COMPARING FIXED STOP AND HAIL STOP MODES OF SERVICE OF FIXED INTRA URBAN BUS OPERATIONS

II. METHODOLOGY FOR COMPARISON OF THE MODES OF SERVICE

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1.0 PREAMBLE

The two modes of service are compared at their optimal states so as to determine under what conditions one is better than the other.

The objective that guides the comparison is that of minimisation of total system cost. The situation where fixed stop operation in better is typified by equation 1, i.e.

$$Z_1 \leq Z_2$$

The condition expressed in equation 1 will hold, depending on principally transit demand level, the value of riding time, ratio of riding time to out-of-vehicle time, costs of operating the vehicle, the length of route under consideration and the size of service area.

Comparisons of the two service types are undertaken in two parts namely: (i) comparing the optimum headways and (ii) comparing the total system cost. The next section considers the optimum headways.

2.0 OPTIMUM HEADWAYS

The inspection of cost minimising headways derived in Part I, equation 16, reveals that the headways do not depend solely on the magnitude of the cost elements but on cost ratios

(e.g. $C_1 = \gamma_n/V_i$, $C_2 = \gamma_s/V_i$, $C_3 = V_0/V_i$).

The numerical values of the model variables specified in Table 1 of part I are used to explore variation in optimum headways. The default values of the cost ratios adopted in the variations are:

$C_1 = 1.12$ $C_2 = 0.5333$ $C_3 = 2.0$ at peak period
$C_1 = 2.80$ $C_2 = 1.3333$ $C_3 = 2.0$ at off- peak period

2.1 EFFECTS OF VARIATION IN COST RATIOS ON OPTIMUM HEADWAYS

The variation of optimum headways with the changing cost ratios are compared at peak period for both services and illustrated in Fig. 1 - 3.

It is evident from Figs. 1 - 3 that optimum headways are higher for fixed stop than for the hail stop operation for all demand levels. It can also be seen that as demand increases the difference in optimum headways between the two services also increases. Thus, optimum headways reduces at a faster rate in hail stop service than fixed stop with increasing demand.

When C_1 increases, higher values of optimum headways are recorded and difference between h_1 and h_2 is slightly more. An obvious implication is that while same vehicle size can provide optimum service at low demand levels for both service modes, larger vehicle will be optimal for fixed-stop and smaller vehicles will optimize hail-stop service at high demand levels.

3.0 TOTAL SYSTEM COSTS

The numerical values specified for model variables in Table 1 are used as the default values of variables in the total cost equations that are not specifically varied in the following comparisons. The findings, along with deductions made in part I, are then used to formulate a methodology for comparing the modes of service.

3.1 COMPARISON OF TOTAL SYSTEM COSTS AT OPTIMUM STATES

The total system cost at various demand levels under optimum headways are shown for fixed stops and hail stops in Figs. 4 and 5 respectively, for both peak and off peak periods. It is apparent that cost always decrease with increasing demand. The cost at off-peak periods are less than peak. However, direct comparison at particular demand levels are not of practical significance since off-peak represents a period of low demand as well as low value to time.

In Fig. 6 the comparison of Z_2 and Z_1 are made. It can be seen that the hail stop service performs better for all demand levels considered. It should be pointed out that operating cost per passenger is always higher for the hail stop service while the users' cost per passenger is higher for fixed stop. In-vehicle costs are lower for fixed stop but out-of-vehicle costs higher. The ratio of users cost to operating costs becomes increasingly lower as demand for hail stop service increases.

3.2 EFFECTS OF VARIATION IN TOTAL SYSTEM COST AS OPERATING COST RATIO, C_1, ARE ALTERED.

The variation in total system costs with operating cost ratio, C_1, is explored here. This is illustrated in Figs 6 - 8, where the comparison between hail stop and fixed stop are made. Generally, the total system cost per passenger increases with C_1. It could be observed that the fixed stop made responds more to the changes. As the ratio increases the total system cost per passenger decreases more with the fixed stop as demand increases. Thus, fixed stop will perform better with increase in ratio.

3.3 VARIATION IN TOTAL SYSTEM COSTS WITH CHANGE IN VALUE OF TIME

The effect of change in in-vehicle time has on total system cost is investigated by varying value of time, V_i, from ₦6.00/hr) (₦0.1/min) to ₦13.5/hr (₦0.225/min) while adopting C_3 - 2.0. It was found out that the two services exhibited similar responses to variation in the value of in-vehicle time. However, when C_3, was reduced to one as against the default value of two, $Z_2 < Z_1$ when demand is less than 300 passenger per hour (37.5 pass/km^2/hr) as shown in Fig 9. At higher demand as expected, as ratio C_1 inreases, $Z_1 < Z_2$ as shown Figs. 10 - 11.

3.4 EFFECTS OF O-D PATTERN ON TOTAL SYSTEM COSTS

So far, we have focussed on situations where either many to - one or one - to - many O-D patterns is in place. The situation now considered is when other O-D patterns obtains. The variables to be affected are passenger service time per passenger (i.e. K for fixed stop operation and K' for hail stop operation), the coefficient j relating number of stops made per passenger carried. For many - to - one and one - to many, j = 1 but in a situation where no common origin and destination are assumed j = 2.

Three examples are used to illustrate the effects, of changing O-D pattern. Example one uses same values for the variables as default except the service time are changed to reflect the assumed j which in this case is 1.5. The results are shown Fig 12. Example two clearly illustrates effects different value of j as shown in Fig 13. Example three demonstrates the effects on total system cost when the route is very long (20km) and O-D pattern corresponds to j = 1.5 with the ratio C_3 = 1.0

The results of this demonstration are shown in Fig. 14.

4.0 COMPARISON OF TOTAL SYSTEM COST

4.1 SOME ILLUSTRATIONS OF CONDITIONS FAVOURABLE FOR OPERATING THE SERVICE MODES

It had already been stated in part I that conditions that favour hail stop obtain when route length is short, value of time high and operating cost low. When the route length is changed from 8km to 4km, the resulting effect on total system cost is captured in Fig. 16, establishing that hail stop operation is favoured.

It has also been mentioned that fixed stop will perform better when the route length is long and value of vehicle time is small. Thus, when L = 16km, value of out vehicle time is reduced to half (i.e. C_3 = 1.0) and operating cost, γ_n = ₦15/km, as represented in figure 17, fixed route operation is favoured

4.2 VALIDATION OF THE HYPOTHESES

Results in section 4.1 have confirmed some of the assertions contained in the hypotheses formulated in part 1 concerning the relative performances of the service modes. Now we seek to validate the two hypotheses, by considering two illustrative cases.

