FEASIBILITY OF DIAL-A-BUS IN BRITAIN

CASE STUDY OF CHELTENHAM

by

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ABSTRACT

FEASIBILITY OF DIAL-A-BUS IN BRITAIN: CASE STUDY OF CHELTENHAM

by

DAVID GLYN WILLIAMS

Submitted to the Department of Urban Studies and Planning on July, 1971 in partial fulfillment of the requirements for the degree of Master in City Planning.

Increasing auto ownership with its consequent pressures for physical and social change is straining the structure of British cities. Concurrently urban bus services have passed their most profitable operations, and appear headed for decline. There is, therefore, an urgent need for urban bus companies to diversify their operations to maintain solvency and to attract auto users from their cars. Dial-a-bus may offer one means for transit companies to stay in business at the same time as providing a viable alternative to the private car.

The thesis selects Cheltenham as a test site to predict the effective demand for Dial-a-Bus in Britain. From the interaction between the demand for the service, and the cost of supplying it, the benefits of a DAB service for the users the operators and the non-users are assessed.

It appears that DAB could be implemented in Cheltenham at a variety of levels and types of service. It would also contribute to reducing congestion in the town.

The significant variables that influence demand in Cheltenham were correlated with those of 28 other cities to make a rough estimate of DAB's role elsewhere in Britain. The indications are that DAB could support a break-even service in most cities, and more profitable levels in some of them.

Thesis Supervisor: Ralph A. Gakenheimer

Title: Associate Professor
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The author is indebted to the following persons and organisation without whose help and advice this thesis would not be possible.

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Special thanks to my wife, Harumi, who typed the final document, and whose hard work and encouragement made this education at M.I.T. possible.
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NOTE ON CURRENCY

The pre-decimal 1970 British currency is used.

12 pence = 1 shilling (sh)
20 shillings = 1 pound (£)

U.S. $2.40 = 1 pound
Chapter I

INTRODUCTION

1.1 The Setting. Urban transit in America and Britain

Following the recent upsurge of concern over the deteriorating quality of city life in the United States, demand responsive, group transit systems are being developed in an attempt to offset the downward spiral of bus transit service – where lower revenue leading to lower levels of service and the consequent lower patronage, in turn produces lower revenue. Since the poor frequently do not have cars, and must rely on public transport, their reduced physical mobility leads to loss of opportunity for jobs in the expanding industries in the suburbs and confirms their encasement in a culture of poverty. The poor in the central areas are not the only ones without adequate transportation. Public transport facilities are low in suburban residential areas where transportation is a problem for sub-groups such as the old and infirm, children, housewives in single car households etc. By providing a bus system which not only can operate at lower demand densities than conventional bus but also provide door to door service Dial-a-bus (DAB)\(^1\) is one attempt to provide mobility to all these groups,\(^2\) at the same time offering a means for the Bus Companies to stay in business.

The hypothesis of this thesis is that DAB has a useful role to play in Britain, and other industrial nations where

---

1. Also known as Dial-a-Ride and CARS (Computer Aided Routing System)
settlement densities are much higher than in the United States but that the role of a DAB system will be different - preventive rather than palliative. The physical causes of transit decline have not advanced so far as in the United States. Car ownership is half that of the U.S.,¹ and the intensive urban roadbuilding which facilitated the explosive growth of suburbs and the dereliction of the inner cities, is not yet fully underway in Britain. Urban densities are typically 1½ to 2½ times those of the equivalent population size in the U.S., and though transit ridership is declining in proportion to total trip making, it is not yet declining in absolute numbers except on country bus routes. Britain is now at a critical stage, where policy decisions made now on the role of the automobile in the city will have far-reaching effects on their physical and social character. The specter of American urban decay might be prevented in Britain, providing (1) Extensive intra urban roads are not built
(2) Land use controls at the city perimeter are enforced
(3) Public transport service improved
(4) Auto congestion is reduced.

The last two items are those where DAB may have a role, by diversifying the market for transit and offering a compet-

¹ In 1963, car ownership in U.S. was 410 vehicles per 1000 population, compared to 193 vehicles per 1000 in Britain. Source: Buchanan, C. "Traffic in Towns" para. 418.
itor to the automobile in terms of service characteristics. If viable, its use would have two important consequences. Firstly as a means of attracting auto users onto transit, but more importantly, it might be viewed as a genuine alternative to auto for intra city travel, and thereby strengthen the hands of legislators in placing more severe controls on the use of private cars.

1.2 Objectives

The broad objectives of this thesis are to test the hypothesis that DAB can complement and diversify the public transport system in British towns. Apart from governmental and other institutional constraints on a new public transport mode, the basic requirement of any mode is that it should generate sufficient demand to justify its operation. Some work has been done on demand for DAB in the US, but direct extrapolation to the British context is invalid due to wide

1. There is an increasing literature in Britain on controls on the use of private cars in urban areas. The following are some important works.
Ministry of Transport, "Better use of Town Roads. The report of a study on the means of restraint of traffic on urban roads" HMSO. 1967
Foster, C.D. "The Transport Problem" pp.195-253
Munby, D., 1968
2. See later references under section 1.4.

- 13 -
differences in population density, auto ownership, land-use, telephone coverage and wage rates. The only feasible approach at this stage is to test potential demand in one selected city, either by theoretical means and/or by direct trial, then to draw broad conclusions for other urban areas based on correlations of the outstanding constraints found in the detailed case study. Since transit operations in British towns are still running on a profit, or break-even basis, it is important to see how DAB can relate to these operations in complementary, rather than competitive way, since DAB would almost certainly be operated by the Bus Companies.¹

The objectives, then, can be summarised as follows:

1. To test potential demand for DAB in one town.
2. To demonstrate how DAB could fit into the existing operation of the local Bus Company.
3. To evaluate the impact of a combined DAB and conventional bus system on reducing automobile usage in the selected town, giving alternative local government constraints on auto use.
4. To evaluate the methodology used.
5. To draw some broad conclusions for other British towns.

1.3 Selection of the Study site

As indicated earlier, DAB is an addition to, not a sub-

¹ Taxi operations are on a much smaller scale than in the U.S., except for London.
stitute of, existing transport modes. It therefore operates most effectively in areas and on types of trips where demand densities are too low to provide a high level of service by conventional bus. Two main types of area suitable for DAB can be defined on this basis. 1. Areas outside the immediate centres of small and medium sized towns (40,000 to 200,000 population).

2. As a feeder service (to main line bus and rail stations) in the peripheral suburbs of large metropolitan areas.

In Britain, where auto density per road mile is the highest in the world, the smaller urban areas are seeking radical solutions to their traffic problem. Perhaps the most urgent cases are those of the historic towns where the desire for conservation and the need to attract tourists conflicts directly with the conventional solution for auto congestion, which is to widen existing roads, and build new ones. Thus the medium sized urban area is a suitable prototype for DAB in the British context.

Cheltenham is a town which fits these criteria. It is a historic city of 100,000 population, famous for its Regency Squares and terraces, suffering increasing auto congestion, and presently considering new road infrastructure as part of a solution to its congestion problems. The consultants for the new land use/transportation study note that Cheltenham
has one of the lowest modal splits to transit for similar
town of its size,¹ and can thus be regarded as a prototype
for the state of public transport in other towns within the
next few years. However, population increase has offset rider-
ship decline, and the Bus Company's patronage has remained
at about the same level for the past four years. The Chelten-
ham bus operations are run by the Bristol Bus Company, whose
networks extend throughout the towns and cities in the south
west of the country. The Company's manager is very aware of
the possible future decline of transit in Britain, and very
eager to seek ways to improve and complement the existing bus
services. He is consequently well disposed towards a DAB
operation, providing it does not reduce the ridership on the
profitable routes in the town.

The author therefore chose Cheltenham as the study site,
and collected some of the information required for an analysis
of DAB in the city during the summer of 1970. Much of this
information is contained in the Appendix,² together with pre-
liminary estimate of DAB demand required for use in the cost
analysis in Chapter 3.

¹ 20% - from "Cheltenham Study. Interim Report" p.8
² Note: reference will be made to information in the Appendix,
particularly the figures. They will be annotated
in the text with a prefix "A" to distinguish them
from figures contained in the thesis proper.
eg. (A. fig.12)
1.4 Available methods

The main problem when introducing a new mode of transport is the assessment of demand. Three basic approaches have been used to date and the following review describes briefly how they have been used, or might be suitable, for predictions of demand for DAB.

The market survey approach has been used by General Motors Corp. in estimating the market for a variety of demand responsive transit services (largely non-computer assigned). Their approach took the form of questionnaires to selected sub-populations inquiring their criticisms of present transit operations and their preferences for the most desirable characteristics of a new mode. This method is useful in indicating a potential market for a new service which an analysis based on areal travel characteristics would not reveal, but its main weakness is that of most market surveys—that the desires stated by the interviewee may not match his actions when a new product or service is introduced. This is especially true in a field such as transportation where the number

GMR-941 "Determining the Importance of User-related attributes for a Demand Responsive Transportation System.
GMR-1037 "An Analysis of Consumer preferences for a Public Transportation System.
GMR-1046 "Economic Analysis of a Demand-Responsive Public Transportation System"
of previous similar innovations is very small and consequent-
ly provide few indications of likely response to a new mode.
Although one survey did assess the impact of a trial demand
responsive service, \(^1\) the trial was on too small a scale to be

---

1. GMR-1047. An un-named city is described in the report. The main conclusions are that:

"The total population of respondents expressed preferences for high levels of service and certain convenience factors. These preference rankings suggest that the individuals prefer a mode that approximates the automobile with regard to level of service. The users indicate that they want to be able to depend on the system and wish to be inconvenienced as little as possible. The level of fare is important, but they are willing to trade-off fare for a system that minimizes inconveniences. Dependability is much more important than extra travel time or fare level."

p. 23

and

"An analysis of market groups revealed that only three of the groups analyzed showed major variations from the preferences exhibited by the total sample. The elderly concerned themselves with the physical problems of riding the vehicle; they preferred not to stand, change vehicles, be crowded or have trouble getting on the vehicle. A low fare was also important. They were willing to trade-off their time conveniences, and a better vehicle design for the solution of these physical problems. The low income group express preferences that imply a greater dependence on the system, since they prefer a dependable system with long hours of service at a low fare, with the provision of protection from the weather at pickup points. The young express different preferences than the other groups. Convenience factors have a much greater importance, while transferring vehicles or being crowded are not as important to this group."

p. 24
able to predict demand over a larger area and a longer period of time. In any event, the expense and time of a market survey put the method beyond the scope of this study.

The remaining methods are not as direct as a market survey and involve some degree of theorizing on the motivations of tripmakers as they choose their mode, together with correlations with existing trip making characteristics. Perhaps the approach which would be the most sensitive to evaluating the introduction of a new mode is a disaggregate behavioral model. It approaches travel mode choice from the analysis of individuals who are representative samples of subpopulations of a given city or country, and combines this with the principle characteristics of the available modes. Those who have developed this approach have variously empha-

sized individual characteristics such as income, value of time, sex, age and sometimes residential location and auto ownership; trip purpose; and mode characteristics relating to speed, frequency, accessibility and relative comfort. However, apart from the issue of value of time\(^1\) very little work has been done to develop disaggregate models of British travel characteristics,\(^2\) and a survey of the Cheltenham population, similar to that which was carried out by Plourde for Cambridge\(^3\) is beyond the scope of this thesis.

The majority of studies dealing with modal split forecasting fall into the category of aggregate behavioral models, and concentrate on the areal travel characteristics analysed by means of travel volumes between zone pairs.\(^4\) They can be

1. This will be discussed more fully in section 2.5. Quarmby gives a useful summary.
2. The most useful work to date has been done by Wootton and Pick, "Travel Estimates from Census Data" Traffic Engineering and Control, July 1967, pp.142-152. It compares individual characteristics with trip volumes by purpose and mode. However, their work related to two large conurbations; London and the West Midlands, and extrapolation to a smaller urban area is suspect.
further subdivided into trip end modal split models\textsuperscript{1} and
trip interchange models.\textsuperscript{2} The trip end models are those
which allocate a portion of total person trip origins and
destinations to alternative modes prior to trip distribution
and on the basis variously of land-use generation, auto owner-
ship and accessibility to employment. They place a great
deal of emphasis on correlation of these factors, but in
general show poor explanatory power. The trip interchange
models are later developments and allocate to modes, portions
of given person trip movements between zones, resulting from
trip distribution to alternative modes. They concentrate on
the characteristics of the trip itself, regarding trip-making
as a market for which various modes compete. Travel time and
costs are deliberately introduced in conjunction with diver-
sion curves in the case of the Washington,D.C., study\textsuperscript{3} where
time and cost differences between modes over given zonal pairs
are plotted against given mode splits for various trip types
as a means of explaining choice of mode. However, these models
are concerned less with introducing a new mode, than in esti-
mating demand for existing modes in a dynamic situation where
the variables are changes in population, land use, and income.
A further development of the T.R.C. procedure has been made

\textsuperscript{1} Examples include Chicago, Pittsburgh, Erie, Seattle,
Milwaukee.
\textsuperscript{2} Examples include Washington D.C., Twin Cities, San Juan,
Buffalo.
\textsuperscript{3} By Traffic Research Corporation.
by Gerald Kraft\(^1\) who separated the supply and demand functions of travel more explicitly by describing each mode in terms of abstract qualities of level of service, cost, etc. In the hope that this approach might provide an explicit way to introduce DAB to an existing travel market, Urbanek\(^2\) attempted to calibrate the Kraft model for the conditions of a smaller city, and to estimate demand for DAB. However, the model proved too cumbersome, and gave poor results for this scale of operation, partly due to its being originally designed for long intercity travel distances.

The main conclusion emerging from this review of demand analysis seemed to be that a simpler method, based on available census and traffic data would be the most suitable approach for Cheltenham. Since the introduction of DAB would be principally a market decision, the T.R.C. and Kraft approach to trip-making as a travel market appeared logical, and the principle of describing each mode in terms of abstract qualities (price, travel time, level of service) which could be reduced to monetary factors was appealing, especially as British research or the value of time was well developed.

---

Soolman\(^1\) had used a modified form of the short-cut modal split formula\(^2\) developed by Wilbur Smith Associates to estimate effect of change in trip cost or travel time on the use of transit for CBD work trips by auto owners at varying values of time. Although it had been developed specifically for CBD oriented trips, Soolman used it for all trip types in his Manchester N.H. study, and verified its accuracy by means of sample plots. However, the use of such a formula in the Cheltenham case appeared inappropriate on two counts. Firstly, the level of transit patronage in Manchester is so low that the more accurate lower portion of the curve is utilized, which would not be the case for Britain where transit patronage is much higher. Secondly, the objectives mentioned in section 1.2 are better served when the travel market is analysed by trip types related to the bus network, which implies a variety of diversion curves expressing different choices of transport according to the level of service offered.

1.5 Method selected

Drawing on the experience of the approaches outlined above, the author concluded that the market survey approach was not appropriate, but was nevertheless useful by indicating a potential travel market not served by any existing mode.

---

Section 2.10.2 briefly assesses the potential untapped travel market in Cheltenham. However, the bulk of the analysis deals with the share of trips DAB is likely to obtain from auto and bus within an inelastic travel market, and the method used is as follows:

1. An interzonal matrix was developed from Census and Traffic survey data to produce the total number of person trips by each mode over each zonal interchange.

2. The trips were then classified into six types reflecting the characteristics of the existing bus system.

3. Each zone in the city was assigned a walk and wait time according to the proximity to bus routes and the level of bus service.

4. A 50% sample of each trip type stratified by distance and volume was developed and the total cost of travel by bus and by car made for each zone pair of the samples.

5. The effective cost differences between bus and car were then plotted against the modal split to transit for that zone pair to produce a diversion curve expressing the travel characteristics of that trip type.

6. The effective cost difference of DAB, first with respect to conventional bus, then with respect to the car, were plotted onto the respective diversion curves of each trip type at five levels of fare. Reading back to the vertical axis, the modal
split to DAB is obtained from bus and from auto. Factoring by the total trips in that trip type the total gross trips diverted to DAB from bus and auto are obtained at the relevant fare levels.

This concludes the estimate of gross demand for DAB under conditions of full accessibility to DAB service. However, final net demand is dependent both on the degree of telephone coverage, and on the cost of providing DAB service. The cost of providing DAB is related to the number of hourly demands on the service. Curves expressing both gross and net demand for DAB at varying fare levels are then plotted against a variety of demands per sq. mile per hour over the entire service area. The curves of system cost are then plotted on a similar basis. Overlaying the two curves indicates the equilibrium points at which DAB can be operated as break-even, and profit operations, and the relevant demand obtained and fare levels required at these points. Factoring back to the gross demand by trip type, produces the net demand for relevant trip types. At this point, by varying the effective cost differences for the CBD oriented trip type, the effect of parking charges in diverting more trips to bus and DAB can be estimated.

1.6 Summary

This chapter looked at some reasons for introducing DAB in Britain, and suggested that it might be particularly useful for
strengthening government policy in favour of transit in urban areas.

The best way to test DAB is to take an actual study site, and Cheltenham was selected on the basis of its size and that its historic and aesthetic quality demanded an answer to urban transport other than urban expressways. Moreover, use of transit is lower than in other similar towns, and Cheltenham can thus be looked at as an example of the state of transit in other British towns in the near future.

One of the problems of assessing the feasibility of a new mode of transit is the potential demand for it. The chapter went on to review the current state of the art in assessing demand, and concluded that the most relevant method for this study is a form of the trip interchange modal split, treating travel as a market commodity, and the choice of mode dependent on the level of service the mode can offer.

We concluded by a brief summary of the method chosen and the steps taken to estimate demand for Cheltenham.

Chapter 2 will describe the process of deriving demand for DAB in more detail and Chapter 3 will produce costs for running a DAB system in Cheltenham. The demand and cost sides are brought together in Chapter 4 which describes the benefits that can be derived by a DAB operation by different sections of the community. Following conclusions on the feasibility of DAB in Cheltenham, Chapter 5 makes a brief review of the potential for DAB in other British cities, and concludes with
some points on the methodology used, and suggestions for further work.
2.1 Data Collection

In order to undertake the analysis described in 1.5, an interzonal trip matrix of person trips split by mode is required. Unfortunately, such a matrix was not immediately available for Cheltenham. However, two parallel sets of data were available. The 1966 10% sample census covers the city and areas outside by Census Wards\(^1\) which enumerate population, auto ownership and journey to work by mode. In addition the Census Bureau has developed an interzonal and intrazonal matrix of journey to work person trips. But total person journeys are not listed, and the shape of the Wards are rather large. In 1969 the County Planning Office undertook a traffic survey in preparation for a land-use/transportation plan. This survey divided the town into traffic zones, and an interzonal matrix was developed which enumerated total vehicle trips excluding busses but including trucks. Unfortunately there was no indication of the ratio of auto occupancy or of bus occupancy and volumes. One indication of the relationship of work trips to total trips was derived by means of a cordon line around the central area. A simple matrix of vehicle volumes by trip purpose for internal to internal, internal to

\(^{1}\) See (A fig.13)
external and external to external trips with origins and destinations within the town were available. Furthermore, the consultant's interim report indicated a total volume of person movements per day for internal to external, and external to external trips with origins and destinations within the town. An overall modal split to bus of 20% was also stated in the report.

Since person trips and mode splits are the important elements in this analysis, the Census information was taken as the basis of the study. First, an interzonal matrix was developed for work trips, factored to 1970 levels by keeping the bus trip growth static (as indicated by bus patronage over the last years) and increasing the auto share of trips by 3% per year as an estimate of the growth of auto usage. Both figures were adjusted by $+2\%$ to correct Census undercounting.

### 2.2 The Service Area

Before describing the final stage in developing the person trip matrix, a word should be said on the definition of the service area for DAB. Originally it was thought that the Municipal Borough of Cheltenham and the Urban District of

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1. Wilson and Womersley "Cheltenham Study. Interim Report" Fig.9
2. Wilson and Womersley. Section 2.26 p.8
3. Auto ownership is expected to double in Cheltenham by year 2000.
4. As directed by instructions from the Census Bureau.
Charlton Kings\textsuperscript{1} would be the relevant service area. However, further examination of the census Wards revealed that some peripheral areas of postwar suburbs should be included beyond the Municipal boundaries. The peripheral areas composed parts of other Wards, and the trip interchange with these Wards was reduced by the proportion of the population of the Ward living in the service area. Fig.1 lists the Wards in the total service area, and fig.2 maps the boundaries of the service area. Wards covering the town's CBD where small parking charges exist, and heavier ones are proposed in the consultants' report,\textsuperscript{2} the author defined as "internal" zones.\textsuperscript{3}

\section*{2.3 Definition of Trip Types}

As noted earlier,\textsuperscript{4} one of the purposes of this study is to see how DAB will compete with, or complement the existing bus service. It was important, therefore, for the trip types to reflect the characteristics of the bus network.\textsuperscript{5} The bus system is highly CBD oriented, with the routes passing through the CBD to the other side of town. The most logical arrangement of trip types thus appeared to be;

1. Internal to internal, and intrazonal trips in internal

\begin{enumerate}
\item Described together as "CCK" in the Appendix.
\item Wilson and Womersley. Section 1.17, p.3
\item See fig.2
\item See (A fig.29)
\end{enumerate}
zones (designated I/I and Iintra.)

2. Internal to external and external to internal trips (I/E and E/I)

3. Intrazonal trips in external zones (Eintra)

4. External to external trips where a direct bus route exists (E/E direct)

5. External to external trips where a bus transfer is required (E/E transfer)

2.4 Final Data Development

The work trip matrix described in 2.1 listed only origin to destination trip pairs. It was assumed that over the course of a day tripmakers would return home, so these figures were doubled. To determine the remaining non-work trips, the I/E, E/I trips and E/E trips were factored up by the proportion of total trips of that type listed in the consultants' report, and the modal split was factored by .4 for each trip type to agree with an overall modal split for the town of 20%. However, the trip types are only aggregations of a total of 92 interzonal trip pairs and 14 intrazonal pairs. Each trip pair was then adjusted by the appropriate trip type factor to yield the correct modal split for the diversion curve samples.

1. See fig.3
2.5 Value of Time

We will turn shortly to the other element which will enable us to plot our diversion curves, namely the effective cost differences between auto and bus for each trip pair. However, these costs are dependent not so much on out of pocket auto running costs and bus fares, but rather the disutility costs of time wasted during travel. The importance of time is based on the assumption that in a labour scarce economy, the value of time which could be put to productive use is valued highly. Within such an economy, however, the values of time in monetary terms for different segments of the community will vary. A low income worker may value his opportunity to earn money at his work or spend time with his family equally as highly as a high income executive, yet the executive is able to pay more to save time spent in commuting. Strictly speaking, therefore, value of time is a misnomer, and willingness to pay, or cost of time would be more suitable. Nevertheless value of time is commonly understood to mean cost of time, and we will continue using the former term. Since value of time is thus dependent on income, it would appear desirable to stratify the O.D. zones into income levels. However, information on income by Ward is not available in Britain, and when the total amount of time only amounts to less minutes, the difference in yearly income becomes / important.

