESIDENTIAL	=	1
MAX. NUMBER OF SIMULTANEOUS SERVICES	=	4

DETERMINISTIC VARIABLES

SET COST OF THE OPERATION	0.40000E+06
OPERATING COST OF A PIECE OF EQUIPMENT FOR 1 HOUR	0.10000E+03
OPERATING COST AT ASSISTING EQUIPMENT FOR 1 HOUR	0.30000E+03
PROBALILITY OF NOT HAVING FIRE IN A GIVEN PERIOD	0.86000E+02

INPUT RANDOM VARIABLES

CUM.PCT	NUMBER OF SIMULTANEOUS FIRES	NUMBER OF EXT. TRUCKS AVAILABLE AT SUPPORTING LOCALITIES	NUMBER OF SUPPORTING EQUIPMENT TO RETURN	DISTRIBUTION OF FIRE FOR RESIDENTIAL OR COMMERC. SECTOR	DISTRUBUTION OF FIRE FOR RESIDENTIAL OR COMMERC. SECTOR	DISTRIBUTION OF FIRE FOR RESIDENTIAL OR COMMERC. SECTOR
0.	0.10000E+01	0.0	0.0	0.0	0.0	0.0
5.	0.10000E+01	0.0	0.0	0.0	0.0	0.0
10.	0.10000E+01	0.10000E+01	0.0	0.0	0.0	0.0
15.	0.10000E+01	0.10000E+01	0.0	0.0	0.0	0.0
20.	0.10000E+01	0.10000E+01	0.0	0.0	0.0	0.0
25.	0.10000E+01	0.10000E+01	0.0	0.0	0.0	0.0
30.	0.10000E+01	0.20000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
35.	0.10000E+01	0.20000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
40.	0.10000E+01	0.20000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
45.	0.10000E+01	0.20000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
50.	0.10000E+01	0.30000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
55.	0.20000E+01	0.30000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
60.	0.20000E+01	0.30000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
65.	0.20000E+01	0.40000E+01	0.0	0.10000E+01	0.10000E+01	0.10000E+01
70.	0.20000E+01	0.40000E+01	0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+01
75.	0.20000E+01	0.50000E+01	0.20000E+01	0.10000E+01	0.10000E+01	0.10000E+01
80.	0.30000E+01	0.50000E+01	0.30000E+01	0.10000E+01	0.10000E+01	0.10000E+01
85.	0.30000E+01	0.60000E+01	0.40000E+01	0.10000E+01	0.10000E+01	0.10000E+01
90.	0.30000E+01	0.70000E+01	0.50000E+01	0.10000E+01	0.10000E+01	0.10000E+01
95.	0.40000E+01	0.80000E+01	0.60000E+01	0.10000E+01	0.10000E+01	0.10000E+01
100.	0.40000E+01	0.90000E+01	0.70000E+01	0.10000E+01	0.10000E+01	0.10000E+01
DIST. TYPE	0.	0.	0.	0.	0.	0.

