OVERSEAS ROAD NOTE 4

Field survey techniques and analysis for urban bus operators

Overseas Unit
Transport and Road Research Laboratory · Crowthorne Berkshire United Kingdom

Transport and Road Research Laboratory Overseas Unit

Department of Transport
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OVERSEAS ROAD NOTES

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1. INTRODUCTION

OBJECTIVES

1.1 This guide explains how the quality of management information in the bus industry can be improved by means of field surveys. It further explains how the efficiency of public transport operations in towns and cities in Third World countries can be improved by the use of information collected from these surveys.

1.2 The guide is aimed primarily at the middle management of public transport operators and at those who have been delegated the responsibility of collecting relevant data.

THE NEED FOR SURVEYS

1.3 It is often argued that because demand for conventional stage-carnage services in Third World cities is presumed to be captive, operators need only concern themselves with getting the maximum use out of their vehicles while the demand side will take care of itself. Such an attitude ignores factors such as

- the need or pressure to introducenew modes of public transport (para transit types, for example) which may compete for custom;

- the growth in ownership of cheap personal transport (like cycles and motorcycles);

- the need for operators to present to Government (or other finance sources) requests for investment based on sound analysis of market prospects;

- the pressures which build up amongst users faced with consistently poor services.

1.4 It is important for an operator to be aware of the market structure and how users are likely to respond to fare changes, service changes and the like. The opinions and attitudes of users towards the service are rarely sought and neither is investigation made of how their demand is generated and how they choose their mode of conveyance.

1.5 Most urban bus operators in the developing world collect statistics for purposes of management accounting and control but these data sources are seldom adequate to throw light on the effectiveness of bus services in meeting demand.

1.6 Field surveys of bus operations and the use made of buses should be used to provide information for operators on;

- better use of existing resources in providing the busservice;
- more effective long term planning to meet future travel needs.

CONTENT AND STRUCTURE

1.7 This guide is structured in two parts: the initial section examines in some detail the inadequacies of existing data sources and the need for appropriate performance and planning indicators; the following sections explain the task of collecting appropriate material, its analysis and presentation. The techniques and analysis employed should find wide application with bus operators throughout the Third World.

1.8 While the emphasis of this guide is on survey data for planning purposes, the role of other information sources is explained, and briefly commented on. This gives some context to the survey data, as well as drawing attention to the overall management information system required for monitoring service levels and long term planning.

2. INFORMATION SOURCES AND PERFORMANCE INDICATORS

DATA SOURCES

2.1 Data concerning the performance of bus fleets usually comes from three main functions: engineering, traffic and accounts. Table 2.1 presents typical data sources and the information which is readily available from each.

Maintenance records

2.2 Information is usually kept in depots and/or central workshops which records maintenance, servicing and daily preparation performed on vehicles. Sometimes vehicle log-books are used to monitor the service record of a vehicle, recording maintenance and servicing together with vehicle kilometrage operated.

2.3 Vehicle log-books are often poorly completed and the information available is thus of dubious quality. Furthermore, vehicles can he so transformed through their lives by the replacement of major assemblies (engine, axles, gearbox, etc) and general 'cannibalisation' (making one serviceable vehicle out of two or more unserviceable vehicles) that it is difficult to say whether any individual vehicle maintains a unique identity which can be recorded in a log-book.

Traffic supervision

2.4 Traffic supervisory staff monitor the service to ensure that schedules are being maintained. There may be time keepers at terminals, roving inspectors (who, amongst other things, check on fare evasion), as well as depot staff who ensure that drivers and conductors report for duty and are allocated an appropriate vehicle which leaves the bus depot according to schedule.

Financial accounting

2.5 The financial side of the organisation collects together all cost and revenue information in order to present both the profitability of the company and budget estimates for following years. This information source will contain information of both operating costs and capital costs (including capital structuring or sources of capital).

TABLE 2.1

CURRENT DATA SOURCES AND INFORMATION

	Data source	Information Available
1.	Maintenance records	-rate of consumption of spare parts, fuel and tyres -vehicle availability - vehicle breakdowns and accidents.
2.	Traffic supervision	- crew availability - vehicle outshedding - schedules and trips operated - lost mileage - journey speeds of vehicles - daily vehicle utilisation - breakdowns and accidents.
3.	Financial accounts	- total revenues and sources - total costs and cost components - trends in costs and revenues - unit prices of resources - rates of expenditure - staffing structure and norms.
4.	Ticketing	- number of fare-paying passengers carried - average passenger journey distance (lead) - average fare per pasenger carried - total earnings from fare paying passengers.

Ticketing

2.6 Table 2.1 indicates the information that can be obtained depending on the type of ticketing system used. Systems which provide hand cancelled tickets for each denomination will provide most of this information. Other systems can be used only to record passengers carried (tickets sold) and total revenue per conductor-shift. There is unlikely to be a one to one correspondence between tickets sold and numbers of passengers carried. The sale and use of bus passes, through ticketing (where one ticket covers several bus journeys), free travel concessions and fare evasion all lead to ticket information underestimating total patronage.

2.7 The estimation of passenger lead (ie journey distance) is similarly affected by the structure of the fare scale. A flat fare yields no information about passenger journey distance, since everyone pays the same whatever the length of the journey. Clearly the more fare stages there are in a given route network, the easier it is to make a good estimate of passenger lead.

Performance measures

2.8 The most common performance measures used by bus operators are shown in Table 2.2. These ratios are, for the most part, easily determined from data which must necessarily be recorded in running the company. The values presented are often averaged over the fleet as a whole but may sometimes be disaggregated to depot level. They are usually produced daily. The ratios are most usefully employed if some critical values or benchmarks are set for each indicator which are targets set by management. However performance measures give little guidance on the root cause of poor performance and they give little help for long term planning purposes in that they have little information on the way in which output and costs respond to input and fare level changes. Few of the indicators measure the effectiveness of the system and, in general, the data is too coarse because of the amount of averaging that occurs over the total network.

2.9 Clearly, to satisfy the needs of monitoring performance and of planning, there is a requirement to disaggregate information as much as possible and to seek relationships which explain the way in which output and costs respond to changes in inputs and operating environment. Disaggregating information to, say, the route level, obviously calls for the collection of more data. It would therefore seem reasonable to he selective in what is collected.

2.10 Screening indicators can be used to isolate poorly performing routes and, subsequently, more detailed surveys can be carried out to show how to improve the situation.

2.11 Table 2.3 shows the data needed for both monitoring operational performance at different levels of the organisation and for deriving relationships that can be used for use in policy formulation and planning procedures. Screening indicators for route performance might include, for example, the ratio of EPK:CPK, average route waiting times and average load factors (see para 5.4).

2.12 Information is needed not only in overall performance, but in how policy might be changed to induce better performance. Activities like staffing practices and arrangements, maintenance and scheduling procedures, fare setting and investment will be of primary concern. Profitability (or meeting pre-determined financial targets which allow for subsidies) is an indicator of fleet performance. However for long term planning purposes the most critical aspects concern demand and how demand responds to changes in service and fare levels and how unit costs change, as the quality of service changes or as the network expands, (see Appendices A and B for details).

TABLE 2.2

OPERATIONAL RATIOS COMMONLY USED FOR MEASURING PERFORMANCE OF A BUS COMPANY

Fleet availability	- number of vehicles outshed as a proportion of total Fleet stock
Vehicle utilisation	- average daily km per vehicle operated
Schedule out-turn	- proportion of schedules operated
Staff productivity	- number of staff per schedule or per bus
EPK	- earnings per km
CPK	- operating cost per km
Passengers carried	- either absolute or per bus or per bus km
Load factof	- total passenger km/total seat km
Breakdown rate	- per million vehicle km
Accident rate	- per million vehicle km

TABLE 2.3

DATA NEEDS

Monitoring/Planning Activity	Data needs
1. Route performance	- load factor - passenger lead - passenger throughput - fare revenues - use of bus passes - route costs - waiting times - journey speeds/times - causes for delay.
2. Depot performance	- vehicle availability/utilisation - vehicle breakdowns/accidents - rate ofconsumption of resources.
3. Fleet performance	- profitability - load factor - passenger throughput - passenger lead - use of bus passes - fare leakage - vehicle availability - vehicle output - proportion of schedules missed - regularity and punctuality - vehicle breakdowns/accidents.
4. Policy planning and service changes	- all the above items - vehicle handling characteristics (passenger throughput, penalty times, boarding and - alighting times) - passenger travel patterns and use of buses - demand elasticities - opinions of service - staff time use - vehicle time use - staff knowledge and training needs - productivity trends - scale economies.

3. FIELD SURVEYS

PURPOSE OF SURVEYS

3.1 Existing data sources are unlikely to contain sufficient information on items 1 and 4 of Table 2.3 ie route performance, policy planning and service changes. In these cases field surveys will be needed to provide additional information. Table 3.1 lists some of the types of survey that are recommended and the information that they can be expected to produce.

3.2 The type of information yielded refers to broad area of interest such as system effectiveness and the demand for bus services. Some surveys wilt yield information in more than one area of interest. For example, a loading survey will provide data on both system effectiveness as well as passenger handling capabilities.

3.3 Surveys involving interviews are primarily concerned with users obtaining information on their travel habits and opinions of the service. The type of information required determines whether surveys should be conducted on or off the bus. Continuous surveys involve monitoring on a regular basis and will normally be carried out on the basis of a sampling framework.

3.4 In the following sections, these surveys are described in more detail in terms of manpower requirement, questionnaire or pro-forma design and output. These descriptions are based on manual recording and data storage

TABLE 3.1

SURVEY TYPES

	Information	Method	Output
1. Loading surveys	System effectiveness Vehicle performance	In-vehicle, continuous, by observation	Vehicle load patterns Av. load factors Av. passenger lead Passenger throughput Vehicle handling capability Farerevenues/leakage Use of bus passes Journey speeds/time Boarding/alighting Times
2. Journey time and penalty time surveys	Vehicle performance	In and off-vehicle, continuous or *ad-hoc*, by observation	Journey speeds Causes of delay Penalty times.
3. Waiting times and bus frequencies	System effectiveness Demand Vehicle performance	Off-vehicle, continuous or *ad-hoc*, by observation	User waiting times Passenger arrival patterns Bus arrival patterns Boarding/alighting times
4. Passenger interviews	Demand System effectiveness	On or off-vehicle *Ad-hoc* interviews	Travel patterns and use of buses Estimates wait times and travel Times Opinions of service
5. Household surveys	Demand System effectiveness	Off-vehicle *Ad-hoc* by interview	Demand for transport Modal choice criteria.
6. Time and motion surveys	Staff/vehicle performance	On or off-vehicle *Ad-hoc* by observation	Staff time use Vehicle use.
7. Staff interviews	Staff performance	Off-vehicle *Ad-hoc* interviews	Knowledge and training needs.
8. Boarding/alighting	Vehicle effectiveness	*On/off*-vehicle by observation	Time boarding/alighting.

techniques. More sophisticated techniques for directly recording information in machine readable format are rapidly becoming available and should be considered where resources permit.

3.5 The overall logistics of the field surveys are considered in Section 4 and practical applications of the survey results
are contained in Section 5. In order to illustrate the output expected, an example is presented in Appendix C.