Of more importance, however, is the proportion of income that is valued in travel time, and in the different environ-
ments experienced during travel. A useful amount of research
has been done on value of time of travellers in Britain. 1
Lisco, 2 Lave, 3 and Thomas 4 have produced figures for value
of time for U.S. travellers. Fig. 4 summarizes these findings.
It is clear by comparing, U.K. and U.S. percentages of yearly
income, that time is valued more highly as income rises.
Quarmby and Harrison 5 summarize previous value of time studies
in the following propositions:

1. Commuter trips should be valued at 25% of their wage
   rate.
2. This value should also be used for non-work trips.
3. Walking and waiting during non-working hours should
   be valued at a higher rate, say twice, than the in-
   vehicle travel time.
4. The value of time does not vary with the mode used.
5. The value of non-leisure time is proportional to income.

   new evidence" Economica, May 1965, pp. 174-185
2. Quarmby, D.A. "Choice of travel mode for the journey to
   work: Some findings" Journal of Transport Economics
   and Policy, Sept., 1967, pp. 273-314
3. Stopher, P.R. "Predicting Travel mode choice for the work
   journey" Traffic Engineering and Control, Jan. 1968
   pp. 436-439
4. Lisco, T.E. "Value of commuters' time - a study in urban
   transportation" Ph.D dissertation, Dept. of Economics,
   University of Michigan
5. Lave, C.A. "A behavioral approach to modal split forecast-
4. Thomas and Thompton "The Value of Time for Commuting Motor-
   ists as a Function of their Income Level and Amount of
   Time Saved" Highway Research Record, 314, pp. 1-18, 1970
5. Harrison and Quarmby "The Value of Time in Transportation
6. The value of time does not vary with trip length.
7. Marginal time values are estimated to be constant overall journey lengths, and therefore are equal to average values.

Since these propositions have been derived from studies of value of time in Britain, they will well be taken as applicable to Cheltenham. Evidence,\textsuperscript{1} and common sense suggests that waiting is a more adverse and irritating condition than walking, and this study consequently sets the value of waiting time somewhat higher than walk time. Fig. 5 lists the final values of time assumed for Cheltenham.

2.6 Effective Costs

For each trip pair, the following elements must be considered in order to estimate the total cost for each mode:

1. Bus: Walk to bus stop
   - Wait for bus
   - Distance to destination bus stop \{ travel time \}
   - Speed of bus
   - Fare
   - Walk from bus stop to final destination
   - Transfer time (if any)

\textsuperscript{1} Goldberg, L. "A comparison of transportation plans for a linear city" reference from Quarmby, p.280. Goldberg reports that analysis of a survey in Paris showed the value of waiting time as treble "in vehicle" time.
2. Car: Walk to car and unpark

Distance to parking destination \{ Travel Time

Speed of car

Out of pocket running costs

Park and walk to destination

Parking costs (if any)

3. DAB: Wait for vehicle

Distance to destination \{ Travel time

Speed of bus

Fare

To estimate trip distance, the population centroids of each zone were marked and an airline distance trip matrix developed (see fig. 6).

In order to simplify calculations all the elements listed above were reduced to costs per trip. The derivations of the costs are described in the following sections.

2.6.1 Bus

At a walking speed of 270 ft. per minute,\(^1\) a five minute walk translates into a distance of \(\frac{1}{4}\) mile. The isocurves of 3 minute, 5 minute and 8 minute walking times were drawn along the bus routes, and an average walk time noted for each zone. At the value of time for walking of 1.2 pence/minute,\(^2\) walk

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1. Lisco
2. ref. Fig. 5
costs could then be assigned to each zone (see fig. 7).

Waiting time is a function of the frequency of the bus service, constrained by a maximum of 10 minutes wait, since it is assumed that passengers using an infrequent bus service will know the bus schedule and gauge their departure time from home accordingly. The wait times and costs shown in fig. 8 were gained from the bus schedules shown in (A fig. 30). Wait times and costs were then assigned to the zones depending on which bus routes passed through them (see fig. 7).

The distance of bus travel was taken as the airline distance in all cases, except those trip types involving a transfer (E/E (transfer) only) where the airline distance was multiplied by a factor to obtain the total distance. The factor was derived from an examination of the bus routes the passenger would have to travel to get to his destination zone.

To obtain a cost for each trip type depends on the average bus speed. This was found from an examination of the bus time-table for bus times over distances which the author had timed by car for 4 representative trip types (ref. A figs. 21 and 22). The average bus speed came to 10 mph. At a value of time of 0.6 pence/minute this represents a value of 3.6 pence/mile (see fig. 9). Distance was then multiplied by this value to obtain in vehicle travel cost.

The Bus Company charges fares by stages which are not entirely proportional to distance. For the average distance
travelled the fare was estimated at 9 pence/mile (see fig. 9).

On trips involving a transfer, a 5 minute wait for the connection seems reasonable and at 1.5 pence/minute wait time, this gives a transfer cost of 7.5 pence.

2.6.2 Car

Assuming that cars can be parked close to destinations in external zones, an amount of 1 minute, representing 1.2 pence was assigned to walk and unpark, and park and walk times. In central zones, however, congestion is such that an average of 5 minutes is required to walk and unpark and park and walk, representing 6.0 pence.

Airline distance is taken as driving distance, and average speed (derived from figs. A 21 and 22) is 16 mph representing a value of time in travel of 2.2 pence/mile.

Although auto running costs are sometimes discounted in U.S. studies, the much higher cost of petrol in Britain makes their inclusion necessary. In both countries, however, the running costs are the usable factor, not total costs, since a decision to own a car has already been taken. Quarmby decided to use 4 pence/mile as the running costs for cars, but after analysis reduced this to 2-2½ pence/mile, which at that time (1967) just covered petrol costs. He assumed that this was the perceived cost of travel and that this was clearly more important than the actual cost. The cost of petrol has
since risen to 6 shillings/gallon, and at 25 m.p.g., this now represents 3 pence/mile. This figure has been taken as the perceived running costs of travel in this study.

The remaining item in the cost of a trip by car, is the parking charge, which in Cheltenham exists only in the central area. Although the area where parking charges are in force is not coincidental with our "Internal" zones, they have been taken as such for the purpose of this analysis, since the majority of the trips to and within the Internal zones will be to the central area. The consultants' interim report states\(^1\) that there are 1800 public parking spaces (where charges are made), out of a total of 13,250 spaces for on and off street, public and private parking. The 1800 spaces are approx 14% of the total, and charge an average of 18 pence/day. The average charge spread over all auto trips to the central area can therefore be stated as \(14\% \times 18\) pence = 2.5 pence/trip. The effective costs for car travel are summarized in fig. 10.

2.6.3 Dial-a-Bus

Since DAB will provide a door to door service, the trip and times are reduced to waiting for the vehicle to arrive, after phoning for service. The average waiting time is a system variable, which is suggested as 10 minutes\(^2\) for a level

\[\text{1. Section 2.29, p.8} \]
\[\text{2. Ref. Soolman, p.57} \]
of service of 2.5.\textsuperscript{1} Since the user can continue to do useful or pleasurable activities at home until the vehicle arrives, it seems appropriate that his value of time would be lower, say one half of in vehicle time. This analysis thus takes $0.3$ pence/minute as the value of time spent indoors, which for a 10 minute wait is $3.0$ pence.

The very nature of a many to many demand responsive ride sharing system suggests that from an individual rider's point of view, the vehicle will probably divert slightly off course to pick up and drop off other passengers over the course of his trip. Recent studies indicate that the total distance travelled by the individual rider will be about 1.5 times the direct auto route distance he would have chosen if he had decided to use his auto.\textsuperscript{2} Since it is more maneuverable and makes fewer stops than a conventional bus, but is more cumbersome and stops more frequently than a car, the overall speed of the DAB vehicle is assumed to be 13 mph, representing a value of 2.8 pence/mile.

The fare the user has to pay is largely dependent on system costs and is discussed in Chapter 3. The five fare levels chosen to derive demand curves, were 4.50, 4.00, 3.75, 3.50 and 3.00 shillings. However, it is important to note that the type of DAB service eventually chosen to be implemented

\begin{footnotesize}
\begin{enumerate}
\item See Chapter 3.0 Cost Analysis
\item Hamilton, Rausch and Dunlavey "A manual CARS service for Cambridge - Vehicle and Communications Aspects" Internal memo for M.I.T. project CARS, April 14, 1970
\end{enumerate}
\end{footnotesize}
should be based on one average fare for all lengths of journey. One of the purposes of implementing DAB, is to encourage auto riders to travel by DAB. Since a higher proportion of auto owners live in suburban areas where trip distances are longer and bus service is poorer, an average fare will discriminate in their favour. Moreover, a high proportion of people in Cheltenham walk. (14% of the working population walks to work.) Since journeys undertaken by walking are normally short, and one of the purposes of a DAB service is to reduce road congestion, both the health of the population and case of movement within the city are better served by DAB discouraging very short trips, by charging an average fare.

The effective costs for travel by DAB are summarized in fig. 11.

2.6.4 Effective Cost Example

Our samples of effective costs are based on trip pairs within each trip type. Since travel (especially the journey to work) is generated largely by the differences in land use (eg. residential to industrial) the volume of trips generated by different land uses will vary. Although the zones in this study each comprise several land uses, they have large differences in trip generative power (eg. central as opposed to peripheral zones). Since the trip end costs (walk, wait, parking, transfer, etc.) are variable by zone, the effective costs
for each mode within each trip pair should be modified by the proportion of trips in each direction. The following example of an effective cost calculation incorporates that proportion.

Example: I/E, E/I trip (short distance). Zones CCD and CCC.

**Bus**

CCD to CCC

\[
(3.6 + 7.50 + (1.3 \times 3.6) + 1.3 \times 9.0) + 6.0 \times \frac{30}{490} = 2.05
\]

CCC to CCD

\[
(6.0 + 6.75 + (1.3 \times 3.6) + (1.3 \times 9.0) + 3.6) \times \frac{460}{490} = 30.23
\]

**TOTAL TRIP PAIR COST BY BUS (pence) = 32.28**

**Car**

CCD to CCC

\[
(6.0 + (1.3 \times 2.2) + (1.3 \times 3.0) + 1.2) \times \frac{30}{250} = 1.68
\]

CCC to CCD

\[
(1.2 + (1.3 \times 2.2) + (1.3 \times 3.0) + 6.0 + 2.5) \times \frac{220}{250} = 14.48
\]

**TOTAL TRIP PAIR COST BY CAR (pence) = 16.16**

**DAB**

I/E, E/I (short) trip type. Av.Distance = 1.2 miles

\[
(3.0 + (1.2 \times 1.5 \times 2.8) + \text{fare})
\]

**THEREFORE TOTAL TRIP TYPE COST BY DAB (pence) = 5.04 + \text{fare}**
where  
\[ a = \text{walk cost} \]
\[ b = \text{wait cost} \]
\[ c = \text{distance in miles} \]
\[ d = \text{cost per mile of bus travel} \]
\[ e = \text{bus fare per mile} \]
\[ f = \text{trip pair proportion factor} \]
\[ g = \text{walk and unpark} \]
\[ \quad \text{park and walk} \quad \text{central zone} \]
\[ h = \text{cost per mile of car travel} \]
\[ i = \text{petrol costs per mile of car travel} \]
\[ j = \text{walk and unpark} \]
\[ \quad \text{park and walk} \quad \text{external zones} \]
\[ k = \text{car parking charge} \]
\[ l = \text{cost of waiting for DAB} \]
\[ m = \text{cost per mile of DAB travel} \]

DAB has been calculated for the trip type, rather than for the particular sample, since it will be introduced later after the diversion curves based on the bus/auto samples have been developed.

2.7 Samples

Effective costs for a 50% sample of each of the trip types listed in fig. 3 was developed. Each trip type was stratified on the basis of long and short distance, and high and low total trip volume. These characteristics, therefore, each repres-
sented 12.5% of the total trips of each trip type.

2.8 Diversion Curves

Differences in the effective costs of two modes between a given zone pair would, in theory, imply that the whole population of the zone would travel by the cheaper mode. Clearly this is not the case, and the diversion curve is an attempt to express the cumulative distribution of a variety of factors which influence mode choice. These factors include not only the average cost and time, which the effective costs include, but also preferences based on taste, on lack of choice (ie. "captive" transit riders), and on a mixture of trip purpose. Indeed, the diversion curve itself represents the mean of all the trip pairs within the trip type. The effect of amalgamating these variables is discussed in section 6.3.

Since we have concluded that the most important variable in this study is the bus orientation, separate diversion curves have been developed for each major trip type by bus, according to the six types listed in fig. 3.

The construction of each diversion curve involved subtracting the effective cost of the less expensive mode from that of the more expensive mode (in this case, bus) and plotting the result against the modal split to the more expensive

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1. Effective cost ratios, as in the Washington, D.C., Buffalo, (continued overpage)
mode for the relevant trip pair. The diversion curve was then drawn by hand through the mean of these plots. The curve was checked by plotting the effective cost difference against the modal split for all the zone pairs in the trip type, the average distance of all the trip pairs being taken for this purpose. Figs. nos. 12, 13, 14, 15, 16, 17 show the results. The plots in most cases describe a reasonable curve and their validity was verified by the averaged plotting. But in the case of the I/E, E/I (short) trip type (fig. 13) there is a divergence between the majority of the samples showing low mode splits, and a few showing very high ones for the same effective cost difference. On further inspection, these samples proved to be mode splits from zones CCC and CCD, which are largely lower income areas of public housing at the periphery of the town. The significance of this finding will be discussed later in section 6.3. At the moment it is sufficient to note that the author considered the mean drawn through the lower group of samples (solid line) described the travel character better than the upper line, and thus the lower diversion curve was used for the latter part of the analysis.

Note continued:
Puget Sound, and Erie studies have usually been chosen rather than effective cost differences. However, effective cost differences are more suitable for a town the size of Cheltenham, since the ratio method would not be so sensitive to the shorter trip lengths involved.
2.9 Diversion to Dial-a-Bus

Diversion curves have usually been used to predict new mode splits obtained by offering changes in the level of service of one of the two modes used to plot the curve. However, as the effective costs express abstract qualities which are attributes of any mode, there is no reason why the curves cannot be used to introduce a new mode whose level of service is expressed in effective costs.

2.9.1 Diversion from Bus

The effective cost difference between bus and DAB for each trip type was developed using the average trip distance for the respective mode and DAB at five fare levels. The average effective costs are listed in fig. 18. The relevant modal split was read off the diversion curve for each level of fare and multiplied by the total number of trips of that trip type by bus (from fig. 3), to produce the mode splits and volumes to DAB listed in fig. 19.

2.9.2 Diversion from car

Soolman has demonstrated cogently that DAB can reach

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1. For an illustration of the procedure see Wynn, F.H. "Shortcut Modal Split Formula" Highway Research Record no.283, p.53.
two distinct groups of people who travel by car. The larger group are those who are licensed drivers and use the car to drive themselves to their destination. The other group are those who are not licensed, or do not choose to drive themselves, and call upon a relative or friend to drive them. This second group can be called serve passenger trips, and are likely to be very responsive to a DAB service, since the net cost to the family involves two people instead of one, and a total of three times the journey length that the individual would have to make, were he driving himself.

Coverage of driving licences by Ward was not readily available for Cheltenham, and proportion of serve passenger trips to total trips was inferred from Soolman's data on the assumption that the proportion of serve passenger trips are a function of the level of bus service. Since a serve passenger trip involves considerable inconvenience for the driver - unless, of course, he is driving his girl friend home - it seems likely that the trip-maker will take the bus, unless the bus service is so poor that he must call on someone to drive him.

(1) The data from Manchester N.H. is as follows:

In 1964 32,900 daily trips were made by unlicensed trip-makers.
This number was 12% of all daily trips.
The transit company served only 13% of the 32,900 trips.
The overall modal split to transit is 3-8%.
(2) Thus 87% of the 32,900 trips were serve passenger trips.

(3) \(12\% \times \frac{87}{100} = \) the percentage of all trips which were serve passenger trips = 10.44%

(4) The overall modal split to transit in Cheltenham is 20%.

(5) \(\frac{3.8}{20} = \) the proportion of Manchester N.H.'s modal split to Cheltenham's = 0.19.

(6) Thus \(10.44 \times 0.19\% = \) the percentage of all trips in Cheltenham which are serve passenger trips = 1.98%.

If our assumptions are correct this provides a rough indication of the volume of serve passenger trips in Cheltenham. Similar effective cost calculations to those described for bus trips were made for licensed trip-makers and serve passenger trips, and the results listed in fig. 19. It can be seen that although the actual volumes of serve passenger trips are low, the proportion diverted to DAB is almost twice that of the licensed trip-makers. Whether this volume will grow is likely to depend on the future level of bus service and level of auto ownership.

2.10 Demand Curves

The average cost per passenger of supplying a given level of service is a function of the average demand density over the area in which DAB is operating. The total ridership di-
verted to DAB at each fare level should thus be divided by the total area over which DAB is operating multiplied by the hours of operation per day to yield the number of demands per square mile per hour. These figures can then provide the same basis for comparison with the costs of supplying the service, to determine the fares that can be charged for any given level of service. Fig. 20 lists the gross and net demand for DAB for a variety of conditions.

2.10.1 Gross Demand for Dial-a-Bus

The curves of gross demand drawn on figs. 21 and 22 show the potential demand for DAB assuming 100% access to phones and the limitation of an inelastic travel market. The variation on these gross amounts are discussed in the next subsections.

2.10.2 Elasticities in Gross Demand

In Chapter 1 we noted that the bulk of this analysis would be concerned with a re-distribution of existing vehicular trips by the introduction of DAB. However the door to door service characteristics which DAB offers may reach a segment of the population who would wish to travel but cannot do so - specifically the old and/or infirm who cannot afford a taxi for regular travel. From the days when it was developed as a Spa, Cheltenham has attracted a high proportion of older people
which today is reflected in its percentage of people over 60 (20% - ref. A fig. 17) compared to the average for the County (17.75%). The town has several large retirement and nursing homes where the residents would have access to a telephone. Consequently, this is a group of people who could greatly benefit from a DAB service, and if the fares proved too high for their ability to pay, a good case can be made for a municipal subsidy to older residents for travel by DAB. Since we assume that this group of people do not travel by existing modes to the same extent as other age groups, in proportion to their size, this travel market cannot be integrated into the present analysis and would properly be the subject of a home interview survey. They will thus be left out of the but estimates of demand in this study, are a group whose travel needs should be seriously considered before a final decision to use DAB is made.

A further group of people who travel yet do not use vehicular modes are cyclists and walkers who comprise 41% of the total journeys to work in Cheltenham (ref. A fig. 36). But apart from the argument that from the points of view of personal health and traffic congestion, it is better for this group to maintain their present modes of travel, it is unlikely that more than a small fraction would choose DAB in preference to their present modes. It can be argued that they are able-

bodied enough to have chosen the bus if they had wished to do so, and since their journeys are likely to be very short (especially the walkers) a DAB service based on an average fare would be expensive for very short journeys, and thus not attract them.

2.10.3 Telephone Coverage

Since the use of DAB is dependent on easy access to a telephone, phone coverage is a very important variable in assessing actual demand for DAB. In 1968 these were 109,255,000 phone connections in the United States\(^1\) serving a population of approximately 195 million. In the same year phone connections in Britain totalled 12,799,000\(^1\) for a population of approximately 50 million. In 1970 this had risen to 14 million connections in Britain with installation rising at the rate of 8.7% per year.\(^2\) Nevertheless phone coverage in Britain is clearly far below the per capita coverage in the U.S. and new connections are both more expensive and slower to instal.\(^3\) Coverage in the southwest of Britain is slightly above the national average\(^4\) and coverage for Cheltenham is above that of the region.

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3. Ref. A.9.12. £25 for a connection. Installation may take up to 3 months.
4. Ref. A Fig. 38.
We can assume that the critical figure is the percentage of households having a phone, since it is certain that all members of the household with phone have access to it, and phone coverage at workplaces is much higher than residential coverage. The figures for residential phone connections in Cheltenham and Charlton Kings\(^1\) adjusted to 1970 coverage (11,568) were thus divided by the number of households in the same area\(^2\) (30,462) and multiplied by 100 to yeild 38% of all households covered by phone. This was assumed to be the coverage for the whole of the DAB service area. It is the author's impression that residential phone coverage is closely correlated to income. Unfortunately, no breakdown of phone coverage within the Cheltenham area is made by the G.P.O. so the 38% was applied to the whole area. In the case of the demand curve for E/E trips only (fig. 22), demand is also shown constrained by 60% phone coverage since it is likely that the higher income areas are generally on the outer areas of the town and hence have a higher phone coverage and are also the trip makers of E/E trips. Moreover, since phone connections are rising rapidly (8.7%/yr.) it may not be long before such phone coverage is obtained in this area. Nevertheless, this

1. Ref. A fig. 37. Including "residential shared" and "Coin box rented" The latter are mostly installations in the public spaces of apartment buildings, and thus qualify as residential since they can, in fact, serve several households.
2. From the adjusted 1966 Sample Census.
curve is for indicative purposes only, and a more accurate survey of phone coverages in the town should be undertaken before any implementation of DAB is decided.

2.10.4 Net Demand for Dial-a-Bus

The remaining curves drawn in solid line on figs. 21 through 23 show the gross demand reduced by the percentage of households which have access to a telephone. The precise points on these demand curves where a DAB system can be operated on break-even, and profit operations is discussed in Chapter 4.

2.10.5 Off-Peak Demand for Dial-a-Bus

An inherent problem in any conventional transit operation is that the system must be designed to meet peak hour demand, thus leaving labour and capital resources underused, and hence unprofitable, during off-peak hours. Since labour is the major cost of a bus service, one possible use of DAB is at off-peak hours, when bus drivers could change to driving DAB vehicles. At the same time as economising on labour costs, would not divert passengers from the bus at their this/profitable peak hour periods. However, this policy would considerably reduce DAB's benefit to the community and would not provide the competitive or legislative opportunity to divert car drivers to DAB during the peak hour rush. A possible compromise is to offer peak hour DAB travel on E/E trips only, where the bus service in any case is poor. These are issues
which the DAB operator and the community in general have to
decide and are discussed further in Chapter 4.

Assessing demand for DAB at off-peak was possible through
data furnished by the consultants' interim report\(^1\) where the
relevant items of data were as follows:

Bus morning peak 11% of total daily trips.
Bus evening peak 18% of total daily trips.
Peak periods for all traffic: 8 a.m. - 9 a.m.
5 p.m. - 6 p.m. (11% of total).

Interpolating from the bus figures the morning peak for all
traffic should be about 8% to 9% of total trips. Assuming
that bus drivers will drive DAB vehicles, three peak hours
per day should be allowed to give drivers time to transfer to
DAB vehicles. Assuming that demand reduces slightly during
the extra half hour of each peak, we can conclude a peak demand
over each of the three hours of 9% of total trips per hour.
For the three peak hours this would amount to a total of 27%
of the daily trips. Although some computer time can be sold
during the peak hours, the DAB base station staff costs remain
during this unproductive period, so the off peak demand has
been spread over the full 16 hour day for the purpose of analysis.
The demands per sq. mile per hour constrained by 73% of total
trips, and a 38% phone coverage and spread over a 16 hr. day
are listed on fig. 20 and the demand curve drawn on fig. 23.

---

1. Sections 2.24 and 2.25.
2.11 Summary

This Chapter, opened by describing the problem of data collection, and the method taken to secure an interzonal person trip matrix split by mode. The analysis was stratified into trip types following the characteristics of the present bus system which in turn follow the principal trip-making characteristics of the city.

