DETERMINATION OF OPTIMUM NUMBER OF TRUNK LINES FOR CORPORATE NETWORK BACKBONE IN NIGERIA

C.I. Ani
Department of Electronics Engineering
University of Nigeria, Nsukka

ABSTRACT
The problem of determining the optimum number of telecommunication trunk lines subscribers' common equipment) for a given average traffic intensity is contributory, among other things, to the problem encountered in providing cost effective and high quality telecommunication services to corporate network users. Therefore, an accurate means of determining the optimum number of trunk lines required to be leased from public network backbone is vital. It is usual, in the developed countries, to assume a reliable public network while determining the optimum number of trunk lines required to be leased. In most developing countries, this assumption will lead to errors in determining the number of trunk lines required to be leased. In this paper, therefore, a template is developed for corporate network providers in Nigeria for the determination of the precise number of required trunk lines based on the concept of equipment failure and restoration.

1 INTRODUCTION

Telecommunication network is comprised of a variety of common-equipments including the trunk lines that link the network junction points referred to as nodes. In this paper, an exchange station is regarded as a node. The number of trunk lines needed between any two nodes in a network to provide standard quality of service is quite unpredictable because of the random nature of service requests. Since all users of the network do not need service at the same time, economics generally precludes designing a network to immediately carry the maximum offered traffic (service requests) [1,2,3]. A small percentage of offered traffic typically experiences network blocking or delay -the traffic that are not given instant service are regarded as blocked. The probability that the arriving traffic would meet the network blocked (would not get instant service) is referred to as the network's blocking probability. The blocking probability concept formulated by the Swedish scientist, Erlang, is a measure of quality of service [1,21].

The problem of determining the optimum number of telecommunication trunk lines for a given average traffic intensity is contributory, among other things, to the problem encountered in providing cost effective and quality telecommunication services to corporate network users. In this era of information explosion, a slight error in the determination of the exact number of the trunk lines required will result in an extensive degradation of quality of services offered and consequent rise in the cost of providing the services. Degradation in the service, in its turn, reflects adversely on the productivity of corporate network users. Therefore, an accurate means of determining the optimum number of trunk lines required to lease from public network is vital.

It is usual in the developed countries, to assume a reliable network while determining the optimum number of trunk lines required to be leased in order to provide standard quality of service to corporate network users. Therefore, the ratio of the rate of failure of the trunk lines to the rate of its restoration parameter is not put into consideration. No doubt, this parameter influences the performance of an exchange [4]. In the developed economy environment this parameter is usually much below unity. The formulation of blocking probability by Erlang might not properly suit the prevailing situations in most developing countries, specifically Nigeria where maintenance state of telecommunication systems is obviously below standard the rate of equipment failure is mostly higher than the rate of restoration The reason for this could be traced to unavailability of maintenance facilities in the locality the standard of maintenance culture and the poor economic state of most developing countries [5]. The analysis of an exchange with unreliable equipment, up till now, has been considered analogous to the operation of a similar exchange with absolute traffic prioritization (interrupt system) [6,7]. This approach assumes, at least a standard state of maintenance of telecommunication facilities. In the case of the developing country this assumption is far from valid. In determining the optimum number of trunks for any given traffic intensity the state of maintenance of the exchange including the trunk lines, should be directly taken into consideration.

Therefore, in this work an original attempt is made at developing a template for the determination of the precise capacity of trunk lines required for an effective and efficient operation of corporate network operation in the developing countries. The template is defined on the basis of the concept of equipment failure and restoration.

2 **NETWORK ARCHITECTURE**

The architecture of a typical corporate network that is connected to public network is shown in Figure 1. As can be seen at the interface to the public network, a gateway is used to interconnect the two networks - private and public. The gateway is employed primarily as a multiplexer/demultiplexer system. It is also used to provide alternative user interface and appropriate adaptation functions to and from the duplex access circuit linking it to a local node (exchange). In the network, nodes are interconnected by fixed- capacity trunk circuits that provide network backbone for frame switching network.