We consider first the hypothesis one by retaining the condition specified in Fig 16 where L = 4km but modify the operating cost to γ_n = ₦11/km. The result on system cost is shown in Fig 18 and it confirms hypothesis one, by establishing the better performance of hail-stop service at slight reductions in total system cost.

Second example is used to test hypothesis two, condition specified in Fig. 17 is adopted with changes to γ_n and L as follows: γ_n = ₦20/km but L = 16km and C_3 = 1.0. The results, shown in Fig. 19, still confirm that fixed route operation is better and confirms hypotheses two.

5.0 METHODOLOGY FOR COMPARING THE SERVICE MODES

The hypotheses 1 and 2, formulated in part 1 and validated in preceding section, indicate that if a bus operator wants to choose between the fixed stop and hail stop modes of service, the operator needs to know the conditions on the route particularly as it pertains the following parameters: route length, value of time, operating cost and demand on the route. Hypothesis 1 indicates that if the hail stop is found to perform better at current conditions on the bus route, then it will for most practical situations perform better if any of these changes are made on the bus route: (a) route length is

reduced (b) value of user's time increases (c) operating cost reduces. Similarly, the hypothesis 2 indicates that changes aimed at increasing service coverage (e.g. increasing route length), or increasing operating cost are introduced and if fixed stop is found to be superior at current conditions, then it will continue to perform better. Increasing demand would generally also tend to favour fixed-stop operation.

In cases indicated above it will be better to retain the service found superior. However, if changes are not as indicated further investigations are required. The effect of O-D patterns and number of fixed stoppings have also been considered. It has been found that diversed trip end points and low fixed stoppings favour fixed-stop service mode.

Given the above findings, a general methodology for picking the better of the two service modes is now proposed as follows:

STEP #1 Compare the two service modes for peak demand conditions.

If hail stop operation is superior to fixed stop, then it would be suitable for all levels of operation in as much as the O-D patterns and number of allowable fixed stoppings remain at the peak conditions. Where these parameters change substantially from the peak conditions, a seperate analysis would be required.

If, however, fixed stop operation is superior for peak demand conditions, further investigation of off peak demand conditions would be necessary to establish the complete dominance of the fixed stop operations for all levels of operations

STEP #2 Compare the two service modes for peak demand conditions. Actually this step is neccessary only if fixed stop operation is found superior in step #1.

If fixed stop is found superior at this level of demand, then it is appropriate to adopt it exclusively. However, If hail stop operation is found to be superior at this level of demand, the implication is that both service modes are applicable. The threshold demand level at which it is appropriate to switch from one mode of service to other would need to be determined by iteratively solving for the value of g for which $Z_1 = Z_2$

In situations where exclusive use of one service mode cannot be justified, it may be more realistic to jointly operate the two service modes. Special marks on the vehicles could be used, among other possible distinguishing features, to indicate which vehicles are offering which type of service. Of course, it would only be fair to attach a premium charge to hail stop operation as the analyses have shown it costs the operator slightly more.

6.0 CONCLUDING REMARKS

It was observed in the first part of this paper, that demand level, length of fixed route, cost of vehicle operation and value of users' time are important factors that principally determine which of fixed stop operation and hail stop operation is more appropriate in a given situation. Further analyses contained in this part of the paper have established that the users' trip- end patterns (as typified by the O-D patterns) as well as the density of fixed stoppings allowed on the bus-route are additional factors that influence the relative performance of the service modes. A methodology for comparing the service modes has also been proposed. It involves comparing the service modes, first at peak period demand. If hail stop operation in found superior at this level of demand, unless there are substantial changes in O-D patterns of the users or the number of fixed stoppings allowed in other demand periods, it should be used exclusively. The second comparison is at the offpeak demand level, if fixed stop operation is found to be superior, then is should adopted exclusively. A case has also been made for the mutual adoption of both service modes for cases where neither service mode is superior for all situations. A premium fare can be then be set for hail stop operation since it costs slightly more.

REFERENCE

1. **OLOWOSULU** (1996) "Comparing Fixed Stop and Hail Stop Mode of Service of Fixed Route Intra Urban Bus Operations." Unpublished M.Sc. Thesis, Dept. of Civil Engineering, ABU, Zaria.

Fig 1 Variation in Optimum Headways with Changing Demand (C1 = 1)

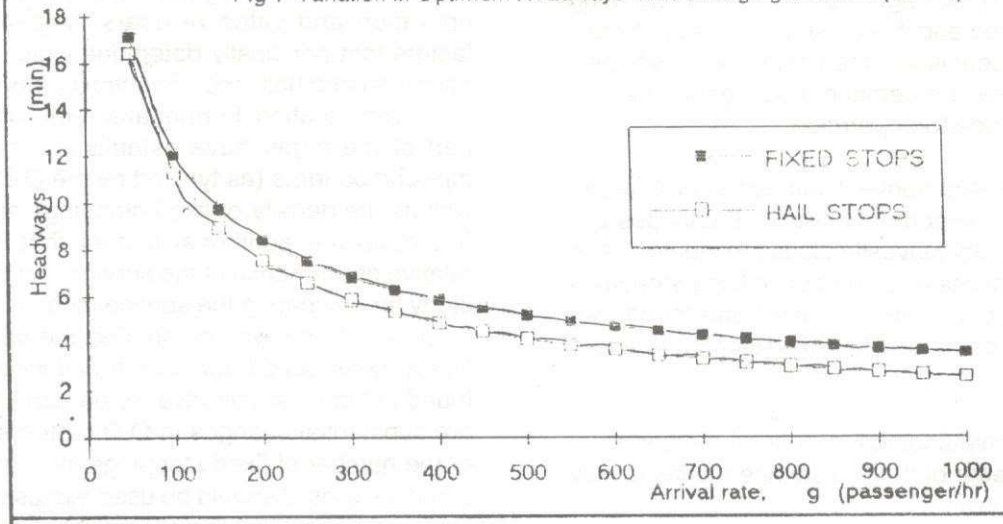


Fig 2 Variation in Optimum Headways with Changing Demand (C1 = 3)

