EXPANSION POLICY FOR A TELEPHONE COMPANY

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ABSTRACT

Busy lines are a persistant and persuasive problem common to all telephone systems, whether it counts with the most advanced digital technology and network management or no, there will always be a period during the day on the week where telephone calls cannot be completed due to busy line with the resultant loss of revenue. If expansion programs for telephone lines were not in accordance to actual demand growth telephone calls, this problem will grow to the point where retrials would seriously impair the telephone system operation. This paper describes the use of a system dynamics model for designing and evaluating expansion policies that respond to actual demand and ameliorate problem.

1. Introduction

The aim of this paper is to describe the use of a system dynamics model to simulate the effect of demand for telephone calls on the telephone system and the response of the company to adjust the capacity of the system to process communications traffic. The case used here is that of the Mexican Telephone Company's long distance service.

The decision to initiate this project was made on the basic of strategic priority since the long distance service has always been the main revenue source of the Company and has been continously afflicted by capacity deficiencies and bad service quality problems.

System Dynamics Methodology has been used for devising policies that would ameliorate those problems and ensure adequate and stable growth in an environment of rapid economic growth.

Actual demand for telephone calls is very difficult to estimate and forecast with a sufficient degree of accuracy since all the proxy and explainning variables used to estimate demand will be affected by busy lines and will underestimate demand. However it is possible to use information of the total number of calls to the system, succesful or not, in order to obtain a better estimation of actual demand. This information is easily gathered and can be measured on a real time basis. The expansion policy designed and tested uses this information to attain a closer adjustment of the expansion of capacity to demand evolution.

2. The problem

The Mexican Telephone System is at present facing a serious problem of traffic congestion in the long-distance service. The aparent problem is the inadequacy of the existing capacity to efficiently process the actual demand for calls, caused by a structural deficiency of the acquisition policy which is common to capacity acquisition policies in capital intensive industries with long time lap between decisions and coming on a stream of equipment.

The decision of how much capacity to order each year is mainly based on a demand forecast for the third year ahead since the construction of an exchange takes that long, and the demand forecast is based on the history of tha annual total of completed calls.

Since the actual demand is not a total of calls but a pattern of demand for calls the forecasting method tends to under-estimate peak demands and to originate by compensation ever larger periods of traffic congestion which is the compounded by the absence of effective network management.

On the other hand the ursers react to the ensuing low quality of service by reatempting unsuccessful calls, thus aggravating even further the traffic congestion, leading any number of deferred or abandoned attempts to communicate, so that the annual completed calls is lesser than the actual demand it is inherent to the situation that the indicated growth trend is very substantialy and increasingly weakened.

The special danger of the existing planning situation is that apparent underestimation of demand generates a tendency towards using proportional correction factores, resulting in tentative overbudgeting which is then corrected under financial criteria and orginates orders for equipment which are unrelated with true demand both in size and in technical characteristics.

Although this is nothing new in the world of planning, it is obvious that the continuation of the described planning situation is not unavoidable in the present state of systems management techniques, and every effort must be made to apply this critical bottle-necks of growth of the fast developing economy of Mexico and it would be obviously self-defeating to try to remedy the situation by the use of a policy of over investment when it is perfectly feasible to move towards goals of adequate service at a minimum investments.

The project reported here is the result of the recognition of the problem by our communications authorities and the management of the telephone system.

It is well known fact that situations of traffic congestion plague all telephone systems regardless of the specific conditions of each country and that no two situations of systems congestion are identical.

However it may be assumed that the problem faced by Telmex could be typical for certain stages of system's development so that our attempts to cope with it and our experiences in handling it may be a useful methodological and policy guideline for planning in similar situations.

3. The approach

System Dynamics methodology has been used to develop a model for simulating the interactions and effects mentioned above.

The structure of the model is shown in the cause-effect diagram of Fig. 1.

As can be seen in Fig. 1 the model simulates: 1) The effects of the network of demand for long distance service; 2) Customer retrial behaviour in response to network congestion; and 3) System response through its capacity expansion process.

In a situation of network under capacity the level of congestion would increase the number of reattemps causing a congestion build up.

Moreover this build up would decrease the probability of completion limiting the number of completed calls which would result in a low traffic forecast and consequently in low orders for circuits aggravating even further the capacity short-fall and the network congestion.

Although the limiting of completed calls would alleviate to some extent the network congestion and the number of attemps each customers is likely to made is limited, the total number of retrials might reach a critical level where a reduction in the number of completed calls could actually happen. In addition to these effects it was pausibly assumed that, in the log range, the customer would react to low demand satisfaction by inhibiting demand. This could eventually reestablish the systems ability to meet demand, however the customers might react to the high quality service by simulating demand again this making the system to oscillate.