Trunk lines, as shown in figure 1, can be leased from public network backbone in order to interconnect geographically separated corporate networks. The determination of the precise number of lines to lease is very essential and depends largely on the approach and available tools employed [6,7,8]. In this paper, attention is given particularly to the pattern of service request arrival and departure at the gateway. Traffic flow pattern is neglected as it plays a negligible role in the determination of optimum number of trunk lines. The two main corporate network traffics (voice and data) have similar service request arrival and departure pattern.

At the gateway, the corporate leased trunk lines are assigned to service requests that emanate from the corporate network. Leased trunk line assignment is based on availability at the time the service requests are made. Arriving service requests may not be assigned trunk lines for two reasons:

- ❖ At the time of service request arrival, all the leased trunk lines are occupied serving requests, trunk lines are busy and therefore not available, and
- ❖ At the time of service request arrival, the trunk lines that are not occupied serving requests are out of service - trunk line(s) failure

For each of the above cases, the requests involved are referred to as blocked (rejected) requests [1,2,3]. This work neglects the case where request is blocked because the trunk line engaged in serving the request fails. In the network, (see figure 1) the function of line assignment is entirely performed at the gateway and that is why the entire analysis is performed on the gateway.

3 NETWORK MODEL

The essence of the model is to provide the medium on which the operation of a corporate network, with low reliability, can be analyzed without practically meddling with the operations of the real system. It has been shown that the operation of a network can be satisfactorily analyzed by considering an isolated node -gateway [6,7]. Therefore, the network modeling will be based on the gateway. There are three approaches to developing models graphical, analytical and computer simulation [6,7,8,9]. The combination of computer, graphical and analytical simulation modeling methods is preferred to the individual computer, graphical or analytical simulation method. Information Technology offers the capability to exploit in one system the merits of the individual simulation methods [6,7].

The simulation model, as can be seen in figure 2, is comprised of trunk line, request source and restoration modules,

3.1 Trunk Lines Module

This module assigns trunk *lines* to the arriving requests on the basis of line availability; and the module also generates the failed line event occurrences using the failure rate parameter *(a)"* Failure is generated as a random quantity using Poisson statistical function with parameter a .. Failure rate parameter is defined as shown in equation (1).

$$\alpha = \frac{\text{average number of failures recorded within a day}}{24*3600[\text{seconds}]} \qquad (1)$$

The generated failure events appropriately reflect on the available trunk lines, m. This is related to the blocking probability generating entity in the module. This entity also relates restoration event occurrences to blocking probability generation.

Corporate network service providers usually place requisition for capacity of trunk lines to be leased from the public network backbone on the basis of the level of quality of service required and average traffic intensity supported. Quality of service parameter, Q, is defined through blocking probability, P, as shown in equation (2).

$$Q = 1 - p \qquad (2)$$

This implies that the number of leased lines required to sustain a given standard of service under a defined failure/restoration rate level may be determined from Erlang's loss- system analytical formula as given in equation (3) [1,2].

$$P = \frac{\frac{A^m}{m}}{m! \sum_{i=o}^{m} (\frac{A^i}{i!})} \qquad (3)$$

Where,

$A = \lambda t_m$ = request intensity,

m = number of tnmk lines, and

t_m = average holding time (average length of time it takes to serve a request)

The blocking probability generating entity bases its function on equation (3). This entity reflects the request event occurrence in the blocking probability generation.

3.2 Request Source Module

The request source module simulates the arrival of requests reaching the gateway from corporate network. It is assumed that the arrival process at the gateway is Poisson in nature. This assumption is based on the generally adopted research approach on teletraffic [1, 2, 3, 6, 7]. Therefore, the function of this module is basically to actions simulate request generation through the use of Poisson statistical process. The arrival of the requests is indicated by the module using impulses that are separated by time (the time separations are distributed exponentially). Statistical exponential function is employed by the module in generating holding time, t_m;[1,10,11].