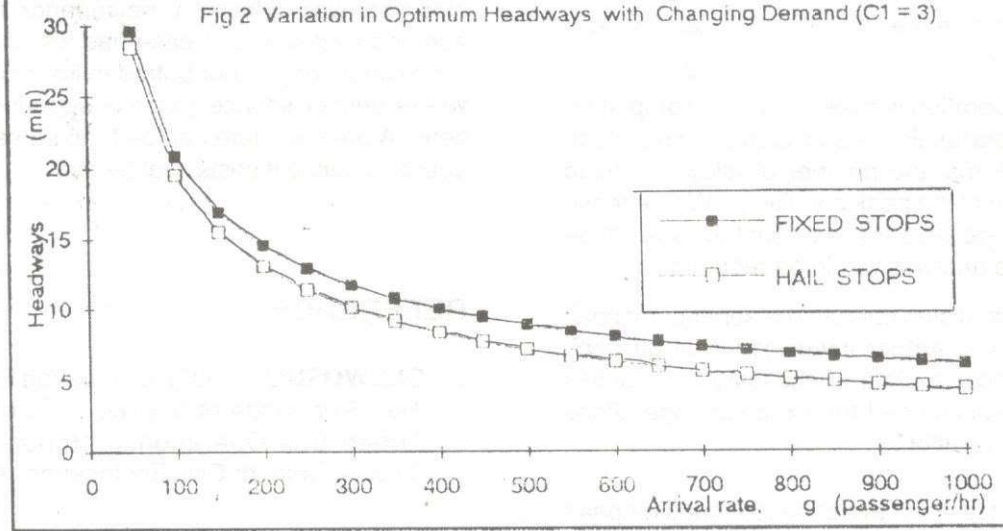
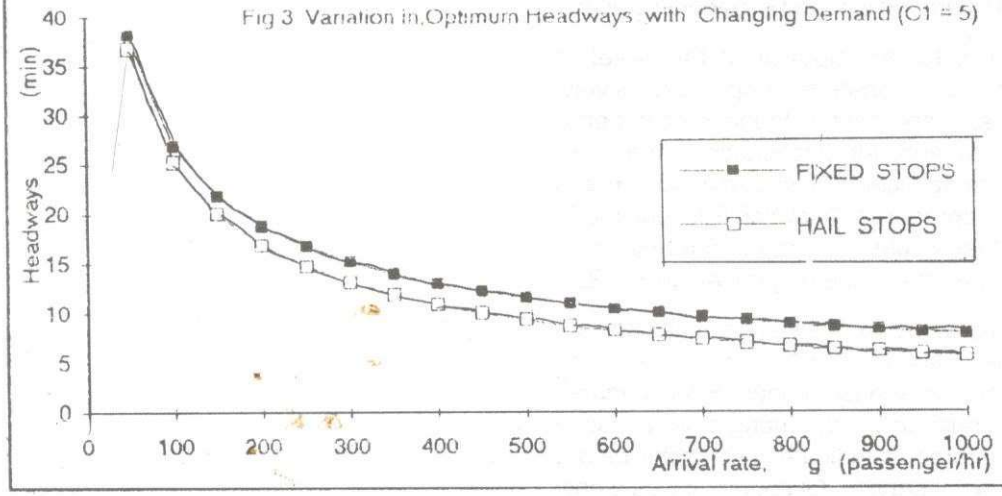
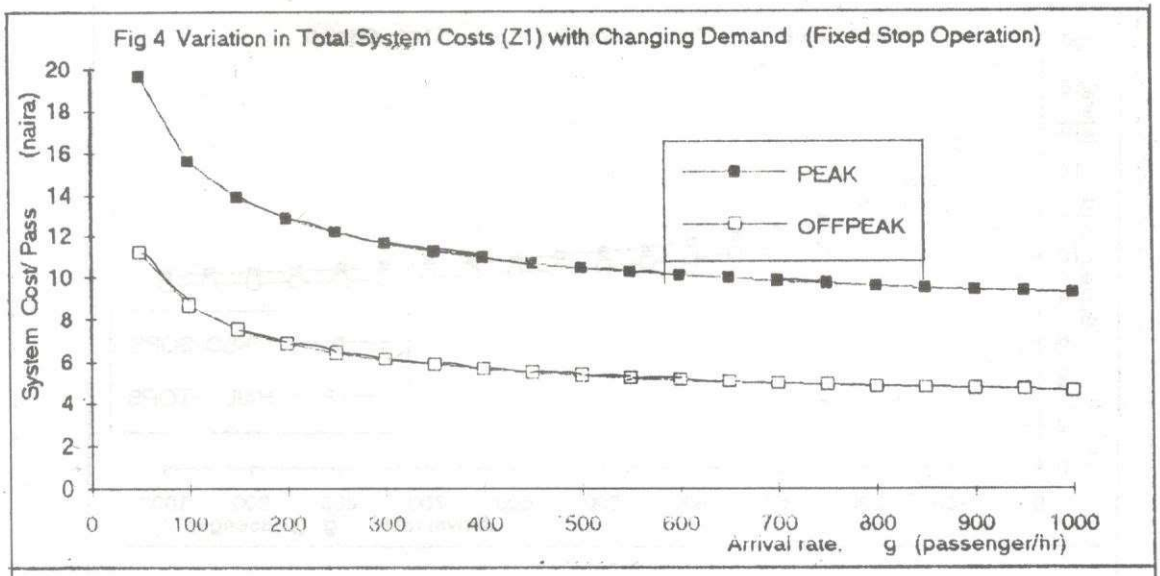
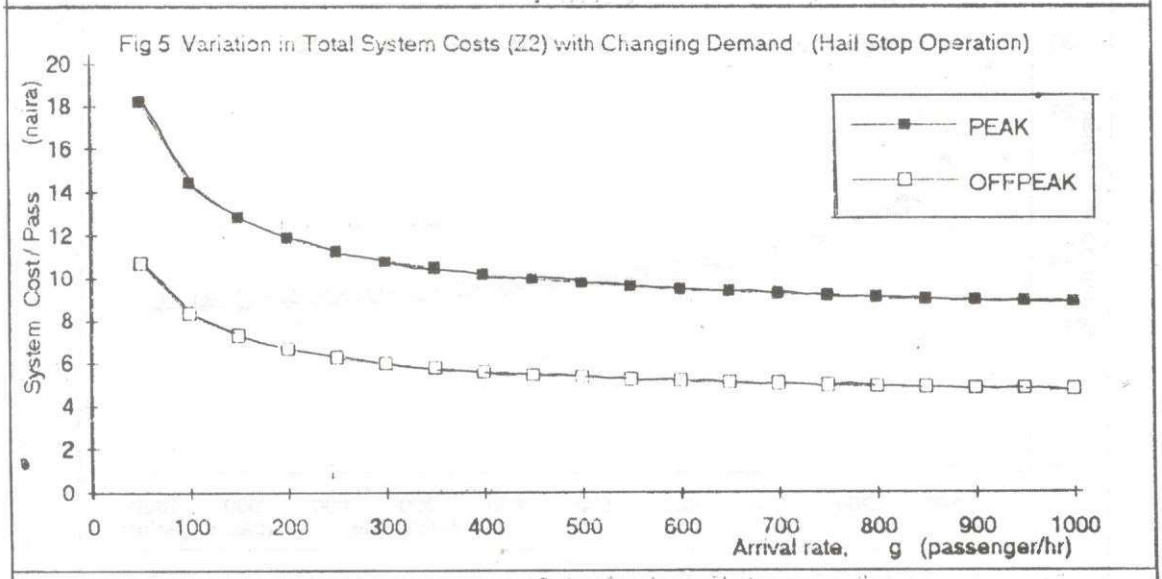
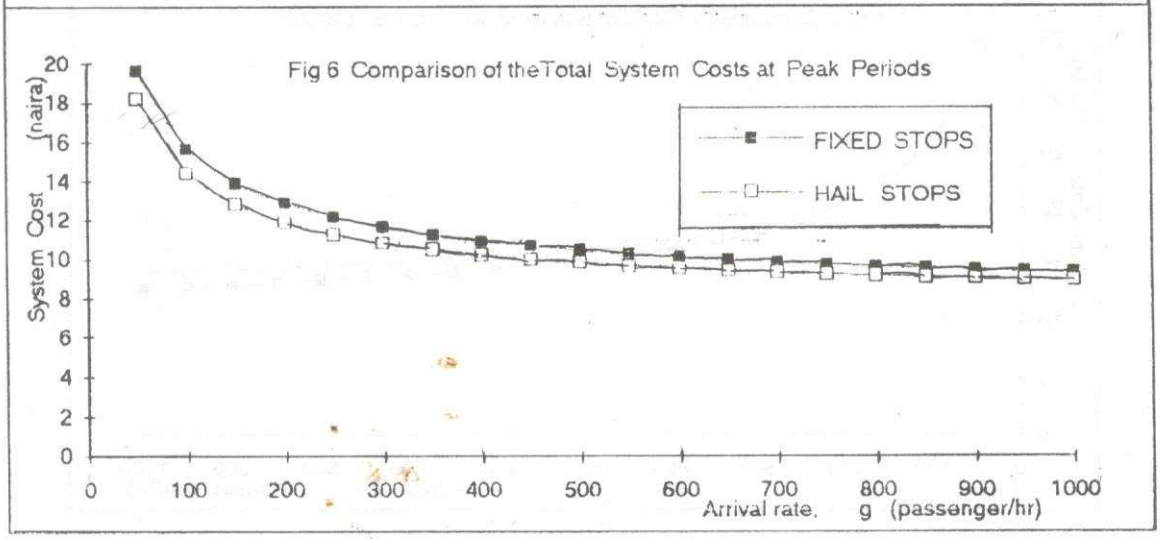