The most important results of the analysis presented in this chapter are the demand curves for DAB, derived from introducing the qualities of DAB service into the curves drawn to express the diversion between bus and car. The net demand curves show the demand densities obtainable in the town at five levels of fare and constrained by the existing phone coverage. Three principal types of demand curves are drawn which relate to three potential forms of service which DAB might offer in Cheltenham.
### SELECTED DAB SERVICE AREA

<table>
<thead>
<tr>
<th>Census Ward</th>
<th>Internal or External Zone</th>
<th>Area Sq. Mile</th>
<th>Trip Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCA</td>
<td>E</td>
<td>0.81</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCB</td>
<td>I</td>
<td>0.50</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCC</td>
<td>E</td>
<td>1.56</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCD</td>
<td>I</td>
<td>0.62</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCE</td>
<td>E</td>
<td>0.87</td>
<td>x 1.00</td>
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<td>I</td>
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<td>x 1.00</td>
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<tr>
<td>CCG</td>
<td>E</td>
<td>0.50</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCH</td>
<td>I</td>
<td>0.37</td>
<td>x 1.00</td>
</tr>
<tr>
<td>CCI</td>
<td>E</td>
<td>0.94</td>
<td>x 1.00</td>
</tr>
<tr>
<td>Part CB</td>
<td>E</td>
<td>1.88</td>
<td>x 1.00</td>
</tr>
<tr>
<td>&quot;</td>
<td>CHI</td>
<td>0.81</td>
<td>x 0.60</td>
</tr>
<tr>
<td>&quot;</td>
<td>CHN</td>
<td>0.62</td>
<td>x 0.90</td>
</tr>
<tr>
<td>&quot;</td>
<td>CHK</td>
<td>1.38</td>
<td>x 0.60</td>
</tr>
<tr>
<td>&quot;</td>
<td>CHJ</td>
<td>0.31</td>
<td>x 0.60 (destination trips only)</td>
</tr>
</tbody>
</table>

**TOTAL SERVICE AREA**  11.86
KEY TO FIG. 2

Fig. 2 see overleaf

External zone with population centroid

Internal zone with population centroid

Central area
Parking, ref. section 4.5
CHELTENHAM SERVICE AREA

TOTAL DAILY TRIP VOLUMES BY TRIP TYPE AND MODAL SPLIT

<table>
<thead>
<tr>
<th>Trip type</th>
<th>Bus total</th>
<th>Car total</th>
<th>Licensed tripmaker</th>
<th>Serve passenger</th>
<th>All total</th>
<th>Percent MS to transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/I and intrazonal</td>
<td>4,535</td>
<td>11,702</td>
<td>328</td>
<td>16,565</td>
<td></td>
<td>27.4</td>
</tr>
<tr>
<td>I/E (short)</td>
<td>17,906</td>
<td>49,546</td>
<td>1,360</td>
<td>68,812</td>
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<td>26.1</td>
</tr>
<tr>
<td>I/E (long)</td>
<td>3,493</td>
<td>10,708</td>
<td>287</td>
<td>14,488</td>
<td></td>
<td>24.1</td>
</tr>
<tr>
<td>External Intrazonal</td>
<td>835</td>
<td>10,796</td>
<td>234</td>
<td>11,865</td>
<td></td>
<td>7.1</td>
</tr>
<tr>
<td>E/E direct</td>
<td>3,000</td>
<td>23,662</td>
<td>538</td>
<td>27,200</td>
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<td>11.0</td>
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<tr>
<td>E/E transfer</td>
<td>3,260</td>
<td>22,500</td>
<td>520</td>
<td>26,280</td>
<td></td>
<td>12.4</td>
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<tr>
<td><strong>TOTAL DAILY TRIPS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>165,210</strong></td>
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</table>
### VALUE OF TIME STUDIES

<table>
<thead>
<tr>
<th>Author</th>
<th>Trip Purpose</th>
<th>Income Levels</th>
<th>Mean Trip Length</th>
<th>Value of time (% of wage rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Beesley</td>
<td>Work</td>
<td>Middle</td>
<td>Urban trips</td>
<td>33% (total)</td>
</tr>
<tr>
<td>* Quarmby</td>
<td>Work</td>
<td>All</td>
<td>5.5 miles</td>
<td>20%-25% (total)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40%-60% (walk/wait)</td>
</tr>
<tr>
<td>Lisco</td>
<td>Work</td>
<td>Middle to High</td>
<td>15 miles</td>
<td>50% (total)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150% (walk)</td>
</tr>
<tr>
<td>* Stopher</td>
<td>Work</td>
<td>All</td>
<td>Urban trips</td>
<td>20%-25% (total)</td>
</tr>
<tr>
<td>Thomas</td>
<td>Work</td>
<td>All</td>
<td>Long</td>
<td>40%-80% (total)</td>
</tr>
<tr>
<td>Lave</td>
<td>Work</td>
<td>All</td>
<td>8.6 miles</td>
<td>40%-75% (total)</td>
</tr>
</tbody>
</table>

Asterisks refer to time valued in British cases.
If income = £1620/yr./hh. for southwest Britain

= 550 shillings/week + 20% 
= 660 shillings/hh/week

Per worker income = \frac{median\ income}{1\ dwelling\ unit} \times \frac{no.\ dwelling\ units}{no.\ workers} \times \frac{income}{workers}

= \frac{660}{1} \times \frac{34,045}{46,161}

= 488 shillings/week

Worker wage rate

= 488 \times \frac{1}{40} \times \frac{1}{60} \times \frac{12}{1} = 2.4\ pence/min.

Travel time at 25% of wage rate = 0.6\ pence/min.
Walk time at twice travel time = 1.2\ pence/min.
Waiting time at 2\frac{1}{2} \times travel\ time = 1.5\ pence/min.

   Central Statistical Office.
2. The County Planning Office suggests income in Cheltenham is above the regional average.
### INTERZONAL AND INTRAZONAL AIRLINE DISTANCES

<table>
<thead>
<tr>
<th></th>
<th>CCA</th>
<th>CCB</th>
<th>CCC</th>
<th>CCD</th>
<th>CCE</th>
<th>CCF</th>
<th>CCG</th>
<th>CCH</th>
<th>CCI</th>
<th>CB</th>
<th>CHI</th>
<th>CHJ</th>
<th>CHK</th>
<th>CHN</th>
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<tr>
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<td>3.0</td>
<td>2.3</td>
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<tr>
<td>CCB</td>
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<td>1.9</td>
<td>0.5</td>
<td>0.7</td>
<td>1.0</td>
<td>1.5</td>
<td>1.0</td>
<td>1.3</td>
<td>1.0</td>
<td>1.3</td>
<td>2.0</td>
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<td>1.9</td>
<td>3.0</td>
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<tr>
<td>CCG</td>
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<td>1.7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>2.6</td>
<td>2.5</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TRIP TYPE

<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Average Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/I trips and I (Intrazonal)</td>
<td>Average distance = 0.72 miles</td>
</tr>
<tr>
<td>I/E and E/I (short distance)</td>
<td>&quot;</td>
</tr>
<tr>
<td>I/E and E/I (long)</td>
<td>&quot;</td>
</tr>
<tr>
<td>External (Intrazonal)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E/E (direct bus route)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E/E (transfer)</td>
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</tr>
<tr>
<td><strong>AVERAGE DISTANCE (ALL ZONE TYPES)</strong></td>
<td>= 1.2 MILES</td>
</tr>
</tbody>
</table>

- 61 -
**BUS WALK & WAIT TIMES AND COSTS BY ZONE**

Walk time takes into account density of bus routes. It is an average walk time to a bus stop for a given zone. Wait time takes into account frequency of bus routes and is a function of the level of service of bus routes in that zone.

<table>
<thead>
<tr>
<th>Zone location</th>
<th>Walk time(min.)</th>
<th>Walk Cost in pence</th>
<th>Wait time (min.)</th>
<th>Wait Cost in pence</th>
</tr>
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</tr>
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<td>CCB</td>
<td>5</td>
<td>6.0</td>
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<td>5.0</td>
<td>7.50</td>
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<td>CCH</td>
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<td>6.0</td>
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<td>9.6</td>
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<td>7.50</td>
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<td>CHI</td>
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<td>9.6</td>
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<td>15.00</td>
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<td>CHJ</td>
<td>8</td>
<td>9.6</td>
<td>6.4</td>
<td>9.6</td>
</tr>
</tbody>
</table>

* Walk time at 1.2 pence/min. ** Wait time at 1.5 pence/min.
3 min. = 3.6 d
5 min. = 6.0 d
8 min. = 9.6 d
BUS ROUTES. WAIT TIMES

Average wait time over 16 hour day.
Average wait time is $1/3$ average headway, but not above 10 minutes. (To account for some degree of knowledge of bus time tables)

<table>
<thead>
<tr>
<th>Route no.</th>
<th>Minutes</th>
<th>Cost at 1.5 pence/min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>590, 591</td>
<td>4.5</td>
<td>6.7</td>
</tr>
<tr>
<td>588, 589</td>
<td>5.0</td>
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<tr>
<td>594, 595</td>
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<tr>
<td>592</td>
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<td>9.6</td>
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<tr>
<td>596</td>
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</tr>
<tr>
<td>587</td>
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<td>15.0</td>
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<tr>
<td>597</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>598</td>
<td>10.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Average transfer time. 5 min. = 7.50 pence
BUS SPEED AND FARES PER MILE

Speed
Average bus speed = 10 m.p.h.
= 0.17 miles per minute
so 1 mile = 6 minutes
Value of time in travel is 0.6 pence/minute
Value of time = 3.6 pence/mile

Fares
For 4 miles (our max. zonal distance) = 10 pence/mile
For 0.7 " (min. average zonal distance) = 6.3 pence/mile
For 1.2 " (average zonal distance) = 10 pence/mile
Since there are more shorter than longer bus trips
compromise fare taken as 9 pence/mile
Walk and unpark (E/E trips only) = 1.2 pence
Park and walk " " " = 1.2 pence
Walk and unpark (I/E and E/I and I/I trips) = 6.0 pence
Park and walk " " " " " = 6.0 pence
Travel value of time/mile = 2.2 pence
Running costs/mile = 3.0 pence
Parking charge (Internal zones only) = 2.5 pence
Cost of waiting for vehicle = 3.0 pence
Travel value of time/mile = 2.8 pence/mile
Distance travelled = airline distance x 1.5
Fare: One of the following levels

4.50 shillings
4.00 shillings
3.75 shillings
3.50 shillings
3.00 shillings
Percent Mode Split to more Expensive Mode

Effective cost difference. Cost of more expensive - Cost of less expensive mode (in pence)

Fig. 12
INVERSION CURVES I/E, E/I TRIPS.

Effective cost difference, more expensive mode - less expensive mode (in pence)

Percent Mode Split to more expensive mode

Average plot for whole trip type

Fig. 13
Effective Cost Difference. More Expensive Mode - Less Expensive Mode (in pence)

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DIVERSION CURVE. EXTERNAL (Intrazonal) TRIPS  Fig.15

Percent Mode Split to more Expensive Mode

Effective Cost Difference. More Expensive Mode - Less Expensive Mode (in pence)
Effective Cost Difference. More Expensive Mode - Less Expensive Mode (in pence)

Fig. 16
Average Plot for Trip Type

Effective Cost Difference. More Expensive Mode - Less Expensive Mode (in pence)

Percent Mode Split to More Expensive Mode

DIVERSION CURVE. E/E TRIPS.
BUS TRANSFER

Fig. 17
AVERAGE EFFECTIVE COSTS BY TRIP TYPE AND MODE

<table>
<thead>
<tr>
<th>Trip type</th>
<th>Effective cost by mode in pence</th>
<th>Bus</th>
<th>Auto licensed serve</th>
<th>DAB</th>
<th>At 5 fare levels (shillings)</th>
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</thead>
<tbody>
<tr>
<td>I/I and I (Intra)</td>
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<td>28.33</td>
<td>13.55</td>
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<td></td>
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<td>51.02</td>
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<td>48.02</td>
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<td></td>
<td></td>
<td>42.02</td>
</tr>
<tr>
<td>I/E and E/I (short)</td>
<td></td>
<td>37.10</td>
<td>16.00</td>
<td>24.00</td>
<td>59.04</td>
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<td>47.04</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>41.04</td>
</tr>
<tr>
<td>I/E and E/I (long)</td>
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<td>51.20</td>
<td>21.64</td>
<td>31.20</td>
<td>63.24</td>
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<td>45.24</td>
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<td>External (Intrazonal)</td>
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<td>36.84</td>
<td>6.74</td>
<td>14.00</td>
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<td></td>
<td>39.53</td>
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<tr>
<td>E/E (direct)</td>
<td></td>
<td>46.54</td>
<td>12.28</td>
<td>27.60</td>
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<td>44.15</td>
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<td>44.40</td>
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## GROSS TRIPS DIVERTED TO DAB BY TRIP TYPE AND MODE AT 5 FARE LEVELS

<table>
<thead>
<tr>
<th>TRIP TYPE AND MODE</th>
<th>4.50 shillings</th>
<th>4.00 shillings</th>
<th>3.75 shillings</th>
<th>3.50 shillings</th>
<th>3.00 shillings</th>
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<td>m.s. trips</td>
<td>m.s. trips</td>
<td>m.s. trips</td>
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<tr>
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<td>263</td>
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<td>340</td>
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<td>I/I TOTALS</td>
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<td>7560</td>
<td>9177</td>
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<td>I/E (long)</td>
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<td>65.0</td>
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<td>E. Intra.</td>
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<td>7.0</td>
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<td>117</td>
<td>20.5</td>
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<td>8</td>
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<tr>
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<td>461</td>
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<td>1020</td>
<td>42.4</td>
<td>1260</td>
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<td>E/E transfer</td>
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<td>112</td>
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<td>bus route from bus</td>
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<td>57.0</td>
<td>1860</td>
<td>60.0</td>
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<td>28.0</td>
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<td>16.2</td>
<td>3642</td>
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<td>13901</td>
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<td>All types</td>
<td>13280</td>
<td>20396</td>
<td>24214</td>
<td>28169</td>
<td>37313</td>
</tr>
</tbody>
</table>
GROSS AND NET DEMAND FOR DAB IN DEMANDS/SQ.MILE/HOUR AT 5 FARE LEVELS

Service Area 11.86 sq. miles
Period of Service 16 hours/day (except off peak service)

<table>
<thead>
<tr>
<th>TRIP TYPES</th>
<th>FARE LEVELS (shillings)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>4.5</td>
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<td><strong>All Types</strong></td>
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</tr>
<tr>
<td>Gross demand</td>
<td>69.9</td>
</tr>
<tr>
<td>Net demand (constrained by 38% phone coverage)</td>
<td>26.5</td>
</tr>
<tr>
<td>Net demand off peak (constrained by 38% phone coverage)</td>
<td>19.4</td>
</tr>
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<td><strong>E/E Trips Only</strong></td>
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</tr>
<tr>
<td>Gross demand</td>
<td>33.8</td>
</tr>
<tr>
<td>Net demand (constrained by 38% phone coverage)</td>
<td>12.8</td>
</tr>
<tr>
<td>Net demand (constrained by 60% phone coverage)</td>
<td>20.3</td>
</tr>
</tbody>
</table>

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DAB Demand Curves. All Trip Types

- DAB Fare in shillings

- Cost of DAB at cost level 1

- Net demand (constrained 38% phone coverage)

- Gross demand

- Demands/sq.mile/hr.

Fig. 21
DAB 
Fare in shillings

DAB DEMAND CURVES. E/E TRIPS ONLY Fig. 22

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DAB DEMAND CURVE, OFF PEAK
ALL TRIP TYPES

Fig. 23

Net demand (constrained by 38% phone coverage)

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Chapter 3  

COST ANALYSIS

3.1 General

The following analysis will develop the costs of operating a DAB system in Cheltenham on a per passenger basis, which can then be directly compared with the per passenger fare on which the demand curves were based. The average cost per passenger is dependent on two variables:

1. Hourly cost of vehicle operation.
2. Vehicle productivity (number of passengers carried by the vehicle in an hour).

Since there is no DAB system yet in operation, the estimated hourly operating costs is based on the analysis of the current labour, vehicle and communication market prices in Cheltenham. Productivity estimates are based on a modification of the CARS simulation model.¹

3.2 Types of Cost

Any DAB system operates on two basic cost components; communication costs, and passenger transport costs. Communication costs can be further subdivided into message handling costs relating either to the customer or the vehicle, and message processing functions which are related to the costs and needs of the computer. Passenger transport costs relate to

the DAB vehicle and its personnel, and can be subdivided into vehicle driving, and non-driving costs. Fig. 24 illustrates these elements diagramatically.

3.3 Scale of Operations

Urbanek¹ has defined six levels at which Dial-a-Bus could work. They grow in complexity from the simplest operation where the driver is his own dispatcher, and is little more than an extension of fixed route service, to a complex system where the computer receives, analyses and routes the users' call directly to an on-board computer on the vehicle. The decision as to which level of operation to use is dependent on the number of vehicles in the system, and the number of demands per hour. As the system size grows, it becomes not only uneconomic to use people for assignment decisions but increasingly impossible due to the complexity involved, and a computer must take over the assignments.

On the basis of the initial survey in 1970, it appeared likely that DAB could realise at least 30 demands/sq.mile/hr. in Cheltenham.² This translates to 356 demands/hr. over the total service area of 11.86 sq.miles, and puts the Cheltenham operations in the range where a computer is required to make

---

2. Appendix A fig. 48.
the assignment decision. In Chapter 4 we will see that demands approaching 60 per sq. mile/hr. could be realised in Cheltenham, which brings this system close to its maximum capacity, beyond which digital methods should be used so the human dispatchers can be eliminated, and a computer transmit the message directly to a printer on board the vehicle. However, a few years will pass before the level of telephone service in Cheltenham allows demands higher than 60 per sq. mile/hr. Moreover, other types of DAB service that could be considered in Cheltenham would yeild a much lower demand, and the analysis will thus proceed on the basis of 30 demands/sq. mile/hr. This would require the following basic arrangement:

(1) Telephone operators to receive incoming calls and inform users of the vehicle arrival time.

(2) Computer personnel to key the calls into the computer, and programme the daily demand.

(3) Dispatchers who transmit the assignment decisions to the vehicle drivers.

(4) Vehicles and drivers.

The costs in the following section are based on a 16 hr. day service over 26 days per month at 356 demands/hr., and the wage rates and equipment costs listed in fig. 25.

---

1. Urbanek's system D. ref. p.85. This system configuration would handle up to 75 vehicles and/or 750 demands/hr.
3.4 Communications Costs

3.4.1 Message Handling Costs

Telephone operators. At productivities of 60 calls/hr.\(^1\)

\[
\frac{356 \text{ demands/hr}}{60 \text{ calls/hr/operator}} = 6 \text{ operators}
\]

6 operators at 15.6 shillings/hr each = 93.6 S/hr
1 telephone supervisor at 18.3 S/hr = 18.3 S/hr

Telephone equipment costs

\[
\frac{(6 \text{ operators} \times 880) + 6,200}{416 \text{ hrs/month}} = 27.6 \text{ S/hr}
\]

6 Dispatchers\(^2\) at 11.7 S/hr each = 70.2 S/hr

Floor space rental for 12 people

\[
\frac{212 \times 10}{416} = 6.1 \text{ S/hr}
\]

Base station costs. 1 radio per dispatcher

\[
\frac{46 \times 100}{416} = 1.4 \text{ S/hr}
\]

Vehicle equipment costs

= 0 S/hr

(Although the radio receiver is strictly speaking, part of the message handling costs, it will be treated as part of the passenger transport costs since it is dependent on the number of vehicles used.)

TOTAL = 217.2 S/hr

On a per demand basis: \[
\frac{217.2}{356 \text{ dem/hr}} = 0.61 \text{ shillings per demand}
\]

2. Although the dispatcher's message is shorter than the
3.4.2 Message Processing Costs

Urbanek\textsuperscript{1} advises that almost all components must be backed up by duplicate equipment to account for system unreliability. However, time on the duplicate equipment can be sold and this revenue can cover its cost. The following analysis therefore eliminates duplicate equipment for accounting purposes.

IBM computer 370/135 or equivalent and all associated hardware

"3215" costs ie. teletypewriters and data-phones. One for each telephone operator

\begin{align*}
6.0 \times 1,660 &= 9,660 \\
\text{One input and one output 2702's} &= 16,000 \\
\text{Personnel for two 8 hr shifts} &= \\
2 \text{ control centre supervisors} \times 5,460 &= 10,920 \\
2 \text{ computer operators} \times 3,380 &= 6,760 \\
1 \text{ programmer} &= 5,460 \\
1 \text{ assistant programmer} &= 3,380 \\
\text{Space requirements (3 people, one shift)} &= 636 
\end{align*}

\textit{continued from p.}

operator's, and dispatcher productivity is consequently twice that of the operator's, each pick-up and delivery will require communication with the dispatcher. Thus each passenger requires that two messages be sent between the dispatcher and the vehicle. Ref. Urbanek, p.27.

1. Urbanek p.52.
2. From discussion with N.H.M.Wilson, May 1971

- 83 -
Computer space 1500 sq. ft. = 4,250 s/month
Extra power (for cooling etc.) = 4,000 "

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>102,965 s/month</td>
</tr>
</tbody>
</table>

On a per demand basis:

\[
\frac{102,965}{356 \text{ dem/hr.} \times 416 \text{ hrs/month}} = 0.69 \text{ shillings/demand}
\]

Adding the message handling to the message processing costs, the total communication costs come to 1.30 shillings per demand.

3.5 Transport Related Costs

As every transport operator knows, labour is the largest item in a company's costs, and DAB is no exception. As we shall see later, all the communication costs of DAB comprise only one quarter of the total cost. The correct wage level of DAB vehicle drivers is thus of great importance.

The 1970 wages for bus drivers in Cheltenham are shown in Fig. 32. It may be objected that bus drivers do not have the comprehensive and accurate knowledge of a city that is demanded of a DAB driver who has to drive unerringly to unscheduled destinations. While this may be true in a large city, it is much less so in a town the size of Cheltenham, where most of the bus drivers are local people and know the town well. Since the Bus Company would probably want to use
its bus drivers at off-peak times on DAB vehicles, it would be worthwhile to provide extra training for drivers at the instigation of the service. Although the drivers need a good knowledge of the town, the work is less arduous than driving a conventional bus, and the wage rate suggested here is that presently paid to drivers of one man busses. Drivers currently work a 40 hour week. The costs shown below are by vehicle/hours and are listed more fully in fig. 25.

Drivers = 14.60 shillings/veh. hr.
Vehicle supervisor (1 per 12 vehicles) = 1.58 " "
Maintenance and repairs = 1.20 " "
Petrol consumption = 7.00 " "
Taxes and licenses = 0.20 " "
Vehicle capital cost amortised = 3.80 " "
Garaging = 0.21 " "
Insurance = 0.52 " "
On vehicle equipment (radio etc.)= 0.55 " "

TOTAL 29.66 sh/veh hr.

3.6 Per Passenger Costs

To estimate the total cost of providing an area with DAB service, it is necessary to find the number of vehicles required to provide a given level of service to that area. Knowing the total cost of service for various demand densities will indicate the average cost per passenger.
The following DAB productivity relationship for Cheltenham is based on an extensive series of simulation experiments conducted by the Project CARS Algorithms group.¹

\[
N = A \left[ 0.68 + 0.072 (D) \right] \frac{1}{(LOS - 1)^{\frac{1}{2}}}
\]

where:

- \( N \) = the number of vehicles operating
- \( LOS \) = the mean level of service over the service area, where the level of service is defined as follows.

\[
LOS = \frac{\text{Total time on System (waiting and travel)}}{\text{Direct driving time by auto.}}
\]

which = 2.50 for Cheltenham.

- \( D \) = demand density in demands/sq.mile/hour
- \( A \) = size of service area in square miles

The following example illustrates the method used to calculate the average cost per passenger for various demand densities.

Given:

- Cost of operations. 29.66 shillings/vehicle hour
  plus 1.30 shillings/demand.
- Area. 11.86 square miles
- LOS 2.5
- Example demand density. 30 demands/sq.mile/hr.