The number of the impulses generated represents the number of the requests arriving at the gateway in a given time. The parameter, A, is therefore defined as stated in equation (4)

$$\lambda = \frac{average\ number\ of\ request\ arrivals\ within\ a\ day\ (24hrs)}{24*3600[seconds]} \qquad (4)$$

As the simulation runs, random values are generated with the parameter,λ The random values represent time intervals between request arrivals.

3.3 Restoration System Module

Restoration system module sees to the generation of restored failed line event occurrence. Restoration is generated as a random value using exponential statistical function with restoration rate parameter, β, [6,7]. Restoration rate is defined as shown in equation (5).

$$\beta = \frac{average\ number\ of\ restorations\ recorded\ within\ a\ day}{24*3600[seconds]} \qquad (5)$$

Number of trunk lines, m, is therefore modified by the generated value to reflect trunk line restoration.

4. MODEL SIMULATION FLOWCHART

There are different methods of developing the model in readiness for simulation. Such methods include the use of a high level programming language and the adoption of one of the custom-built block oriented software packages that are commercially available. Whichever method is adopted for the simulation of the model, a simulation flowchart that outlines the logical sequence of actions to be carried out by the host computer is required. Figure 3 illustrates the main sequence of such

In this work, a commercially available custom-built professional network simulation software package (Network 11.5 that is vended by CACI) is used to implement and run the model [12]. The choice of this package is mainly guided by its professional nature and availability.

5 SIMULATION RESULTS

The model (see, figure 2) was simulated using the flowchart of figure 3. The results obtained from the simulations are shown in figures 4- 8.

Figures 4 -7, illustrate the trend in relationship between traffic intensity and blocking probability for varied number of trunk lines, failure and restoration rates. The trend is quite the same in the figures. Equations (1) - (5) were employed in the calculation of the required simulation parameters.

Figure 4, shows the relationship between traffic intensity and blocking probability for failure rate,α, equal to 1.157E-5, and restoration rate, β, equal to 5.787E-6:and for the case of 5 trunk lines. In other words, a network with 5 trunk lines is simulated under the condition that the trunk lines fail at the average rate of 1 per day and will be restored at the average rate on trunk line in every two days.

In figure 5; failure rate, α, equals 2.315E-5, and restoration rate, β, is equal to 1.157E-5 for the case of 10 trunk lines. In this case, a network with 10 trunk lines is simulated under the condition that the trunk lines fail at the average rate of 2 per day and will be restored at the average rate of 1 trunk line per day.

Also, in figure 6, failure rate, α, equals 3.472E-5, and restoration rate, β; is equal to 1.736E-5 for the case of 15 trunk lines. In this case, a network with 15 trunk lines is simulated under the condition that the trunk lines fail at the average rate of 3 per day and will be restored at the average rate of 2 trunk lines per day.

In figure 7, failure rate, α, equals 5.787E-5, and restoration rate, β, is equal to 2.894E-5 for the case of 20 trunk lines. Therefore, network with 20 trunk lines is simulated under the condition that the trunk lines fail at the average rate of 5 per day and will be restored at the average rate of 3 trunk lines per day.

The behaviour of the model's characteristics was observed on the above cases for a given ratio of restoration rate to failure rate, ρ, that is equal to 0.5 (i.e. ρ = 0.5). Resultant characteristics show that as traffic intensity increases, quality of service is progressively reduced. The error involved in using the usual approach in contrast with the approach that directly considers failure and restoration rates is illustrated in the graph using the shaded region. Calculations show that the average quality of service degradation experienced as a result of the error is 15%.

Figure 8 illustrates the characteristic curves of the relationship between quality of service and traffic intensity for varied values of trunk lines at a given value of the ratio of restoration rate to failure rate. Thus, the values of restoration and failure rates are kept constant for a specific quality of service and average traffic intensity. The precise required capacity of trunk lines can be determined graphically as shown in figure 8.