Fig 3 Variation in Optimum Headways with Changing Demand (C1 = 5)




Fig 4 Variation in Total System Costs (Z1) with Changing Demand (Fixed Stop Operation)
System Cost/ Pass (naira)
PEAK
OFFPEAK
Arrival rate, g (passenger/hr)


Fig 5 Variation in Total System Costs (Z2) with Changing Demand (Hail Stop Operation)
System Cost/ Pass (naira)
PEAK
OFFPEAK
Arrival rate, g (passenger/hr)


Fig 6 Comparison of the Total System Costs at Peak Periods
System Cost (naira)
FIXED STOPS
HAIL STOPS
Arrival rate, g (passenger/hr)

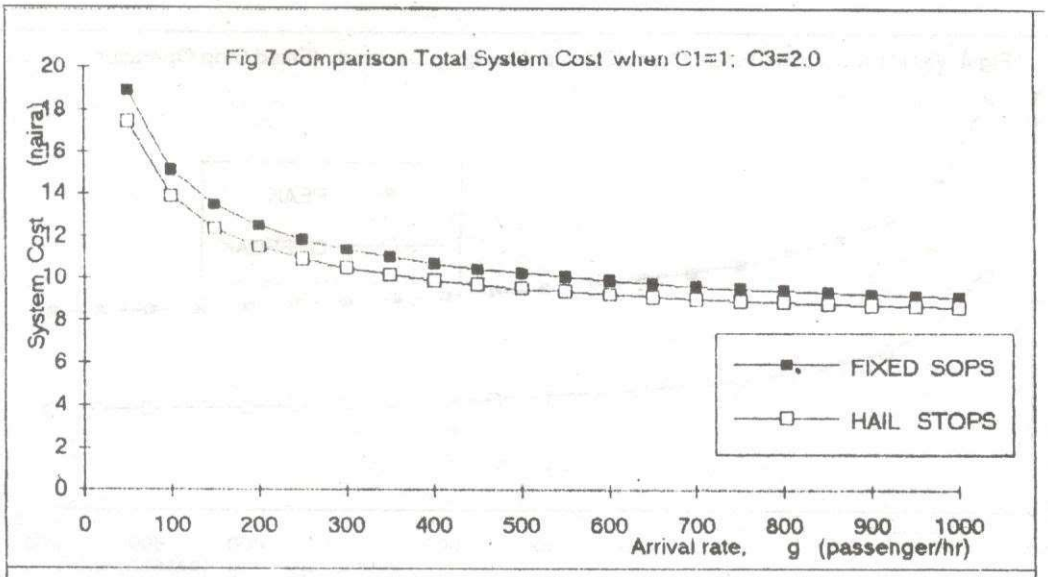


Fig 7 Comparison Total System Cost when C1=1; C3=2.0

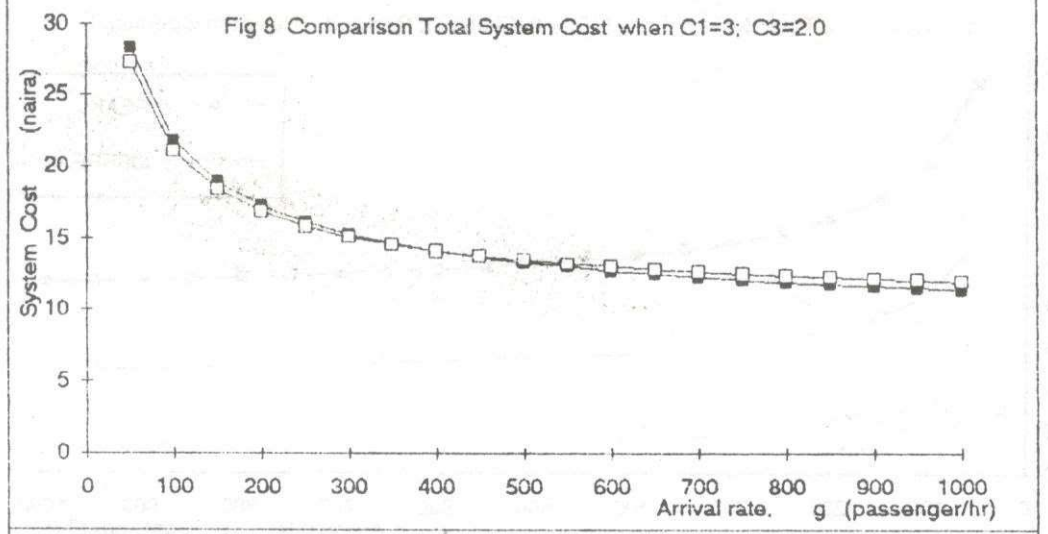


Fig 8 Comparison Total System Cost when C1=3; C3=2.0

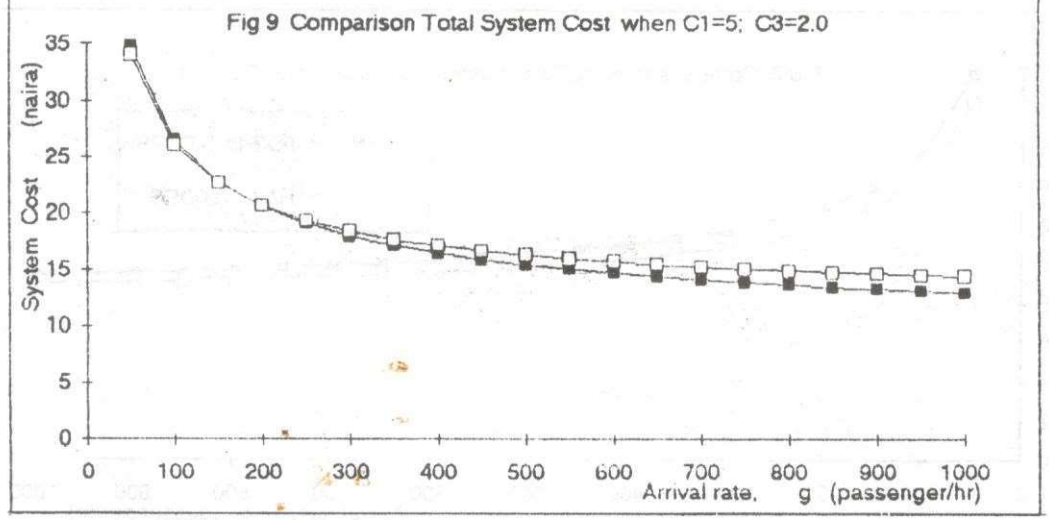


Fig 9 Comparison Total System Cost when C1=5; C3=2.0

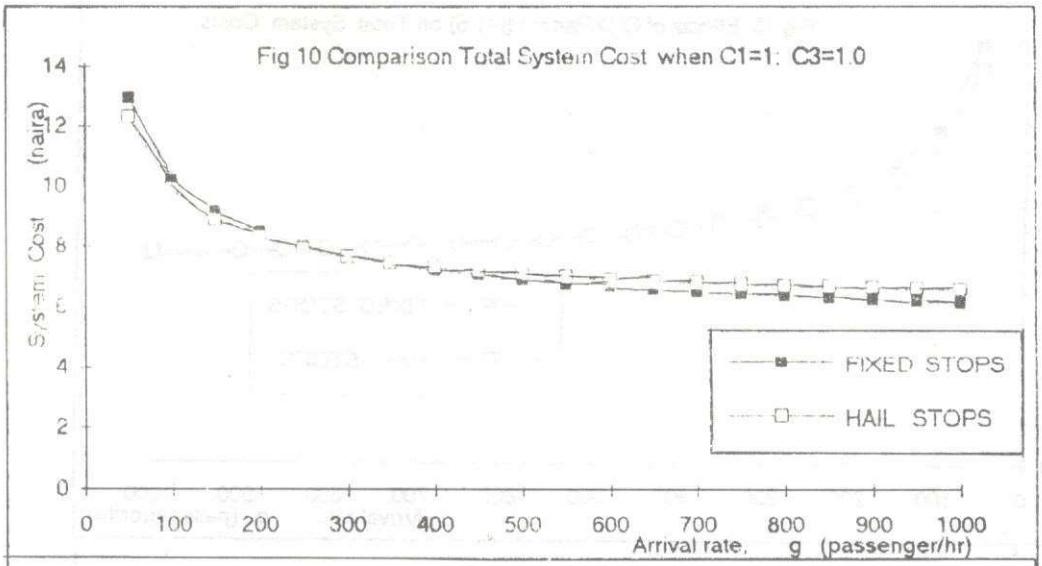


Fig 10 Comparison Total System Cost when C1=1; C3=1.0

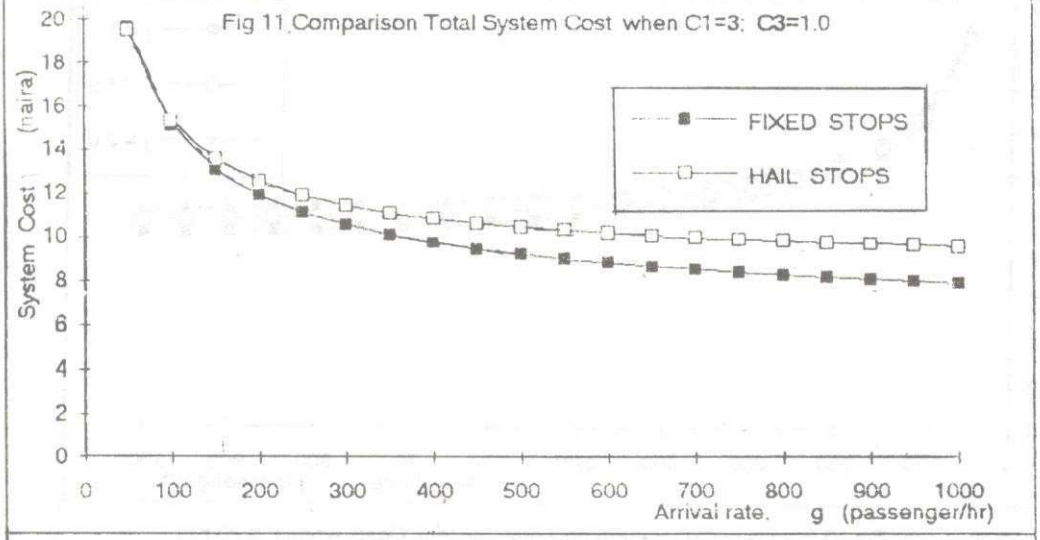


Fig 11 Comparison Total System Cost when C1=3; C3=1.0