0=DISCRETE, 1=CONTINUOUS

Table 1: S I M U L A T I O N R E S U L T S

INPUT RANDOM VARIABLES

CUM.PCT	DELAY FOR RESIDENTIAL SECTOR	DELAY FOR RESIDENTIAL SECTOR	DELAY FOR RESIDENTIAL SECTOR	COST OF DAMAGE COMMERCIAL SECTOR $	COST OF DAMAGE COMMERCIAL SECTOR $	COST OF DAMAGE COMMERCIAL SECTOR $
0.	0.0	0.0	0.0	0.20000E+04	0.20000E+04	0.20000E+04
5.	0.0	0.0	0.0	0.50000E+04	0.50000E+04	0.50000E+04
10.	0.0	0.0	0.0	0.10000E+05	0.10000E+05	0.10000E+05
15.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
20.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
25.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
30.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
35.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
40.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
45.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
50.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
55.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
60.	0.0	0.0	0.0	0.15000E+05	0.15000E+05	0.15000E+05
65.	0.0	0.0	0.0	0.20000E+05	0.20000E+05	0.20000E+05
70.	0.0	0.0	0.0	0.20000E+05	0.20000E+05	0.20000E+05
75.	0.0	0.0	0.0	0.25000E+05	0.25000E+05	0.25000E+05
80.	0.0	0.0	0.0	0.25000E+05	0.25000E+05	0.25000E+05
85.	0.0	0.0	0.0	0.30000E+05	0.30000E+05	0.30000E+05
90.	0.0	0.0	0.0	0.35000E+05	0.35000E+05	0.35000E+05
95.	0.10000E+01	0.10000E+01	0.10000E+01	0.40000E+05	0.40000E+05	0.40000E+05
100.	0.10000E+01	0.10000E+01	0.10000E+01	0.45000E+05	0.45000E+05	0.45000E+05
DIST. TYPE	0.	0.	0.	1.	1.	1.

0=DISCRETE, 1=CONTINUOUS

INPUT RANDOM VARIABLES

CUM.PCT	COST OF DAMAGE COMMERCIAL SECTOR $	COST OF DAMAGE RESIDENTIAL SECTOR $	COST OF DAMAGE RESIDENTIAL SECTOR $	COST OF DAMAGE RESIDENTIAL SECTOR $	COST OF DAMAGE RESIDENTIAL SECTOR $	LINEAR FACTOR COMMERCIAL
0.	0.20000E+04	0.30000E+03	0.30000E+03	0.30000E+03	0.30000E+03	0.0
5.	0.50000E+04	0.10000E+04	0.10000E+04	0.10000E+04	0.10000E+04	0.10000E+01
10.	0.10000E+05	0.20000E+04	0.20000E+04	0.20000E+04	0.20000E+04	0.13000E+01
15.	0.15000E+05	0.30000E+04	0.30000E+04	0.30000E+04	0.30000E+04	0.20000E+01
20.	0.15000E+05	0.40000E+04	0.40000E+04	0.40000E+04	0.40000E+04	0.26000E+01
25.	0.15000E+05	0.40000E+04	0.40000E+04	0.40000E+04	0.40000E+04	0.30000E+01
30.	0.15000E+05	0.50000E+04	0.50000E+04	0.50000E+04	0.50000E+04	0.35000E+01
35.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.41000E+01
40.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.43000E+01
45.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.45000E+01
50.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.47000E+01
55.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.48000E+01
60.	0.15000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.51000E+01
65.	0.20000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.53000E+01
70.	0.20000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.55000E+01
75.	0.25000E+05	0.60000E+04	0.60000E+04	0.60000E+04	0.60000E+04	0.59000E+01
80.	0.25000E+05	0.65000E+04	0.65000E+04	0.65000E+04	0.65000E+04	0.63000E+01
85.	0.30000E+05	0.70000E+04	0.70000E+04	0.70000E+04	0.70000E+04	0.68000E+01
90.	0.35000E+05	0.80000E+04	0.80000E+04	0.80000E+04	0.80000E+04	0.75000E+01
95.	0.40000E+05	0.90000E+04	0.90000E+04	0.90000E+04	0.90000E+04	0.85000E+01
100.	0.45000E+05	0.10000E+05	0.10000E+05	0.10000E+05	0.10000E+05	0.10000E+02
DIST. TYPE	1.	1.	1.	1.	1.	1.

0=DISCRETE, 1=CONTINUOUS

Table 1: S I M U L A T I O N R E S U L T S

Cont.