Figure 8 is the simplified version of the desired template. In practice, such template should be generated for more numbers of trunk lines and also for more values of the ratio of restoration rate to failure rate, ρ. The template is quite easy to use.

Given the value of quality of service and also the value of traffic intensity for a particular p the required number of trunk lines, m, is read from the curve that falls on the point of intersection of the values of quality of service and traffic intensity. For the two cases illustrated in figure 8, m is read for ρ = 0.5 as follows:

L_1: 15 trunk lines for 0.58 quality of service (0.42 blocking probability) and 15.8 traffic intensity, and L_2: 18 trunk lines for 0.7 quality of service (0.3 blocking probability) and also 15.8 traffic intensity.

6 CONCLUSION

It has been demonstrated that determining the number of trunk lines for a given value of quality of service and traffic intensity without taking into consideration trunk line failure and restoration rates results in the wrong predictions of the number of trunk lines required. It is clear that the obtainable situation could be worse than the simulated cases.

In practical terms, the results show that if trunk line allocation is handled in Nigeria using the usual approach, there must be an addition made to the number of trunk lines calculated using the usual approach in order to maintain the expected quality of service. In the cases considered, the exact increase is one, two, three and five extra trunk lines form m=5, m=10, m=15 and m=20 respectively. Figure 8 is therefore the desired template that takes care of the extras

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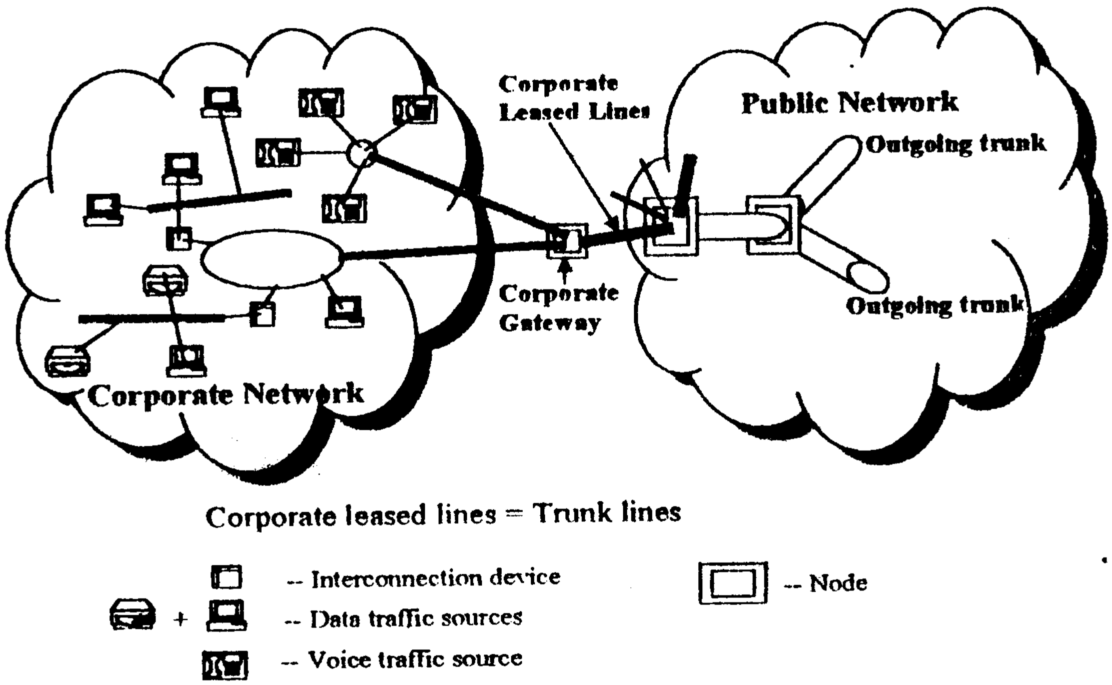

Figure 1: Corporate Network Architecture.