Required: average cost per passenger.

\[ N = \frac{A \left[ 0.68 + 0.072 (D) \right]}{(LOS - 1)^{\frac{1}{2}}} \]
\[ = 11.86 \left[ 0.68 + 0.072 (30) \right] = 28 \text{ vehicles} \]

Total cost of operations:
\[ = (28 \text{ vehicles} \times 29.66 \text{ sh/veh/hr}) + (1.30 \text{ sh/demand} \times 30 \text{ demands/sq.mile/hr} \times 11.86 \text{ sq.miles}) \]
\[ = 1304 \text{ shillings/hr.} \]

Average cost per passenger:
\[ = \frac{1304 \text{ shillings/hr}}{30 \text{ dem/sq.mile/hr} \times 11.86 \text{ sq.miles}} \]
\[ = 3.63 \text{ shillings/passenger} \]

The results of a series of calculation similar to that above are shown in fig. 26 and plotted in fig. 28. (cost level 1)

3.7 Alternative Cost for Off-Peak Service

In a conversation last summer, the manager of the Bus Company suggested that DAB running costs might be reduced if conventional single decker busses were used at off-peak times. Clearly, they would only be used if an off-peak DAB service was contemplated, since little would be saved by having DAB vehicles lying idle while busses were used on a DAB service, which would be the case in a 16 hr. service.

Referring to sections 3.4 and 3.5, the communication costs would decrease marginally, but the passenger transport costs

1. See section 2.10:4 for the demand analysis of this configuration.
Drivers' cost: 14.60 sh/veh.hr.  

Vehicle supervisor: included as part of regular service  

Taxes and licences: as part of it  

Vehicle capital cost:  

Garaging:  

Insurance:  

Maintenance and repairs: 1.20 sh/veh.hr.  

Fuel consumption: 6.00 sh  

On vehicle equipment (radio etc.): 0.55 sh  

TOTAL: 22.35 sh/veh.hr.  

Since the vehicle productivity of a DAB service is dependent more on level of service than vehicle capacity, productivity would not improve by using large busses. Thus substituting in the previous example the total hourly cost of operations would be as follows:  
(28 vehicles x 22.35 sh/veh.hr.) x (1.30 sh/demand x 30 demands/sq.mile/hr. x 11.86 sq. miles)  
= 1096 shillings/hr.  

Average cost per passenger:  

= \frac{1096 \text{ shillings/hr.}}{30 \text{ dem/sq.mile/hr. x 11.86 sq.miles}}  
= 3.1 \text{ shillings/passenger}  

This represents a reduction of 14.6% of the per passenger cost by using conventional busses instead of DAB vehicles for
an off-peak service. The costs representing this lower amount are listed on fig. 27 and plotted on fig. 28 (cost level 2). One can question the wisdom of using conventional busses when the reduction in cost is so small, in view of inconvenience that large busses would cause in small residential streets, and the danger of confusing the image of a DAB service with a conventional bus service in the users' mind.

A more powerful case for this type of operation may be gained if the cost reductions are larger. This is possible if not only the vehicle costs are considered amortised in the regular bus operations, but the drivers' costs as well. Whether the 28 drivers who could operate the DAB service are, in fact, standing idle during off-peak times is a matter for further investigation. The analysis would be as follows:

Drivers' cost: included as part of the regular service.
Vehicle supervisor: 
Taxes and licenses: 
Vehicle capital costs: 
Garaging: 
Maintenance and repairs 1.20 sh/veh.hr.
Fuel consumption 6.00 "
On vehicle equipment 0.55 "

TOTAL 7.75 sh/veh/hr.
Total cost of operations:
\[(28 \text{ vehicles} \times 7.75 \text{ sh/veh.hr}) + (1.30 \text{ sh/demand} \times 30 \text{ demands/sq.mile/hr} \times 11.86 \text{ sq. mile})\]
= 689 shillings/hr.

Average cost per passenger:
\[
\frac{689 \text{ shillings/hr.}}{30 \text{ dem/sq.mile/hr.} \times 11.86 \text{ sq. mile}}
\]
= 1.9 shillings/passenger

This represents a reduction of 47.7% below the original DAB vehicle and driver costs. The passenger costs representing this lower amount are listed on fig. 27 and plotted on fig. 28 (cost level 3).

This amount is a substantial reduction in cost, and could thereby reach a greater number of travellers. Nevertheless, the earlier arguments against using conventional busses remaining, and perhaps the best arrangement would be to use the surplus bus drivers, but in DAB vehicles. This final configuration yields a cost of 2.5 shillings/passenger for 30 dem/sq. mile/hr. representing a reduction of 31% below the original DAB vehicle and driver costs. The results are plotted on figs. 27 and 28 (cost level 4).

3.8 Summary

In this chapter, the 1970 costs for operating a DAB service in Cheltenham have been estimated, and plotted in fig. 27 against various demand densities. Cost level 1 indicates the
costs of a full DAB service over a 16 hr. day, 26 days a month. The other cost levels show a variety of configurations pertaining to off-peak services.

By themselves, neither the demand, nor the cost curves can indicate the revenue potentials of the service. The next chapter will describe how they are combined to yield different forms of service each with its appropriate revenue.
Communication Costs

Message handling costs

Consumer related
- Telephone operator
- Telephone related costs
- Phone supervisor
- Floor space

Vehicle related
- Dispatcher
- Base station
- On floor electronics
- Floor space

Message processing function

Fixed
- Computer (partial)
- Space
- Extra air and electricity
- Personnel

Variable
- Computer (partial)

Passenger Transport Costs

Vehicle driving

Supervision
- Drivers

Variable
- Repairs
- Maintenance
- Petrol, Oil

Fixed
- Insurance
- Taxes
- Vehicle amortisation
- Permits
- Garaging

Non vehicle driving
## WAGE RATE AND EQUIPMENT COSTS

<table>
<thead>
<tr>
<th>Function</th>
<th>Subtotal in shillings</th>
<th>Total in shillings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Message handling</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone operator. Basic wage</td>
<td>12 s/hr</td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; Benefits etc.</td>
<td>12x0.3 s/hr</td>
<td>15.6 s/hr</td>
</tr>
<tr>
<td>Telephone supervisor. Basic</td>
<td>14 s/hr</td>
<td></td>
</tr>
<tr>
<td>wage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; Benefits etc.</td>
<td>14x0.3 s/hr</td>
<td>18.3 s/hr</td>
</tr>
<tr>
<td>Telephone equipment. Rental/</td>
<td>880 s/month</td>
<td></td>
</tr>
<tr>
<td>operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; amortisation</td>
<td>6,200 s/month</td>
<td></td>
</tr>
<tr>
<td>Floor space rental per person</td>
<td>212 s/month</td>
<td></td>
</tr>
<tr>
<td>at 75 sq.ft/person and 34 s/sq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ft/year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispatcher. Basic wage</td>
<td>9 s/hr</td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; Benefits etc.</td>
<td>9x0.3 s/hr</td>
<td>11.7 s/hr</td>
</tr>
<tr>
<td>Base station (radio)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>amortisation cost/dispatcher</td>
<td>100 s/month</td>
<td></td>
</tr>
</tbody>
</table>
### WAGE RATES AND EQUIPMENT COSTS (cont)

<table>
<thead>
<tr>
<th>Function</th>
<th>Subtotal in shillings</th>
<th>Total in shillings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Message processing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM 370/135 computer or equivalent rental cost</td>
<td>40,000 s/month$^1$</td>
<td></td>
</tr>
<tr>
<td>Teletypewriters and dataphones</td>
<td>1,660 &quot;</td>
<td></td>
</tr>
<tr>
<td>rental per operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two &quot;2072&quot;s amortised at £400 each</td>
<td>16,000 &quot;</td>
<td></td>
</tr>
<tr>
<td>Control Centre Supervisor..Salary 4,200 s/month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; &quot; Benefits, etc. 4,200 x 0.3</td>
<td>5,460 &quot;</td>
<td></td>
</tr>
<tr>
<td>Computer operator. Salary 2,600 s/month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; &quot; Benefits, etc. 2,600 x 0.3</td>
<td>3,380 &quot;</td>
<td></td>
</tr>
<tr>
<td>Programmer. Salary 4,200 s/month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; &quot; Benefits, etc. 4,200 x 0.3</td>
<td>5,460 &quot;</td>
<td></td>
</tr>
<tr>
<td>Assistant programmer, Salary 2,600 s/month</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; &quot; &quot; Benefits, etc. 2,600 x 0.3</td>
<td>3,380 &quot;</td>
<td></td>
</tr>
<tr>
<td>Computer space 1500 sq. ft.</td>
<td>4,250 &quot;</td>
<td></td>
</tr>
<tr>
<td>Extra power (for cooling etc.)</td>
<td>4,000 &quot;</td>
<td></td>
</tr>
</tbody>
</table>

---

1. Estimate of this rental in Britain derived from a conversation with N.H.M. Wilson, May 1971.
### Transport Related Costs (costs per vehicle hour)

<table>
<thead>
<tr>
<th>Function</th>
<th>Subtotal in shillings</th>
<th>Total in shillings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver's cost. Basic wage</td>
<td>11.25 s/hour</td>
<td>14.6 s/v/hr</td>
</tr>
<tr>
<td>&quot; &quot; Benefits etc.</td>
<td>11.25 x 0.3</td>
<td>14.6 s/v/hr</td>
</tr>
<tr>
<td>Vehicle supervisor. Basic wage</td>
<td>14.65 s/hour</td>
<td>14.65 x 0.3</td>
</tr>
<tr>
<td>&quot; &quot; Benefits etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>assume 1 supervisor per 12 vehicles</td>
<td>14.65 x 1.3 divided by 12</td>
<td>1.58 s/v/hr</td>
</tr>
<tr>
<td>Maintenance and repairs at say 2 pence/mile. Vehicle speed 13 m.p.h.</td>
<td></td>
<td>1.2 s/v/hr</td>
</tr>
<tr>
<td>Petrol consumption. Assume &quot;Ford Econoline&quot; or similar type vehicle 13 miles/gallon at 13mph petrol at 7 shillings/gallon</td>
<td></td>
<td>7.0 s/v/hr</td>
</tr>
<tr>
<td>Taxes and licenses, at say £42/yr.</td>
<td></td>
<td>0.2 s/v/hr</td>
</tr>
<tr>
<td>Vehicle capital cost amortised at 8% interest and 4 year life and £2,700 per vehicle = £731/yr</td>
<td></td>
<td>3.8 s/v/hr</td>
</tr>
<tr>
<td>Garaging say £4/month</td>
<td></td>
<td>0.21 s/v/hr</td>
</tr>
<tr>
<td>Insurance say £100/year</td>
<td></td>
<td>0.52 s/v/hr</td>
</tr>
<tr>
<td>On vehicle equipment (radio receiver) amortised at 230 s/mon.</td>
<td></td>
<td>0.55 s/v/hr</td>
</tr>
</tbody>
</table>
## Average Demand Density by Average Cost Per Passenger 1970

![Figure 26](image)

<table>
<thead>
<tr>
<th>Average demand density (demands/sq. mile/hr.)</th>
<th>Cost Level 1 Average Cost/passenger (shillings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4.80</td>
</tr>
<tr>
<td>15</td>
<td>4.31</td>
</tr>
<tr>
<td>20</td>
<td>3.94</td>
</tr>
<tr>
<td>30</td>
<td>3.63</td>
</tr>
<tr>
<td>40</td>
<td>3.52</td>
</tr>
<tr>
<td>50</td>
<td>3.43</td>
</tr>
<tr>
<td>60</td>
<td>3.36</td>
</tr>
<tr>
<td>70</td>
<td>3.34</td>
</tr>
<tr>
<td>80</td>
<td>3.30</td>
</tr>
<tr>
<td>90</td>
<td>3.28</td>
</tr>
<tr>
<td>100</td>
<td>3.23</td>
</tr>
</tbody>
</table>
DEMAND DENSITY BY AVERAGE COST PER PASSENGER AT THREE COST CONFIGURATIONS

<table>
<thead>
<tr>
<th>Average demand density (demands/sq.mile/hr.)</th>
<th>Cost level 2</th>
<th>Cost level 3</th>
<th>Cost level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4.10 sh.</td>
<td>2.51 sh.</td>
<td>3.31 sh.</td>
</tr>
<tr>
<td>15</td>
<td>3.68</td>
<td>2.26</td>
<td>2.98</td>
</tr>
<tr>
<td>20</td>
<td>3.36</td>
<td>2.06</td>
<td>2.72</td>
</tr>
<tr>
<td>30</td>
<td>3.10</td>
<td>1.90</td>
<td>2.49</td>
</tr>
<tr>
<td>50</td>
<td>2.92</td>
<td>1.79</td>
<td>2.37</td>
</tr>
<tr>
<td>70</td>
<td>2.85</td>
<td>1.75</td>
<td>2.30</td>
</tr>
<tr>
<td>90</td>
<td>2.80</td>
<td>1.72</td>
<td>2.26</td>
</tr>
</tbody>
</table>

Cost level 2: Conventional bus used. Vehicle costs considered as amortised in regular service. 85.4% of cost level 1.

Cost level 3: Conventional bus used. Vehicle and driver costs considered as amortised in regular service. 52.3% of cost level 1.

Cost level 4: DAB vehicles used. Driver cost only considered as amortised in regular service. 69% of cost level 1.
Average Cost per Passenger (shillings)

Fig. 28
Average DAB cost curves for service area of 11.86 sq.mi. based on 30 dem/sq.mi/hr. at four cost levels

Average Demand - 98 -

Density (demands/sq.mile/hr.)

- 98 -
4.1 General

The purpose of this chapter is to find the benefit that the users, the bus company and society would derive by the implementation of a DAB system at various levels of service. The basis on which these benefits are measured is described below.

The quantity used to describe the gross benefit of a transit service to society is commonly referred to as willingness to pay. The importance of this measure is based on the premise that people will reflect the utility they derive from a service by their willingness to pay for it. Graphically, this can be represented as the shaded area shown in fig. 29a. The net benefit which society derives from a service is its total willingness to pay minus any charge that may be made for the service. If the social objective is to maximise the net benefit which users derive from a public transport system, then an appropriate measure is the consumer's surplus criterion which, for any given fare level is the benefit the users derive from the service above and beyond that which the most marginal user derives. This quantity can be represented by the shaded area in fig. 29b, which is the difference between what the

1. ReNeufville R. and Stafford J.H. "Engineering Systems Analysis"
users are willing to pay, and what they are required to pay.

Since the Cheltenham transit operations do not operate on a subsidy, we are concerned only with the conditions of service between a break-even, and a maximum profit operation. Although the eventual form of service may lie at some point between these extremes, only these two levels will be analysed for purposes of clarity.

The break-even operation is that where the average revenue per passenger (fare) and the average cost per passenger are equal. Graphically this point is the intersection of the cost and demand curves - point B in fig. 30. At no other point along the demand curve can society derive any greater benefit without incurring a subsidy. The net benefit to the users (or consumer surplus) at this point is the area BDI.

For any given operation, the level of maximum profit is where the difference between the demand and the cost curve is maximised. In the case of fig. 30, this is the distance CE, where the fare is at level 3 and the profit to the operator is presented by the rectangle CE23. The shaded area above level 3, ie. 3CD is the net benefit to the users in the case of a maximum profit operation, and the amount the users lose by the difference between a maximum profit, and a break-even operation is area BC3l.
4.2 Dial-a-Bus: Possible forms of Service

The previous two chapters estimated first, the demand for DAB at given levels of fare which produced a variety of demand densities over the service area, and secondly, the cost of providing a service at those demand densities. These estimates produced the demand and cost curves respectively. Since the estimates are on a comparable basis of revenue/cost, and demand density, they can be used to derive the measures of benefit described above.

Three alternative types of service are described below together with their relevant measures of benefit to the users, and the Bus Company. However, it is not the purpose of this study to recommend any one form of service, since the benefits to the users, and to the Bus Company will be different. Rather, it is the subject for negotiation between the town's representatives and the Bus Company to decide whether to implement any DAB service, which type of operation it might be, and whether on a break-even, or profit basis. Fig. 31 lists the relevant benefits to the users and the Bus Company for the types of service described below.

4.2.1 All Trip Types. 16 Hour Service.

By referring to fig. 21 we can see that the cost and demand curves intersect at a fare of 3.4 shillings and 59 demands/sq. mile/hr. This is the break-even point for DAB
operations, and the user's surplus, being the area below the demand curve and above the fare level, can be calculated as follows:

\[ 59 \text{ dem/sq. mile/hr.} \times 11.86 \text{ sq. miles} \times 16 \text{ hour day} \times (4.65 - 3.4) \text{ shillings/passenger} \]
\[ = 13990 \text{ shillings/day} = £699 \text{ per day.} \]

For a maximum profit operation, the greatest vertical distance between the cost and demand curves interest the demand curve at a fare of 4.5 shillings, and 26 demands/sq.mile/hour. The bus company's profit, namely the rectangular area between the fare of 4.5 shillings, and the cost of 3.8 shillings can be calculated as follows:

\[ 26 \text{ demands/sq. mile/hr.} \times 11.86 \text{ sq. miles} \times 16 \text{ hour day} \times (4.5 - 3.8) \text{ shillings/passenger} \]
\[ = 3450 \text{ shillings/day} = £172 \text{ per day.} \]

The user's surplus can be calculated for this fare level as before:

\[ 26 \text{ dem/sq. mile/hr.} \times 11.86 \text{ sq. miles} \times 16 \text{ hr/day} \times (5.2 - 4.5) \text{ shillings/passenger} \]
\[ = 3450 \text{ shillings/day} = £172 \text{ per day.} \]

Thus to society as a whole, the maximum profit operations result in a total benefit of £172 + £172 = £344/day compared to £699/day, with the break-even operation. However the bus company's fixed route operations suffer more under a break-even operation since the fare is lower than with a maximum
profit operation, and more bus passenger will be diverted. Referring to fig. 22, it is clear that a profit operation is out of the question assuming a 38% phone coverage. The break-even operation indicates a fare of 4.5 shillings at 13 demands/sq. mile/hr., producing a user's surplus of £86/day.

If after further inquiries, it was found that 60% of the households in the external zones were covered by phone, the
amounts noted in fig. 31 indicate that both a breakeven, and a profit operation would be feasible for this type of service. At a break-even service, the user's surplus would amount to £441/day at a fare of 3.7 shillings/passenger and 31 demands/sq. mile/hr., diverting a total of $3560 \times \frac{60}{100} = 2137$ bus passengers. The maximum profit operation, at a fare of 5.1 shillings and 15 demands/sq. mile/hr. yeilds an operator's profit of £114/day, a user's surplus of £128/day, and a total of 1392 passengers diverted from the regular bus service, representing £70/day lost from the conventional bus operations.

4.2.3 Off-Peak Service. All Trip Types.

In section 2.10.4 we assumed that a total of three hours should be allowed for the two daily peaks. The following calculations at three of the cost levels described in section 3.7 thus use a 13 hour day, the greater volume of peak traffic having been accounted for already in the reduced demand curves.

At cost level 1 (DAB vehicles and DAB drivers) for a break-even operation with a fare of 3.5 shillings and 40 demands/sq. mile/hr., the users surplus amounts to £308/day (ref. fig. 23). Since a greater proportion of bus passengers travel at peak hours compared to off-peak than do car passengers, for the three hour peak, bus passengers are estimated at 33% of all daily passengers.\(^1\) Thus off-peak bus passengers diverted

---

1. The consultants' report notes that "the morning peak (one hour) accounts for 11% of this (ie. total daily bus passengers) and the evening peak (one hour) 18%" section 2.25, p.8, my brackets.
to DAB = (12,606 x \( \frac{67}{100} \)) x \( \frac{38}{100} \) = 2,790 passengers/day. At a maximum profit operation, the fare would be 4.5 shillings producing a demand of 19/sq. mile/hr. The user's surplus is £88/day, and the operator's profit £73. However, 1,560 passengers are diverted which represent a cost of £78 to the regular bus operations. At this cost level, therefore, operating DAB at maximum profit would just cover the bus company's combined costs and would appear to be the only feasible type of operation for cost level 1.

At cost level 2 (conventional buses and DAB drivers) a break-even DAB operation could charge a fare of 2.9 shillings yeilding 57 demands/sq. mile/hr. and a user's surplus of £570. However, 4,160 bus passengers would be diverted. A maximum profit operation at a 4.6 shilling fare and 18 demands/sq.mile/hr. produces a user's surplus of £138 and an operator's profit of £72. 1,570 passengers would be diverted, costing the regular bus operations £76. An equitable break-even solution for the bus company as a whole would be at a fare level of 3.6 shillings yeilding 38 demands/sq. mile/hr. The user's surplus in this case would be £292/day, the operator's profit of £176/day breaking even with the cost of £157/day representing 3,140 passengers diverted from the regular bus service.

The author concluded in section 2.10.4 that if conventional bus drivers were available, the most attractive solution might be for them to drive DAB vehicles at off-peak times (cost level
4). With this configuration a break-even operation would charge a fare of 2.3 shillings, producing 77 demands/sq. mile/hr., and a user's surplus of £950. But approximately 6,650 bus passengers would be diverted to DAB. Following a maximum profit operation, a fare of 4.7 shillings producing 18 demands/sq. mile/hr. would produce a user's surplus of £69, and an operator's profit of £249. 1,530 bus passengers would be diverted to DAB, representing a loss of £77. We therefore have a wide latitude here for a break-even operation which is equitable to the bus company as a whole, and it can be found at a fare level of 3.0 shillings yeilding 54 demands/sq. mile/hr. The user's surplus would be £540/day, the operator's profit of £291/day offsetting the £208/day representing 4,160 passengers diverted to DAB from the regular bus service.

4.3 Dial-a-Bus Service Configurations. Summary.

From an evaluation of the previous sub-sections, it appears that DAB would be feasible in Cheltenham at various configurations. A break-even fare would in all cases maximise the benefit to users, yet penalise the bus company by diverting passengers from its regular service without compensating the loss. If these losses were compensated by a higher DAB fare, the most favourable operations from the user's point of view would be the full DAB service (all trip types) or the off-peak DAB service at cost level 4. If the bus company wished to maximise its profits by initiating a DAB operation its best choice would again be the off-peak service at cost level 4, followed
by the full DAB 16 hour service. The external only trip types offer only a marginal return to the bus company at present, but might improve if a closer inspection of the telephone distribution revealed a higher than average phone coverage in external zones.

It should be emphasized that the configurations described here are not the only, nor even the optimal bus/DAB mixture. Since the present bus operation have been taken as a constant, alternative fare levels, frequencies, and routing characteristics of the conventional bus should be examined. Moreover, only the "many to many" DAB system has been investigated. The presence of large employment centres at the perimeter of Cheltenham such as the Foreign Office and Dowty's suggested that a "many to one" and "one to many" DAB system scheduled to fit the work shift time may be an important supplement to the "many to many" DAB service. A market survey is probably the best means to estimate demand for this type of service. Lastly, the market elasticities described in section 2.10.2 indicate an untapped market for DAB which has not been analysed here.

As regards the prospects for future demand for a DAB type of service, little can be said at present. However, we can see from this analysis that over half DAB's ridership comes from former car users. Since DAB provides a doorstep service with similar characteristics to a car, and both car ownership
and phone rentals are growing rapidly, a bus company could reasonably expect to offset a decline in conventional bus ridership by the operation of a gradually expanding DAB service.

4.4 Congestion

Our analysis of the benefit DAB could bring to Cheltenham is not complete without estimating how DAB might contribute to reducing the problem of traffic congestion in the town.