INPUT RANDOM VARIABLES

CUM.PCT	LINEAR FACTOR COMMERCIAL	LINEAR FACTOR COMMERCIAL	LINEAR FACTOR COMMERCIAL	EXPONENTIAL FACTOR COMMERCIAL	EXPONENTIAL FACTOR COMMERCIAL	EXPONENTIAL FACTOR COMMERCIAL
0.	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+00	0.10000E+00	0.10000E+00
10.	0.13000E+01	0.13000E+01	0.13000E+01	0.20000E+00	0.20000E+00	0.20000E+00
15.	0.20000E+01	0.20000E+01	0.20000E+01	0.31000E+00	0.31000E+00	0.31000E+00
20.	0.26000E+01	0.26000E+01	0.26000E+01	0.36000E+00	0.36000E+00	0.36000E+00
25.	0.30000E+01	0.30000E+01	0.30000E+01	0.41000E+00	0.41000E+00	0.41000E+00
30.	0.39000E+01	0.39000E+01	0.39000E+01	0.45000E+00	0.45000E+00	0.45000E+00
35.	0.41000E+01	0.41000E+01	0.41000E+01	0.47000E+00	0.47000E+00	0.47000E+00
40.	0.43000E+01	0.43000E+01	0.43000E+01	0.50000E+00	0.50000E+00	0.50000E+00
45.	0.45000E+01	0.45000E+01	0.45000E+01	0.55000E+00	0.55000E+00	0.55000E+00
50.	0.47000E+01	0.47000E+01	0.47000E+01	0.62000E+00	0.62000E+00	0.62000E+00
55.	0.49000E+01	0.49000E+01	0.49000E+01	0.68000E+00	0.68000E+00	0.68000E+00
60.	0.51000E+01	0.51000E+01	0.51000E+01	0.70000E+00	0.70000E+00	0.70000E+00
65.	0.53000E+01	0.53000E+01	0.53000E+01	0.72000E+00	0.72000E+00	0.72000E+00
70.	0.55000E+01	0.55000E+01	0.55000E+01	0.74000E+00	0.74000E+00	0.74000E+00
75.	0.59000E+01	0.59000E+01	0.59000E+01	0.76000E+00	0.76000E+00	0.76000E+00
80.	0.63000E+01	0.63000E+01	0.63000E+01	0.81000E+00	0.81000E+00	0.81000E+00
85.	0.69000E+01	0.69000E+01	0.69000E+01	0.85000E+00	0.85000E+00	0.85000E+00
90.	0.75000E+01	0.75000E+01	0.75000E+01	0.90000E+00	0.90000E+00	0.90000E+00
95.	0.85000E+01	0.85000E+01	0.65000E+01	0.96000E+00	0.96000E+00	0.96000E+00
100.	0.10000E+02	0.10000E+02	0.10000E+02	0.10000E+01	0.10000E+01	0.10000E+01
DIST. TYPE	1.	1.	1.	1.	1.	1.