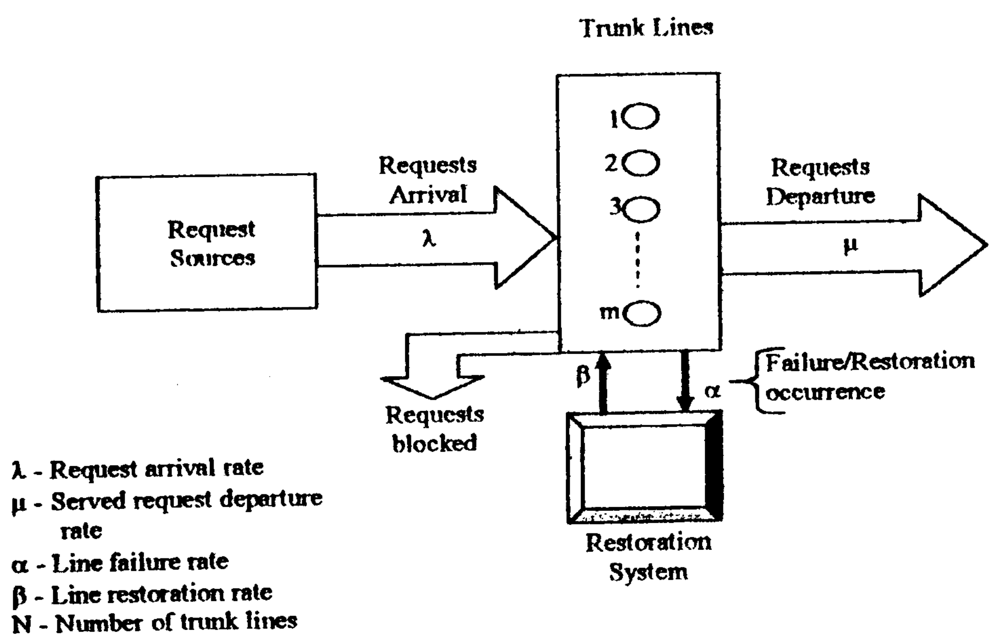

Figure 2: Corporate Network Model

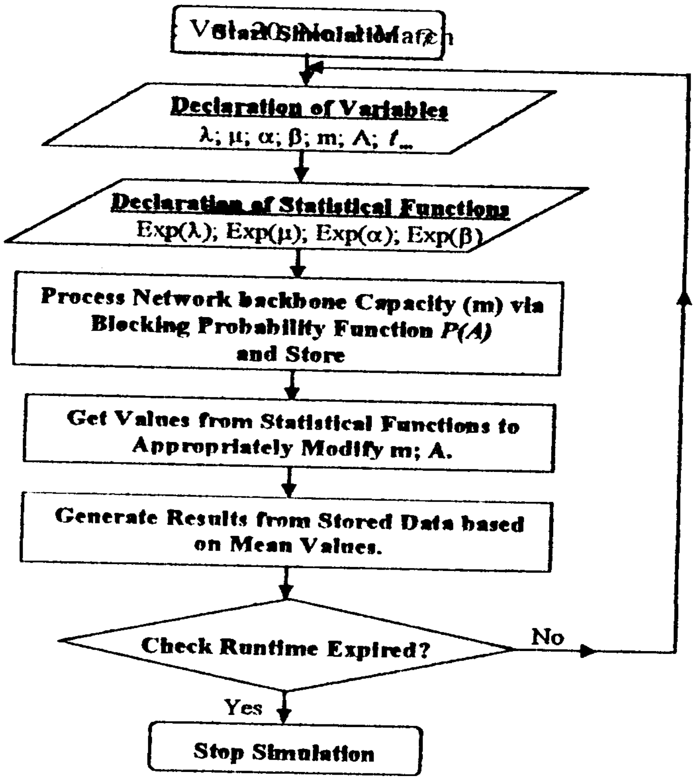

Figure 3: Model simulation flowchart.