On the other hand, the type of the capacity adjustment involved in the acquisition policy of the Mexican Telephone Company is prone to result in an unstable pattern of orders as has been the case of other capital intensive industries where there exists long construction lags.

Therefore the purpose of this work was to use the model for devising and testing alternative capacity acquisition policies that would not only ameliorate the effects of consistent demand under forecasting and provide an adequate level of capacity but work well in the future.

4. Model Formulation

Since the porpose of this model is to simulate the effects of traffic intensity on the circuits of the transmission network for the long distance service and to determine how the circuit acquisition policy could be improved, the section of the telephone system modelled is the one including the long distance switching exchanges and the transmission network only (enclosed by the broken line in fig. 2).

It was assumed that the local exchanges have enough switching capacity to meet demand and are not affected by traffic intensity; therefore they were assigned a constant loss probability (P1) depending on its design and average age.

Thus, considering the complection of each switching step and independent event, the global probability of completion of a long distance call is calculated as:

$$Pg=(1-P1)^2\,(1-Pc)$$

where Pc is the probability of finding a busy line and is calculate, using Erlang's traffic formulas, as the average proportion of time a circuit is occupied with a succesful call or a busy number of retrails we used:

Where

R =	(D/Pg) - D
R =	Total number of retrails
D =	Actual demand for long distance calls
Pg =	Global probability of completion

This formulations implies the assumption that on average the total number of calls to the telephones system is given by the inverse of the global probability of completion times the actual demand for calls.

For calculating the orders for circuits placed each year we used the actual method used by TELMEX which can be formulated as:

$$\left[\begin{array}{c}\text{Circuit}\\\text{Order}\end{array}\right] = \left[\begin{array}{c}\text{Future}\\\text{Desired}\\\text{Capacity}\end{array}\right] - \left[\begin{array}{c}\text{Installed}\\\text{Circuit}\\\text{Capacity}\end{array}\right] - \left[\begin{array}{c}\text{Circuits}\\\text{Under}\\\text{Construction}\end{array}\right] + \left[\begin{array}{c}\text{Circuit}\\\text{Scrapping}\\\text{Programme}\end{array}\right]$$

Where the Future Desired Capacity is determined from the Adopted Traffic Forecast for the third year ahead as follows:

$$\left[\begin{array}{c}\text{Future}\\ \text{Desired}\\ \text{Capacity}\end{array}\right] = \left[\begin{array}{c}\text{Adopted}\\ \text{Traffic}\\ \text{Forecast}\end{array}\right] * \left[\begin{array}{c}\text{Desired}\\ \text{Level of}\\ \text{Circuit}\\ \text{ccupation}\end{array}\right]$$

Where the Desired Level of Circuit Occupation which in this case is a constant, will, to a great extent, determine the quality of the service provided by the system. The traffic forecast is a mathematical extrapolation of the historical trend of completed calls.

In addition to this formulation representing the structure of the systems, equations were included in the model for simulating. Demand Satisfaction calculated as:

$$\left[\begin{array}{c}\text{Demand}\\ \text{Satisfaction}\end{array}\right] = \frac{\left[\begin{array}{c}\text{Completed}\\ \text{Calls}\end{array}\right]}{\left[\begin{array}{c}\text{Demand}\\ \text{for Calls}\end{array}\right]}$$

5. Model Performance

In order to test the model performance a 30-year simulation was carried out using the present capacity acquisition policy of TELMEX (Eq. 3) and actual values for parameters such as conversation time, operation time, constriction lag, etc., under an exponential growth demand scenario.

As can be seen from Fig. 3 the effect of a traffic forecast based on completed calls is an ever windening gap between the actual demand and completed calls causing a sharp decline in demand satisfaction. Demand underforecasting results in inadequate capacity to meet demand thus producing a congestion build up and a decrease in the probability of completion

On the other hand, the effects of the capacity acquisition policy can be seen from the highly unstable pattern of annual ordes for circuits show in fig. 4. This behaviour is characteristic if this type of policy based on proportional control for correcting a discrepancy between the desired and actual values.

6. Policy Design

Aming at correcting both the capacity short-fall and the sharp variations in the pattern of orders several alternative acquisition policies were tested using the model for simulating their effects of the system.