INPUT RANDOM VARIABLES

CUM.PCT	EXPONENTIAL FACTOR COMMERCIAL	LINEAR FACTOR RESIDENTIAL	LINEAR FACTOR RESIDENTIAL	LINEAR FACTOR RESIDENTIAL	LINEAR FACTOR RESIDENTIAL	EXPONENTIAL FACTOR RESIDENTIAL
0.	0.0	0.0	0.0	0.0	0.0	0.0
5.	0.10000E+00	0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+00
10.	0.20000E+00	0.14000E+01	0.14000E+01	0.14000E+01	0.14000E+01	0.20000E+00
15.	0.31000E+00	0.19000E+01	0.19000E+01	0.19000E+01	0.19000E+01	0.33000E+00
20.	0.36000E+00	0.21000E+01	0.21000E+01	0.21000E+01	0.21000E+01	0.49000E+00
25.	0.41000E+00	0.23000E+01	0.23000E+01	0.23000E+01	0.23000E+01	0.60000E+00
30.	0.45000E+00	0.25000E+01	0.25000E+01	0.25000E+01	0.25000E+01	0.66000E+00
35.	0.47000E+00	0.27000E+01	0.27000E+01	0.27000E+01	0.27000E+01	0.70000E+00
40.	0.50000E+00	0.28000E+01	0.28000E+01	0.28000E+01	0.28000E+01	0.73000E+00
45.	0.55000E+00	0.28500E+01	0.28500E+01	0.28500E+01	0.28500E+01	0.76000E+00
50.	0.62000E+00	0.29000E+01	0.29000E+01	0.29000E+01	0.29000E+01	0.79000E+00
55.	0.68000E+00	0.32000E+01	0.32000E+01	0.32000E+01	0.32000E+01	0.82000E+00
60.	0.70000E+00	0.36000E+01	0.36000E+01	0.36000E+01	0.36000E+01	0.84000E+00
65.	0.72000E+00	0.42000E+01	0.42000E+01	0.42000E+01	0.42000E+01	0.86000E+00
70.	0.74000E+00	0.48000E+01	0.48000E+01	0.48000E+01	0.48000E+01	0.88000E+00
75.	0.76000E+00	0.57000E+01	0.57000E+01	0.57000E+01	0.57000E+01	0.90000E+00
80.	0.81000E+00	0.66000E+01	0.66000E+01	0.66000E+01	0.66000E+01	0.92000E+00
85.	0.85000E+00	0.77000E+01	0.77000E+01	0.77000E+01	0.77000E+01	0.93000E+00
90.	0.90000E+00	0.85000E+01	0.85000E+01	0.85000E+01	0.85000E+01	0.95000E+00
95.	0.96000E+00	0.94000E+01	0.94000E+01	0.94000E+01	0.94000E+01	0.98000E+00
100.	0.10000E+01	0.10000E+02	0.10000E+02	0.10000E+02	0.10000E+02	0.10000E+01
DIST. TYPE	1.	1.	1.	1.	1.	1.

0=DISCRETE, 1=CONTINUOUS

Table 1: S I M U L A T I O N R E S U L T S

Cont.

SUMMARY STATISTICS

DISTRIBUTION SUMMARY

PCT.	1	2	3	4	5	6	7
100.0000	0.30000E+01	0.20000E+01	0.80000E+01	0.80000E+01	0.0	0.12566E+04	0.33950E+05
90.0000	0.10000E+01	0.10000E+01	0.20000E+01	0.20000E+01	0.0	0.65662E+03	0.45010E+04
80.0000	0.0	0.0	0.10000E+01	0.10000E+01	0.0	0.55662E+03	0.16220E+04
70.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
60.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
50.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
40.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
30.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
20.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
10.0000	0.0	0.0	0.0	0.0	0.0	0.55662E+03	0.0
0.5000	0.0	0.0	0.0	0.0	0.0	0.45662E+03	0.0

DISTRIBUTION PARAMETERS

MEAN	0.18000E+00	0.21500E+00	0.52500E+00	0.52500E+00	0.0	0.58509E+03	0.16475E+04
ST. DEV.	0.53628E+00	0.48865E+00	0.11745E+01	0.11745E+01	0.0	0.63108E+02	0.46844E+04

COLUMN TITLES :