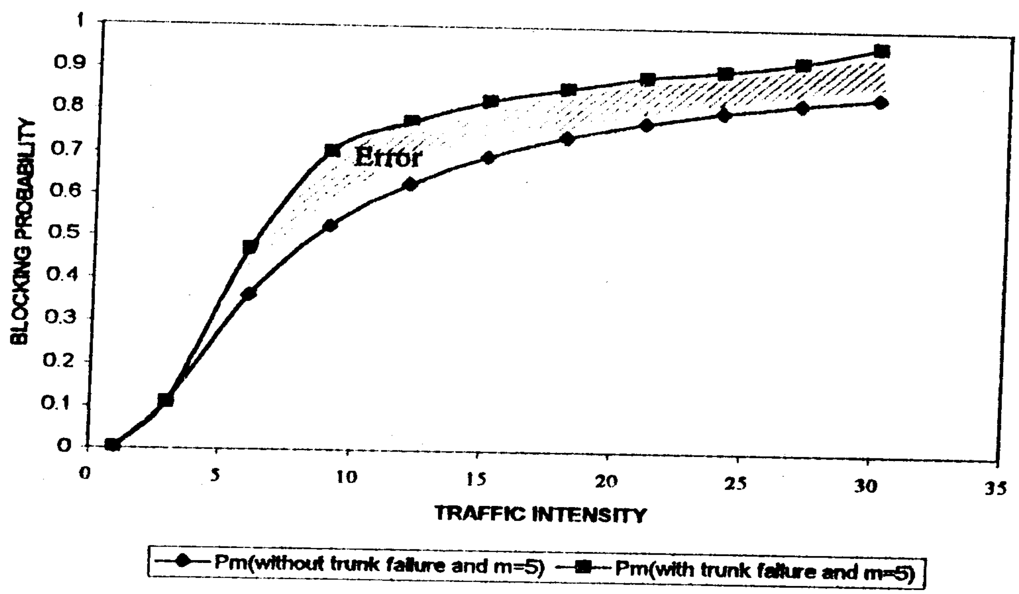

Figure 4: Blocking probability vs traffic intensity for m=5; α=1.157E-5; β=5.787E-6