BUS LOADING SURVEYS

3.6 The main purpose of the bus loading survey is to determine passenger load patterns on vehicles and routes. Other information on revenue generation, the use of bus

DAY: Wednesday
DATE: 28 . 6 . 78

DIRECTION OF TRIP: Moti Nagar to Central Secretariat

ROUTE NO: 80
ROUTE LENGTH: 8 km

NO OF TICKETS 15 paise: 2 REVENUE: 0-30
30 paise: 96 REVENUE: 28-80

NO OF BUS PASSES: 5

TRIP START TIME: 18-20
TRIP FINISH TIME: 18-47
TOTAL TRIP TIME: 0-27 mins

TOTAL FARE REVENUE: Rs 29-10

TOTAL NO OF PASSENGERS: 103

VEHICLE TYPE
SINGLE DECK ✓
DOUBLE DECK
MINIBUS
OTHER (SPECIFY)

NAME OF BUS STAND	TIME		PASSENGERS			JOURNEY REMARKS
	ARRIVAL	DEPARTURE	BOARDING	ALIGHTING	REMAINING	
Moti Nagar		6.20.00	63	-	63	
Industrial Area	6.23.20	6.23.35	4	-	67	
Shadipur Depot	6.25.30	6.25.30	8	-	75	
DTC Colony	6.28.40	6.29.00	2	-	77	
West Patel Nagar	6.30.55	6.31.05	3	1	79	
South Patel Nagar	6.33.20	6.33.32	3	2	80	
East Patel Nagar	6.34.35	6.35.50	13	-	93	
Shankar Road	6.36.06	6.36.10	2	3	92	
New Rajendra Nagar	6.38.30	6.38.40	4	3	93	
Ridge Road (Downhill)	6.4045	6.41.40	1	36	58	
Willingdon Hospital	6.44.30	6.44.50	-	14	44	
North Ave. (MPs Flats)	-	-	-	-	44	
North Avenue	6.46.15	6.46.20	-	2	42	
Central Secretariat	6.47.00	-	-	42	-	
TOTAL			103	103	-	

Fig 3.1 Pro-forma for bus loading survey

passes, journey speeds and boarding/alighting times are also determined from this type of survey.

3.7 A bus loading survey requires two survey assistants per monitored bus trip. They sit in the vehicle, one at the entrance and the other at the exit. Where the vehicle has only one exit/entry door, two survey assistants are still required to cope with data collection. The pro-forma for data collection is shown in Fig 3.1, completed for a typical bus trip. Times are recorded with stop watches (if available) or wrist-watches, which have been synchronised.

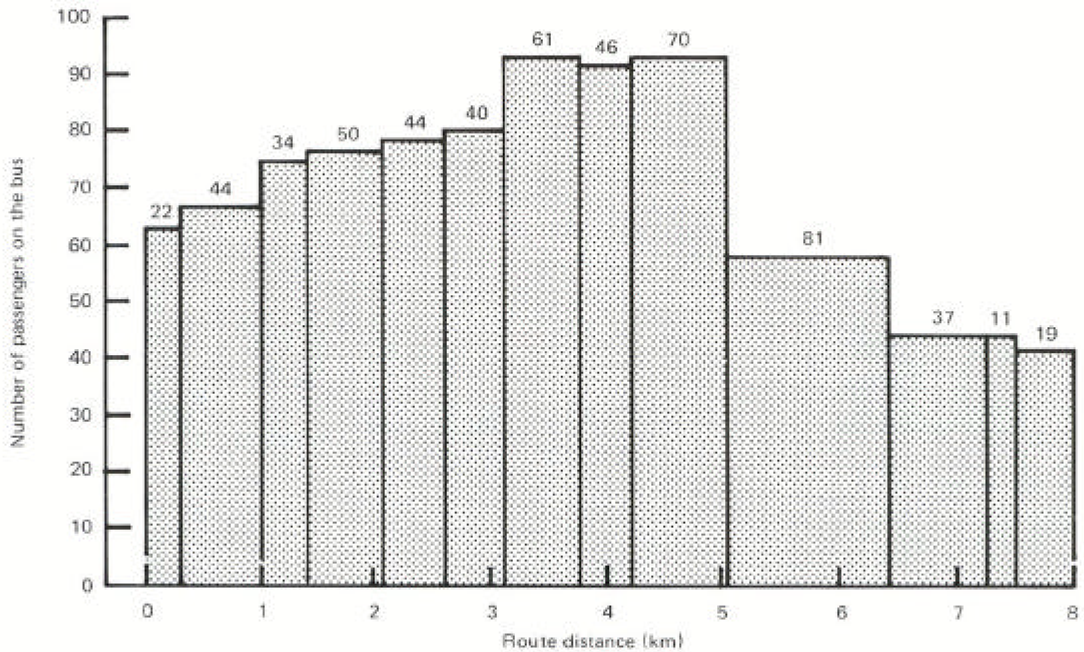
3.8 At the start of each bus trip the following are recorded:

- day and date of survey;
- route number;
- journey direction;
- vehicle type;
- start time.

3.9 Each survey assistant records the times of arrival and departure from each bus stand at which the vehicle stops. The man at the entry door records the number of passengers boarding, while the man at the exit door notes the number of passengers alighting. During the trip, any undue delay (caused by congestion, accident, etc) can be noted in the remarks column, together with any action taken by traffic staff as a result. At the trip destination the finish time is noted so that total trip time can be determined. Information on trip revenue (from the number of tickets sold by denomination) can also be recorded from the conductor's waybill. The conductor should also be able to provide information on the number of bus passes produced by travellers, particularly if he has been prompted by the survey assistants to make a note of this.

3.10 During the terminal turn-round period, the survey assistants can undertake preliminary analysis such as calculating bus stand times and bus loadings along the route. The latter is determined by comparison of individual observations of number of passengers boarding and alighting along the route.

3.11 Apart from information on trip times and speeds, trip revenues and total number of passengers carried. it is also possible to determine the average passenger trip length (or lead) and the vehicle load factor for the trip. The lead is determined from a histogram of passenger loadings along the route. Fig 3.2 presents the loading pattern for the trip information contained in Fig 3.1, where each bar represents the number of passengers on the bus at any point along the route. The height of each bar is proportional to the number of passengers on each link (ie section of the route), and the width proportional to the link distance. The shaded area of the histogram is equal to the total number of passenger-km undertaken on the bus trip, each bar representing a certain number of passengers who have travelled the link distance; the summation of all these bars is the total passenger-km for the bus trip. The average passenger lead is the total passenger-km divided by the total number of passengers carried.



Note: The figures above the columns represent the pass.km completed between each bus stand.
For example, between the first and second stands, 63 passengers travel 0.35km, i.e. 22 pass.km

Fig. 3.2 Histogram of number of passengers on the bus at any point along the route

3.12 For accuracy, the distances between bus stands should be known. Where this is not known, one approximation is to assume that bus stands are spaced equally along the route, with the inter-bus stand distance equal to the route length divided by the number of stands less one. Thus the passenger lead for a trip is given by the expression:

sum of (passengers on the bus on each link x link distance)

total number of passengers using the bus.

3.13 From Fig 3.2 the total passenger kilometrage was 559 while from Fig 3.1 the number of passengers carried (ie who boarded the vehicle) was 103. Thus the average passenger lead on this trip was 5.4 km.

3.14 The load factor relates passenger km to seat km, the latter being the route length times the number of seats (or rated bus capacity) on offer. For the trip illustrated the load factor was 1.2 or 120 per cent.

3.15 The timing information contained on the data sheets (shown in Fig 3.1) can be used in a number of ways. For time and motion studies it is possible to assess the amount of staff time which is spent actively, ie steering time (when the vehicle is being productively driven) as a proportion of total time. It is also possible to extract information on passenger boarding and alighting times, together with journey times and speeds. The variability in journey times can be determined, though relating this to specific causes may not be possible from the loading survey. Journey time surveys (see below) are required to assess the importance of different journey time components, and the factors which affect them. The analysis of journey time data which is available from loading surveys is included in the next section.

JOURNEY TIME SURVEYS

3.16 There are three broad components of bus journey time:

- free running time;
- bus stand delay;
- other delays which can be subdivided into
  a) stop or stationary delays;
  b) general delays.

3.17 Stop or stationary delays include delay at traffic signals whereas general delays do not involve stops but take account of periods when speeds are below those which might reasonably be achieved on open roads. General delay is due to such factors as prevailing traffic or weather conditions.

3.18 Each bus stand or stop delay involves two separate elements: the time when the vehicle is stopped and the so called penalty time which is incurred due to deceleration from and acceleration to the optimum travel speed.

3.19 The objective of journey time surveys is to identify the importance of the component parts of travel time and to identify possible causal relationships. Fig 3.3 illustrates how

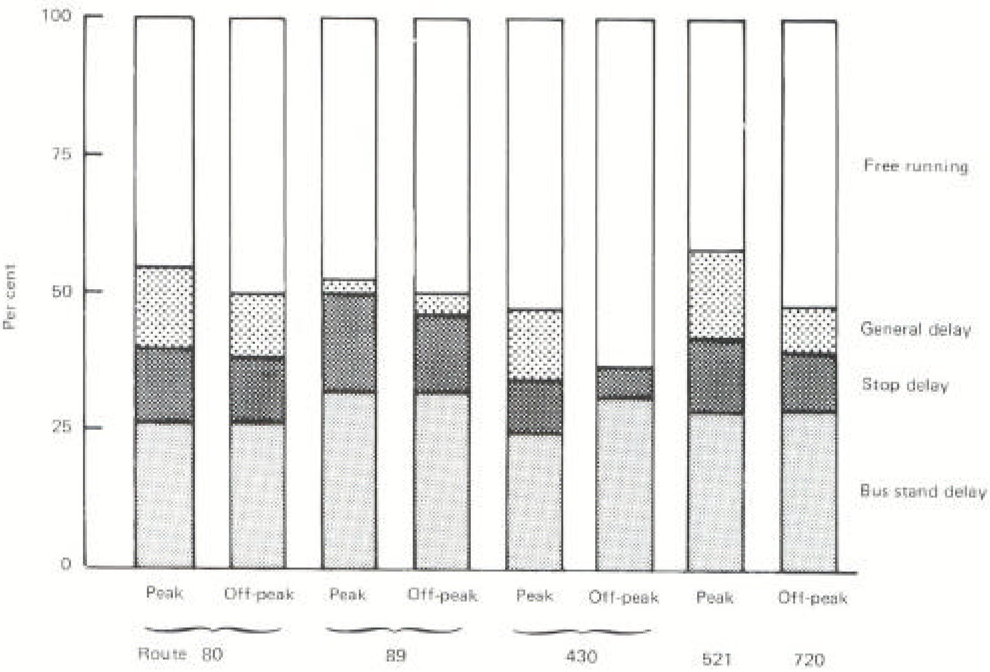


Fig. 3.3 Examples of a breakdown of bus running times

components of bus running time can be analysed and presented. Detailed analysis of this sort is useful when considering such things as new bus interior designs or other changes which might affect vehicle passenger handling characteristics. The data would also be useful to support a case for traffic management measures to improve bus journey times.