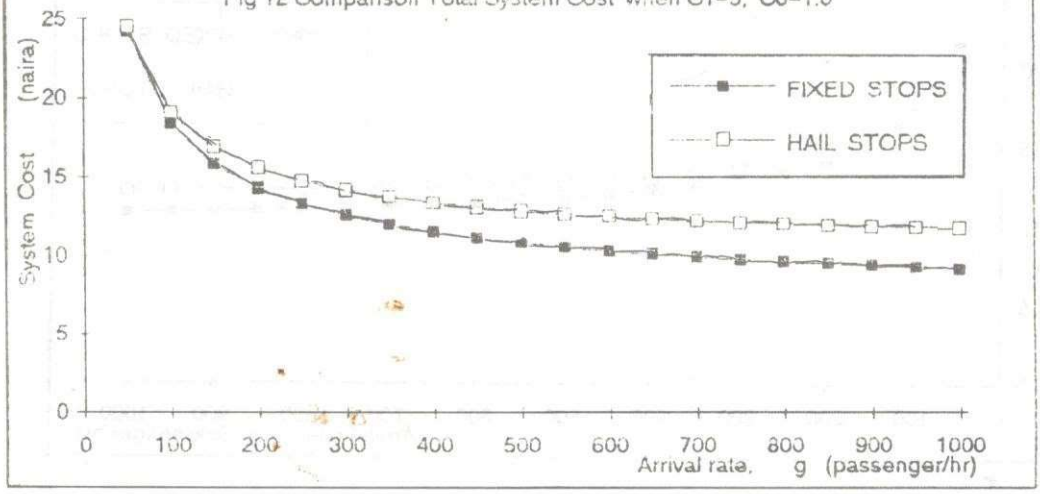
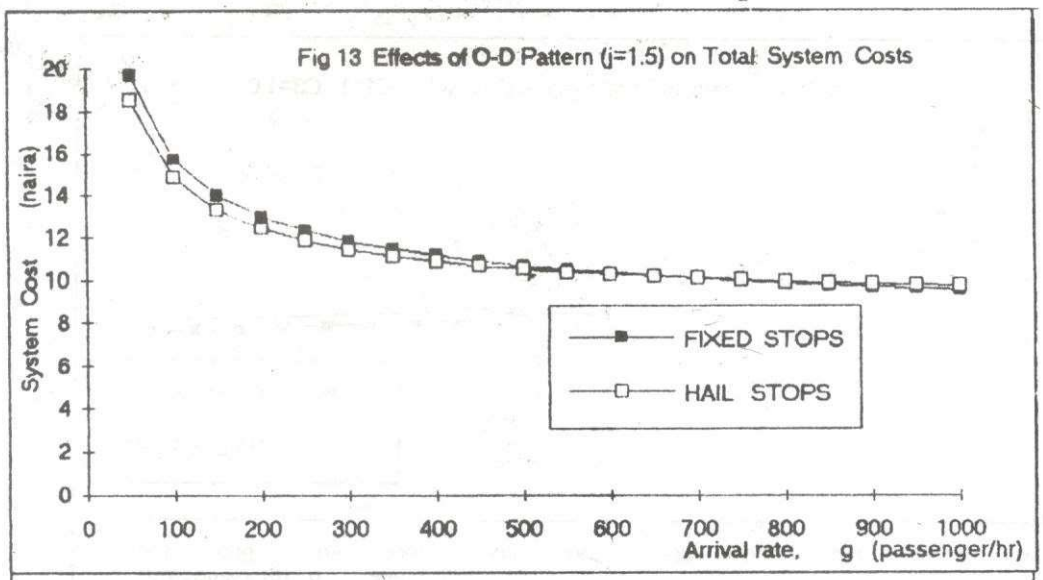
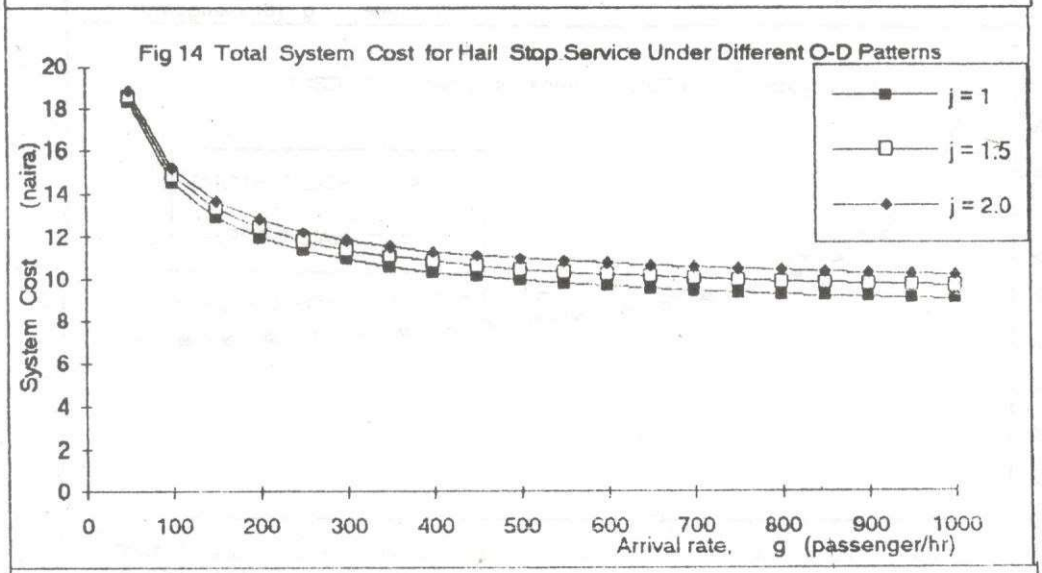


Fig 12 Comparison Total System Cost when C1=5; C3=1.0


Fig 13 Effects of O-D Pattern (j=1.5) on Total System Costs
System Cost (naira)
Arrival rate, g (passenger/hr)
FIXED STOPS
HAIL STOPS


Fig 14 Total System Cost for Hail Stop Service Under Different O-D Patterns
System Cost (naira)
Arrival rate, g (passenger/hr)
j = 1
j = 1.5
j = 2.0