COLUMN 1 : DIST. OF NUMBER OF FIRES IN COMMERCIAL ZONE

COLUMN 2 : DIST. OF NUMBER OF FIRES IN RESIDENTIAL ZONE

COLUMN 3 : DIST. OF NUMBER OF NECESSARY EQUIPMENT BY PERIOD

COLUMN 4 : DIST. OF NUMBER OF EQUIPMENT IN SERVICE

COLUMN 5 : DIST. OF NUMBER OF PRESENTLY ASSISTING EQUIPMENT

COLUMN 6 : DIST. OF OPERATING COST FOR THE PERIOD

COLUMN 7 : DIST. OF DAMAGE COST FOR THE PERIOD

Table 2: S I M U L A T I O N R E S U L T S

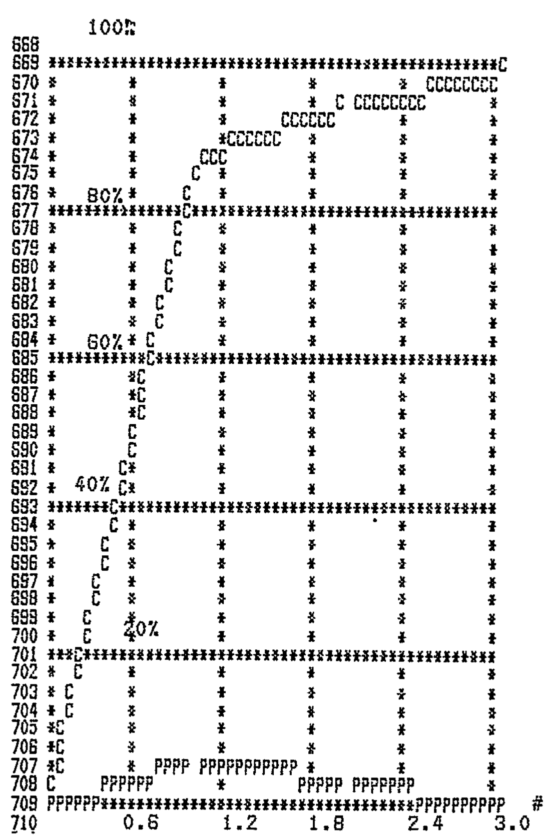

Figure 3:

DISTRIBUTION OF FIRES IN COMMERCIAL ZONE (C: CDF; P: PDF)

NO. EQPT	OPERATING μ	OPERATING σ	DAMAGE μ	DAMAGE σ	TOTAL μ	TOTAL σ
1	334	224	2178	5831	2512	5836
2	332	220	2080	5500	2412	5504
3	325	190	1830	5039	2155	5042
4	312	120	1561	4552	1873	4553
5	356	103	1561	4552	1917	4553
6	400	88	1561	4552	1961	4553
7	448	80	1673	4714	2121	4715
8	494	93	1648	4684	2142	4685
9	539	93	1648	4684	2187	4685
10	585	93	1648	4684	2233	4685

Table 3: TOTAL COST AS A FUNCTION OF NUMBER OF EQUIPMENT

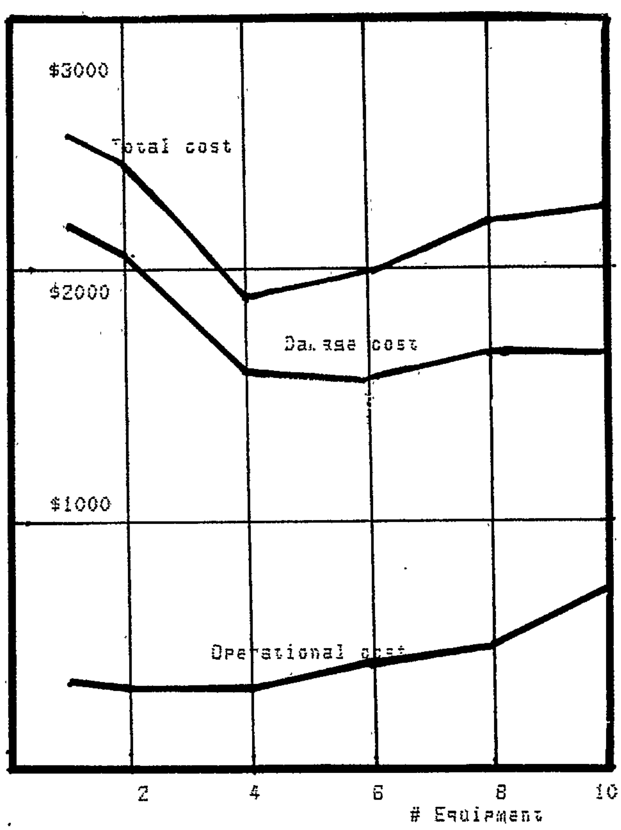

Figure 3: COSTS AS A FUNCTION [illegible]R OF # [illegible]MENT

REFERENCE:

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