The policies tested, apart from the actual one, were:
Policy 1.- 30% of margin of spare capacity
This policy consists in increasing the level of desired capacity for the third year ahead by a

constant margin of space capacity of 30% with the purpose of correcting the consistent deficit of capacity.

$$\left[\text{Circuit Orders}\right] = 1.3 \times \left[\text{Desired Future Capacity}\right] - \left[\text{Installed Circuit Capacity}\right] - \left[\text{Circuits Under Construction}\right] + \left[\text{Circuit Scrapping Programme}\right]$$

The results of using this policy show that although the decline in demand satisfaction is not as drastic as with the actual policy (Fig. 5). Since the improvement in demand satisfaction achieved with this policy is not worth the negative financial effects of the sharp variations in annual investment a more relevant change to the acquisition policy was used. (Fig. 6)

Policy 2.- 30% MSC and FF + FB acquisition policy

This policy involves the introduction of a feet-forward element using the average annual growth of completed calls:

$$\left[\text{Circuit Orders}\right] = 1.3 \left[\text{Desired Future Capacity}\right] - \left[\text{Installed Circuit Capacity}\right] - \left[\text{Circuits Under Construction}\right] + \left[\text{Circuit Scrapping Programme}\right] + \left[\text{Circuits Equivalent to Average Annual growth of Traffic}\right]$$

This type of policy has been proposed by Sharp and Thillainathan and studied extensively by them and the authors applied to production planning systems and to capacity acquisition systems as in this case with encouraging results.

As can be seen from Fig. 7 and Fig. 8 the use of this policy results in a considerable improvement over the previous two policies. The ratio of demand satisfaction attains a stable value at round 72% (Fig. 7) indicating a significant reduction of the capacity deficit. Moreover the pattern of orders has been stablized by the use of this policy (fig. 8) and follows a smooth path over the simulation period.

Nevertheless there still exists a gap between actual demand and completed calls that can not be explainded by the effect of the constant loss probability of 10% assigned to the local exchanges, therefore another change was proposed for the capacity acquisition policy.

Policy 3.- Variable Margin of Spare Capacity and FF + FB

It seems plausible to think that a constant margin of spare capacity would not produce satisfactory results in the long range as it runs the risk of both excess and deficit of capacity. Therefore we used the FF + FB element combined with a variable margin of spare capacity depending on the quality of the service provided by the telephone system measured as:

$$\left[\text{Quality of Service Ratio}\right] = \frac{\left[\text{Total Calls to the System}\right]}{\left[\text{Total Calls to the System}\right] - \left[\text{Completed Calls}\right]}$$

thus the margin of spare capacity in this case a function of:

$$\left[\begin{array}{l} \text{Margin of} \\ \text{Spare Capacity} \end{array} \right] = f \left[\begin{array}{l} \text{Quality of} \\ \text{Service Ration} \end{array} \right]$$

The function used for testing this policy was 45° slope straight line as shown in Fig. 9. The results of this policy show a considerable improvement in both demand satisfaction (Fig. 10) and the pattern of annual orders for circuits (Fig. 11). The ratio of demand satisfaction attains now a stable value at around .81 which is aproximately the value of (1-Pc)2 meaning that the system has reached the capacity limit of local exchanges.

Since the drawing of statistical samples of the variables involved in Eq. 8 are standard practice in telephone companies, this policy was considered suitable for easy implementation. We are presently testing other forms for the function of Eq. 9 and studying its variability of implementation at TELMEX.

7. Conclusions

Although, as has been mentioned above, this work has concentrated in the analysis of one sector of the telephone system, the result of this study, given the general nature of the expansion problem, show the usefulness of the System Dynamics approach for devising policies that would ensure stable growth for other sectors of the system as well.

The changes proposed here for the capacity expansion policy are relatively simple and based on well tried ideas for policy design. For this reason, however, there are capable of being implemented and, in particular, do not involve the need for complex predictions about future values of different variables.

The results of this study reinforce the case for a systematic approach to strategic palnning as opposed to the traditional "ad hoc" approach to the solution of specific problems. The fact that it is perfectly possible that the source of the traffic congestion problem could be in other parts of the network already started have emphasized even further the need a wholistic approach to the expansion problems the Mexican Telephone System is facing in the present situation of rapid economic development.