On the assumption that a DAB system would be implemented for the whole town at a fare level which gives the bus company sufficient profit to cover its losses on the conventional bus operations (as described in section 4.2.1) the reduction of private cars in the city can be estimated as follows:

At a fare of 4.00 shillings, fig. 19 indicates a gross diversion of 466 serve passenger trips to DAB, and 10,089 "licensed" trip-makers to DAB. Reduced by 38% phone coverage, these figures fall to a net of 177 and 3,830 respectively. Since the serve passenger trips cause a double journey, thus doubling congestion, their trips should be doubled. Thus are 177 x 2 = 354 cars/used for serve passenger trips which a DAB service has eliminated. The occupancy rate of cars not used for serve passenger trips is not directly obtainable. However, the 1963 survey¹ indicated an occupancy ratio of 0.1 passengers

¹. Gloucestershire County Council "County of Gloucestershire Development Plan. Cheltenham Town Map Amendment Map and Comprehensive Development Area no. 3 (Cheltenham), Report of Survey and Analysis.
per car for work trips (excluding drivers). It is very likely
that non-work trips will carry more passengers, and the author
suggests 0.3 non-driving occupants per car for all trip types
as an intelligent guess. Thus \( \frac{1}{1.3} \times 3830 = 2950 \) cars of
"licensed" tripmakers which DAB has eliminated. A 4.00
shilling fare produces a net demand of 40 demands/sq.mile/hr.
From the productivity formula described in section 3.6, we
find that 35 DAB vehicles are required for this demand density.
A DAB vehicle is a small bus seating between 9 and 20 people,
and can be considered the equivalent of 1.5 automobiles. Thus
the DAB vehicle equivalents in passenger car units (PCU's)
are: 35 vehicles x 16 hours x 1.5 = 840 PCU's. The overall
daily reduction of congestion expressed in PCU's is therefore
\((354 + 2950) - 840 = 2464\) PCU's/day.

It thus appears that a DAB service can make a modest con-
tribution to reducing congestion in Cheltenham.

4.4.1 DAB Versus the Second Car

An examination of the 1966 Sample Census reveals that
6.52% of households in Cheltenham and Charlton Kings owned
two or more cars. Although small in size compared to U.S.
ownership levels this proportion is larger than the average
for Britain, and in the absence of deterrents is likely to
grow rapidly as incomes increase. It is highly desirable
from the point of view of reducing congestion that the owner-
ship and use of a second car should grow as little as possible.
Moreover, assuming that some people will choose the least costly mode for their journey to work, a DAB system may be able to capture a part of the market which would otherwise buy a second car for these trips. The following analysis estimates how much a family may be willing to pay in DAB fares to avoid the expense of buying and operating a second car.

Assuming a 4 mile round trip to commute to work, and 250 working days a year, a second auto will travel 1000 miles per year in commuting to work. In the absence of immediately available data some of the following annual charges are an intuitive estimate of the cost of car operations in Cheltenham in 1970.

**Fixed Costs.**

- **Insurance and taxes**
  
  = £50

- **Depreciation at 20%/year**
  
  for 5 years assuming a used car is bought for £400
  
  = £80

- **Maintenance and repairs**
  
  = £30

**Subtotal**

= £160/year

**Fixed cost per mile**

\[
\text{Fixed cost per mile} = \frac{160 \times 20 \text{ shillings}}{1000 \text{ miles}}
\]

= 3.20 sh/mile

---

2. Soolman, p.91.
Marginal operating Cost

Parking fee (assuming I/E type trips)
\[
\frac{2.5 \text{ pence}}{4 \text{ miles}} \times \frac{1}{12 \text{ pence}} = 0.05 \text{ sh/mile}
\]

Petrol at 7 shillings/gallon and 25 mpg. = 0.28 sh/mile

Total operating costs per mile = 3.53 sh/mile

Total operating costs per year = 3.53 sh/mile \times 1000 \text{ miles/year} = 3530 \text{ sh/year}

Value of Commuting Time per Year

Walk and unpark = 1 min. \times 1.2 \text{ pence/min.} = 1.2 \text{ pence}

Park and walk = 5 min. \times 1.2 \text{ pence/min.} = 6.0 \ "

Travel time = 2 miles \times 2.2 \text{ pence/mile} = 4.4 \ "

\[11.6 \text{ pence/trip} \times \frac{500 \text{ trips/year}}{12 \text{ pence}} = 483 \text{ sh/year}\]

Total cost of car per year

\[3530 \text{ sh/year} + 483 \text{ sh/year} = 4013 \text{ sh/year}\]

Cost of DAB to Commuter

Wait at home for vehicle = 10 min. \times 0.3 \text{ pence/min.} = 3.0 \text{ pence}

\[\text{Travel time} = 2 \text{ miles} \times 2.8 \text{ pence/mile} = 5.6 \ "\]

\[\text{Fare} + \frac{8.6 \text{ pence/trip}}{12 \text{ pence}} = 8.6 \text{ sh/trip}\]

For 500 trips/year, DAB cost = 500 \left(\frac{\text{fare} + 8.6 \text{ pence}}{12 \text{ pence}}\right)

\[= 500 \text{ fare} + 360 \text{ shillings.}\]
For a family to be indifferent about the purchase of a second car, or the use of DAB service, for the journey to work, the annual cost of DAB should not exceed the annual cost of a car.

Therefore,

\[ 4013 \text{ shillings} = 360 \text{ shillings} + 500 \text{ fare} \]

Fare = 7.30 shillings/trip.

From the likely forms of service reviewed in section 4.2, the DAB fares fall between 2.3 and 4.5 shillings/trip. Since these fares are well below the 7.3 shilling fare representing the break-even point with a second car cost, the DAB system can potentially divert some families from the second car ownership decision.

4.5 Diversion to Bus through Parking Charges

Several studies have indicated that offering a better transit service alone will not reduce auto use to "acceptable" environmental levels. The consultants' interim report for Cheltenham indicates that even if a "free" bus service were offered, auto congestion would not drop to acceptable levels. Some form of taxation is therefore necessary to discourage use of cars, or as some may put it, to start motorists paying a small proportion of the money they owe society if all the economic and social disbenefits of car use were assessed. Since the worst congestion occurs at the town centre, a parking charge seems the easiest form of tax to collect. However,
since Cheltenham is a popular shopping centre, and discouraging shoppers is bad for business, the parking charge should differentiate between short-term parkers (shoppers), and long-term parkers (commuters).

In this analysis, the diversion curves are used to indicate the parking charges the municipal government should impose to obtain a modal split to transit of 59% from the present 26.0%. Diversion to DAB is omitted, since if this policy were imposed, the level of bus service to the central area would be much improved (the author assumes that the level of bus service would rise to meet the demand) and the demand densities would be above the suitable maximum for a DAB operation.

The area defined as suitable for the imposition of higher parking charges is shown on fig. 2. The parking charge area covers 0.70 sq. miles of the "Internal" zones comprising the larger central area. The proportion of "Internal" trips in the parking charge zone = \[
\frac{0.70}{2.18} \times \text{total I/I trips} = 5,320 \text{ trips.}
\]
The remaining I/I trips = 16,565 - 5,320 = 11,245

Factoring the Bus and car trip totals by \[
\frac{11,245}{16,565} = 0.679,
\]
the following I/I trips will be added to the I/E (short) trips.

---

1. The consultants' report recommends reducing the present mode split to car to 41%. This means conversely, that the modal split to transit should be increased to 59%.
2. The "Internal" zones together cover 2.18 sq. miles.
3. From fig. 3.
<table>
<thead>
<tr>
<th>Bus</th>
<th>Car</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,080</td>
<td>8,160</td>
<td>11,245</td>
</tr>
<tr>
<td>17,906</td>
<td>50,906</td>
<td>68,812</td>
</tr>
<tr>
<td>20,986</td>
<td>59,066</td>
<td>80,057</td>
</tr>
</tbody>
</table>

The consultants' report states\(^2\) that of all private cars entering the central area, 10,000 were commuters, and 32,000 (76.2% of total) were others, mostly shoppers. Altogether they average a stay of 1.75 hours. Assuming that these percentages can be applied to person trips, on this basis the trips stratify as follows:

<table>
<thead>
<tr>
<th>Trips to CBD by car</th>
<th>New I/E (short)</th>
<th>I/E (long)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commuters (person trips)</td>
<td>14,060</td>
<td>2,620</td>
</tr>
<tr>
<td>Others (&quot;&quot;&quot;)</td>
<td>45,006</td>
<td>8,375</td>
</tr>
</tbody>
</table>

Quarmby indicates a theoretical diversion to bus of +59% when car parking charges are increased by 3 shillings/day, plus ensuring that those bringing cars have to walk an average of 6 minutes longer from their parking places, making public transport faster by 15 minutes. But the consultants for Cheltenham suggest\(^3\) that the increase of +33% required to transit must incur a parking charge of 40 np (8 shillings) per hour for the long term parker, and 10 np(2 shillings) per hour for the short term parker, averaging to 50 np (10 shillings) per trip per day.

---
1. From fig. 3.
2. Section 2.30, p.8.
3. Quarmby, p.299.
4. Section 5.81, p.30.
over both types. The Cheltenham consultants' estimates seem exceptionally severe, and Quarmby's rather light. The following estimate is based on a parking charge of 1.0 shilling per hour for the long-term parker and 0.5 shillings per hour for the short-term parker.

If 100% of the cars travelling to the central area stayed 1.75 hours, then a likely split would be the commuters (23.8% of the total) staying 8 hours, and the shoppers (76.2%) staying an average of 2.1 hours, (their combined percentages averaging 1.75 hours). Thus per trip, the commuter would pay 8 hours x 1.0 sh/hr. = 8 shillings/trip, and the shopper 2.1 hours x 0.5 sh/hr. = 1.05 shillings/trip. Referring to fig. 18, where the average effective costs by trip type are listed, the following statements can be drawn up on effective costs differences by trip type including the new parking charges mentioned above.

1. Long term parkers
   I/E (short) trips
   Bus effective cost = 37.10 pence
   Car " " = 16.00 + 96 = 112 pence
   Bus - Car = - 74.9 pence
   I/E (long) trips
   Bus effective cost = 51.20 pence
   Car " " = 21.64 + 96 = 117.64
   Bus - Car = - 66.44 pence
2. Short term parkers

I/E (short) trips

Bus effective cost = 37.10 pence

Car " " = 16.00 + 12.60 = 28.6 pence

Bus - Car = 8.5 pence

I/E (long) trips

Bus effective cost = 51.20 pence

Car " " = 21.64 + 12.60 = 34.24 pence

Bus - Car = 16.96

Turning to the respective diversion curves for these trip types (figs. 13 and 14) the astute reader will have noticed that there are no plottings above 50% m.s., and the estimation of the minus quantities noted above is not possible by inferring directly from the curve expressing the actual samples. Experience\(^1\) and theory\(^2\) suggest that diversion curves take a logistic form, and the upper part of the curves shown in figs. 13 and 14 were extended to a logistic shape by hand-fitting. The effective cost differences noted above then produced the following diversions to bus.

1. Long term parkers

   I/E (short) trips 99%

   I/E (long) " 100%

---

1. From a study comparing diversion to a toll road when the toll road is competing with other routes. ref. Wohl and Martin "Traffic System Analysis" p.134.

2. Short term parkers

I/E (short) trips  34%
I/E (long)       45%

The following table lists the resulting volumes when the above percentages are applied to the relevant volumes noted on p.114.

<table>
<thead>
<tr>
<th></th>
<th>I/E short</th>
<th>I/E long</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long term parkers (commuters)</td>
<td>13,900</td>
<td>2,620</td>
</tr>
<tr>
<td>Short term parkers (others)</td>
<td>15,300</td>
<td>3,770</td>
</tr>
<tr>
<td>Existing bus users</td>
<td>20,896</td>
<td>3,493</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>50,096</strong></td>
<td><strong>9,883</strong></td>
</tr>
</tbody>
</table>

Total 50,096 + 9,883 = 59,979
Total all I/E trips = 80,057 + 14,488 = 94,545
So the overall mode split to transit = \( \frac{59,979}{94,545} \times 100\% = 63.3\% \)

Thus the desired mode split to transit of 59% which the consultants consider will reduce congestion in the town centre to acceptable levels can be attained, according to this analysis, by a parking charge of 1.0 shillings/hour to the commuter and 0.5 shillings/hr. to others. This policy could be implemented by opening Municipal car parks at the perimeter of the central area, and charging 1.5 shillings/hour in these car parks, and charging 0.5 shillings/hour for Kerbside parking for shoppers, with a 2 hour restriction. However some commuters may evade this policy by re-parking their cars every 2 hours, and charges on private car parks may be dif-
ficult to enforce under this system. A network analysis should also be carried out to see if the streets immediately outside the central area become overloaded, before such a policy is put into effect.

4.6 Summary and Conclusions

The demand curves developed in Chapter 2, and the cost curves developed in Chapter 3 are brought together in this chapter in an attempt to identify the types of operation where a DAB service could first allow the transit company to break-even and maximise the net benefit to the users, and secondly, allow the transit company to maximise its profits.

It was found that the bus company would have to charge some profit on its DAB service in order to compensate for the riders diverted from its regular bus service. With this constraint, the indications are that either a service covering all trip types over a 16 hour day, or an off-peak service, assuming that bus drivers would change to DAB vehicles, would be the most beneficial forms of operation, both for the users, on a break-even basis, and for the bus company, if operated on a maximum profit basis.

Further riders for DAB may be found by a combination of the many to many system analysed here with a dedicated service to employment centres, and in the future, a segment of the population may prefer to ride DAB than to buy a second car for work trips.
The implementation of a DAB service in Cheltenham could, therefore provide three principal benefits.

1. An alternative transport service to car and bus users.
2. Help to maintain the solvency of the public transport operator by offering a more complete public transport service, and if necessary, subsidizing the conventional bus service by a profitable DAB service.
3. Provide a handle for policy-makers to enable them to place stricter controls, or taxes on the use of private cars. Although not possible to use immediately, this potential will gradually become more usable as phone coverage is increased.

A DAB system can make a modest contribution to reducing congestion in the town, and help to keep down future congestion levels by the diversion from the second car ownership decision mentioned above. This contribution is likely to grow with auto ownership, since over half of DAB riders are estimated to be previous car users.

The diversion curves were also used to estimate the parking charges required in the town centre to divert more travellers from their cars onto the bus system. The analysis indicates that the charges required are less than those recommended by the consultants, but it is recognised that they may be difficult to put into effect and may cause further congestion on the streets immediately outside the parking area.

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Drawing on conclusions from the Cheltenham study, the next chapter makes a brief review of other British towns and cities to indicate those which may be suitable for DAB operations, and which deserve further study.
WILLINGNESS TO PAY, AND CONSUMER'S SURPLUS

Fig. 29

Fig. 29a

Price
(fare)

willingness to pay

Volume (passengers)

Fig. 29b

Price
(fare)

consumer's surplus

Volume (passengers)

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Three levels of transit operation
A. "Free" Transit
B. Break-even operation
C. Maximum profit operation

Fig. 30
### DAB Benefit at Two Levels of Service

#### Fig. 31

<table>
<thead>
<tr>
<th>Trip Type</th>
<th>Break-even operation</th>
<th>Maximum Profit Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fare (sh.) to users.</td>
<td>Pounds/day</td>
</tr>
<tr>
<td></td>
<td>net benefit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All trip types</td>
<td>3.4</td>
<td>700</td>
</tr>
<tr>
<td>E/E trips (38% phone coverage)</td>
<td>4.5</td>
<td>86</td>
</tr>
<tr>
<td>E/E trips (60% phone coverage)</td>
<td>3.7</td>
<td>441</td>
</tr>
<tr>
<td>Off peak. All trip types.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>at cost 1</td>
<td>3.5</td>
<td>308</td>
</tr>
<tr>
<td>at cost 2</td>
<td>2.9</td>
<td>570</td>
</tr>
<tr>
<td>at cost 4</td>
<td>2.3</td>
<td>950</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>4.6</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>4.7</td>
<td>69</td>
</tr>
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<tr>
<td></td>
<td>172</td>
<td>114</td>
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<tr>
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<td>172</td>
<td></td>
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<td>73</td>
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<td></td>
<td>172</td>
<td></td>
</tr>
<tr>
<td></td>
<td>249</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5  DIAL-A-BUS IN OTHER BRITISH CITIES

5.1  Choice of City

This chapter attempts to gain a broad overview of the kinds of cities in Britain where DAB might have a role. Only rough indications of potential towns worthy of further study are intended, and the results should be treated with reserve, since the method used is to infer DAB suitability for other cities, from its suitability in Cheltenham.

The 28 cities chosen are intended to be a representative sample of British cities based on the following criteria.

1. Discreet urban areas, and not portions of a larger metropolis.
2. Drawn from all over the country.
3. Representative of small, medium, and large cities.

The largest conurbations\(^1\) were excluded, and the author considered that towns below 14,000 population were not large enough for a DAB system, and they were also excluded. The cities were finally stratified into the following groups.

1. Small. 14,000 to 70,000 population
2. Medium. 70,001 to 200,000 "
3. Large. 200,001 to 500,000 "

The city populations and areas were extracted from the Municipal Year Book 1970 for the United Kingdom. There is

\(^1\) London, Birmingham, Manchester, Liverpool, Leeds, Sheffield, Glasgow.
thus some uncertainty as regards the correlation of population size with area for the purpose of a transport analysis, since the Municipal boundaries may or may not reflect the whole population dependent on that urban area. The information on modal split to transit was obtained through personal letter to the relevant city officials, and a 50% reply was obtained. This information is listed in fig. 32.

5.2 Types of Dial-a-Bus Service

The "many to many" form of DAB service is assumed, and the estimates are derived on that basis although additional "many to one" types of service may be suitable especially in cities which have a high industrial concentration outside their central areas.¹

It is hypothesized that for the largest cities DAB would be most suitable for suburban to suburban (ie. E/E type) trips together with feeder services to CBD oriented bus routes. It was felt that these types of service would be preferable to a city wide DAB service for the following reasons.

1. Population densities are generally higher in large cities bringing the demand densities for transit to levels able to support frequent and profitable bus services, especially in and to the central areas.

¹ The following cities would probably qualify. Nos. 7, 13, 14, 15, 19, 20, 22, 23, 25, 27, 28, 29.
2. Congestion is greater in the centre of large cities than smaller ones, and the normal effectiveness of DAB in reducing travel time would be eroded, thus making the service less attractive.

3. Trip lengths in large cities are long enough for DAB to be an attractive service to feed radial bus routes.

The chart of gross population versus modal split shown in fig. 33 illustrates the increase in transit usage as city size grows, and tends to confirm the first reason mentioned above.

The analysis will thus proceed by testing for a city-wide DAB service for the small and medium size cities, and the suburban and feeder service for the large size ones.

5.3 Levels of Dial-a-Bus Service

Following the levels of service defined in Cheltenham, the characteristics of the selected cities will be reviewed to see if DAB could operate at one or more of the following levels.

1. Break-even DAB service.

2. DAB service breaking even and compensating for the likely loss of bus passengers to DAB.

3. Maximum profit DAB service.

Reviewing the operations in Cheltenham, the following points appear crucial to support a DAB service.

1. Telephone coverage

2. Population density
3. Modal split to transit
4. Driver wage rates

5.3.1 Telephone Coverage

Section 2.10.3 described how the telephone coverage listed by the G.P.O. for Cheltenham (fig. A. 37) was adjusted to yield a coverage by household of 38%. Cheltenham is located in the South-west G.P.O. district which is listed as having a 29% phone coverage (fig. A.38). Since we are considering other urban areas, the 28 cities have been classified into the G.P.O. regions, and the regional percentage increased to reflect the likely household coverage of the cities in those regions in 1970. The increases were determined as follows.

Difference between Cheltenham and S.W. region

\[ 38 - 29 = + 9\% \]

Increases in other areas is related to the proportion of phone coverage in those areas related to the S.W. region.

Thus, North area increase.

\[ \text{North regional coverage} \times (\text{Chelt. h/h coverage} - \text{S.W. regional coverage}) \]

\[ = \frac{19}{29} \times 9\% = + 5.9\% \]
The following increases were applied.
+ 9% South-west, Scotland, South-east, East.
+ 7.5% Midlands, North-west.
+ 5.9% Wales and Marches, North.

The adjusted phone coverages are listed in fig. 34 and applied to the relevant cities in fig. 32.

5.3.2 Population density

For the small and medium class of cities, the Gross population density is multiplied by the percent phone coverage for that city to give a Net population density suitable to compare to Cheltenham's.

In the case of the large cities, the suburban to sub-urban DAB service has characteristics akin to the E/E DAB service in Cheltenham. However, DAB will also provide a feeder service to radial bus routes, which is not likely to be the case in Cheltenham. Therefore the net population density likely to generate this type of service at a breakeven level will probably lie between the 59 demands/sq. mile/hr. breakeven level of fig. 21, and the 15 demands/sq. mile/hr. of the breakeven level of fig. 22. Halfway between these points breakeven demand is 35 demands/sq.mile/hr., and the gross population densities for the large cities have been reduced to this level in the following manner.
Net Pop. density = Gross pop. density \times \text{percent phone coverage} \times \frac{35}{59}

The net population densities are listed in fig. 35.

5.3.3 Costs

Thus far we have addressed ourselves to factors influencing demand for DAB. The range of cities we are reviewing here would probably cover three types of DAB system configuration, varying with the scale of DAB operation and the demand densities obtained. However, Urbanek points out that the cost per demand varies very little as the system size grows. A glance at fig. 28 shows that costs per demand for Cheltenham do not vary significantly between 20 and 90 demands/sq. mile/hr. which tends to confirm Urbanek's statement.

The other main variable would be driver's wage rates. However, the transport industry is unionized in Britain on a country-wide basis, and it is unlikely that wage rates will vary greatly. Cost curve no.1 shown in fig. 28 for Cheltenham has therefore been taken as applying to the other cities we are considering.

---

5.4 Effective Demand for Dial-a-Bus

Effective demand for DAB at the three service levels described in section 5.3 has been derived for the 28 cities by correlating their net population densities with that of Cheltenham's, and relating this to the Cheltenham demand densities which yeild those three service levels.

The service levels for all trip types in Cheltenham can be summarised as follows.

<table>
<thead>
<tr>
<th>Demand density</th>
<th>Phone coverage</th>
<th>Net pop. density</th>
<th>Types of DAB service possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>59dem/sq.mi/hr.</td>
<td>yes</td>
<td>2890</td>
<td>yes break-even compensta- no profit</td>
</tr>
<tr>
<td>40</td>
<td>yes yes</td>
<td>no</td>
<td>yes break-even no</td>
</tr>
<tr>
<td>26</td>
<td>yes yes yes</td>
<td>yes</td>
<td>yes break-even yes</td>
</tr>
<tr>
<td>18</td>
<td>no no no</td>
<td>no</td>
<td>no break-even no</td>
</tr>
</tbody>
</table>

The net population densities have already been brought to a comparable basis in all cities by adjustment for phone coverage and trip type. Taking 59 demands/sq. mile/hr. as the maximum break-even point for the Cheltenham operations (ref. fig. 21), the net population density required to support this is 2890 persons/sq.mile. Therefore the demands per sq. mile for other cities can be inferred as follows.

Maximum break-even demand density in city X

\[
= \frac{X \text{ city net pop. density}}{\text{Chelt. net pop. density}} \times 59
\]

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The lower limit in all cases is 18 demands/sq.mile/hr. below which even a breakeven operation cannot make ends meet.

A maximum profit operation can be calculated by multiplying the breakeven demand by the proportion of demands in Cheltenham representing the maximum profit with the breakeven demand. Thus.