3.20 Fig 3.3 shows that in this example, bus stand delays represent about ***25*** per cent of journey time, whilst other delays (stop and general) account for between 2030 per cent of journey time. Traffic management techniques for improving bus running speeds can therefore be expected to reduce journey times by up to 2~30 per cent. As a proportion of total journey times total delay ranges from 3854 per cent with some evidence suggesting it is higher in the peak period.

DAY: Wednesday
DATE: 16.8.78

ROUTE NO: 89
ROUTE LENGTH: 19 km

TRIP START TIME: 11.55
TRIP FINISH TIME: 12.31
TOTAL TRIP TIME: 96 min

VEHICLE TYPE:
- SINGLE DECK ☐
- DOUBLE DECK ☐
- MINIBUS ☐
- ARTIC DOUBLE DECK ☑
- OTHER (SPECIFY) ☐

DIRECTION OF TRIP:
Rohtak Road to S N Depot

CAUSES
1. ROUNDABOUT
2. TRAFFIC SIGNALS
3. BUS STANDS
4. PEDESTRIANS
5. ANIMALS
6. UNCONTROLLED JUNCTION
7. CONTROLLED JUNCTION
8. ACCIDENT
9. OTHER

TIME SLOWER THAN WALKING SPEED	STOP TIME	TIME FASTER THAN WALKING	CAUSES OF DELAY	DELAY TIME IN SECONDS	DELAY LOCATION
11.56.19	11.56.29	11.57.00	1	41	ANAND PARBAT
12.03.00	DNS	12.03.13	1	09	
12.05.01	DNS	12.05.14	1	13	
12.05.49	12.05.58	12.06.12	3	23	MADRAS HOTEL
12.07.43	12.08.11	12.08.21	1	38	
12.08.30	12.08.34	12.09.05	3	35	
12.10.01	DNS	12.10.44	1	43	AIR
12.11.30	12.11.37	12.11.57	2	27	
12.12.50	DNS	12.13.09	1	19	
12.13.28	12.13.33	12.13.54	2	26	
12.15.14	12.15.18	12.15.31	3	17	
12.16.01	12.16.06	12.16.28	3	27	
12.18.58	DNS	12.09.06	1	08	
12.19.57	12.20.03	12.20.28	3	31	UBHAVAN
12.20.54	12.20.58	12.21.20	1	26	
12.22.01	12.22.07	12.22.50	3	49	
12.23.33	DNS	12.23.56	1	23	
12.24.30	DNS	12.24.57	1	27	
12.25.07	12.25.11	12.26.45	3	98	S N MARKET
12.27.30	12.27.37	12.28.20	3	50	

Fig. 3.4 Pro-forma used to carry out bus journey time surveys

3.21 In its simplest form, the journey time survey is undertaken by one survey assistant per bus trip. He is located near the driver where he can observe traffic conditions. A pro-forma like that shown in Fig 3.4 is used, together with a stop-watch. The survey assistant records the day, date, route number, direction of trip and vehicle type before the trip starts. He then records the start time, followed by all further relevant timings. when the vehicle slows to a speed slower than walking pace (as estimated by the survey assistant) but does not actually stop; when the

Day: Thursday Date: 17.9.78 Location: Sewi Nagar

Vehicle type: Single deck - SD Direction: SN Depot to C. Secretariat
double deck - DD
artic double deck - ADD
minibus - MB

Vehicle type	Bus registration number	Number of entry exit doors	Depart time	Stop time (secs)
SD	1635	2	8.08.44	14
SD	460	2	8.09.28	22
SD	2536	2	8.09.42	3
ADD	869	1	-	0
SD	202	2	-	0
DD	427	1	8.14.14	8
SD	5725	2	8.16.23	11

(a)

Vehicle type	Bus registration number	Passing time	Vehicle type	Bus registration number	Passing time
SD	1635	8.07.93			
SD	460	8.08.73			
SD	2536	8.09.07			
ADD	869	8.10.12			
SD	202	8.12.30			
DD	427	8.13.72			
SD	5725	8.15.75			

(b)

Fig. 3.5a,b Proformas used for carrying out penalty time surveys

vehicle picks up a speed *faster* than walking pace again, when a vehicle actually stops and starts; trip finish time. The causes of each delay are denoted by one of the codes 1 to 8. It will be seen that stop delays are recorded separately from general delays (which do not involve stops). Delay locations are noted so that congestion points can be identified. Stop or stationary delay is the delay to vehicles caused by stops other than at bus stands. It is defined as the extra time taken by delayed buses to travel between bus stands over and above that taken by undelayed buses. The measurement of time is that from when a bus first stops in a queue to when it clears the area of congestion (taken to be when the vehicle is moving faster than walking pace). Stop delays are the addition of stop times and the penalty time incurred as a result of slowing down.

3.22 Penalty times are monitored off the vehicle at bus stands. The location of the survey site for penalty times should offer a flat gradient, good line of sight for the survey assistants and traffic conditions which are free of congestion. Three survey assistants are required, one located 200 metres before the stand, one at the stand and one 200 metres beyond the stand. The person at the bus stand has a pro-forma like that shown in Fig *3.5(a),* on which he records the arrival and departure times of each bus which stops at the stand. A description of each bus is also kept: vehicle type, registration number, number of exit! entry doors. Timings are made using a stop-watch, if available. The other two assistants use stop-watches which are synchronised with that of the assistant located at the bus stand. They use the pro-forma shown in Fig *3.5(b)* to monitor the exact time that every bus passes them, the bus being identified by its registration number. Vehicles that do not stop at the stand do not have to decelerate or accelerate and therefore travel the distance of 400 metres (between the two assistants located 200 metres either side of the stand) at a much faster speed than vehicles which do stop (ignoring the actual stop time). The penalty time associated with stopping vehicles can be determined by comparing the travel times of non-stop and stopping vehicles over the 400 metre section, allowing for the actual stop time of vehicles which do stop. These times are determined by comparing the information from the three observers: vehicle numbers are matched, stopping vehicles appearing on all three proformas, non-stopping vehicles only on the pro-formas of the two outer observers.

3.23 An analysis pro-forma is shown in Fig3.5(c). Average values of penalty time should be determined for different vehicle types, if relevant. From a series of surveys in Delhi the weighted average penalty time value was 13 seconds which is high in comparison to observations in the UK where values of 9 seconds have been monitored. The high penalty time may be connected with extreme overloading experienced in single deck operations or the lower performance of some technologies in use in India when the surveys were implemented.

3.24 The penalty time information is used to provide additional information to that obtained during the journey time survey. It provides additional material on the time losses caused by stops and starts which the survey assistant sitting on a bus would be unable to monitor on his own.

3.25 Bus stand delay (which includes both penalty time and the time when the vehicle is not in motion) is dependent on a number of factors which include vehicle design, driver and passenger behaviour and numbers waiting to board or alight. The latter information will have been collected as part of the loading survey (see above) or the waiting time frequency survey (see below). For predictive purposes a statistical test known as linear regression* can be used to determine relationships between times of boarding and alighting, and the numbers of passengers involved, for given vehicle types. The bus stand stop time has two elements which are the dead time (time between bus coming to a standstill and persons boarding and/or alighting) and the actual boarding and/or alighting time (total time taken by those boarding and/or alighting).

3.26 The dead time should be independent of the number boarding and alighting. For single entrance vehicles the boarding and alighting times are additive, ie those boarding must wait till those alighting have finished. The total stop time will thus be dependent on the total numbers boarding and alighting. The marginal alighting time (the time each passenger takes to alight) is likely to be smaller than the marginal boarding time (the time that each passenger takes to board), and therefore total stop time will vary with the proportion of alighting to boarding passengers. Total stop time for single entrance buses can be represented by:

$$Y = C + aA + bB$$

where Y is the total time, C is the dead time, A and B are the numbers alighting and boarding and a and b the marginal alighting and boarding times.

3.27 For double door buses boarding and alighting take place independently of one another. At any stand, the stop time will be the result of dead time plus the boarding or alighting time, whichever is greater. Total boarding and alighting times can be represented separately by:

$$YA = C1 + a1A$$

$$YB = C_2 + b1B$$

where YA and YB are the total alighting and boarding times respectively.

*(Linear regression is a statistical technique which seeks to derive an equation which best explains any relationship between two or more variables)

Day Thursday Date 17.9.78 Location Sewi Nagar

Direction SN Depot to C. Secretariat

VEHICLE TYPE	BUS NUMBER	TIME AT FIRST POINT	TIME AT ARRIVAL	BUS STAND DEPARTURE	TIME AT SECOND POINT	TOTAL JOURNEY TIME (mins)	STOP TIME (mins)	ACTUAL JOURNEY TIME (mins)
SD	1635	7.93	8.30	8.44	9.03	1.10	0.14	0.96
SD	460	8.73	9.06	9.28	9.70	0.97	0.22	0.75
SD	2536	9.07	9.39	9.42	9.89	0.80	0.30	0.77
ADD	869	10.12	-	-	10.73	0.61	-	0.61
AD	202	12.30	-	-	12.89	0.59	-	0.59
DD	427	13.72	14.06	14.14	14.70	0.98	0.08	0.90
SD	5725	15.75	16.12	16.23	15.72	0.97	0.11	0.86
SD	1875	16.12	16.47	16.49	17.20	1.08	0.02	1.06
SD	2070	17.27	17.54	17.66	18.13	0.86	0.12	0.74
SD	2527	17.67	18.01	18.06	18.56	0.89	0.05	0.84
SD	2079	18.40	18.71	18.55	19.40	1.00	0.14	0.86
ADD	338	19.27	-	-	19.94	0.67	-	0.67
SD	1225	22.32	22.66	22.68	22.90	0.58	0.06	0.52
SD	1237	22.62	-	-	23.15	0.53	-	0.53
SD	335	25.43	25.88	26.04	26.60	1.17	0.16	1.01
SD	2358	26.35	-	-	26.96	0.61	-	0.61
SD	1708	27.53	-	-	25.12	0.89	-	0.59
ADD	104	28.57	28.95	29.07	29.68	1.11	0.12	0.99

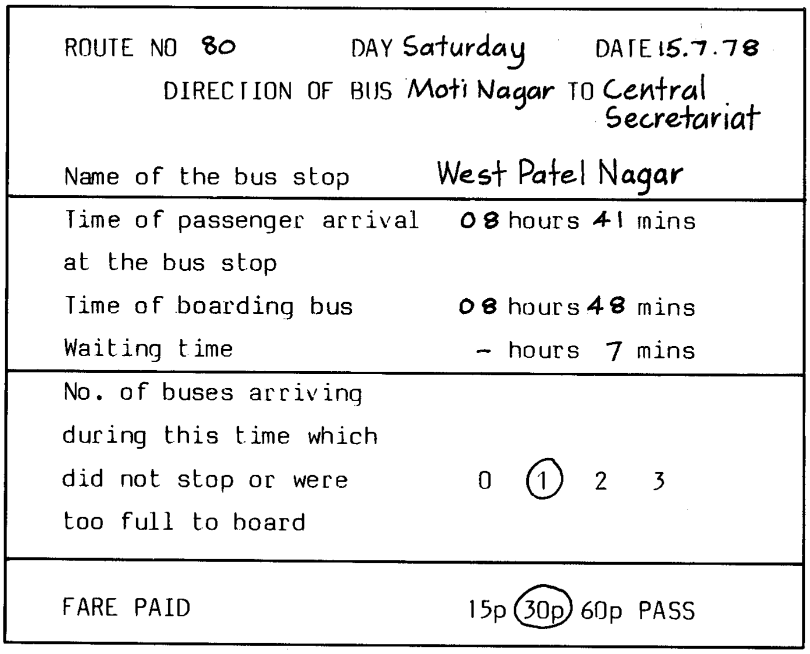
(c)

Fig. 3.5c Pro-forma for analysis of penalty time survey

SURVEYS OF PASSENGER WAITING TIMES AND BUS FREQUENCIES

3.28 The purpose of these surveys is to measure user waiting times and the reliability of the bus service, both key components of the overall level of service effectiveness. The same surveys can also be used to monitor boarding and alighting times, as well as passenger arrival patterns.