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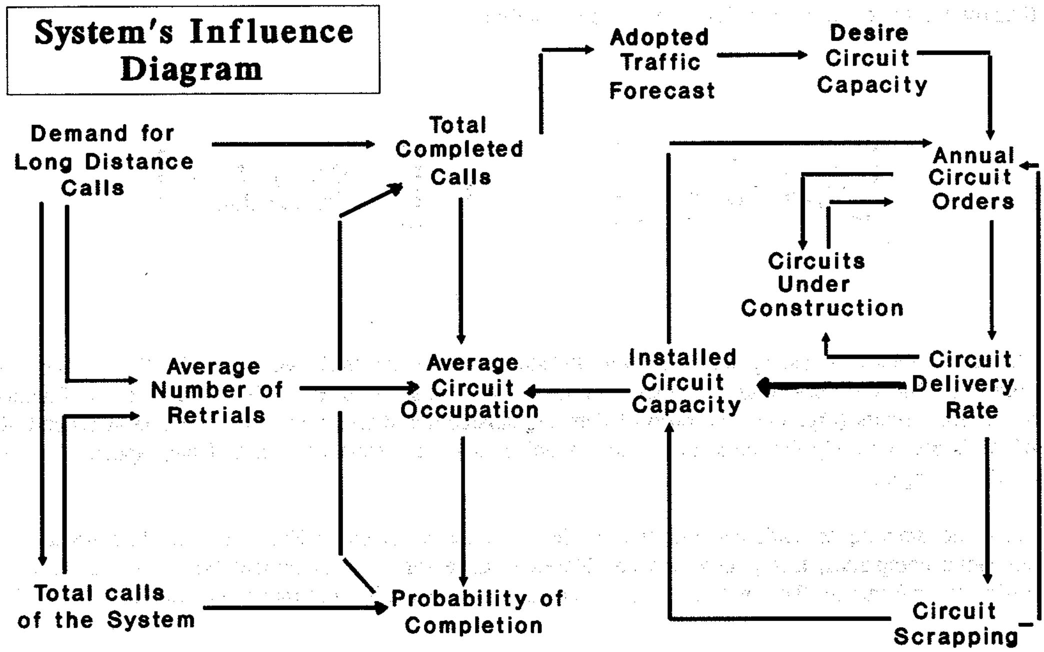

System's Influence Diagram
Demand for Long Distance Calls
Total Completed Calls
Adopted Traffic Forecast
Desire Circuit Capacity
Annual Circuit Orders
Circuits Under Construction
Average Number of Retrials
Average Circuit Occupation
Installed Circuit Capacity
Circuit Delivery Rate
Total calls of the System
Probability of Completion
Circuit Scrapping

FIG.1

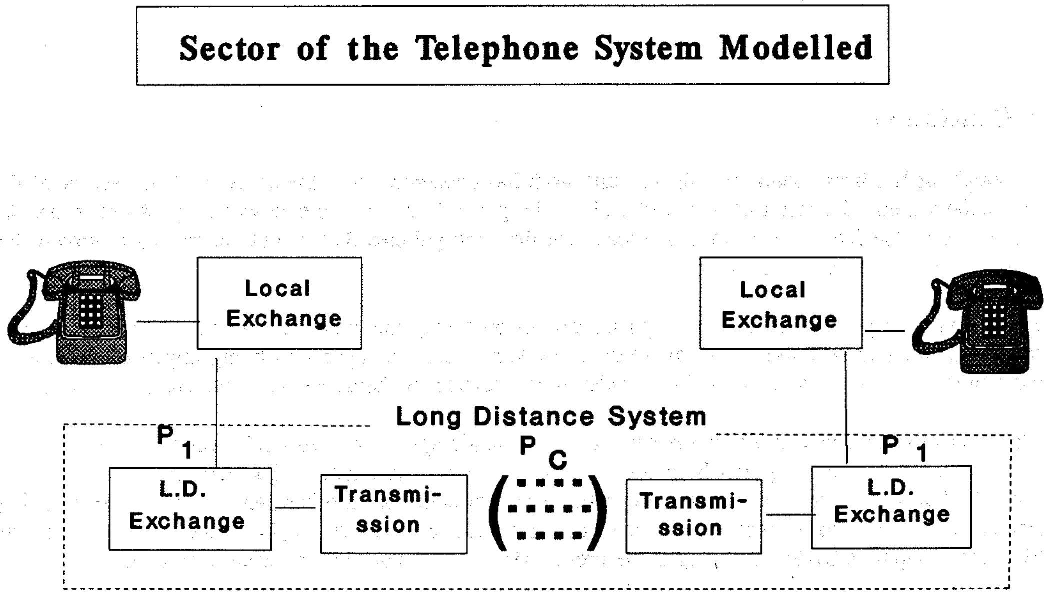

Sector of the Telephone System Modelled
Local Exchange
Local Exchange
Long Distance System
P 1
P C
P 1
L.D. Exchange
Transmi-ssion
Transmi-ssion
L.D. Exchange