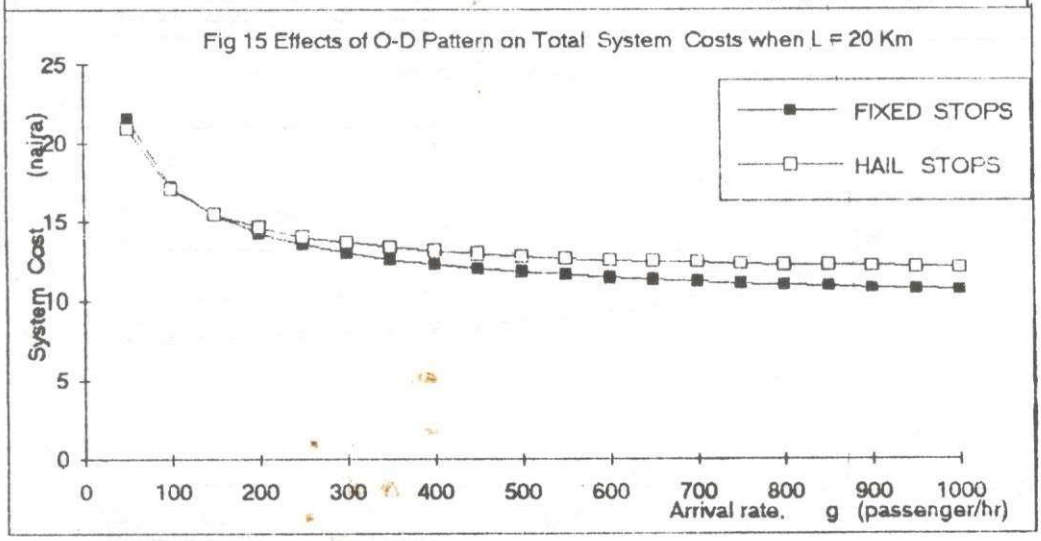

Fig 15 Effects of O-D Pattern on Total System Costs when L = 20 Km
System Cost (naira)
Arrival rate, g (passenger/hr)
FIXED STOPS
HAIL STOPS

Fig 16 Comparison of Total System Cost : L= 4 km, all other default values obtain

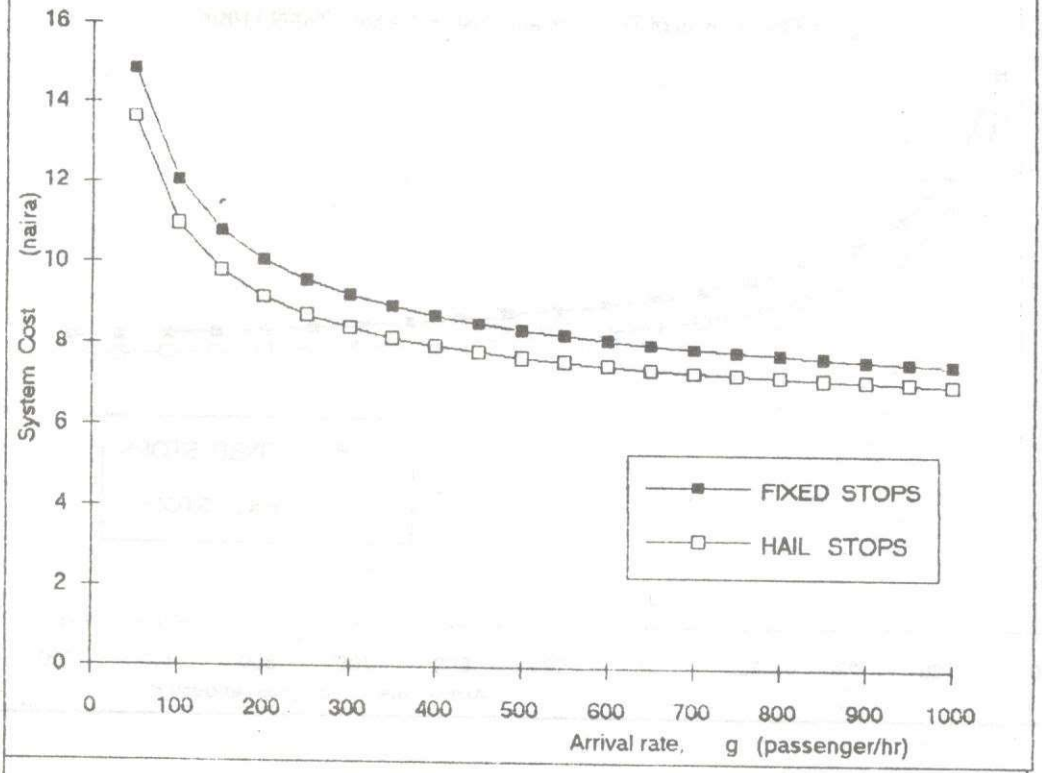
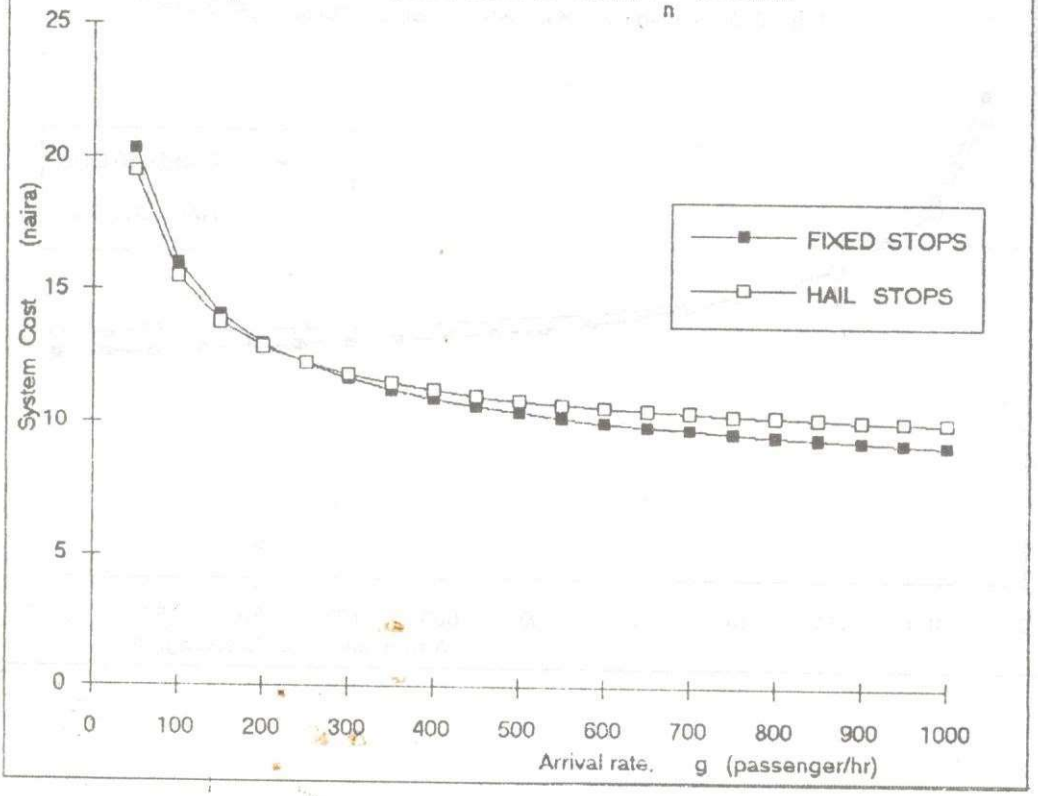