Maximum profit demand density in city X
\[ \text{Maximum profit demand density in city X} = \frac{X \text{ city net pop. density}}{\text{Chelt. net pop. density}} \times 59 \times \frac{26}{59} \]

For a breakeven DAB operation which would compensate the operating bus company for its bus passengers lost to DAB (ie. a limited profit DAB service). we have to consider the transit share of trips in the city under consideration compared to the modal split to transit in Cheltenham. In the case of the small and medium size cities the author has assumed that since almost half DAB's share of the travel market in Cheltenham is diverted from bus, that proportion of bus passengers would be similarly diverted in other cities. Therefore:

Breakeven demand density compensating loss of bus passengers in city X
\[ \text{Breakeven demand density compensating loss of bus passengers in city X} = \frac{X \text{ city net pop. density}}{\text{Chelt. net pop. density}} \times 59 \times \frac{40}{59} \times \frac{\text{Chelt. mode split to transit}}{\text{X city mode split to transit}} \]

However, in the case of large cities, the type of DAB service proposed will consist largely of circumferential trips, and indeed is designed to divert passengers to the bus by a feeder service. The modal split in the large cities has therefore been reduced by the
5.5 Summary and Conclusions

This chapter attempts to evaluate the potential for DAB in other cities by comparing their characteristics with those of Cheltenham. The results should be treated with caution and regarded only as an indication as to which cities are worth further investigation. This is especially true concerning the levels of DAB service since the number of cities in the sample are so small.

Examining fig. 35 we can see that Cheltenham's net population density is 24% above the average for the other 28 cities. We can therefore expect rather less net benefit to users in the majority of our sample cities. As regards the types of DAB service which could probably be implemented the following conclusions emerge.

1. Breakeven DAB service. 86% of the cities could support a breakeven service. The two which could not are both in the smallest city size.

2. Breakeven DAB service compensating loss of Bus passengers. 71.5% of the cities supplying mode split information could support this type of service. 50%
of the small cities could support it, 85% of the medium size and 67% of the large.

3. Maximum profit DAB service. 46.5% of our sample could support an operation yielding a sizable profit to the operator. The 13 which could not are mostly small ones because of lack of overall demand, and the large ones because of the type of service chosen.

In general there appears to be a worthwhile market for DAB in Britain. The main limiting factor in all cases is the telephone coverage, and as this improves, DAB will attract an increasing share of the travel market.
### CHARACTERISTICS OF SELECTED CITIES

<table>
<thead>
<tr>
<th>City number</th>
<th>City</th>
<th>Population</th>
<th>Area sq. miles</th>
<th>Gross pop. density persons/sq. mile</th>
<th>phone coverage by household percent</th>
<th>Motorized person trip mode split percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cheltenham (service area)</td>
<td>90,330</td>
<td>11.86</td>
<td>7,620</td>
<td>38.0</td>
<td>20.0</td>
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</table>

**SMALL CITIES**

<table>
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<th>City</th>
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<th>Area sq. miles</th>
<th>Gross pop. density persons/sq. mile</th>
<th>Phone coverage by household percent</th>
<th>Motorized person trip mode split percent</th>
</tr>
</thead>
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<tr>
<td>Bangor</td>
<td>14,740</td>
<td>2.8</td>
<td>5,270</td>
<td>25.9</td>
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<td>Chester</td>
<td>60,620</td>
<td>7.3</td>
<td>8,400</td>
<td>25.9</td>
<td>55.0</td>
</tr>
<tr>
<td>Durham</td>
<td>25,090</td>
<td>7.2</td>
<td>3,520</td>
<td>24.9</td>
<td>?</td>
</tr>
<tr>
<td>Leamington</td>
<td>44,970</td>
<td>4.5</td>
<td>10,000</td>
<td>31.5</td>
<td>20.0</td>
</tr>
<tr>
<td>Shrewsbury</td>
<td>53,760</td>
<td>14.5</td>
<td>3,700</td>
<td>25.9</td>
<td>?</td>
</tr>
<tr>
<td>Stafford</td>
<td>53,590</td>
<td>7.95</td>
<td>6,750</td>
<td>31.5</td>
<td>25.0</td>
</tr>
<tr>
<td>Warwick</td>
<td>18,690</td>
<td>7.9</td>
<td>2,360</td>
<td>31.5</td>
<td>30.0</td>
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</table>

**MEDIUM CITIES**

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
<th>Area sq. miles</th>
<th>Gross pop. density persons/sq. mile</th>
<th>Phone coverage by household percent</th>
<th>Motorized person trip mode split percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basildon</td>
<td>119,470</td>
<td>42.5</td>
<td>2,817</td>
<td>50.0</td>
<td>?</td>
</tr>
<tr>
<td>Bath</td>
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<td>7,700</td>
<td>38.0</td>
<td>36.0</td>
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<td>Bournemouth</td>
<td>151,460</td>
<td>18.2</td>
<td>8,340</td>
<td>38.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Cambridge</td>
<td>100,470</td>
<td>15.7</td>
<td>6,400</td>
<td>42.0</td>
<td>?</td>
</tr>
<tr>
<td>Gloucester</td>
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<td>13.0</td>
<td>6,960</td>
<td>38.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Luton</td>
<td>155,390</td>
<td>16.7</td>
<td>9,300</td>
<td>50.0</td>
<td>27.0</td>
</tr>
<tr>
<td>Northampton</td>
<td>123,840</td>
<td>18.0</td>
<td>6,880</td>
<td>31.5</td>
<td>?</td>
</tr>
<tr>
<td>Norwich</td>
<td>118,940</td>
<td>15.1</td>
<td>7,810</td>
<td>42.0</td>
<td>32.8</td>
</tr>
<tr>
<td>Oxford</td>
<td>110,050</td>
<td>13.6</td>
<td>8,120</td>
<td>38.0</td>
<td>29.4</td>
</tr>
<tr>
<td>Reading</td>
<td>127,330</td>
<td>14.2</td>
<td>8,950</td>
<td>50.0</td>
<td>?</td>
</tr>
<tr>
<td>Swansea</td>
<td>171,240</td>
<td>33.8</td>
<td>5,080</td>
<td>25.9</td>
<td>?</td>
</tr>
<tr>
<td>Swindon</td>
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<td>11.1</td>
<td>8,800</td>
<td>38.0</td>
<td>55.0</td>
</tr>
<tr>
<td>York</td>
<td>110,560</td>
<td>11.4</td>
<td>9,700</td>
<td>24.9</td>
<td>?</td>
</tr>
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</table>

**LARGE CITIES**

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
<th>Area sq. miles</th>
<th>Gross pop. density persons/sq. mile</th>
<th>Phone coverage by household percent</th>
<th>Motorized person trip mode split percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bradford</td>
<td>294,440</td>
<td>40.0</td>
<td>7,380</td>
<td>24.9</td>
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</tr>
<tr>
<td>Bristol</td>
<td>427,780</td>
<td>42.3</td>
<td>10,100</td>
<td>38.0</td>
<td>44.4</td>
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<tr>
<td>Cardiff</td>
<td>287,460</td>
<td>35.4</td>
<td>8,120</td>
<td>25.9</td>
<td>?</td>
</tr>
<tr>
<td>Coventry</td>
<td>335,410</td>
<td>31.4</td>
<td>10,670</td>
<td>31.5</td>
<td>?</td>
</tr>
<tr>
<td>Edinburgh</td>
<td>446,464</td>
<td>54.0</td>
<td>8,640</td>
<td>40.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Leicester</td>
<td>280,340</td>
<td>28.4</td>
<td>9,880</td>
<td>31.5</td>
<td>53.0</td>
</tr>
<tr>
<td>Nottingham</td>
<td>305,050</td>
<td>28.6</td>
<td>10,700</td>
<td>31.5</td>
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</tr>
<tr>
<td>Wolverhampton</td>
<td>264,840</td>
<td>26.6</td>
<td>9,980</td>
<td>31.5</td>
<td>?</td>
</tr>
</tbody>
</table>
Gross population (in thousands)

SELECTED CITIES, POPULATION VERSUS MODAL SPLIT TO TRANSIT

E/E and feeder services

All trip types

Percent Modal Split to Transit

Fig.33

- 135 -
TELEPHONE CONNECTIONS BY HOUSEHOLD 1970 COVERAGE  Fig. 34
(modified from (A fig. 38) by amounts noted in section 5.3.1)

<table>
<thead>
<tr>
<th>Cities in areas below</th>
<th>Percent households covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern</td>
<td>42.0</td>
</tr>
<tr>
<td>South-East (excl. London)</td>
<td>50.0</td>
</tr>
<tr>
<td>Midlands</td>
<td>31.5</td>
</tr>
<tr>
<td>North</td>
<td>24.9</td>
</tr>
<tr>
<td>North-West</td>
<td>32.5</td>
</tr>
<tr>
<td>South-West</td>
<td>38.0</td>
</tr>
<tr>
<td>Wales and Marches</td>
<td>25.9</td>
</tr>
<tr>
<td>Scotland</td>
<td>40.0</td>
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</table>
### DAB SERVICE IN SELECTED CITIES

<table>
<thead>
<tr>
<th>City Net pop.</th>
<th>Range of DAB demand</th>
<th>Levels of DAB service possible at indicated demand densities</th>
<th>Breakeven DAB</th>
<th>Breakeven and compensating profit</th>
<th>max. profit bus loss</th>
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</thead>
<tbody>
<tr>
<td>no. density</td>
<td>for DAB service</td>
<td>density per hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 2,890</td>
<td>59.0 to 18</td>
<td>yes 59.0</td>
<td>yes 40.0</td>
<td>yes 26.0</td>
<td></td>
</tr>
<tr>
<td>SMALL CITIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 1,363</td>
<td>27.3 to 18</td>
<td>yes 27.3</td>
<td>no</td>
<td>no 10.9</td>
<td>yes 19.2</td>
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<td>3 2,168</td>
<td>43.6 to 18</td>
<td>yes 43.6</td>
<td>no</td>
<td>yes 27.8</td>
<td></td>
</tr>
<tr>
<td>4 877</td>
<td>17.9</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<tr>
<td>5 3,150</td>
<td>63.2 to 18</td>
<td>yes 63.2</td>
<td>yes 43.5</td>
<td>yes 27.8</td>
<td></td>
</tr>
<tr>
<td>6 922</td>
<td>18.5 to 18</td>
<td>yes 18.5</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<tr>
<td>7 2,122</td>
<td>42.6 to 18</td>
<td>yes 42.6</td>
<td>yes 23.6</td>
<td>no 18.8</td>
<td></td>
</tr>
<tr>
<td>8 743</td>
<td>14.9</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<tr>
<td>MEDIUM CITIES</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9 1,405</td>
<td>28.7 to 18</td>
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<td>no</td>
<td>no 12.7</td>
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<td>10 2,930</td>
<td>59.8 to 18</td>
<td>yes 59.8</td>
<td>yes 21.4</td>
<td>yes 26.4</td>
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</tr>
<tr>
<td>11 3,162</td>
<td>67.7 to 18</td>
<td>yes 64.7</td>
<td>yes 31.6</td>
<td>yes 27.7</td>
<td></td>
</tr>
<tr>
<td>12 2,690</td>
<td>54.8 to 18</td>
<td>yes 54.8</td>
<td>no</td>
<td>no</td>
<td>no</td>
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<td>13 2,642</td>
<td>54 to 18</td>
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<td>yes 23.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 4,650</td>
<td>95 to 18</td>
<td>yes 95.0</td>
<td>yes 51.7</td>
<td>yes 41.9</td>
<td></td>
</tr>
<tr>
<td>15 2,165</td>
<td>44.8 to 18</td>
<td>yes 44.8</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>16 3,280</td>
<td>67.0 to 18</td>
<td>yes 67.0</td>
<td>yes 27.6</td>
<td>yes 29.6</td>
<td></td>
</tr>
<tr>
<td>17 3,082</td>
<td>63.0 to 18</td>
<td>yes 63.0</td>
<td>yes 31.6</td>
<td>yes 27.7</td>
<td></td>
</tr>
<tr>
<td>18 4,470</td>
<td>91.4 to 18</td>
<td>yes 91.4</td>
<td>yes 42.2</td>
<td>yes 40.2</td>
<td></td>
</tr>
<tr>
<td>19 1,315</td>
<td>26.8 to 18</td>
<td>yes 26.8</td>
<td>no 11.8</td>
<td>yes 30.0</td>
<td></td>
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<tr>
<td>20 3,343</td>
<td>68.1 to 18</td>
<td>yes 68.1</td>
<td>no 16.8</td>
<td>yes 21.7</td>
<td></td>
</tr>
<tr>
<td>21 2,415</td>
<td>49.3 to 18</td>
<td>yes 49.3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>LARGE CITIES</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 1,090</td>
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<td>no 20.5</td>
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<td>yes 11.2</td>
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<td>40.7 to 18</td>
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<td>no</td>
<td>yes 17.0</td>
<td></td>
</tr>
<tr>
<td>26 2,050</td>
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<td>yes 42.0</td>
<td>yes 21.5</td>
<td>yes 18.0</td>
<td></td>
</tr>
<tr>
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<td>no 18.0</td>
<td></td>
</tr>
<tr>
<td>28 2,000</td>
<td>40.7 to 18</td>
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<td>no</td>
<td>no 18.0</td>
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</tr>
<tr>
<td>29 1,862</td>
<td>38.0 to 18</td>
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<td>no</td>
<td>no 16.8</td>
<td></td>
</tr>
<tr>
<td>2,263</td>
<td></td>
<td>net average for 28 cities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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6.1 Summary

This thesis analyses one British town in detail to see how a DAB service can be used to help it achieve its public transport needs. The value of a DAB service is viewed from the following perspectives.

1. That of society. How DAB can increase the choice of travel by public transport.
2. That of the bus operator. How DAB can diversify the operator's services, enlarge the transit market and help to offset current or future deficits in its conventional bus operations.
3. That of the policy maker. How DAB can serve as a substitute for the private car in urban areas.

Cheltenham was chosen as a suitable study site. The present bus operations were taken as a constant, and the effective demand for DAB measured by comparing the revenue generated by a given quality of service (Chapter 2) with the cost of supplying that service (Chapter 3). The benefits of the service were estimated at three levels.

1. Maximum benefit to users.
2. Maximum benefit to users without reducing the income of the conventional bus service.
3. Maximum profit to the operator.
Another principal concern both of society and of its policy makers, is traffic congestion. In Chapter 2 estimates were made to find the number of car users diverted to DAB, and the net reduction of cars in the town through the introduction of a DAB service.

Chapter 5 takes a sample of British towns and cities and draws some preliminary inferences on their suitability for a DAB service, based on correlations with the Cheltenham analysis.

6.2 Conclusions

The following are the more significant conclusions for Cheltenham.

1. A town-wide DAB service could be implemented in Cheltenham at a fare which allows the Bus Company to break-even on its DAB operations, and yeilds a user's surplus of £699 per day.

2. The above service would penalise the Bus Company by diverting passengers from its regular service. To compensate for the loss of revenue, a DAB service could be implemented to allow the Bus Company to maintain its present income on conventional Bus service and break-even on DAB. This would yeild a user's surplus of £341 per day.

3. A service yeilding a maximum profit for the Bus
Company could be implemented, producing £172 profit per day for the Company, and a user's surplus of £172 per day.

4. A DAB operation serving the peripheral areas of the town only could not break-even, given the present telephone coverage.

5. An off-peak DAB service on a town-wide basis would operate at the three levels of service described in section 6.1, assuming the cost of DAB drivers is amortised in the operations of the conventional bus service.

It is a matter for negotiations between the representatives of the travelling public and the Bus Company, to decide which of these forms of service to implement and at what levels.

If the town-wide DAB service were implemented maximizing the user's surplus, a net reduction of 2464 passenger car units could be achieved -- a modest contribution to relieving the problem of traffic congestion in the town. In addition, DAB could potentially divert some families from the decision to buy a second car.

As the phone coverage is so low in Britain compared to the United States, policy-makers cannot assume that DAB can substitute for all or most of the car trips, since the majority of households will be excluded from a DAB service due to their lack of a telephone. However, as phone coverage increases, a policy of increasing restriction or taxation on
car use will become possible, on the assumption that DAB is a suitable alternative to the private car within the city.

As regards the prospects for DAB in other cities, indications are that 86% of our sample could support DAB at a break-even level of service, and lesser percentages on the other levels of service. It is interesting to note that of the "historic" cities in the sample, 1 all except one 2 could support at least a break-even DAB service.

### 6.3 Suggestions for Future Work

Several questions and indications for future research arise from the material presented in this study, and the ones which arise in the author’s mind can be classified into those pertaining to the method used in this study, those related to the data, and those concerning the implementation of DAB in Britain.

#### 6.3.1 Questions of Analysis

Plourde 3 casts some doubt on the usefulness of a value of time approach for calculating the mode of intra-urban trips. He found that the value of time 4 decreases with

---

2. Durham
3. "Development of a Behavioral Model of Travel Mode Choice"
trip length, or to put it differently, did not provide a powerful explanation of mode choice for short trips. He found that total cost, distance, travellers' age and sex and the number of unemployed high school age members of the travellers' household gave better explanations. He found that parking charges were by far the most powerful tool to encourage travellers to ride transit. However, his conclusions may be open to question if applied to other cities, since Cambridge, Massachusetts, is a city highly oriented towards students.

Aldana\(^1\) investigated the travel habits of residents in the Boston suburbs and found little correlation between level of transit service offered, and diversion of auto users to transit. Both Aldana and Warner propose that the household'er's decision as to residence location and mode choice are taken concurrently, and once the residential location choice is made, mode choice is not dependent on income.

These propositions are corroborated to some extent by some findings in this thesis. We noted in section 2.8, that the diversion curve for the I/E (short) trips was skewed due to low car ownership in public housing areas on the western fringe of Cheltenham. These residents ride the bus in spite of the extra cost involved, largely because they are captive

customers, not only in the transit market, but the housing market as well. The frequent British practice of locating government housing in the peripheral rather than the central areas of cities affects the diversion curves in a way which does not occur in American studies, where there is high collinearity of poorer residential areas in central areas together with good transit accessibility on the one hand, and high auto ownership in suburban areas on the other. In order to form diversion curves which represent a real choice, it would be better to segment them into transit riders who do, and who do not own cars. This was not possible in this study, due to the lack of this type of data, a point which will be elaborated in the next subsection.

From the point of view of adjusting current transit operations as well as forecasting demand for a new mode such as DAB, further studies on the significance of value of time as an explanatory factor for tripmaker choice in medium sized cities need to be made. Studies to discover trip-making decisions based on individual characteristics, especially if they can be related to Census material, would be even more valuable for the transport analyst and planner concerned with the future of public transport in Britain.

6.3.2 Data and Survey Methods

Urban Transport analysis in Britain has in the past been
largely concerned with traffic congestion. Hence many of the traffic surveys concern themselves with vehicle volumes rather than person trips, and information is frequently sparse on the characteristics of the tripmaker. Cordon and screen traffic counts have often been used instead of interzonal flows although this is now being superceded by home interviews based on traffic zones. Consequently, many of these surveys are of little use in designing transit systems or assigning person trips to transit networks. The expense of a transport survey implies that its data should be usable for as many purposes as possible, and points to future transport data being more oriented to individual behavior and person trips, as well as aggregate flows of vehicles, if it is to be useful in analyses introducing new modes of travel. To be of most use in evaluating a city for a DAB system, person trips should be split into home and non-home based, trip purpose, and whether the tripmaker has access to a car.

6.3.3 Dial-a-Bus. Implementation Problems

Finally, a brief word on a problem that has recurred throughout this thesis -- that of access to a telephone. From the point of view of demand analysis for DAB, information on telephone coverage by Ward, Enumeration District or Traffic Zone is needed. For non-home-based non-work trips in central areas, lack of access to a public telephone may eliminate much potential demand. Possibly a financial en-
couragement for shopkeepers to rent the portable phone described in the Appendix (A fig. 39) would be suitable, and the DAB operator might consider a discount in fares to residents having a phone newly installed and meeting a quota of DAB rides per year.

At peak times, however, there may be a problem of excess demand from localised points in central areas, and a modified "one to many" system whereby DAB collects commuters at a few points in the centre at scheduled times may provide a solution.
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APPENDIX

Data Collected on the Cheltenham Study Area
Notes on Terminology

CCK = Cheltenham and Charlton Kings

The study area comprises Cheltenham Municipal Borough and Charlton Kings Urban District.

Money. The 1970 pre-decimal British currency is used.

DAB = Dial-a-bus, interchangeable with

CARS = Computer Aided Routing System, as developed in the Urban System Lab. at M.I.T.
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1.0 INTRODUCTION

1.1 The summer research work was devoted to data collection to be used in analysing where DAB might fit, if at all, in the public transportation system of Cheltenham. This report describes the data collected, its degree of coverage and its sources. The study draws some intuitive conclusions for the prospects of Dial-a-Bus in Cheltenham.

1.2 Choice of Cheltenham as the study area

I choose Cheltenham as a suitable study area for DAB for the following reasons.

1. It is a "historic" town. Perhaps the best example of Regency architecture in Britain, where the whole town centre is a carefully designed urban landscape. Its beauty attracts residents to the town, and they form a powerful conservation lobby, having already thwarted a plan to drive a distributor expressway through some of the Regency squares and terraces. A DAB system could be designed as an additional public transportation mode, helping to reduce cars in the town, together with the need for further roads. Thus historic towns are the most likely areas where DAB would get a positive response.

2. The future physical development of Cheltenham is at a critical moment. Following the failure to implement the Gloucestershire County Council plan for the town, largely due to the arguments of the conservation lobby at the Public Inquiry, private consult-

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ants have been appointed to prepare a further traffic/land use/urban design master plan. Their studies have recently commented, and now is an appropriate time to introduce the possibility of using DAB, both to the planning consultants, and to the public.

3. Income levels in Cheltenham are not low. People could better afford to pay the fares that a non subsidized version of DAB would demand, than in a poorer town, especially in the upper income areas which are poorly served by the present bus system.

1.3 Source of Data

The following organisations have been very helpful in supplying raw data for this study:

1. The Gloucestershire County Planning Office
   Statutory land-use plans
   1963 O/D survey: Car ownership in Gloucestershire, 1967
   1968 basic data for new traffic survey (uncompleted)
   Subregional study

2. Bristol Bus Company
   Information on bus routings, costs, company policies
   Computer coverage

3. G.P.O. telephone
   Telephone coverage, cost, types, computer coverage

4. Census Office
   1966, 10% sample census data
5. Leyland Bus Company

Mini-bus designs

1.4 Organisation of Data

The greatest interest in this DAB project was shown by the Bristol Bus Company, who are the operating company for Cheltenham Borough and surrounding areas. They would be the most likely operators should DAB prove to be feasible in Cheltenham. The data has therefore been organised to provide suitable information for a demand model where DAB would complement existing bus services (with some modifications) and attempt to extend public transport to a wider market throughout the town. The future study would estimate the costs and benefits which the Bus Company, society as a whole, and the transit users could expect with the introduction of DAB.

The data gathered also provides most of the details for a future network analysis for both Bus and DAB should the results of the demand model be sufficiently positive to pursue the study further. By the time that decision is reached, the consultants working on the new Development Plan for Cheltenham will have analysed the data more comprehensively, and a network analysis could be developed against alternative future road & transport schemes they may propose. DAB might possibly be included as part of one alternative transport system in their proposals.
2.0 CHELTENHAM AREA. SETTING.

2.1 Location (Fig. 1)

Cheltenham lies on the Severn valley at the foot of the Cotswold hills, on the border of the southwest and Midlands area of England. Together with its "twin" town of Gloucester (7 miles away) it lies in rural surroundings between the large industrial areas of Birmingham and Bristol.