3.29 Waiting times can be monitored using a 'Q' Enquiry card as shown in Fig 3.6. Two (or three) survey assistants are required who are located at a bus stand. One (or two) is required to issue the cards to passengers arriving at the bus stand, while the other assistant monitors the arrival and departure times of buses at the stand. A 'Q' Enquiry card is handed to each passenger as he arrives at the bus stand. (Where demand is heavy only a sample of passengers may be selected, say every other one, or every third one to arrive.) The survey assistant completes a few of the details before handing out the card: day, date, intended route number, direction of the bus and, most important, arrival time (of the passenger) at the bus stand. Additional



ROUTE NO 80 DAY Saturday DATE 15.7.78

DIRECTION OF BUS Moti Nagar TO Central Secretariat

Name of the bus stop West Patel Nagar

Time of passenger arrival at the bus stop	08 hours 41 mins
Time of boarding bus	08 hours 48 mins
Waiting time	– hours 7 mins
No. of buses arriving during this time which did not stop or were too full to board	0 1 2 3
FARE PAID	15p 30p 60p PASS

Fig. 3.6 'Q' Enquiry card

information on fare to be paid, use of bus pass and destination can also be sought, though this is not essential to the main purpose of the survey. The passenger is instructed to return the card to the survey assistant when his (the passengers') bus arrives. At this point the survey assistant notes the arrival time of the bus on the card, and the waiting time is the difference between passenger arrival and bus arrival time. Where possible a note is made of the number of buses that arrived which the passenger could not board (either the bus did not stop or the vehicle was too full to board). This can be obtained from the assistant who is monitoring bus arrivals, or by asking the passenger.

3.30 Problems sometimes arise in the retrieval *of ‘Q’* Enquiry cards, especially when large numbers of passengers try to board a vehicle. It is advisable in these circumstances to have one assistant stationed at the entrance to the bus checking passengers one by one.

3.31 Data collected from the waiting time surveys tends to be more accurate than using passengers' own estimates which can be greatly exaggerated and hence unreliable as an indicator of service reliability.

3.32 The form used for monitoring bus arrival times at bus stands is shown in Fig 3.7. A record is kept of the route number, vehicle registration number, and whether the vehicle stopped or not. The numbers of passengers boarding should also be noted, since this will help verify the sampling rate, if adopted. Stop watches should be used if available, synchronised between all three assistants.

3.33 Both survey types enable the operator to keep a record of the effectiveness of the system overall (and specifically certain routes) and the level of service reliability. Clearly such surveys need to be undertaken frequently throughout the network so that any deterioration can be spotted quickly and investigated. For the existing (and potential) passenger a high service frequency and hence minimal waiting time are key elements as to whether frequent use is made of the service.

PASSENGER INTERVIEWS

3.34 These are undertaken in order to obtain several Sorts of information concerning patterns of travel and use of public transport, as well as attitudes to and opinions of the service. The nature of the survey will strongly influence the way in which it is carried out. Where the information to be obtained is fairly simple, a single card may be sufficient for recording purposes. Information like origin and destination, route number, time of day and journey purpose could be recorded quickly by a survey assistant for all passengers using a bus. (It would be helpful to hand such cards out to passengers for completion, but it cannot be assumed that either all passengers have a pen or that all passengers are literate.) Such a survey might be useful where, for example, the bus company wanted to find out more about the use of bus passes, or the extent to which passengers have to make interchanges in their trips, or passengers' estimates of waiting times.

3.35 Where several sets of information of this type are being sought then the questionnaire becomes more lengthy and complex. The interview may take some time to

Day : Saturday
Date: 15.7.78

Direction of trip: Moti Nagar to Central Secretariat

Route No: 80
Route Length: 8 km

Bus Stand: West Patel Nagar

BUS NUMBER	NO OF PASSENGERS BOARDING	ARRIVAL TIME	HEADWAY TIME (mins)	BUS DID NOT STOP	
				OVERCROWDED	NO REASON
190	1	07.33.06	–		
5403	6	07.46.05	12.59		
618	4	07.47.25	1.20		
617	25	07.50.50	3.25		
2436	7	08.05.25	14.35		
2538	8	08.19.07	13.42		
5487	7	08.23.20	4.13		
918	5	08.27.11	3.51		
190	15	08.40.30	13.19		
5403	NONE	08.45.10	4.40	✓	
618	14	08.48.20	3.10		
617	18	08.50.30	10.10		
2436	19	09.06.30	8.00		
1506	4	09.06.35	0.05		
918	7	09.13.02	6.27		
2383	2	09.17.45	4.43		
5487	8	09.24.20	6.35		
618	12	09.35.02	10.42		
693	10	09.37.50	2.48		
190	12	09.39.37	1.47		

Fig. 3.7 Pro-forma for bus arrival time survey

complete, and it becomes necessary to sample from those using the bus. Processing of the data gathered also becomes more complex, and sorting and tabulating data may best be undertaken using computers, if available.

3.36 The advantage of the in-depth passenger interview is that it is possible to establish something of the travellers' social and economic background, his travel characteristics (when using a bus) and the market structure which is currently being met. It is also possible to seek users' views of the service and their opinions as to how improvements could be made, often a useful public relations exercise in itself. Socio-econonuc data of passengers, in relation to data on their level and frequency of trip making enable the operator to build up considerable information on his actual (and potential) market. This is often crucial when holding discussions with the relevant authorities on the setting of fare levels, amount of subsidy required etc. In addition the data also allows the operator to locate and plan services for certain sectors of the population (or potential markets) specifically catering to their needs eg standing only, express buses, limited stop. seating only, air conditioned services etc.

3.37 Interviews can be undertaken both in or off the vehicle. However, for convenience, the more complex questionnaires are probably best completed off the bus, at bus stands. In this case interviews can take place at a sample of bus stands (perhaps the busiest), and a sample of passengers (say every fifth one) interviewed.

3.38 Appendix D shows an example of an in-depth questionnaire used by the Overseas Unit TRRL to determine the travel and socio-economic characteristics of users of public transport in a number of Third World Cities. Questions were framed to determine the extent to which bus passes were in use, the number of bus interchanges being made, and other details of the trip including waiting and walking times.

HOUSEHOLD SURVEYS

3.39 A disadvantage of the passenger interview survey is that it provides information only on those who use the bus-service, ie the current market. Nothing is learned about potential users and/or users of competing modes. A more comprehensive understanding of the total demand for transport and how this varies with city structure and affluence will help the operator in planning future investments. A household survey should go a long way to meet this requirement. However, it is unlikely that bus operators would become involved in undertaking household surveys on a regular basis. These surveys are usually carried out on a large scale at some considerable cost by urban authorities to assess the potential for city development and/or transport in general. What should be of interest to operators, however, is some of the output from household surveys regarding modal choice and travel patterns associated with the different modes of transport.

4. SURVEY LOGISTICS, SAMPLING AND OTHER CONSIDERATIONS

4.1 The manpower requirement for surveys depends on the type of survey being undertaken, its duration and extent, and the work-rate of survey assistants. The latter can normally be expected to work an 8 hour shift, the same as the bus operating staff. A bus may typically be operated for two shifts (morning and evening) and, consequently, if it is proposed to monitor a complete days operations, two shifts or survey assistants will be required per bus-day. Table 4.1 gives the manpower requirements for the main surveys in terms of the number of man-days per survey working day.

TABLE 4.1

MANPOWER REQUIREMENTS

	Man-days expended per survey working day*
Loading surveys	4
Journey times	2
Waiting times/bus frequencies	4 - 6
Passenger interviews	4

*per bus or per observation point

4.2 In addition to the actual survey manpower requirement there is also the effort required for pre-analysis of the data eg coding (if necessary), sorting, tabulating and presenting material. For every five man days of data collection, one to two man days of manual, analytical effort is probably required.

4.3 From the above figures it is clear that surveys involve considerable manpower requirements. Some form of sampling is required to keep the surveys within manageable limits. It is also wise to have a programme of surveys mapped out well in advance, with the aim being:

- to keep the work load fairly constant;
- to move survey assistants around to relieve boredom;
- to be prepared (in terms of preparation of pro-formas and location of survey points);
- to provide for a mixture of continuous and temporary survey work.

4.44 The sampling rate may well be dictated by the manpower available for survey work. The danger is that the sample might be so small as to produce unacceptable levels of accuracy. Appendix F illustrates an example of the use of the standard deviation of the distribution of sample means (standard error) in calculating a sample size for large populations. As the example shows, some degree of accuracy may have to be lost to keep manpower requirements to an acceptable level. The next problem concerns the sample population and the need to select representative or random samples. The sample population could be the complete network or organisation, a regional area (associated, say, with one depot) or a route. One bus operator in the UK for example samples from the whole network in order to estimate information on passenger loadings, the use of bus passes, etc (CIPFA, 1979). Samples can be drawn from crew duties, having further subdivided these by day of the week, type of duty, garage and type of operation (whether one-man-operated or not). If the survey is continuous, and over a long period of time (several months) information can be built up on individual routes.

4.5 An operator might prefer to rotate his survey team around each route in turn, ensuring that each route is surveyed for a complete days' operations. Where there are a large number of buses employed on one route it may not be possible to survey that route in one day using available manpower; it might take as much as four days to cover all the duties being operated. Although this provides a great deal of detailed information route by route, it may take some time to get a total picture of the network as a whole. For example, if each route occupies the whole of the survey team for one working week then clearly only 50 routes could be surveyed in a year. For large networks routes would be covered only once every two or three years. In this case it may be necessary to sample from all the bus duties associated with each route, thus completing each route survey in only one or at most two days.

4.6 Seasonal variations are likely to be influential in route performance and output. Whatever technique is used for sampling some account of these patterns is necessary when trying to understand data recorded at different times of the year. Obvious distortions due to festivals and other similar events must be avoided by undertaking surveys outside such periods.

4.7 The organisation of surveys is clearly quite complex and forward programming is required, taking account of data needs, priorities and resources available. It is suggested that it would not be unreasonable for a bus operator to spend one per cent of total revenues on planning activities, including both short term monitoring and the development of long-term policies. Not all information need be collected frequently and Table 4.2 sets out a possible timetable for the main data requirements. Some information is specific to a route, and some is of a more general character related to the total network. Some surveys, specific to the monitoring of a particular service change, might be carried out infrequently, but on a 'before and after' basis.