Fig 17 Comparison Total System Cost : L = 16 km, γ_n = N 15/Km



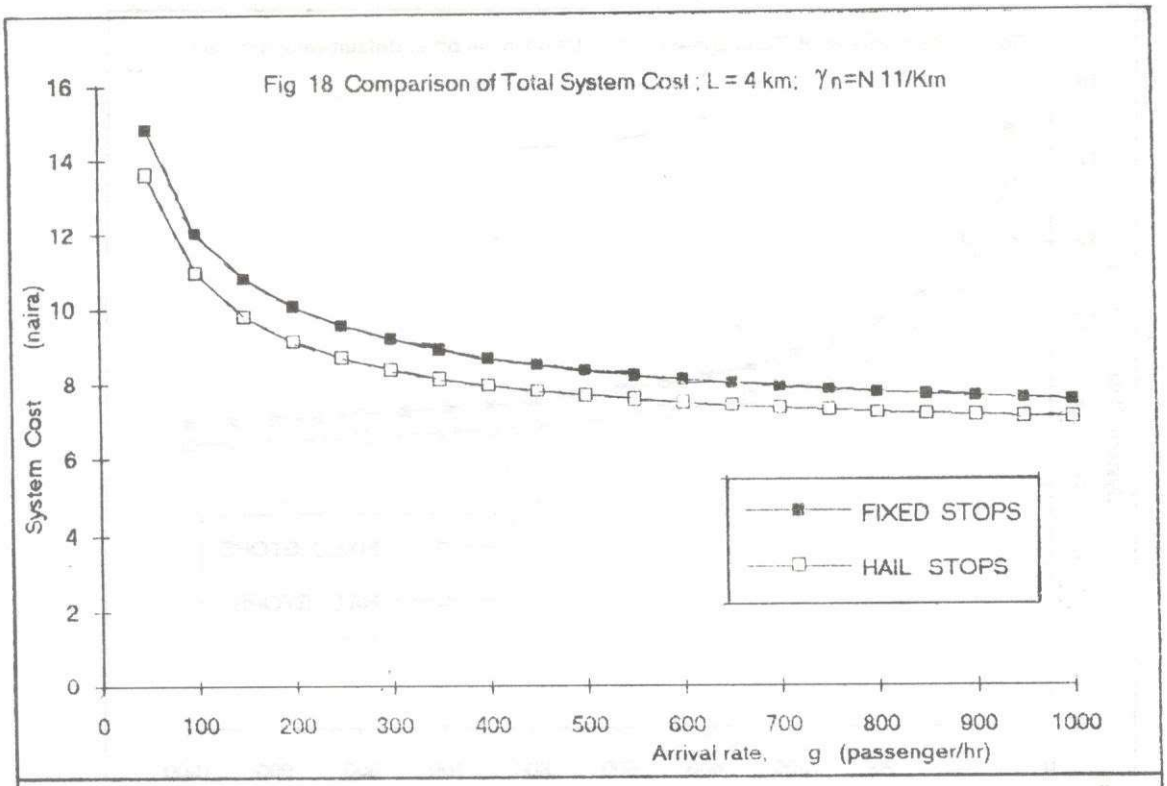


Fig 18 Comparison of Total System Cost ; L = 4 km; γ_n=N 11/Km

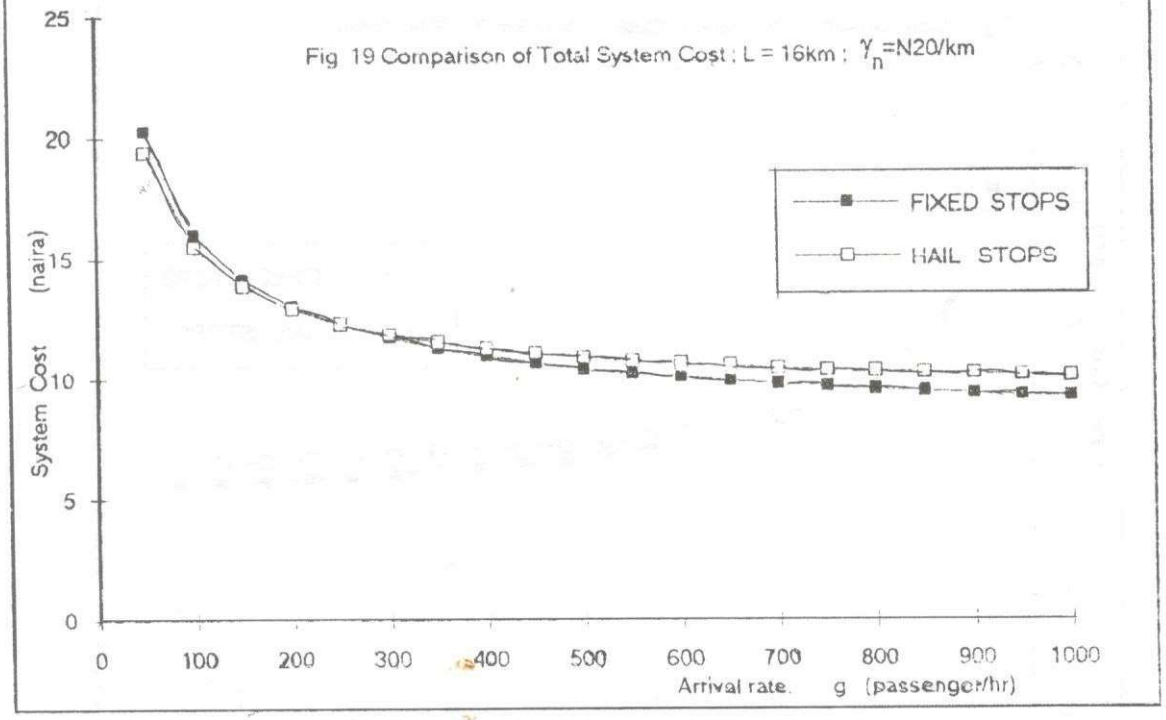


Fig 19 Comparison of Total System Cost ; L = 16km ; γ_n=N20/km