FIG 2

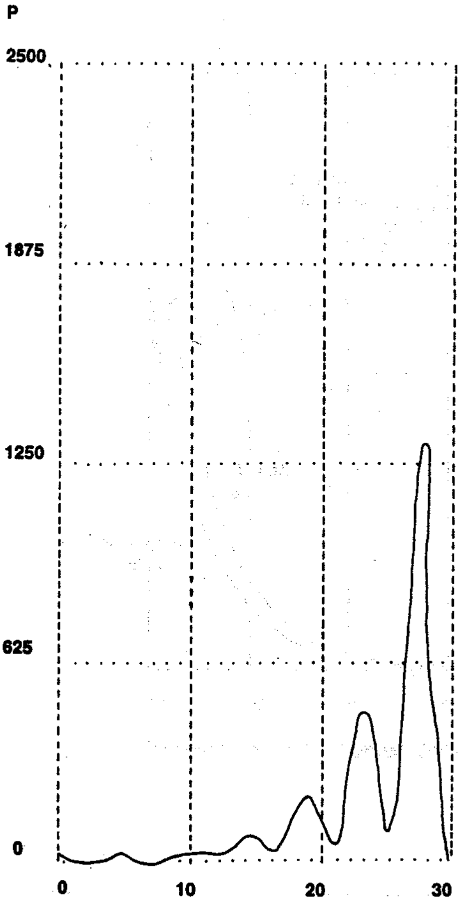


Fig. 4 ANNUAL CIRCUIT ORDERS

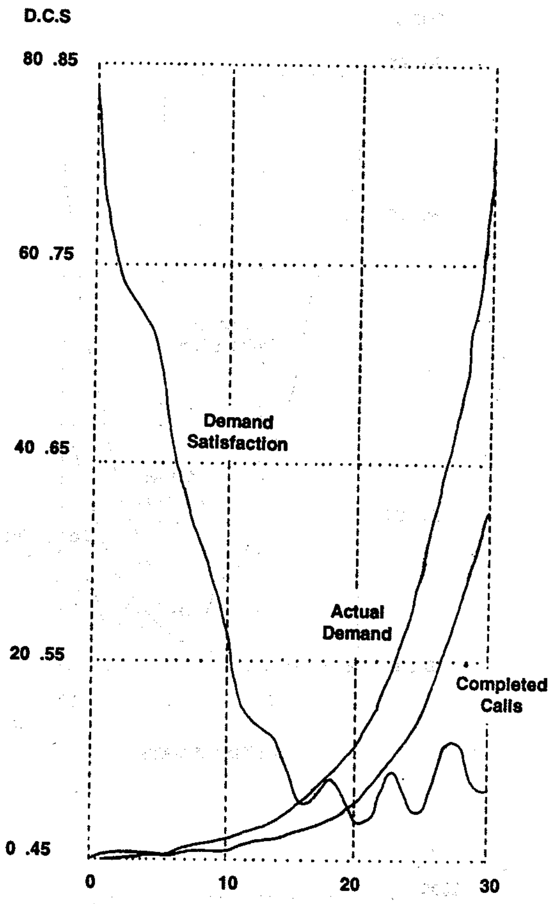


Fig. 3

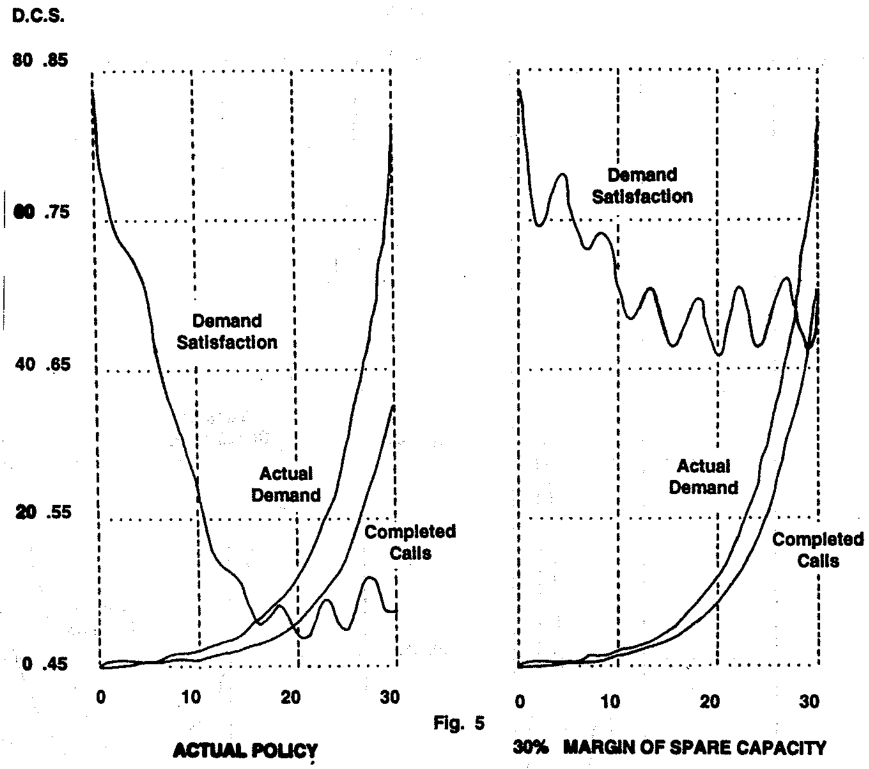

D.C.S.
80 .85
60 .75
40 .65
20 .55
0 .45
Demand Satisfaction
Actual Demand
Completed Calls
0
10
20
30
ACTUAL POLICY
30% MARGIN OF SPARE CAPACITY