4.8 Apart from the programming of surveys, management will also be concerned with the control of staff. Surveys undertaken off the vehicle are more easily controlled because staff are not constantly on the move. Spot checks are necessary, not only to ensure the work is being undertaken in a professional manner, but also to answer queries and to give some moral support in what can be a tiring job. Needless to say, survey assistants should be thoroughly familiar with the work to be done prior to the start; trial runs can provide useful experience for both staff and management.

TABLE 4.2

FREQUENCY OF SURVEYS

	Twice per year	Once per year	Infrequently
Route survey	— load factor — passenger lead — waiting times — bus arrival times	— journey speeds/times — causes for delay — use of bus passes	
Network survey (survey not specific to a route)		— user opinions — passenger travel patterns — fare leakage	— penalty times — boarding/alighting times — vehicle handling characteristics

5. PRACTICAL APPLICATIONS

INTRODUCTION

5.1 As noted earlier, it is in the areas of route performance, policy planning and service changes that current data resources are usually inadequate, and for which special field surveys are necessary. This section is addressed specifically to these topics to show how the information gathered from the surveys, described in Section 3. can be used for better, more informed decision making.

Monitoring route performance - profitability

5.2 Using some of the basic measurements derived from a loading survey it is possible to estimate route revenues. Using a simple cost model (described in Appendix B) it is possible to estimate route costs. Hence, from a knowledge of route costs and revenue it is possible to estimate route profitability.

5.3 Table 5.1 presents the estimated costs and revenues associated with five routes operated in a major Third World city (see Appendix C). The extra buses used on routes 80 and 720 during peak hour operations incur higher costs for the reasons described in Appendix B. Any positive difference in revenues and costs is profit for that route. (More precisely the profit is in fact the contribution to the fixed overheads of the total network, which are not accounted for in the above costs). The average costs and revenues show each route to have been loss-making, given the particular design of each route and the numbers of buses being operated.

TABLE 5.1

EXAMPLE OF ROUTE COSTS AND REVENUES, DELHI

	Route number				
	80	89	155	430	720
Cost per km (Rs)					
Normal duties	1.97	2.86	1.88	1.80	1.85
Extra buses	2.94	-	-	-	2.42
All buses	2.09	2.86	1.88	1.80	2.03
Revenue per km (Rs)					
Peak time	2.23	2.31	1.77	2.07	1.35
Off-peak	1.74	1.61	1.46	1.41	1.19
All buses	1.94	1.89	1.60	1.61	1.29

Monitoring route performance - indicators

5.4 From the operators' view, profitability is most important, while from the users' view adequate service levels are most important. Route profitability can be measured by comparing earnings per Km (EPK) with operating cost per Km (CPK), (ensuring that the data is as near as possible relevant to the route in question). Service level to passengers has many aspects. Perhaps the most easily measured are bus frequency, headway, regularity and punctuality, but waiting times and load factors are also indicators of service levels. It is suggested that the three indicators, ratio EPK to CPK, average route waiting time and average load factor, could provide a useful screening process for route performance.

5.5 Table 5.2 illustrates a possible screening procedure using three ratios and shows how possible improvements could be made to bus operations on the different routes. In all cases the average wait times and load factors on the route maybe high because of poor regularity. Regularity might be assessed by relating average wait times to scheduled headways or expected wait times. Some low-demand routes may also inevitably have high wait times because of low frequency of buses. This must also be taken into account where necessary. To make the screening process as realistic as possible the peak and off-peak operating performance should be separately assessed. Appendix F illustrates the route screening proceedure using values of specified performance criteria for five routes operated by the DTC in Delhi.

Allocating buses between routes

5.6 To maximise profits (or minimise losses) for a given level of operations, an operator would ideally like to switch buses between routes, such that if there is a net gain in demand (or revenue) through switching a bus from one route to another, then, assuming no change in costs, the move would increase profits. (There could well be changes in costs associated with moving a bus from one route to another, and these would have to be off-set against the change in profits to assess whether the move is worthwhile.) As an example, the estimated revenues and costs of Routes *155* and 430 (described in Appendix C) are compared in Table 5.3.

5.7 Overall, Table 5.3 shows that the ten buses on Route 430 are more profitable than the ten buses on Route 155. However, if a choice had to be made between operating a tenth bus on either route, the bus operator should logically choose to put it on Route *155.* On this route the tenth bus looses only Rs 196 per day as against Rs 316 per day on Route 430. Expressed in a different way, for the tenth bus each rupee of net cost on Route 155 generates 44 passenger km, while each rupee of net cost on Route 430 generates only 15 passenger km.

Fare levels and subsidies

5.8 Comparison of the effects of a fares increase with improvements to the service highlights some important

TABLE 5.2

ROUTE PERFORMANCE SCREENING PROCEDURE

CASE 1

	high	low
EPK:CPK	*	
Average wait time	*	
Load factor	*	

Need for extra buses on the route or route shortening.

CASE 2

	high	low
EPK:CPK	*	
Average wait time		*
Load factor		*

Route probably operating well, though reduction in buses or route extension should not be ruled out.

CASE 3

	high	low
EPK:CPK	*	
Average wait time		*
Load factor	*	

Route operating well, although load factor should be reduced, possibly by route alterations.

CASE 4

	high	low
EPK:CPK	*	
Average wait time	*	
Load factor		*

Possibly a low frequency route operating quite well. More smaller buses might be considered.

CASE 5

	high	low
EPK:CPK		*
Average wait time		*
Load factor		*

Too many buses on the route or possibly case for route extension.

CASE 6

	high	low
EPK:CPK		*
Average wait time	*	
Load factor	*	

Route layout may be wrong.

CASE 7

	high	low
EPK:CPK		*
Average wait time	*	
Load factor		*

If low frequency route there may be a case for reduction in buses. Also a case for more, smaller buses or route restructuring.

CASE 8

	high	low
EPK:CPK		*
Average wait time		*
Load factor	*	

Route layout probably at fault. Possibly a case for fewer, large buses.

issues. Small improvements in service levels often provide large increases in demand while large increases in fares cause little loss in demand. This suggests that fares could be raised quite substantially with the expected loss in demand being more than easily compensated by increases in service levels, ie there would often appear to be great scope for increasing fares and using additional revenues generated to expand the service and reduce the need for operating loans. At the same time the probability is that there would be no net loss in demand.

5.9 This type of analysis can also be used to assess the effects of subsidies. For example, an operator who is receiving subsidy may be meeting a demand of 10 passenger-km for every rupee of net cost (or subsidy). If a change in the service gives a higher level of passenger handling per rupee spent than this then it is worth undertaking, because for the same financial loss more demand can be met. Changing the level of subsidy however alters the comparison. If more subsidy is given, it could be used to either expand the service and/or reduce fares. In both cases the amount of extra demand carried per rupee spent is likely to be lower than previously. Which course of action to follow may be pre-determined by the political process of giving subsidy, but given the choice the bus company would ideally use the extra subsidy on the scheme which goes nearest to meeting company objectives (say that which brings in most additional demand per rupee spent). This would set the level against which to compare all other possible schemes. This could be called the 'norm'.

5.10 Apart from changes in subsidy level (or financial target), changes in productivity which affect costs will also have an effect on the value of the norm. Improved productivity will reduce the net loss (or increase net gain, if appropriate) which is equivalent to a reduction in subsidy, thus increasing the value of the norm. There is a very real danger for bus operators that worsening productivity will

TABLE 5.3

COMPARABLE PROFITABILITY OF TWO ROUTES, (COSTS GIVEN IN RUPEES)

Buses	Route 155				Route 430			
	Passenger km(00)	Revenue Rs	Cost Rs	Contribution Rs	Passenger km(00)	Revenue Rs	Cost Rs	Contribution Rs
1	*157*	*452*	444	8	187	*589*	464	125
2	155	446	444	2	186	586	464	122
3	150	432	444	-12	185	583	464	119
4	148	426	444	-18	181	570	464	106
5	145	418	444	-26	170	536	464	72
6	125	360	444	-84	164	517	464	53
7	119	343	444	-101	122	384	464	-80
8	102	294	444	-150	91	287	464	-177
9	98	282	444	-162	59	186	464	-278
10	86	248	444	-196	47	148	464	-316
Total		3701	4440	-739		4386	4640	-252

attract subsidy which is not used for either service improvements or fare reductions.

5.11 A thorough analysis of an operator's market will indicate differences in demand on different types of route, as well as between different times of day and between different journey lengths that passengers make. The latter would be of particular relevance when examining fare structures and the expected revenues that alternatives would yield.

Appraising the development of new services

5.12 It may be the bus companies policy to treat sections of the travelling public differently, perhaps, with a view to providing specialised services. Market surveys should be undertaken before introducing such services, in order to estimate their usefulness. Where these services are already in operation, the operator should check their performance to see if they are meeting their objectives and whether any modifications are required. Individual routes on which the special service is being provided should be monitored for this purpose. These routes should be representative of all other routes where this service is being provided so that actual service performance rather than individual route performance is being assessed.

5.13 One example of a specialised service is the railway special operated by the DTC in Delhi (Maunder and Fouracre, 1983). The railway special services were introduced so that rail passengers could be provided with direct routes from the main railway stations to various residential areas of Delhi at a reasonable fare (by comparison to taxi services). The charge imposed in 1980 was a flat rate of Re 1(50 paise for children) as compared to the average fare on ordinary DTC services of about 40 paise and a typical taxi fare of Rs 15.

5.14 During February, 1980 two railway special routes were monitored over a four day period to obtain the operational data presented in Table 5.4. Data for the whole DTC network for the year 1980/81 is also shown.

TABLE 5.4

COMPARATIVE EARNINGS ON RAILWAY SPECIAL AND ORDINARY SERVICES, DELHI

Route	Av. bus load per trip	Av. fare (paise)	Revenue per trip (Rs)	Revenue per bus per day (Rs)	EPK (paise)	Est. load factor
Railway Sp. 2	33	99	33	396	143	0.43
Railway Sp. 3	41	99	40	480	153	0.50
Total DTC network	91	42	38	460	203	0.80

5.15 Despite lower load factors on the railway services, the earnings per bus/day are of the same order as those for the total DTC network. This is because of the higher fare levels and also better vehicle utilisation of the railway special service. Unfortunately, for the operator, this higher output involves additional (variable) costs and the railway special service was not attracting sufficient additional revenue to cover this extra cost.

5.16 Surveys of users are very appropriate in assessing how well a specialised service is meeting its objectives. An extensive survey by the Overseas Unit TRRL was undertaken to see whether the service was being used for the purposes for which it had been designed, ie to provide a special service for those carrying luggage to or from the railway station. On the two routes monitored only about 20 per cent of passengers were using the railway special in this way; over half the passengers were travelling to or from work. Furthermore, these passengers were undertaking the journey by the rail special on a frequent basis, often daily, although not necessarily in both directions.

5.17 When asked why they used the railway special few users referred to the specific purpose of the service; they seemed to value things like comfort (seating only) and convenience. (Perhaps this explains the fact that the service was clearly being used by commuters, to and from work, rather than the intended market, those travelling to and from the railway station.)