2.2 Sub-regional Planning Study

The North Gloucestershire Sub-regional Study, published July 1970, analyses the Gloucester/Cheltenham area with respect to population, employment, housing, transportation, and natural environment. It projects future trends and produced alternative strategies for the development of the area. The following are the salient points of the report which have a bearing on this study:

2.2.1 Population (Fig. 2, 3)

The sub-region is increasing in population faster than England and Wales as a whole (see Fig. 2). The sub-region's share of the total population rose from 0.80% in 1939 to 0.95% in recent years. Most of the population increase is centered in Gloucester and Cheltenham which are the major towns of the region. The study's preferred strategy is to lo-
cate new areas of industrial and housing development between Cheltenham and Gloucester, south of Gloucester, and to a lesser extent, north of Cheltenham. The Cheltenham population and its projections are dealt with in more detail in section 3.3.

2.2.2 Employment (Figs. 4, 5, 6)

Cheltenham and Gloucester again dominate the subregion with employment evenly distributed between them. However, Cheltenham's basic sector of engineering and government service has grown very rapidly in recent years. Cheltenham predominates as a shopping centre, claiming 29% (£6,700,000) of the subregional trade in 1966 compared to Gloucester's 27%. No other town has more than 7% of the total. Half of Cheltenham's retail expenditure originated from inside the town, and half from rural areas, Cheltenham's dominance as the regional shopping centre, based on its high quality shops and pleasant urban environment seem likely to continue.

2.2.3 Transportation (Figs. 7, 8)

Cheltenham is approximately equidistant between Birmingham (50 miles), Bristol (40 miles) and Oxford (40 miles). The town is served by train to these cities, and to London. The national expressway network will have increasing importance for the town especially when the Birmingham/Bristol link (now open from Birmingham to Cheltenham) is completed in two years time. The likely effect of this road, together with the Golden Valley bypass (linking Gloucester and Cheltenham) will be to slightly reduce the
volume of through traffic in the town, to make shopping in Cheltenham more accessible to the population in the Severn valley, and to offer the possibility of commuting by road to Birmingham or Bristol. The journey to work flow diagram (Fig. 8) illustrates the heavy peak flows between Gloucester and Cheltenham, which will tend to increase if the study's proposals of locating new activities between the towns, is realised. The diagram also indicates the region's self-contained nature, as far as work journeys and employment are concerned. The modal split for Gloucester and Cheltenham is about 25% for bus travel, indicative of the frequent local services, and fairly high population densities, compared to similar size cities in the U.S.

2.2.4 Natural Environment (Fig. 9)

Cheltenham lies in flattish land in the Severn valley. The river Chelt which runs through the town does not form a barrier to development. To the east and south, however, town expansion is rigidly contained by the escarpment of the Cotswold Hills, designated an area of outstanding natural beauty by the planning authority, and where only agricultural development and small variations in residential development are allowed. The area between Cheltenham & Gloucester is at present designated as a green belt, although restrictions on development here will be relaxed to some extent in the future.

2.3 Severnside

Due to lack of information from the Central Government, the sub-
regional study did not take into account the new urban development proposed between Bristol and Gloucester on the east bank of the Severn. It will probably be some years, however, before any urban growth in this area occurs. The likely effect may be to shift the economic centre of gravity more towards the south, thus possibly increasing commuter journeys from Cheltenham.
3.0 CHELTENHAM. MARKET CHARACTERISTICS.

3.1 The Boundaries of the Study Area (Fig. 10, 13)

Gloucester and Cheltenham are so interdependent that a definition of a suitable study area is difficult to make. However, the combination of Cheltenham Municipal Borough and Charlton Kings Urban District (CCK) was finally chosen for the following reasons:

1. They include most of the continuous built-up area.
2. Although the residential areas between Gloucester & Cheltenham are likely to expand, they are at present limited by the green belt, and will have controls on them in the future. The present limitations of land use funnel most of the bus journeys onto the main line bus routes.
3. The Bristol Bus Company operates most of its town service within the Cheltenham MB and Charlton Kings UD.
4. The traffic survey zones of 1963 and 1969 lie within these areas, plus a small amount outside.
5. The areas outside Cheltenham and Charlton Kings to the east and south have been designated as areas of outstanding landscape value, where little new development is expected to occur.

The total trip generation for a potential DAB service will therefore lie approximately within this area.

3.2 Land Area (Fig. 11)

The CCK area covers approx. 11.50 sq. miles, all of which has been
developed except for 1.38 sq. miles (available) and 1.69 miles of exceptional landscape area (not available for development).

3.3 Population

<table>
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<th>Location</th>
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<tr>
<td>Cheltenham MB</td>
<td>72,390</td>
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<tr>
<td>Charlton Kings</td>
<td>9,610</td>
</tr>
<tr>
<td></td>
<td>82,000</td>
</tr>
<tr>
<td>+2% census error</td>
<td>1,640</td>
</tr>
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<td></td>
<td>83,640</td>
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Source: 1966 10% sample census grossed up

Population is growing at approx. 2% per year, which indicates a 1970 population of approx. 90,330. Given the slower rate of growth projected by the regional plan, the 1980 population will probably reach approx. 100,000.

3.4 Land uses, Population densities, Past and Projected Residential

(Figs. 11, 12, 13)

As of 1965, approx. 41% of the total CCK area had been developed with residential units, or 57% of the net developed land area. The total population density per developed sq. mile (8.43 sq. miles) at 1966 pop. figures is thus approx. 9,800 (and for 1970 approx. 10,200). The net residential area of 4.75 sq. miles yields a net residential density/sq. mile of approx. 17,500 (and for 1970, approx. 19,000). The population density of the
Regency and Victorian terrace housing, extending out approx. 1 mile from the town centre and covering (3.14 sq. miles) (see Fig. 12) averages almost the same as the total, the higher density of residences, balanced by other land uses. The housing outside the 19th century development is a mixture of small detached and semi-detached privately developed post war houses in the south and north on approx 1/4 acre plots, and Municipal housing, mostly in terraces, to the west. Conversion of the town centre to office development is likely to continue, although the attractive quality of the centre, and the suitability of the terrace houses for small apartments demanded by the office workers is likely to retain population in the central areas. Building of council housing has now almost stopped and private development in the suburban areas will probably provide the major new housing especially in the west and south west. See Fig. 15 for population by traffic zone areas of Fig. 16.

3.5 Commercial and Industrial (Figs. 11, 12, 14, 15, 16)

Employment in CCK in 1966 totalled 38,647 (ref. fig. 14). Of this 40% (15,400) were employed in the central area comprising traffic zones 1, 2, 3, 4 (ref. figs. 15, 16), predominantly retail business and government employment. Immediately to the south of the central area, and to some extent an extension of it, zones 11, 12, 13, employed a further 4,900, mostly in educational, office and retail. Three other areas lying at different places on the perimeter of the CCK provided major employment. Zone 17 (3,200) mostly central government employees, zones 34, 35 (3,600) form a light industrial area in the north, and zones 28, 29 (2,500), another
light industrial and government employee area in the west. Thus, employment population per sq. mile of developed commercial & industrial land area of the CCK (1.4 sq. mile) is approx. 27,500.

As noted earlier, Cheltenham is the principal shopping area for the sub-region with 29% of the total sub-regional shopping expenditure. In 1961, consumer durables alone accounted for £10,830,000 trade, and this is expected to rise to about £14 million by year 2000. The sub-regional study also mentioned the rapid growth of light industry - electrical and engineering goods especially. However, employment in service activities has grown approx. twice as fast as activities in the "basic" sector.

Traditionally Cheltenham has been a retirement centre based on the spa waters, and its age structure reflects its continued attraction for older people. Education is another major activity, especially public (U.S. "private") schools and training colleges.

Employment is projected to rise less rapidly in the future, although urban development on vacant railway ground (St. James's station) is proposed.

3.6 Education

Higher education, in the form of 3 public (boarding) schools, 2 teachers training colleges, one regional art college in addition to the normal complement of primary, secondary and high schools, make Cheltenham an important educational centre for its size. School age students 5-16 years total about 13,726 and I estimate the college population at approx. 3,500-4,000 students.
3.7 **Shopping and Recreation trips**

Pending the results of the 1966 sample census on workplace residence movements, compared with overall traffic volumes, information for the exact split between journeys to work and shopping recreation trips is not available. However, certain indications can be inferred from the length of parking times gained from the 1963 traffic survey, and there seems to be no reason to believe the proportions of work journey/recreation should have changed drastically since.

The survey discovered that 85% of all vehicles parked during the peak hour were cars or taxis and 35% of all vehicles were parked all day i.e. 10 a.m. - 4.30 p.m. This would appear to indicate that approaching 50% of all trips to the town centre (within the cordon radius of approx. 3/4 mile) were for shopping and recreation. Furthermore the drivers interviewed indicated that of those arriving between 8 a.m. and 9 a.m., 13% expected to leave within the next hour, but 54% expected to leave after 5 p.m.

These figures tend to confirm the importance of Cheltenham centre for shopping & recreation. There are few attractions within the CCK area beyond the Cheltenham centre, although a proportion of recreation trips are likely to occur between Cheltenham and Gloucester, and to a lesser extent to the golf course in Charlton Kings and on Cleeve Hill.
4.0 DEMOGRAPHIC CHARACTERISTICS

4.1 Age, Sex and Household (See Fig. 17)

The 1966 sample census shows the CCK population as comprising 31% from 0-19 years, 49% from 20-59 years, and 20% being over 60. In the 0-19 age group, female and male population is approximately equal. Between ages 20 and 59, male and female is 48% and 52% respectively. The 60+ age group shows a large difference, with 28% males and 72% females.

The household structure in the CCK differs from the rest of the sub-region in that it is much smaller (2.90 persons in 1966, compared to an average of 3.02 for the sub-region as a whole). The average percentage of elderly per household is not available, but is likely to be close to 13.50% given the proportion of elderly people in the town. The slight preponderance of older people in Cheltenham compared to the national average is due to its tradition and attraction as a retirement centre. There are several nursing and old persons homes in the town.

4.2 Income (See Fig. 17 and Fig. 17A)

The income for CCK residents was not easily available, and the following comments are from comparison with national income figures, and personal knowledge of the area:

The average income per household for southwest Britain in 1969 (source Monthly Digest of Statistics, Dec. 1969) was £1,620. However, the household size, which has been shown to be inversely proportional to personal income, is much lower in the CCK (2.90 persons) compared to the sub-
regional average of 3.02, which closely follows the national average. Moreover, CCK's proportion of professional and employer population (approx. 18% disaggregated into 16% for Cheltenham Borough, and 30% for Charlton Kings) was much higher than the sub-regional average (15.4%) or nearby Gloucester (12.4%). The income per worker in the CCK, therefore, is likely to be somewhat higher than the national average - a guess would be, about 20% higher, producing an average income per household of approx. £1,940:0:0 for 1969.

As regards the distribution of income over the CCK area, the map on Fig. 17A shows my intuitive division of the town into income quintiles. Basically, the high income areas lie within or on the edges of the Cotswold escarpment - areas of outstanding natural beauty, to the south and east; the upper middle and middle incomes in a band of postwar housing developments, and Victorian and Regency buildings in the inner suburbs in the south, the lower middle income areas largely in the public housing to the west and north, and the lowest income in the north of the central area. The relative positions of the income groups in the CCK area do not appear to be changing greatly, although middle income development is expanding in the north of Cheltenham.

4.3 Ethnic (See Fig. 17)

Fig. 17 illustrates the small number of residents born elsewhere than in the U.K. Proportional to the total population, they are as follows: Irish (from Northern Ireland and Eire) 1.70%; Commonwealth and colonies (largely India, Pakistan and West Indies) 1.20%; Foreign countries (some
non British, but mostly British born abroad) 2.30%. The neighborhoods are not defined sharply by ethnic background, although there is likely to be some small rise in the proportion of Indian, Pakistani and West Indian origin population.
5.0 TRANSPORTATION CHARACTERISTICS

5.1 Barriers (See Fig. 18)

The only natural barriers in the CCK area are the steep slopes of the Cotswold escarpment on the southern boundary of the town. The designated area of outstanding natural beauty running along the south and east of CCK will tend to restrict any further urban development in this direction. At present the green belt between Cheltenham and Gloucester restricts development to the west, but this is likely to be reduced, if the preferred strategy of the sub-regional study is adopted, and restrictions to development in the green belt are partially relaxed. The Gloucester/Birmingham railway, and the disused Cheltenham/Oxford line are barriers, though not extreme ones.

5.2 Network Representation (See Figs. 19, 20)

Traffic flows in Cheltenham tend to be radial (see Fig. 19), the principal arms being the London/Tewkesbury and the Prestbury/Gloucester axes. Flow directions of central area traffic have been modified to some extent by the one way street systems. Street network in the town centre is more rectilinear than in most British towns, though not to the same extent as in U.S. cities. Road width is generally wider than in British towns of comparable size, main carriageways varying from 20 to 40 ft. again due to the Regency layout. Connections are generally good throughout the town, though impeded to some extent across the railway lines, and across Sandford Park and Battledown Hill in the south east.
5.3 Traffic Volumes, variations, Speed, and Congestion

(Figs. 16, 21, 22, 23, 24, 27)

Although residence/work journey volumes were available from the 1966 survey (see fig. 20), total traffic volumes were not obtainable and the following figures were developed from the 1963 survey. The figures for 1970 were calculated by multiplying the 1963 figures by a factor of 0.35 (5% compound increase i.e. pop. and car ownership increase). The figures were converted into passenger car units. A cordon (see fig. 23) count on 16 points was made in 1963 which showed typical double peaking times of traffic flowing to the centre area, morning peak 8-9 a.m. 9,869 (13,322 for 1970) and 12,551 (16,943 for 1970) for the 5-6 p.m. evening peak. The minimum flow during 8 a.m. - 6 p.m. was at 10 a.m. - 11 a.m., 5,835 (7,877 for 1970). See fig. 24.

Total flows to the central area over 8 a.m. - 6 p.m. were 40,000 (54,000 for 1970) in each direction. Examples of the flow volumes in vehicles on principal routes between 5 p.m. & 6 p.m. are shown on the table on fig. 24. However, all these figures were traffic volumes checked crossing the central area. Approx. 15% of total traffic within CCK was bypassing the town centre with origins & destinations outside CCK. Figs. 20 and 25 illustrate traffic desire line volumes for 1963, and expected for 1985. Approx. 13.3% of all traffic was heavy vehicles with a maximum of 24% on the London Road. Trips to CCK from outside were estimated at 26,500 (35,775 for 1970) by car, and 3,250 (4,387 for 1970) by bus and

1. As stated in Cheltenham Plan Report, p. 11.

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train. This modal split for journeys to the town is, however, much lower than the split for journeys within CCK.

Fig. 27 illustrates the journey to work matrix developed for the 1968 Traffic survey. As would be expected, the principal traffic flows are to the main areas of employment described in section 3.5.

Fig. 21 describes times made by car over typical journeys in CCK shown on fig. 22. They were timed on a Saturday morning with somewhat below average congestion compared to most Saturdays in the town. The average speed was 16 1/2 m.p.h., though on Journey 2 which passed around the town centre, the average speed was higher, 24 m.p.h., leaves the journeys through the centre at an average speed of 14 m.p.h.

Congestion in the town is becoming increasingly serious as car ownership rises together with population. In 1963, vehicles accumulated at a rate of 1,200 per hr. during the morning in the town centre, which is 46% the rate of arrival. Over half are parked at the roadside. The study estimated that only 50% of the streets were not congested. Friday and Saturday mornings are the busiest periods. The situation improved slightly after an extensive one way street system was introduced.
6.0 TRANSIT ORIENTATION

6.1 The Bristol Bus Company (Fig. 28)

The Bristol Bus Company is the operating company for Cheltenham and most of the cities in the west of England, including Bristol. The only other bus companies in the area are small ones serving country areas, and a few large companies running inter-city services. Information was obtained through Mr. Butcher, the general manager, at Bristol, and Mr. Carpenter, the local manager at Cheltenham.

The Bristol Group of Bus Companies operates under a franchise from the Ministry of Transport to exclusive operation of bus transit within the towns of its region. These operations are not subsidized. Along with other bus companies, it also operates country services which are subsidized. In general, the city services are retaining their ridership and increasing it slightly in some cases, Cheltenham being an example. However, their share of the total trips is declining. Fig. 28 shows a table of the total income and expenses of a typical four weekly period for the whole company. Mr. Butcher considered that the comparative proportions of expenses and revenues in this list would be similar for not Cheltenham, though individual records are kept comparing both income and expenses by city. The head management is very aware of the possible decline of ridership in the future, and is actively seeking methods to improve service. Currently a university group is working on computerizing timetables to maximise existing service and a computerized monitoring system to locate vehicle positions is being installed in Bristol. A manage-
ment consultant showed a lively interest in the DAB potential. However, Mr. Butcher made three main points if DAB were to be considered by his company.

1. Any DAB system should not reduce the main line profitability.
2. DAB might be used to supplement main lines by a feeder system. This may be more applicable to Bristol than to Cheltenham.
3. Perhaps DAB could use the surplus busses and drivers in the off-peak periods, say 2 p.m.- 4 p.m. and 6 p.m. onwards.

6.1.1 The Cheltenham Operations, Routes and Frequencies

(Figs. 29, 30, 31, 32)

Cheltenham is a regional shopping centre and this has probably had a beneficial effect on the town's transit operations, making the off-peak periods less unprofitable than they would otherwise be. Fig. 29 shows the layout of the present bus routes, and an analysis of the present time tables yeilds frequencies for each route, shown in fig. 30. The average trip length per person was estimated at about 1 1/2 miles. Most busses are routed across town. Route length and service frequency has remained constant over the past 3 years.

6.1.2 Patronage, Peak/Off-peak Characteristics

The bus service has increased over the years, but in recent years its increase in ridership has not kept up with the rate of increase in population. In 1970 there was 30% more route mileage than in 1946, and 30% higher
frequency on the routes. Busses are reckoned to be 85% - 90% full during peak hours and 25% - 30% full during off peak. The lowest off-peak is from 7 p.m. - 9 p.m. and after 10.30 p.m. The largest demand is between the centre and the public authority housing developments -Hesters Way in the north west, and to a lesser extent, Whaddon/Prestbury in the north east. Low demand in the south (Hatherley, Warden Hill, Leckhampton), east (Charton Kings, Battledon) and north (Pittville).

For a typical week in 1970 patronage was as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Singles</td>
<td>143,784</td>
</tr>
<tr>
<td>Returns</td>
<td>5,426</td>
</tr>
</tbody>
</table>

Total no. in single units. 154,636

Busses carrying these passengers during this week travelled a total of 23,084 miles.

Cheltenham possesses wider streets than most British towns and traffic congestion for the busses is not a serious problem except along the High Street and Promenade up to about 1/4 mile radius from the town centre.

6.1.3 Fares

The fare structure is organised according to distance travelled. Typical amounts in 1970 are 7d 1/- and 1/5 giving an average of approx. 1/- for approx. 1 1/2 miles travel. However, as the lower income areas which generate the highest demand are on the perimeter of the town, the average fare may be closer to 1/-. There is no subsidy for old age pensioners at present. Children travel 1/2 fare. There is also a monthly
fare card system, but this is not widely used. Fig. 31 shows the fare structure by length of trip.

The company is now having to increase fares more frequently than in the past, there being one increase a year for each year from 1967-1970. Fig. 31 shows receipts by bus route for a typical week in 1967 and 1970 (fares having increased in the intervening period).

6.1.4 School Bus

The bus company does not operate a regular school bus service. No other company provides a bus service within the town, although there are services from outlying villages. It would appear that the residential densities are high enough and distances short enough for children and scholars to walk, or use the regular service to school. However, 1/2 price fares are made, and these account for approx. 14% of the company's receipts.

6.1.5 Bus Company Costs

Costings are accounted centrally in Bristol, and the percentage of office, labour, capital costs etc. can be obtained from an analysis of fig. 28. Fig. 32 shows the hourly rates for labour, by bus type, together with a table of bus types and their capacities. The company is gradually phasing the service over to single man single decker busses.

6.2 Auto Ownership (Figs. 33, 34, 35)

CCK had an auto ownership level of 5.1 persons/auto in 1967, compared
with the districts immediately surrounding it which yielded between 4.3 and 3.4 persons/auto. Fig. 33 illustrates the density of autos by area together with the no. persons/auto. Although auto ownership in CCK was higher than in Gloucester (5.91 persons/auto), the difference between CCK and surrounding areas is nevertheless large, and may be attributed to lower income, higher proportion of young office workers and students in apartments, difficult parking and better public transport. Auto ownership is still rising rapidly as fig. 34 indicates, and suggests that 1985 ownership levels may be double those of 1966. No census has been taken of transit riders who are without autos. However some tentative inferences might be drawn from the London Traffic Survey of where the average household size of 2.87 persons is similar to Cheltenham's 2.90.

6.3 Parking

The number of vehicles parked in the town centre in 1963 was 3,600. 1,136 of these were parked on the highway, 722 within private car parks, and 329 in public car parks. 83% of all vehicles parked were private autos or taxis, and 35% of all vehicles were parked all day (ie. 10 a.m. - 4.30 p.m.). The accumulation rate of parking in the centre was 46% rate of arrival of autos in the town centre at peak morning hours. Since 1963 auto ownership has risen dramatically, and in spite of increase public off-street parking, and new one way routing systems, congestion due to parking is increasing. At the same time cars are being parked at increasing distances from the town centre in residential streets, and at peak
periods a walk of 1/4 to 1/2 mile may be common. The reluctance to pull down or convert older terrace buildings to form parking spaces has contributed to the parking problem.

6.4 Taxi

There is one main taxi company in Cheltenham. Information has not yet been obtained on level of use of taxis and the fare structure, but my impression is that they are little used. There is one open air taxi stand in the centre of the town where approx. 4-5 taxis are normally parked.
7.0 TRIP GENERATION BY MODAL SPLIT (See Fig. 36)

The 1969 trip movement analysis was not complete when this data was collected. The following figures were based on the 1966 sample census (+20% for 1970 auto movements) which is also the basis for much of the 1969 analysis. The 1966 Census lists workplace moves, and recreation/shopping moves were estimated as being equal to work moves (ref. Section 3.7), and approx. 1.6 times workplace moves in the case of bus. The figures are developed into a three way modal split, where total residence/workplace moves are considered at twice one way residence/workplace moves.

7.1 Auto Driver and Auto Passenger

51,600 trips were made by persons in auto during an average week day in 1966 (61,920 for 1970). Half (25,800) the author estimated as residence/workplace moves, and half as recreation/shopping moves. In 1963 10% were auto passengers. Modal split for auto was 43% in 1966. These figures do not account for autos with origins outside the CCK and destination inside. These may account for a further 15% of trips.

7.2 Taxi Passenger

Figures are not available, but an estimate may be in the order of 1000 to 1500 trips per day.
7.3 Bus Passenger

25,600 trips were made on a normal week day of which 9,600 were residence/workplace moves within CCK, 12,160 were estimated as recreation/shopping moves, and 3,840 school riders (1/2 price). Modal split to transit for total is 20% (including walk/cycle), or 35% (compared to auto only). The 1963 survey expects the modal split for bus to drop to 20% by 1981 although total ridership may not drop.