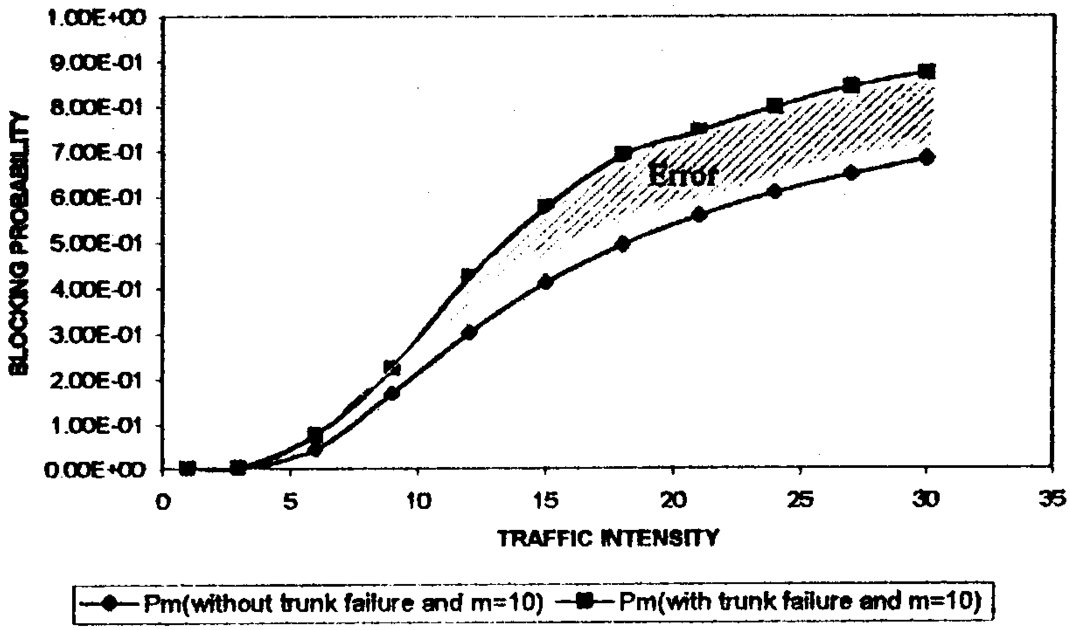

Figure 5: Blocking probability vs traffic intensity for m=10; α=2.315E-5; β=1.157E-5

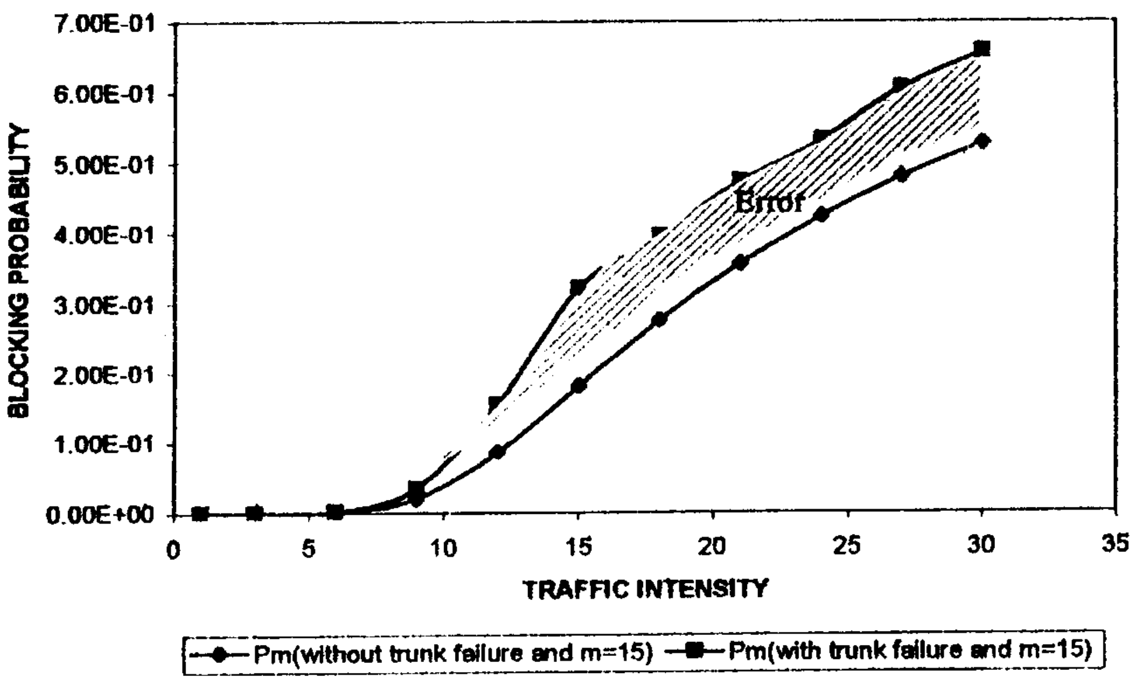

Figure 6: Blocking probability vs traffic intensity for m=15; α=3.472E-5; β=1.736E-5