5.18 Faced with evidence like this the operator might well question the value of railway specials. However, it would appear to demonstrate a demand for more specialised commuter services such as a seating only high-fare service on high demand corridors.

Journey times and bus priority

5.19 Monitoring the causes of bus journey delays can indicate specific bottlenecks, places where priority for buses could improve journey time and/or service reliability. For example bus lanes were introduced in Bangkok in 1980. Surveys carried out on six different sections, before and after the event, showed that in almost all cases, either bus travel times, or car travel times, or both, were improved significantly (Marler, 1982). The most successful section showed improvements to both bus and car mean travel times of 25-30 per cent Figure 5.1 shows the change in travel time distribution for a particular bus lane introduced in Bangkok. It can be seen that average bus travel times were reduced by 27 per cent and journey time variability improved considerably.

5.20 It is unlikely in any city that the introduction of a bus priority system will be the responsibility of the operator. This is usually carried out by the City Traffic Engineers Department. However, the bus operator by means of journey time surveys can indicate to the Traffic Engineers Department places where bus lanes etc could most sensibly be located.

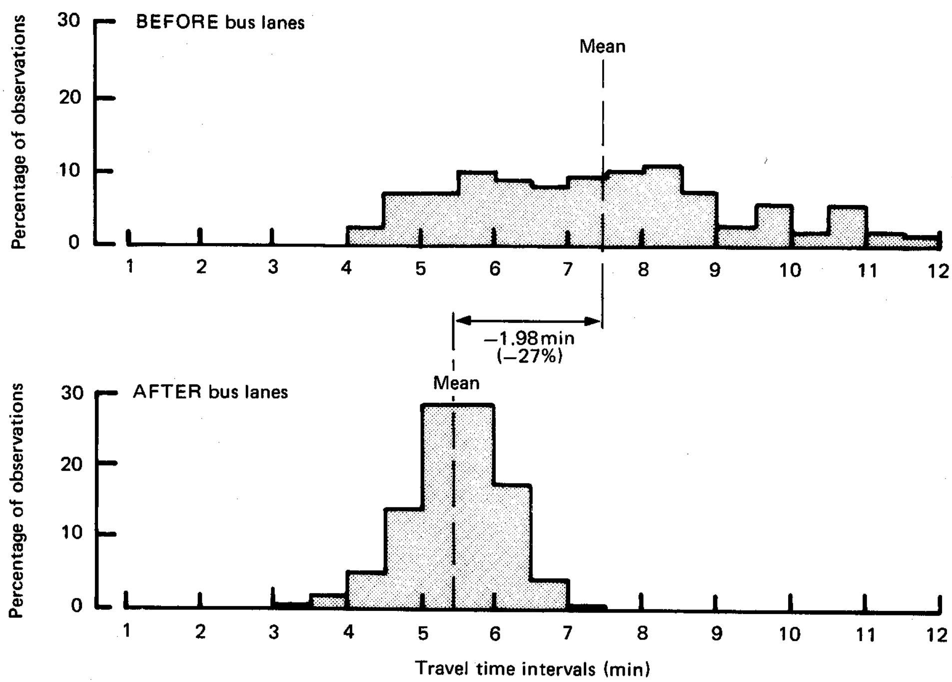


Fig. 5.1 Bus travel time changes, Paholyothin Road

6. CONCLUDING REMARKS

6.1 This note has examined the purpose, logistics and implementation of field surveys designed to improve management information on bus service performance. Practical examples of the analysis of survey findings have also been presented to demonstrate how this information can be positively used.

6.2 Prevailing operating conditions, available resources, size of operations and company objectives vary considerably between operators. As a result, management information systems and requirements are likely to differ considerably. This note has presented a range of practical options which can be developed by an operator to meet his specific needs.

6.3 The control and development planning of bus operations should be based on sound quantitative data of both the efficiency and effectiveness of the service. The use of some, or all, of the techniques described in this note will greatly contribute to this management process, to the general benefit of the urban transport sector of the Third World.

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7. APPENDIX A DEMAND ELASTICITIES

7.1 The demand for services is usually measured in terms of passengers or passenger kms per unit of time (eg per peak hour, per day, per annum). Total demand will be affected by such factors as city size and land use, per capita incomes, vehicle ownership levels, fares on competing modes, and service levels. From the planning point of view it is important to know how demand varies with these (and other) factors. The measure of response in demand to any one of these factors is called the demand elasticity with respect to that particular factor. If demand elasticities can be established with any confidence they are then extremely useful in the planning process.

7.2 The elasticity is the ratio of the percentage change in demand to the corresponding percentage change in the factor being considered:

$$e = (Äy/y)/(Äx/x)$$

where x represents a factor which influences demand (an independent variable) Äx is a small increase in that factor, y is the demand level associated with x and Äy is the change in demand resulting from Äx.

7.3 There is little documented evidence on the way in which demand for public transport in Third World cities responds to changes in fare and service levels. What little data there is tends to correspond with the findings of the more voluminous research undertaken in the highly industrialised nations. Until more studies are undertaken in the developing world it would seem appropriate to make use of this material. Table Al contains such estimates of elasticity values, together with values for two Third World cities.

7.4 Fare elasticities are likely to be high in situations where choice of other modes is readily available: for example, in small compact cities the possibility of using a cycle or walking exists as an alternative to using a bus; in larger cities when two or more modes (say bus and trains) are running in parallel, then an increase in fares on one mode is likely to make the other mode(s) more attractive, financially.

7.5 The calculation of elasticity values is usually undertaken on the basis of a statistical analysis of 'cross section' data (ie for say a number of bus companies in a single time-period) or 'time-series' data (for one bus company over an extended period of time).

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TABLE Al

FARES AND SERVICE ELASTICITY VALUES FOR BUS OPERATIONS

Demand elasticity with respect to	Location	Value or likely range	Comments
Fares	Developed Countries (I)	-0.1 to –0.6 Av. –0.3	For: large towns –0.1 to –0.5 small towns –0.2 to –0.7 During: peak –0.1 to –0.35 off-peak –0.25 to –0.7
	Bombay (ii) (iii)	-0.28 to –0.75 Mean value -0.4 to –0.48	Higher values in poorer suburbs and where rail competes with bus.
	Delhi (iv)	-0.11 transit.	Little or no competition for mass
Service level	Developed Countries (i)	0.4 to 0.5	
	Bombay (ii)	0.3 to 0.45	
	Delhi (iv)	0.6	Probably an overestimate.

Sources: (i) TRRL, 1980
(ii) Buchanan, 1980
(iii) Modak and Bhanushali, 1985
(iv) Fouracre et al, 1981

8. APPENDIX B A SIMPLE COST MODEL

8.1 **A** change in the public transport system will usually result in a change in operating costs. The structure of the operatingcostsofacompanycangivenan indication of how changes in costs of the different items affect total costs. For example, Table B 1 shows the per cent distribution of costs incurred by a major Third World bus operator in the financial year 1977-78.

8.2 If, due to external circumstances, the cost of the diesel fuel is increased by 10 per cent, relative to all other components of cost, then the total costs will rise by 1.8 per cent (ie 10 per cent of 18.3 per cent). Usually a change in output creates changes in more than one cost component.

8.3 The way in which the different parts of total costs change as output changes is important. Establishing each cost components' relationship with a particular measure of output is the basis of a cost model which can be used to analyse any planned system change. The measures of output commonly used in the bus industry are bus Ion, bus hours and number of vehicles in use (or peak hour requirement). A system change may affect one or more of these output measures: for example, rescheduling or rerouting of buses may affect only bus km run, while an increase in fleet size will affect all three measures, with additional bus km, bus hours and buses in use.

8.4 The rate of response of the change in the cost component to the change in output varies greatly. Additional kilometres will immediately affect consumption of fuel and hence the cost of this item. On the other hand, costs such as rent and rates of buildings and administration costs are unlikely to be affected by small changes in fleet size. Only large fleet additions requiring the acquisition of new buildings and administrative staff would affect costs. Three cost categories are usually specified which are variable costs, semi-variable costs and fixed costs. Variable costs are taken as those which respond almost instantaneously to changes in output. They are particularly important when considering the more productive use of the existing stock of vehicles. Semi-variable costs are the costs incurred when there is a marginal increase in stock of vehicles, or the costs which result from the longer term (several weeks or months) effects of the more productive use of existing stock. Fixed costs are those costs which, though dependent on output, are not particularly responsive to changes in level of output except when the changes are very large.

8.5 Typically, then, in a cost model the costs are broken down as far as possible and allocated in a way which is based on their degree of variability over time and the measure of output to which they most directly respond. There is no standard format for such a model since different operators will undoubtedly have different views on which output and time factors have most effect on each component.

TABLE BI

OPERATING COST STRUCTURE (WORKING EXPENDITURE) 1977-78

	Per cent of total
Variable costs	
Diesel	18.3
Oil	4.3
Tyres	8.7
Spares	12.8
Tickets	0.4
Sub-total	44.5
Semi-variable	
Drivers and conductors	26.0
Traffic Supervisory staff	2.6
Central workshop staff	1.7
Depot staff (maintenance)	7.1
Uniforms	1.0
Tax on vehicles	2.2
Insurance	0.3
Welfare and superannuation	3.9
Sub-total	44.8
Fixed costs	
HQ: officers, clerical and cash staff	3.0
Central workshops: officers and clerical	0.3
Depots:officers and clerical	0.8
Other admn. staff and expenses	3.0
Rent and rates	1.1
Sundries	2.5
Sub-total	10.7
Total	100.0

8.6 In Table B 1, all costs itemised as variable could be taken as dependent on bus km; all the semi-variable coald be taken as dependent on number of buses held; all fixed costs depend on aset number of vehicles (for example, these costs may increase in units of 100 vehicles, this being the equivalent of one new depot).

A simple cost model could be expressed in the form:

$$TC = FC + b_1K + b_2V$$

where TC is the total daily operating cost, FC is the fixed cost per day (for the given output level), K is the daily kilometrage of the fleet, V is the number of vehicles in use per day, b_1 is the cost per km and b_2 is the cost per vehicle employed. Thus b_1K is the variable cost and b_2V is the semi-variable cost. The daily cost of an individual vehicle is given by: $C = b_1K_1 + b_2 (V = 1)$ where k_1 is the daily kilometrage output of a vehicle.

9. APPENDIX C EXAMPLES OF SURVEY OUTPUT

BASIC ROUTE CHARACTERISTICS

9.1 In order to iflustrate the output expected from the surveys described in Section 3, material from six routes studied in Delhi in 1978 (Fouracre et al, 1981) is presented. As background to these surveys, Table Cl presents the physical characteristics of the routes which were monitored.

9.2 Table ~ shows typical output from a loading survey carried out on five of the routes studied in Delhi during a complete days operations in 1978. The presentation of survey material in this basic form (averaged for the whole route, with some distinction made between peak and off-peak operations) provides useful background information for further analysis. For example, on all routes passenger lead tended to be slightly higher in the peak than in the off-peak. Further, as would be expected, passenger lead was higher for the longer routes, except in the case of Route 89 which had a lead of only about 8 km for a route length of 18.5km. Route 89 is a cross-city route, and many travellers would be using the service for up to half its trip length (to and from the city centre).