Fig. 5

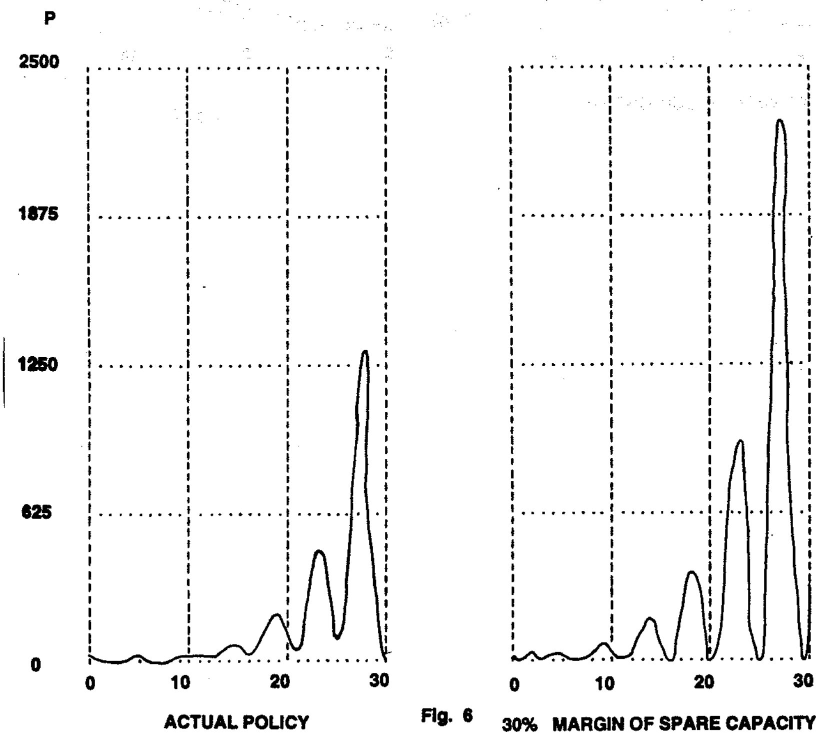
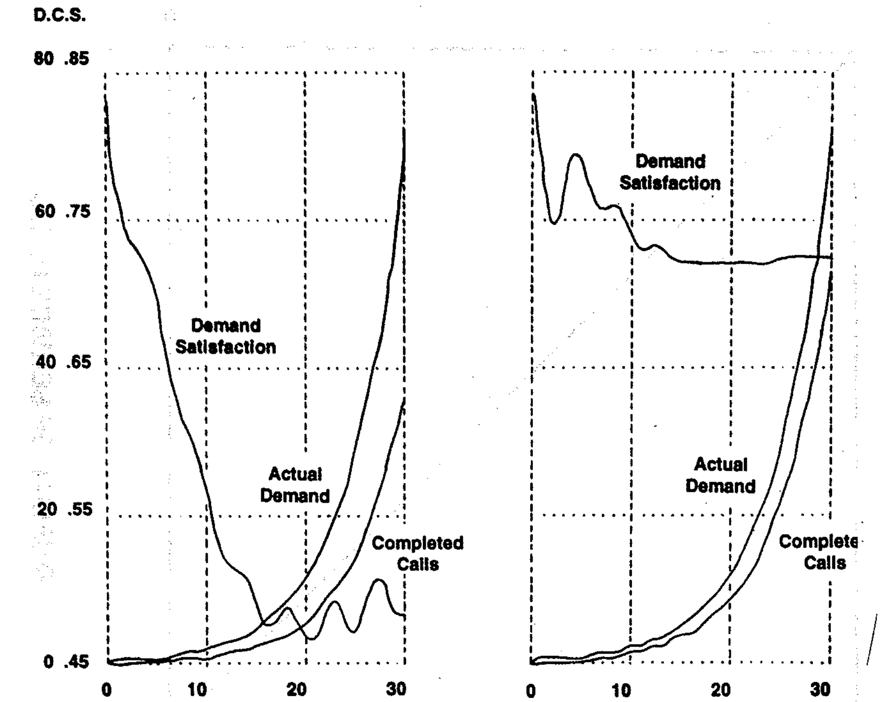
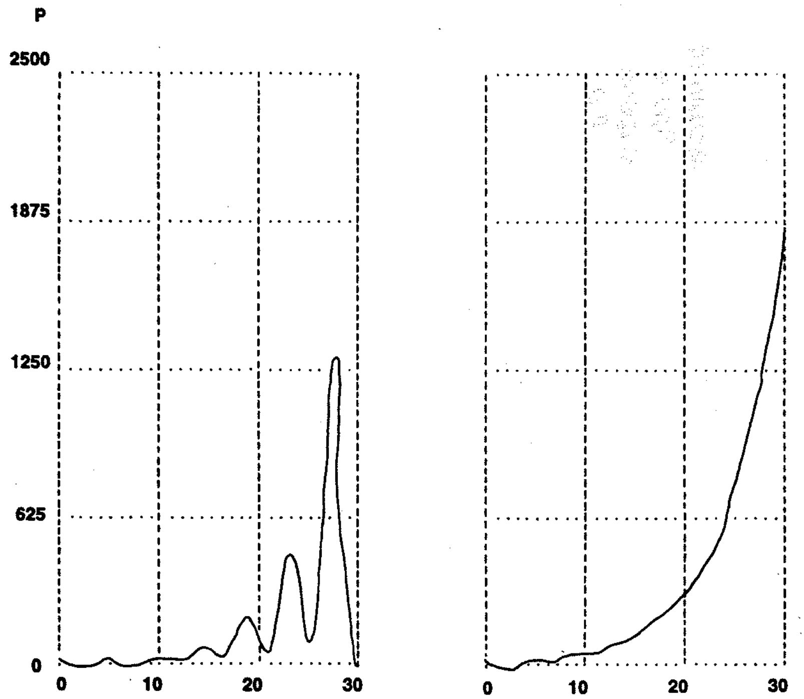