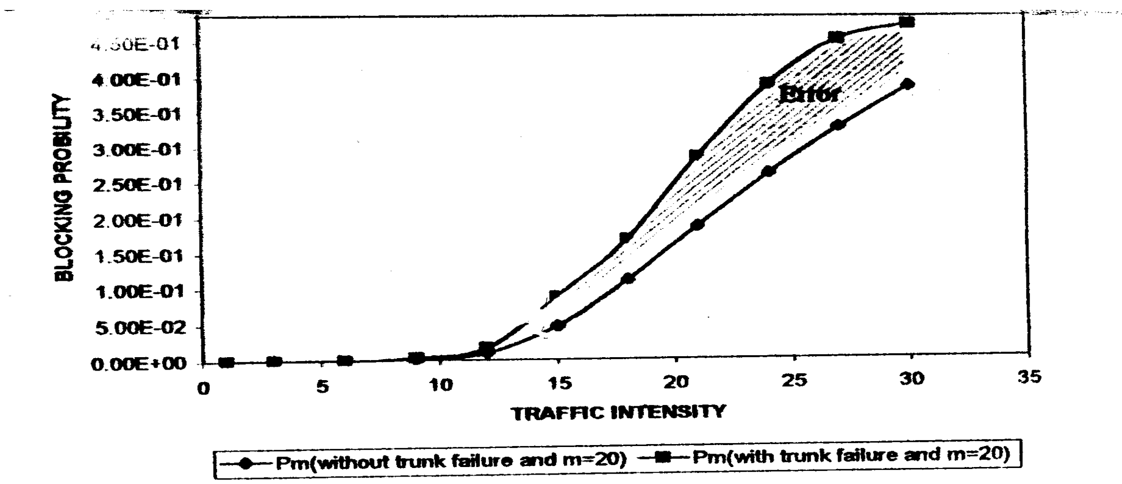

Figure 7: Blocking probability vs traffic intensity for m=20; α=5.787E-5; β=2.894E-5

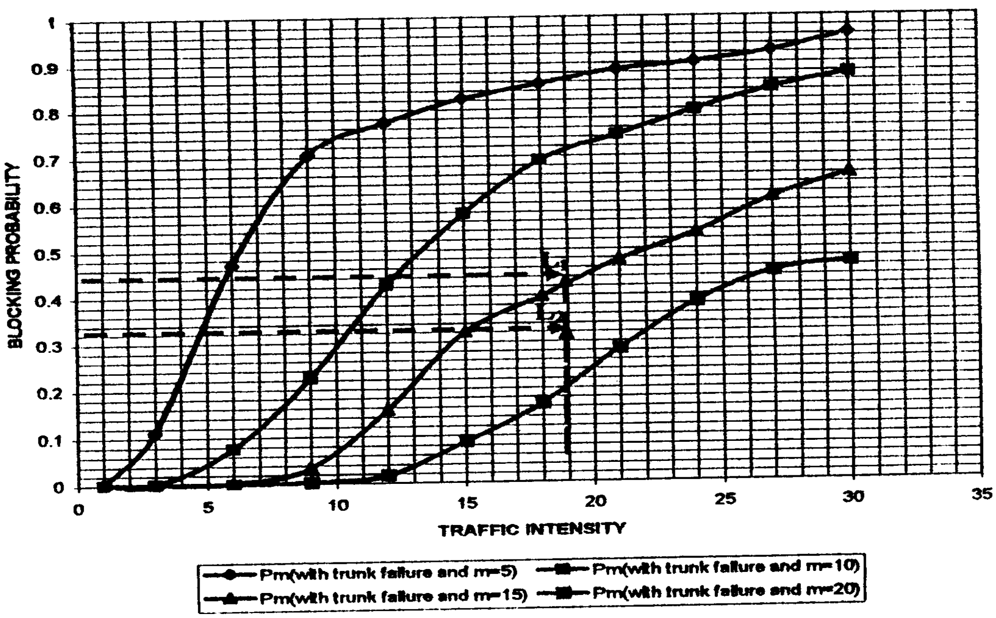

Figure 8: Blocking probability vs traffic intensity for varied numbers of trunk lines with failure.