9.3 As expected load factors were significantly higher on all routes in the peak direction during the peak period, than in the off-peak. Route 430 has a fairly even load factor in the peak for both directions of travel whereas route 720 was extremely 'unbalanced' in this respect.

9.4 The high revenues earned by buses on route 89 reflect the fact that high capacity double-deck vehicles were used on this route.

9.5 Average journey speeds are shown for both peak and off-peak periods; the figures include both direction speeds. Average speeds were marginally higher than scheduled, which were themselves high for urban traffic conditions. Only route 89 with its use of double-deck buses had average trip speeds of less than 20 km/h.

JOURNEY TIME COMPONENTS

9.6 In a journey time survey in Delhi the average stop time at bus stands was measured at between 0.31 and 0.42 minutes on a selection of routes. Penalty time was found to be 0.22 minutes per bus stand, giving a total delay time at bus stands of between 0.53 and 0.64 minutes per stand. Table C3 provides more detailed information for the routes surveyed, of how bus stand delay is incurred.

9.7 Penalty time will also include stationary delays (ie when the vehicle comes to a halt for reasons other than setting down or picking up passengers). Table C4 shows the

TABLE Cl

PHYSICAL CHARACTERISTICS OF SIX BUS ROUTES IN DELHI

	Route number						
	80	1	8955	430	521	720	
Route length (km)	8.0	18/19*	21.1	16.4	14.9	20/21*	
Number of bus stands	14/15*	36/39*	33	33	27/28*	36/39*	
Number of vehicles used:							
peak		6	7	10	10	7	6
off-peak	2	-		-	-	3	5
Scheduled daily km	1488	1554		2532	2624	1937	2132
Scheduled daily km per bus:							
normal services	219	222	235	262	226	248	
peakextra	88	-	-	-	119	114	
Scheduled journey time (mm)	25	55/60*	60	40	43	50	
Scheduledjoumeyspeed(km/h)	19.2	19.3	21.1	24.6	20.8	25.1	

*Some routes have differences in route layout and bus stand locafion depending on direction.

TABLE C2

BASIC OUTPUT DATA FROM A LOADING SURVEY

	Route number				
	80	89	155	430	720
Km. operated	1472	1332	2363	2575	2050
Operated: Schedule km	0.99	0.86	0.93	0.98	0.96
No. of passengers: peak	4620	3998	5933	5320	4178
off-peak	5199	4177	5732	8408	2609
Av. passenger lead (km): peak	5.3	8.3	11.8	10.2	11.3
off-peak	5.0	7.3	10.4	9.1	9.7
Load factor:					
peak (peak direction)	0.94	0.65	1.53	1.16	1.23
peak (both directions)	0.70	0.53	1.02	1.10	0.64
off-peak	0.49	0.33	0.71	0.71	0.50
Av. revenue per bus (Rs): peak	17.9	42.8	37.4	34.0	27.7
off-peak	13.9	29.8	30.9	23.2	24.4
Av. revenue per pass. (paise)	29	31	32	30	38
Earning per km (paise): peak	223	231	177	207	135
off-peak	174	161	146	141	119
Av. journey speed (km/h):					
peak	20.8	19.5	23.1	24.6	24.3
off-peak	23.3	19.8	24.5	26.6	26.2

importance of penalty time in these delays for the same selection of routes in Delhi.

9.8 For these routes the average stationary delay time per km ranged from 0.10 to 0.54 minutes per km. (These differences broadly reflected known operating conditions.)

This measure provides an important indicator of the relative congestion faced on different routes and points to those routes which have particular problems. Where a particular congestion black-spot affects a number of routes there may weH be a case for remedial action involving traffic management techniques. Yet another part of total delay is

TABLE C3

BUS STAND DELAYS SURVEYS IN DELHI, 1978

Route/time	Average total stop time at bus stands per trip (min)	Average number of stops at stands per trip	Average stop time per bus stand (min)	Average penalty time per trip (mm)	Total average bus stand delay per trip (min)	Bus stand delay as percentage of total trip time
80 am peak	3.4	10	0.34	2.2	5.6	26
am off-peak	3.1	9	0.35	2.0	5.1	26
89 pm peak	12.0	29	0.41	6.3	18.3	32
pm off-peak	10.6	29	0.37	6.3	16.9	31
430ampeak	5.1	19	0.27	4.1	9.2	25
am off-peak	5.6	21	0.27	4.6	10.2	32
521 pm off-peak	8.0	19	0.42	2.2	10.2	24
720pm off-peak	8.2	26	0.31	5.6	13.8	30

TABLE C4

STOP DELAYS - SURVEYS IN DELHI, 1978

Route/time	Average number stops per trip	Average stop time per trip (min)	Average penalty time per trip (min)	Total average delay time per trip (min)	Average delay time per km (min)	Stop delay as a percentage of total trip time
80 am peak	5	1.7	1.1	2.8	0.35	13
am off-peak	4	1.3	0.9	2.2	0.28	11
89 pm peak	13	7.1	2.8	9.9	0.54	17
pm off-peak	12	4.7	2.6	7.3	0.39	13
430 am peak	7	1.8	*1.5*	3.3	0.20	9
am off-peak	4	0.8	0.9	1.7	0.10	5
521 pm off-peak	12	3.2	2.6	5.8	0.39	14
720 pm off-peak	6	3.6	1.3	4.9	0.24	10

the effect on vehicle speeds of general traffic conditions and the like, ie those factors which cause slow running (below some optimum for the type of road) rather than actual stoppages. This can only be estimated by assuming some free-running speed and comparing the time it would take to cover the route distance at that speed with actual observed speeds (allowing for the stops and starts due to serving bus stands and stop delay). Taking route 80 of Table C4 as an example: a bus would cover the 8 km route distance in 9.6 minutes, plus 0.2 minutes penalty time, if travelling at 50km per hour an assumed optimum speed. Assuming the same pattern of stops and starts (at bus stands and because of stationary delay) then the total estimated travel time, operating at 50 km per hour between stops, is 18.2 minutes in the am peak and 17.1 minutes in the am off-peak. Actual observed average journey times for these same periods were 21.2 and 19.3 minutes respectively. The difference may be ascribed to general delay.

9.9 In Table CS all the journey time components for the same routes in Delhi are combined.

9.10 In this particular example bus stand delays accounted for about *25* per cent of journey time. Other delays (both stationary and general) accounted for between 20 to 30 per cent of journey time. Traffic management techniques for improving bus running speeds could therefore be expected to reduce journey times, in these examples, up to a maximum of 20 to 30 per cent. More efficient passenger handling techniques (through better interior design or off-bus ticket sales) could possibly reduce bus stand delays especially in the peak period, though to assess the value of

TABLE C5

COMPONENTS OF BUS JOURNEY TIME - SURVEYS IN DELHI, 1978

Route/time	Average journey time (mm)	Stationary delays and penalty	Bus stand delays and penalty	General delay (min)	Total delay as a percentage of total journey time
80ampeak	21.2	2.8	5.6	3.0	54
amoff-peak	19.3	2.2	5.1	2.2	49
89pmpeak	57.3	9.9	18.3	1.1	51
pm off-peak	54.1	7.3	16.9	1.9	48
430 am peak	36.7	3.3	9.2	4.3	46
amoff-peak	32.0	1.7	10.2	0.2	38
521 pm off-peak	42.3	5.8	10.2	6.3	53
720pm off-peak	46.7	4.9	138	6.3	53

TABLE C6

TYPICAL BUS BOARDING AND ALIGHTING TIMES - SURVEYS IN DELHI, 1978

Bus type	Peak/off-peak	Dead time (secs)	Boarding time per passenger (secs)	Alighting time per passenger (secs)
Double-decker (single entrance/	peak	7.2	1.3	0.7
exit)	off-peak	5.0	1.4	1.1
Single-decker	peak (boarding)	3.0	2.1	-
(separate entrance	off-peak (boarding)	3.1	1.9	-
and exit)	peak (alighting)	3.0	-	1.5
	off-peak (alighting)	3.4	-	1.3

this requires an understanding of boarding and alighting rates.

9.11 Some typical values for boarding and alighting rates are contained in Table C6. The base data for these estimates was a loading survey undertaken in Delhi. With information in this form it is possible to compare different vehicle designs and their impact on passenger handling and overall journey times.
during the survey period. Three or four bus stands had been selected for each dfrection of each route, the stands having been identified as having high passenger activity from a previous loading survey.

PASSENGER WAITING TIMES AND BUS FREQUENCIES

9.12 Typical data obtained in a waiting time survey in Delhi are shown in Table C7. Weighted averages of observations at stands along each route are shown. The weightings were the number of passengers boarding at each stand monitored

during the survey period. Three or four bus stands had been selected for each direction of each route, the stands having been identified as having high passenger activity from a previous loading survey.

9.13 The coefficient of variation is a uselul measure of service regularity. If passengers arrive at a bus stand in a random way and can board the first arriving bus, then thefr average waiting time (AWT) can be expressed as:

$$AWT = \bar{H}/2\ (1 + V^2)$$

where H is the mean headway and V is the coefficient of variation of the distribution of headways. This expression is minimum when V = 0, ie when the service is regular and every bus arrives at a bus stand exactly H minutes behind the last bus. Irregular services will have a high of V, as shown for most routes in Table C7.

Typical data obtained in a waiting time survey in Delhi are shown in Tabl

TABLE C7

BUS HEADWAYS AND WAITING TIMES - SURVEYS IN DELHI, 1978

	Peak hours				Off-peak hours			
Route	W min.	H min.	V	P	W min.	H min.	V	P
80	7.0	6.9	0.63	0.24	8.2	9.8	*0.55*	0.13
89	18.8	24.9	0.51	0.13	16.1	24.2	0.49	0.09
155	11.5	14.9	0.34	0.18	13.3	20.5	0.41	0.07
430	9.1	8.4	0.44	0.36	9.2	9.8	0.57	0.15
521	10.0	11.9	0.46	0.26	15.4	19.6	0.45	0.15
720	15.3	17.9	0.63	0.17	21.8	31.9	0.60	0.13

Key W - observed average waiting time
H - mean headway
V - coefficient of variation (ratio of standard deviation of distribution of headway times to the mean)
P - probability of not being able to board first arriving bus

TABLE C8

PASSENGER SURVEY OUTPUT - DELHI, 1978

Time period	Distance travelled (km)	Total journey time (mm)	Travel fo r work purposes (%)	Passholder (%)
Single journeys				
Peak morning	11.5	47	80	7
Peak evening	10.9	48	76	6
Off-peak morning	9.9	43	49	6
Off-peak evening	10.5	47	60	8
*Multiple journeys**				
Peak morning	18.1	75	80	10
Peak evening	19.1	82	71	11
Off-peak morning	18.7	78	55	6
Off-peak evening	21.5	85	92	11

*Journeys involving at least one interchange

9.14 The probability of a passenger being unable to board a bus, shown in Table C7, is derived directly from the 'Q' Enquiry cards. For the routes shown this probabilitv is higher in the peak than the off-peak.

PASSENGER CHARACTERISTICS

9.15 Data derived from the passenger interviews can be by route or for the network as a whole, depending on the survey objectives. A distinction can also be made between peak and off-peak travellers. Table C8 shows some output from the survey which used a questionnaire similar to that contained in Appendix D.