P
2500
1875
1250
625
0
0
10
20
30
ACTUAL POLICY
30% MARGIN OF SPARE CAPACITY

Fig. 6



ACTUAL POLICY Fig. 7 30% MSC AND FF + FB



ACTUAL POLICY Fig. 8 30% MSC AND FF + FB

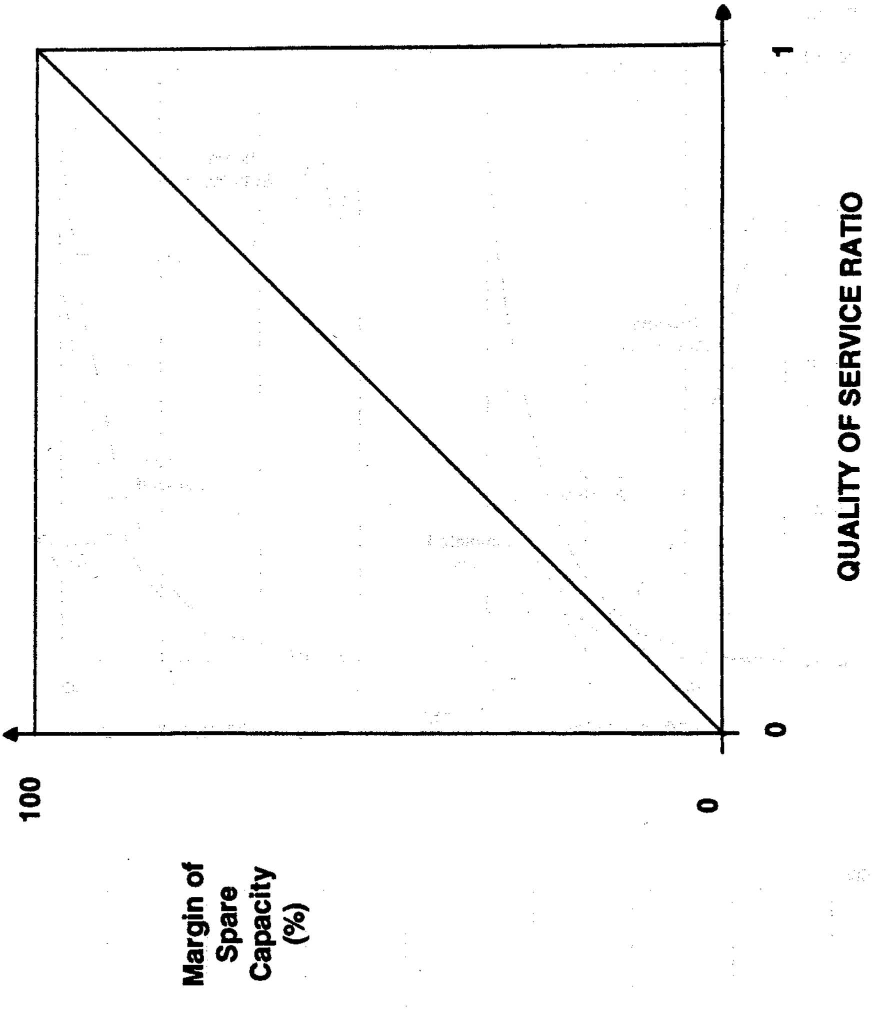


Fig. 9 VARIABLE MARGIN OF SPARE CAPACITY

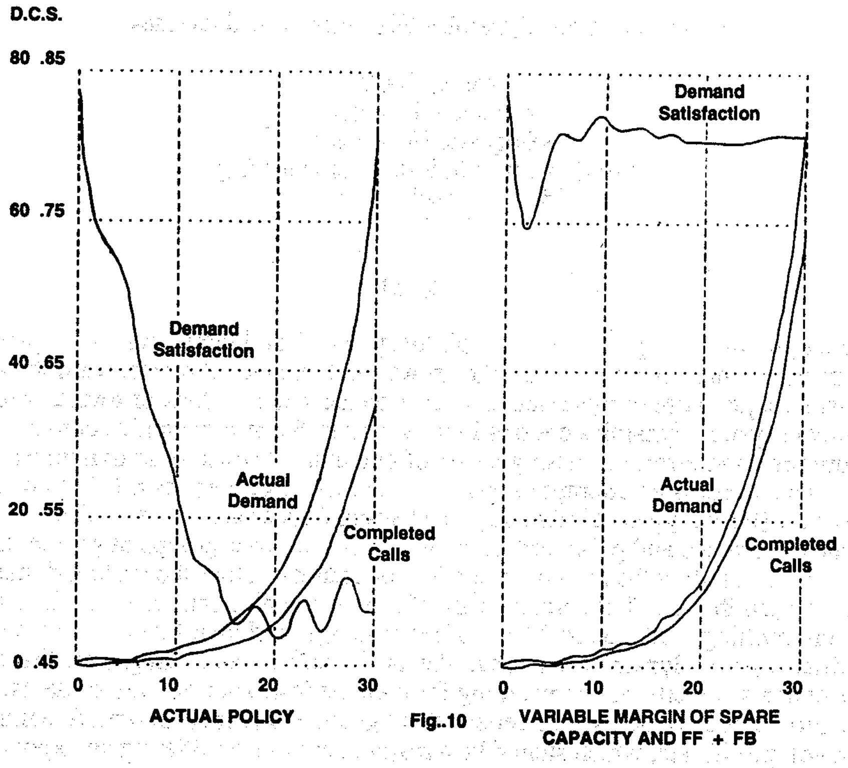

D.C.S.