9.16 In this example the information was aggregated for all respondents, to represent a picture for the network as a whole. Something like 70 per cent of respondents were making single journeys, ie involving no interchange. Information presented by route is shown in Table C9.

REFERENCE

FOURACRE, PR, MAUNDER D AC, PATHAK MG and C H RAO (1981). Studies of bus operations in Delhi, India, Department of Transport. *TRRL Supplementary Report SR 710,* Crowthorne (Transport and Road Research Laboratory)

TABLE C9
PASSENGER SURVEY RESULTS, PRESENTED BY ROUTE - DELHI, 1978

	Route					
	80	89	155	430	521	720
Single journeys						
Distance travelled (km)	*5.5*	*8.5*	13.4	10	9.7	13.7
Total journey time (mm)	36	41	52	40	50	48
Travel for work purposes (%)	60	63	67	77	69	82
Passholder (%)	4	4	9	10	5	7
Monthly income (Rs)	750	830	290	690	410	790
*Multiple journeys**						
Distance travelled (km)	16.5	16.1	18.9	22.8	17.9	19.7
Total journey time (mm)	62	67	66	72	73	66
Travel for work purposes (%)	59	55	65	74	75	67
Passholder (%)	11	9	9	7	10	12
Monthly income (Rs)	520	960	380	610	450	740

*Journeys involving at least one interchange

10. APPENDIX D
PASSENGER INTERVEW QUESTIONNAIRE

DAY:

DATE:

BUS STAND:

SEX:

AGE:

---

1. Journey origin:

2. Mode used to arrive at this bus stand from journey origin:

	distance travelled (km)	time taken (min)	fare paid
walk	☐	☐	■
bus	☐	☐	☐
rickshaw	☐	☐	☐
taxi	☐	☐	☐
car/motor cycle	☐	☐	■
other	☐	☐	☐

3. Details of next bus trip:

route no.	☐
alighting point	☐
distance (km)	☐
fare	☐
expected wait time (min)	☐
expected in vehicle (min) time	☐

4. Final destination:

5. Mode used to reach final destination after next bus trip:

	distance travelled (km)	time taken (min)	fare paid
walk	☐	☐	■
bus	☐	☐	☐
rickshaw	☐	☐	☐
taxi	☐	☐	☐
car/motor cycle	☐	☐	■
other	☐	☐	☐

6. Method of payment for next bus trip:

cash	☐
pre-paid pass	☐
monthly all-route	☐
monthly single-route	☐
student	☐

7. Journey time:

☐	Home — work — home	☐
☐	Work — work	☐
☐	Home — shopping — home	☐
☐	Home — social/leisure — home	☐
☐	Home — educational — home	☐
☐	Home — other — home	☐
☐	Other non-home based	☐

8. Journey frequency

Daily	☐
5–6 days/week	☐
3–4 days/week	☐
1–2 days/week	☐
once per month	☐
rarely	☐

9. Alternative travel means

(a) other modes (best alternative)

	distance (km)	time (min)	fare
walk	☐	☐	■
rickshaw	☐	☐	☐
taxi	☐	☐	☐
car/motor cycle	☐	☐	■
other	☐	☐	☐

(b) alternative bus route

route (a)	☐
No. interchanges	☐
probable time (min)	☐
fare	☐

10. Occupation

11. Monthly income (Rs)

<200	☐	1001–1500	☐
201–400	☐	1501–2000	☐
401–600	☐	2001–2500	☐
601–800	☐	>2500	☐
801–1000	☐		

12. Summary of journey details

Total travel time (min)	☐
Total distance (km)	☐
Total fares paid	☐
No mode changes	☐
No bus routes used	☐

11. APPENDIX E EXAMPLE OF CALCULATING A SAMPLE SIZE FOR LARGE POPULATIONS

11.1 For large populations the standard deviation of the distribution of sample means (known as the standard error of the mean) is approximately equivalent to the standard deviation of the population divided by the square root of the sample size.

ie standard error mean = $\frac{ä}{n}$

when n is the sample size and ä is the standard deviation of the population, represented by the sample deviation. From sampling theory it can be demonstrated that the population mean will lie within two standard errors on either side of the sample mean, with 95 per cent confidence or certainty. For example, if the average daily bus load is to be monitored and it is known to be of the order of 1000, with a population standard deviation of 200, and an accuracy of ±10 percent is required from the sample estimate of the mean, then the following reasoning can be used to determine sample size:

Required accuracy = 1000 + 2se with 95% confidence
where 2se = 100 (ie 10% of mean)
and se = *ä/* n
with se = 50 and ä=200
n = *ä* /se = 4
n = 16

11.2 In this example, sixteen buses should be monitored to give the required degree of accuracy. If each bus is engaged on two shifts or duties. then 32 duties would have to be covered, requiring 64 survey assistants. Clearly some degree of accuracy may have to be lost in order to keep the manpower requirement at an acceptable level. Reducing both the accuracy to ±20 per cent and the confidence of acceptance to 90 per cent gives a sample size of about three vehicles, requiring 12 survey assistants.

11.3 There wlll necessarily be some trial and error involved in selecting the sample size, since population parameters are unlikely to be known prior to sampling.

12. APPENDIX F EXAMPLE OF ROUTE SCREENING USING SPECIFIED PERFORMANCE VALUE CRITERIA FOR FIVE ROUTES IN DELHI

12.1 In Table Fl the values of the performance criteria are specified for five of the routes described in Appendix C.

12.2 In order to see how the screening procedure works it is necessary to specify some cut-off points to distinguish between good and poor performance for each indicator. Ideally, these values should be based on operating experience and an appreciation of what service levels passengers should be able to expect. The process of establishing these cut-off points will involve some trial and error; setting them too low will produce too many poor routes and too high will produce too few. Furthermore if the service is improving (or degenerating) over time, it will be necessary to adjust the target values accordingly. In Delhi, for example, the following seemed appropriate: the EPK to CPK ratio is high if greater than 1.0 in the peak and 0.7 in the off-peak; the average route waiting time is high if greater than 15 minutes in the peak and 20 minutes in the off-peak; the average route load factoris high if greater than 1.0 (measured in the peak direction) in the peak and 0.7 in the off-peak. Using these norms Table P' shows how well the five routes performed.

12.3 Route 80 has a similar profile in both the peak and off-peak with high profitability (relative to other routes), low wait times and low load factors. The route would appear to be working well from both operator's and user's view. However, the low load factor suggests that there may be a case for reducing the frequency of operations.

12.4 Route 89 is characterised by low profitability and correspondingly low load factors. Waiting times are high in the peak periods. There is some suggestion of poor route or possibly the use of the wrong vehicle type. (Route 89 is a cross-city route using double-deck buses.)

12.5 Route *155* has high load factors in both the peak and off-peak, coupled with low waiting times. Profitability is poor in the peak, but good in the off-peak. There might be a case for using larger vehicles on this route, or re-assessing the route layout. Route 430 is in many ways sirailar to Route 155, though it has good profitability throughout the operational periods. Extra buses might be usefully deployed on Route 430. (But see Table 5.3

12.6 Route 720 has a bleak profile in both the peak and off-peak. The high waiting times are associated with low frequency of operations, although further analysis indicates poor reliability. The route suffers badly from poor return loads and a high peak to off-peak imbalance. Route layout may be at fault, or possibly smaller buses (minibuses) might usefully be deployed on this route.

12.7 The screening process may thus indicate particularly poor routes such as 89 and 720 which merit further attention. This procedure does nothing more than this and it would be wrong to take decisions purely on the basis of the indicators.

TABLE Fl

EXAMPLE OF ROUTE PERFORMANCE INDICATORS FOR FIVE ROUTES, DELHI

	Route number				
	80	89	155	430	720
Peak					
EPK:CPK	1.01**	0.81	0.94	1.15	0.64**
Waiting time (mm)	7.0	18.8	11.5	9.1	15.3
Loadfactor*	0.94	0.65	1.53	1.16	1.23
Off-peak					
EPK:CPK	0.88	*0.56*	0.78	0.78	0.64
Waiting time (mm)	8.2	16.1	13.3	9.2	21.8
Load factor	0.49	0.33	0.71	0.71	0.50

*measured in the peak direction
**extra buses are used in the peak on these routes: the CPK for peak-time operations has been calculated as the weighted average of costs for normal duty and extra buses, the weights being the number of buses used.

TABLE F2
EXAMPLE OF ROUTE SCREENING ANALYSIS, DELHI

Route number

	80	89	155	430	720
Peak					
EPK:CPK	high	low	low	high	low
Waiting time	low	high	low	low	high
Load factor	low	low	high	high	high
Off-peak					
EPK:CPK	high	low	high	high	low
Waiting time	low	low	low	low	high
Load factor	low	low	high	high	low

13 APPENDIX G STANDARD PRO-FORMAS

13.1 Pro-forma for bus loading survey

Day:

Date:

Route no: No of tickets 15 paise: Revenue:

Route length: 30 paise: Revenue: 2

No of bus passes:

Trip start time: Total fare revenue: Rs

Trip finish time:

Total trip time: Total no of passengers:

Vehicle type Single deck

Double deck

Minibus

Other (specify)

Name of bus stand	Time		Passengers			Journey
	Arrival	Departure	Boarding	Alighting	Remaining	Remarks
Total						

13.2 Pro-forma used to carry out bus journey time surveys

Day:

Date:

Route no:

Route length:

Trip start time:
Trip finish time:
Total trip time:

Vehicle type: Single deck

Double deck

Minibus

Artic double deck

Other (spectfy)

Direction of trip:

Causes

1. Roundabout
2. Traffic signals
3. Bus stands
4. Pedestrians
5. Animals
6. Uncontrolled junction
7 Controlled junction
8. Accident

Time slower than walking speed	Stop time	Time faster than walking speed	Causes of delay	Delay time in seconds	Delay location

13.3 Pro-formas used to carry out penalty time surveys

Day: Date: Location:

Vehicle type: single deck SD
double deck DD
artic double deck ADD
minibus – MB

Direction:

Vehicle type	Bus registration number	Passing time	Vehicle type	Bus registration number	Passing time

(b)

Vehicle type	Bus registration number	Number of entry exit doors	Depart time	Stop time (secs)

(a)

13~4 Pro-forma for analysis of penalty time survey

Day: Date: Location:

Direction: to:

Vehicle type	Bus number	Time at first point	Time at arrival	Bus stand departure	Time at second point	Total journey time (mins)	Stop time (mins)	Actual journey (mins)

13.5 ‘Q' Enquirey card

ROUTE NO: DAY: DATE: DIRECTION OF BUS: TO: Name of the bus stop				
Time of passenger arrival at the bus stop	hours	mins		
Time of boarding bus	hours	mins		
Waiting time	hours	mins		
No. of buses arriving during this time which did not stop or were too full to board	0	1	2	3
FARE PAID				

Pro forma for bus arrival time survey

Day:
Date:

Direction of trip:

Route No:
Route Length:

Bus Stand:

Bus number	No of passengers boarding	Arrival time	Headway time	Bus did not stop	
				Overcrowded	No reason

NOTES

NOTES

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