80 .85
60 .75
40 .65
20 .55
0 .45
Demand Satisfaction
Actual Demand
Completed Calls
0
10
20
30
ACTUAL POLICY
VARIABLE MARGIN OF SPARE CAPACITY AND FF + FB

Fig..10

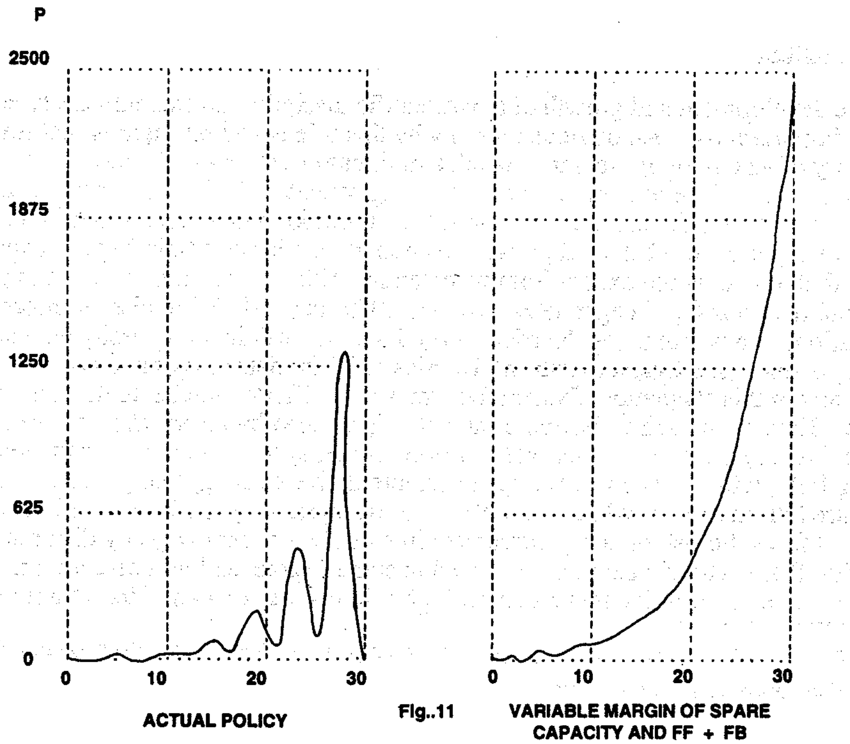

P
2500
1875
1250
625
0
0
10
20
30
ACTUAL POLICY
VARIABLE MARGIN OF SPARE CAPACITY AND FF + FB

Fig..11