7.4 Walkers and Cyclists

41% of the CCK population walked or cycled to work in 1966 which indicates why this mode has been disaggregated from the others. 24,600 were residence/workplace moves (possibly the same in 1970), and possibly the same number again in recreation/shopping although this is open to question.
8.0 INSTITUTIONAL CHARACTERISTICS

8.1 Cheltenham M.B. and Charlton Kings U.D. Authorities

Cheltenham M.B. and Charlton Kings U.D. form the next level of town government above the Parish Councils which have little legal power. The legislative arm is the Town Council where elected representatives make policy and allocate funds within the framework laid down by the County and Central governments. The mayor is the head of the Town Council but it is largely a ceremonial position. The chairmen of committees are frequently the most powerful members of the Council. The towns have a permanent civil service whose membership generally does not change with the political colour of the Council. The administrative arm includes planning departments whose power is largely limited to the execution of plans prepared by the County Planning Office; a Housing department where volume and allocation of public housing is largely determined by Central government guidelines; a School committee where policy is locally determined, but under pressure from the Central government; Police and especially the Surveyor's department (dealing with sewage, roads, water and building codes) are more free from higher government controls and can exercise more power, although funds for "trunk" roads come largely from the Central government who thereby influence the construction of new main roads. Increasingly Building codes are conforming to a national standard.

Although the Town administration has little initiative function, and is largely executive, it has considerable influence to obstruct schemes
proposed by the County and Central governments. A case in point is the new land use/transportation planning proposals made by the County in 1966 (1963 survey) which was turned down by the Minister from the Central government at the Public Inquiry, after rising local opposition, both public, and especially, private.

The present Borough Surveyor is an energetic and capable administrator. He has implemented a new one way street system which has improved traffic flow to some degree. He is also working to implement a scheme for excluding motor vehicles from approx. 1/2 - 2/3 mile of Cheltenham's central streets (some lengths of the Promenade and High street), and to turn them into pedestrian shopping malls with a possible shuttle bus service. I have not, as yet, obtained his reaction to the DAB proposal. The bus company must work in consultation with the Borough Surveyor on matters of routings, and submit any fare increase proposals to the Council.

Property taxes (rates) are levied to support town service, but heavily supplemented in some areas by Central government funds. There is no local income tax.

8.2 The County Government

As indicated in the previous section, County government powers are more extensive than those of the Town especially in matters of planning. Radical proposals for future land use and transportation networks (largely roads) can be made, and generally implemented by the County Planning Office, although guidance as to current norms and methodologies are provided by the Central government. The composition of County government is similar
to Town government and split into Council (legislative) and civil service departmental (administrative) arms.

The County Planning Office has recently commissioned a new land use/transportation study and proposals from a private consultant following the rejection of the 1966 Plan at the Public Inquiry. The new proposals will be submitted in Sept. 1971. The data for the study has been mostly generated by the research arm of the County Planning Office.

A few years ago Cheltenham M.B. wished to change its status to a County Borough, which would have given it County powers of government, but those efforts were thwarted. The whole structure of local government is now in question since the publication of the Maud report, and it is likely that regional powers will be strengthened at the expense of local and County powers.

8.3 The Central Government

The main governmental power over Cheltenham as over every other British towns, finally resides with Whitehall where local governments are guided and controlled by the regulatory and fiscal policies described above.

The power of Whitehall correspondingly inhibits public response and interest in local government as well as restricting the actions of local administrators.

8.4 Response to D.A.B.

The favourable response to DAB from the Bristol Bus Company has already
been mentioned (section 6.1). The County Planning Office appears neutral, and the planning consultants have not yet been approached. The Town Council would probably offer no objection provided the system could pay for itself, although they have not yet been approached. However, both the County and the Town administration would probably require arguments showing that DAB would result in lower congestion levels before contemplating a subsidy. Low income groups in CCK are fairly adequately served by the existing bus service.

The Central government is interested in DAB and at present conducting research into suitable computer software for the British environment.

8.5 Local Media and Public Opinion

The Gloucestershire Echo owned by a national chain, but with local editorship is the only local daily newspaper distributed in Cheltenham. The Cheltenham Chronicle is the weekend pictorial paper. The Echo reflects the conservative politics of the town fairly accurately although editorial opinion is rarely strongly voiced. The principal pressure groups within the town where services and physical change are concerned are the property owners and rates lobby who are very sensitive to increases in the local property tax, or any proposals to demolish their buildings, and the conservationist lobby who is very conscious of the physical quality of the town. Both groups might support DAB even to the extent of a subsidy if the alternative was more expense for road building and demolished property. There is, as yet, no local radio or T.V.
9.0 HARDWARE

9.1 Telephone Coverage (Figs. 37, 38, 39)

The General Post Office (G.P.O.) is the sole operator for all telephones in Britain. Its telephone operations are profitable and tend to subsidize the postal service. The local G.P.O. telephone administration is in Gloucester.

9.1.1 Analysis of Telephone Connections

See Fig. 37. This indicates a total of 19,681 phone connections for an area population of about 100,000. Within the Cheltenham and Charlton Kings district of 31,244 households (excluding businesses) in the area, 10,683 had phones, (ie. exchange connections; phone extensions to be added to this figure). This is 34% of the households served by phone, compared with a National average of 30%.

Fig. 38 shows the analysis of households covered by phone in 1969 and expected coverage by 1981. This indicates an 80% coverage for the Cheltenham area by 1981.

Shared service is not the U.S.A. "H" system, but semi-selective two-party lines.

9.1.2 Costs of Installation and Renting

The connection charge for a telephone is £25, plus £20 a year rental for residential use (£16 if shared), and £24 a year rental for business
use. The charges are rising on the average at 4% to 5% to a year.

9.1.3 Expansion of Telephone Service

The Cheltenham exchange has capacity for three more years, but extensions are being planned to meet the excess expected by that time. As fig. 37 shows, expected increase in phone connections is in the order of 140% by 1981. The General Post Office is trying to encourage shopkeepers to rent portable public phones (see fig. 38). There is not much demand for these at present, but if the town decided to use the DAB system, they might consider a subsidy to shopkeepers to instal the phones, thus increasing phone coverage in the town centre.

9.1.4 Touch-tone Phones

No touch-tone phones in the area yet. Installation expected to begin in the area in about three years time. Complete changeover to touch-tone could take another ten years.

9.2 Computer Accessibility

9.2.1 Local Service

The following organisations rent computer time. However, not all are on I.B.M. 360s, and the rental is largely data bank.

Shire Hall, Gloucester. 48K store.


Bristol Bus Company also has its own computer at Bristol. However, the manager could not confirm whether it was suitable for on line service for DAB.

9.2.2 On Line Service

Computer rental services exist in London and Birmingham and include I.B.M. 360s. Rental rates to be ascertained. The G.P.O. provides 2,400 volt computer connections for on line transmission day and night all year round. Costs for hiring the line only is about £1,400 per year.

9.2.3 Radio Frequencies

For operating on-board bus computers, G.P.O. officials said that radio frequencies in V.H.F. are very limited, due to bands taken by Police, ambulance, fire service, radio, television and continental services.

9.3 Minibus Vehicles Available in U.K. (See Figs. 40, 41)

British Leyland, the largest bus manufactures in Britain were asked what products, plans or studies they had for small busses (10-20 people) and any special designs suitable for town use (low loading platforms, easy access etc.), together with any costs they may have for supplying such vehicles. Fig. 40 is a copy of their reply, and Fig. 41 an illustration of the closest vehicle to my description that they produce.

Although my investigation has not been comprehensive, it appears
that Sparshatt's, Mercedes, Volkswagen & Ford produce viable sizes of mini-busses. None of them however, except the Mercedes, appear particularly suitable or attractive to use in launching an entirely new urban transport service such as DAB.

To reduce the research, development, and lower production costs significantly for a specially designed vehicle, several towns may have to combine to place sufficient orders.

The manager of the Bristol Bus Company mentioned the possibility of using the existing single decker (44 seats), or double decker (58 seats) buses for off peak DAB.

The Ford (U.S.) Econoline (fig. 42B) is another suitable contender for DAB. Costing $6,000 - $7,000 in U.S., its fuel consumption is 9.0-9.5 M.P.G. (U.S. gals.) with 14 seats and space for 5 standing. The bus is being used in a minibus service in Mansfield, Ohio. I am at present obtaining information on its importation & costs in the U.K.
10.0 PRELIMINARY ESTIMATE OF SERVICE AREAS AND DEMAND FOR DAB

The purpose of this section is to make a rough estimate of demand for DAB, so that the geographic areas of operation can be defined, and any further data needs uncovered.

10.1 Objectives

Sections 1.2 and 6.1 describe the objectives that a DAB service seeks to satisfy. They may now be summarised as follows:

1. To reduce urban congestion and vehicle travel movements.
2. To offer a higher level of public transport service.
3. To complement existing bus service, where they are profitable.

10.2 Likely Service Areas (Figs. 43, 44, 45)

Several factors combine to suggest that these objectives are both complementary and best realised by introducing a DAB service in an arc encompassing the southern portion of the CCK (see fig. 43). These are town wards comprising the higher income areas where car ownership per household is higher and thereby produce the highest number of non-transit trips, thus contributing disproportionately to the town's urban congestion. The higher car ownership, and lower population densities has led to a lower level of bus service in these areas. The lower frequency of the bus routes in these wards (routes nos. 587, 596, 597) indicate their lower profitability. All routes except nos. 588/9 and 592 are at 30 min. intervals or more. Route no. 592 extends only a short distance into the selected area, and 588/9 gain their profitability at this end of run, largely
by serving the Charlton Kings shopping area, a concentrated destination that is unlikely to be affected by introducing DAB. A DAB service would thus offer a public transport service in this area, and one likely both to divert a proportion of auto trips, and to serve non car drivers, such as the aged and women who are often isolated without an adequate bus service. The desire lines shown on fig. 20 indicate a substantial cross town movement within our suggested area, and some of this may be captured by a DAB service. The northern sector of the town does not have so many cross-town movements, possibly due to the network barriers of the Pittville Park area, and to two employment centres (government offices) lying on to the west and north east perimeters the town and served by higher income groups in our suggested area in the south.

These wards are also likely to be the most suitable for DAB, all having gross population densities between 4,000 and 10,000 per sq. mile are indicated as the most suitable for DAB operation, from simulation studies in the U.S.A. Telephone coverage is also likely to be higher in these higher income areas. The wards having densities below 10,000 per sq. mile, but excluded from the proposed full service DAB operation area are those dominated by lower income residents and well served by existing profitable bus routes (CCC and CCI). Operationally, DAB in the selected area would service all requested origins and destinations, and would service destinations, but not origins, outside the area, except at the town centre, where DAB service would be provided at one or two points in the centre to serve only those tripmakers returning to the service area.
It also appears that a considerable area outside the CCK has residential densities within the range of 1,000-10,000 persons/sq. mile. They comprise areas contiguous to the CCK in the south (Shurdington, Leckhamptin, Benhall for example) and to the north (Prestbury, Swindon Village, possibly Bishops Cleeve) and the present bus services to these areas are infrequent (eg. route 587). These new suburbs are rapidly forming a small metropolitan area outside the present confines of the CCK, and information on them is at present being sought, in order to include them in the next stage of the analysis.

Within the CCK, the least profitable period for bus operations is the off-peak between 7 and 11 p.m. It seems worthwhile to estimate the demand in the remaining wards in the CCK for this period to see whether an evening DAB service would be feasible.

One of the objectives is to maintain the profitable main line bus services. It would seem worthwhile to calculate the number of riders who would be captured from these profitable lines if DAB were introduced in these areas, and to find the overall profitability and service offered, if both systems were run together.

10.3 Preliminary Estimate of Demand for DAB within Selected Wards of CCK (Figs. 35, 43, 45, 46, 47)

Increase in trip-making has been shown to be closely and positively correlated with increase in income, and car ownership and demand for DAB in this study has been based on trip-making as a function of income. No average income by wards was available, so the analyses of the London
Traffic Survey (1964) were used where they appear applicable to Cheltenham. Fig. 35 shows some principal points of the study, and that household size is almost the same in London as for Cheltenham. Fig. 46 indicates the rise in trip-making by household income for car owning and non car owning households, and an average of 6.8 trips for all households is shown from the incomes described in section 4.2. 6.8 is possibly on the low side as the LTS shows 7.4 trips per household at suburban locations 14 miles from the centre, similar to CCK study area suburbs and the survey also indicated that households in larger cities make fewer trips than those in smaller ones.

The total trips per ward on fig. 47 were then developed from this trip generation per household. Fig. 48 is based on the percentage of the trip making market estimated for DAB in the Manchester N.H. Study. Manchester has similar characteristics as Cheltenham except for a much poorer bus service. However, the bus service within the selected CCK area is also poor and the suburban households more closely approach the New Hampshire car ownership average. The percentages are also based on U.S. costs for running DAB. The phone coverage has been taken as higher than the Cheltenham average, since incomes in these wards are higher. The resultant demands of 30 per sq. mile per hour compare favourably with the 20 demands per sq. mile per hour estimated as a minimum for a profitable operation in the U.S.A. However, at this rate of demand we can rapidly see that DAB would not be feasible for an evening only service throughout the CCK (ref. fig. 47 table B).
There are three factors that may increase the demand for DAB above that shown. 1. The lower labour costs for bus drivers in the U.K. 2. The high proportion of visitors to the town, some of which may wish to visit town residents. 3. The high proportion of elderly some of who may wish to travel, but are immobile, and who cannot afford the taxi fare, but might afford DAB, and would form a new market above the 6.8 trips per household. 4. Variation in telephone coverage, or policies to introduce DAB phones.

These factors will be more closely analysed in the thesis where a DAB cost analysis will be developed for U.K. costs, and a demand analysis developed for a segmented market, plotting demand for DAB by value of door to door journey time for each market segment on diversion curves against auto and bus travel time. The last question in section 10.2, namely, how far DAB would divert bus riders if both systems were implemented throughout the CCK, and the implications of this, will also be answered by reference to diversion curves.

10.4 Conclusion

This preliminary demand analysis indicates that:
1. DAB is likely to be viable within the study area.
2. DAB would not be viable as an evening only service throughout the CCK.
3. Areas outside the CCK may be viable for DAB while not conflicting with profitable main line bus services.
4. Further information is desirable on:
   a. Suburbs surrounding CCK.
b. More detailed information on trips by auto owner, auto passenger, 
bush passenger, and the split between work & recreation trips.
c. Income by wards.
d. More detailed breakdown of telephone coverage by wards.
Sub-region's share of U.K. population increase

The population expansion is clear in the sequence of figures, expanding from 2% to 27%. Previous requirements of the hat sequence con-require increases to the industrial 66%, while 76% is able to an, the

The trialisation portion here is, region in of the compared fever, slightly of ser than a as of the Sub-regional wealth, and age...
NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

POPULATION DISTRIBUTION
1966

APPROXIMATE NUMBER OF PERSONS

- 1000 (range: less than 1500)
- 2000 (range: 1500 – 2500)
- 3000 (range: 2500 – 3500)
Sub-region's total employment distribution

NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

DISTRIBUTION OF TOTAL EMPLOYMENT 1966

APPROXIMATE NUMBER OF JOBS

- 1000 (range: 750 - 1250)
- 1500 (range: 1250 - 1750)
- 2000 (range: 1750 - 2250)

Note:
Locations in rural areas with less than 750 jobs are not shown. Employment thus excluded from this map amounts to about 21,000.
NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

DISTRIBUTION OF
BASIC EMPLOYMENT
1966

APPROXIMATE NUMBER OF JOBS

- 1000 (range: 750 - 1250)
- 1500 (range: 1250 - 1750)
- 2000 (range: 1750 - 2250)
- Jobs in engineering and metals group

Note:
Locations in rural areas with less than 750 jobs are not shown. Employment thus excluded from this map amounts to about 21,000.
NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

DISTRIBUTION OF
SERVICE EMPLOYMENT
1966

APPROXIMATE NUMBER OF JOBS

- 1000 (range: 750 - 1250)
- 1500 (range: 1250 - 1750)
- 2000 (range: 1750 - 2250)

Note:
Locations in rural areas with less than 750 jobs are not shown. Employment thus excluded from this map amounts to about 21000.
Communications in the sub-region

NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

COMMUNICATIONS

Motorways:
- existing
- proposed

Trunk and other "A" class roads

"B" class roads

Railways and passenger stations

Canal

Commercial airport

Fig. 7
Journey to work volumes in the sub-region

NORTH GLOUCESTERSHIRE
SUB-REGIONAL STUDY

JOURNEYS TO WORK
1966

WORKING POPULATION/EMPLOYMENT
(NUMBER IN THOUSANDS)

THE INTERNAL CIRCLE INDICATES THE DIFFERENCE BETWEEN
THE WORKING POPULATION AND THE EMPLOYMENT IN AN AREA:

Employment exceeds working population

Working population exceeds employment

JOURNEY TO WORK FLOWS
(NUMBER IN THOUSANDS)

Approximate boundaries of "employment areas"
LANDSCAPE FACTORS

Areas of outstanding natural beauty

Proposed area of outstanding natural beauty

Dean forest park

Areas elsewhere of high landscape value

Areas elsewhere of intermediate landscape value

Electricity transmission lines:
- 275 - 400 KV
- 133 KV
## LAND USE OF CHELTENHAM AND CHARLTON KINGS BY AREA IN SQUARE MILES

<table>
<thead>
<tr>
<th>Land use</th>
<th>Designation on town maps</th>
<th>Cheltenham central area</th>
<th>Rest of CCK</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Govt. offices (national)</td>
<td>GO</td>
<td>3/8</td>
<td></td>
<td>3/8</td>
</tr>
<tr>
<td>Business offices</td>
<td>Ba</td>
<td>1/8</td>
<td></td>
<td>1/8</td>
</tr>
<tr>
<td>Civic, cultural</td>
<td>C</td>
<td>1/16</td>
<td>1/16</td>
<td>1/8</td>
</tr>
<tr>
<td>School &amp; playing fields</td>
<td>PS SS</td>
<td>3/8</td>
<td></td>
<td>3/8</td>
</tr>
<tr>
<td>Shopping</td>
<td>Sa</td>
<td>3/16</td>
<td>1/16</td>
<td>1/4</td>
</tr>
<tr>
<td>Net residential</td>
<td>Ra (dev. only rest in undev. land)</td>
<td>1/8</td>
<td>4 5/8</td>
<td>4 3/4</td>
</tr>
<tr>
<td>Industrial</td>
<td>In CEGB, MEB</td>
<td>3/8</td>
<td></td>
<td>3/8</td>
</tr>
<tr>
<td>Railway</td>
<td>Ry</td>
<td>1/16</td>
<td>3/8</td>
<td>7/16</td>
</tr>
<tr>
<td>Refuse, water, sewage works</td>
<td>SD WW SW</td>
<td>1/16</td>
<td></td>
<td>1/16</td>
</tr>
<tr>
<td>Inst. &amp; Pub. open space (ie. public parks, allotments, cemeteries)</td>
<td>GR 0 POS</td>
<td>1/16</td>
<td>1 7/8</td>
<td>1 15/16</td>
</tr>
<tr>
<td>Agricultural, green belt and undeveloped land</td>
<td>GB and Ra (undev.)</td>
<td>1 3/8</td>
<td></td>
<td>1 3/8</td>
</tr>
<tr>
<td>Area of great landscape value (very unlikely to be built on)</td>
<td>VL</td>
<td>1 11/16</td>
<td>1 11/16</td>
<td></td>
</tr>
</tbody>
</table>

**TOTALS**                                          | 1/2                      | 11                      | 11 1/2      |

Note: "Central Area" as designated on town map

**SOURCE:** Cheltenham Town Map, gridded and computed visually.
CHELTENHAM CENTRE (1/2 sq. mile total area)

LAND USES AS PERCENTAGE OF TOTAL

<table>
<thead>
<tr>
<th>Use</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>25</td>
</tr>
<tr>
<td>Industry incl. garages</td>
<td>8</td>
</tr>
<tr>
<td>Unused land</td>
<td>10</td>
</tr>
<tr>
<td>Storage bldgs, yards</td>
<td>4</td>
</tr>
<tr>
<td>Civic buildings</td>
<td>10</td>
</tr>
<tr>
<td>Public Open Space</td>
<td>10</td>
</tr>
<tr>
<td>Residential</td>
<td>33</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>
KEY TO LAND USES SHOWN IN FIG. 12

Municipal boundaries

Central area

Outstanding natural landscape

Undev. land & green belt

Railway

Industrial

Govt. offices

Institutional & public open space

Schools, colleges

Commercial

Residential
CCK major land uses

Fig. 12
**CHELTENHAM AND CHARLTON KINGS EMPLOYMENT 1966**

<table>
<thead>
<tr>
<th></th>
<th>Cheltenham</th>
<th>C.K.</th>
<th>Total C.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td>21,371</td>
<td>2,702</td>
<td>24,073</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td>13,168</td>
<td>1,406</td>
<td>14,574</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>38,647</td>
</tr>
</tbody>
</table>

Source: 1966 10% sample census

Of the above total:

- **Manufacturing, Construction, Gas, Water, Electricity employment**: 14,994 @ 40%
- **Transport, Distribution, Civilian Services, national and local government**: 14,280 @ 38%
- **Professional and Employer**: 7,730 @ 18%

Source: sub-regional study
<table>
<thead>
<tr>
<th>TRAFFIC ZONE</th>
<th>RESIDENT POPULATION</th>
<th>NO. OF CARS</th>
<th>NO. RESIDENTS</th>
<th>EMPLOYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,800</td>
<td>290</td>
<td>6.2</td>
<td>5,300</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>80</td>
<td>6.25</td>
<td>6,900</td>
</tr>
<tr>
<td>3</td>
<td>1,000</td>
<td>170</td>
<td>5.9</td>
<td>2,000</td>
</tr>
<tr>
<td>4</td>
<td>3,600</td>
<td>380</td>
<td>9.5</td>
<td>1,200</td>
</tr>
<tr>
<td>5</td>
<td>2,200</td>
<td>510</td>
<td>4.3</td>
<td>700</td>
</tr>
<tr>
<td>6</td>
<td>2,100</td>
<td>470</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>2,400</td>
<td>440</td>
<td>5.5</td>
<td>500</td>
</tr>
<tr>
<td>8</td>
<td>2,700</td>
<td>590</td>
<td>4.6</td>
<td>300</td>
</tr>
<tr>
<td>9</td>
<td>400</td>
<td>90</td>
<td>4.4</td>
<td>400</td>
</tr>
<tr>
<td>10</td>
<td>800</td>
<td>140</td>
<td>5.7</td>
<td>800</td>
</tr>
<tr>
<td>11</td>
<td>700</td>
<td>150</td>
<td>4.7</td>
<td>1,100</td>
</tr>
<tr>
<td>12</td>
<td>1,400</td>
<td>240</td>
<td>5.8</td>
<td>2,400</td>
</tr>
<tr>
<td>13</td>
<td>1,300</td>
<td>240</td>
<td>5.4</td>
<td>900</td>
</tr>
<tr>
<td>14</td>
<td>2,200</td>
<td>590</td>
<td>3.7</td>
<td>100</td>
</tr>
<tr>
<td>15</td>
<td>2,900</td>
<td>520</td>
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<td>500</td>
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<tr>
<td>16</td>
<td>4,300</td>
<td>490</td>
<td>8.8</td>
<td>900</td>
</tr>
<tr>
<td>17</td>
<td>100</td>
<td>20</td>
<td>5.0</td>
<td>3,200</td>
</tr>
<tr>
<td>18</td>
<td>400</td>
<td>100</td>
<td>4.0</td>
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</tr>
<tr>
<td>19</td>
<td>3,900</td>
<td>910</td>
<td>4.3</td>
<td>400</td>
</tr>
<tr>
<td>20</td>
<td>4,800</td>
<td>1,260</td>
<td>3.8</td>
<td>700</td>
</tr>
<tr>
<td>21</td>
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<td>850</td>
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<td>800</td>
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<td>23</td>
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<td>840</td>
<td>4.0</td>
<td>1,400</td>
</tr>
<tr>
<td>24</td>
<td>3,000</td>
<td>680</td>
<td>4.4</td>
<td>100</td>
</tr>
<tr>
<td>25</td>
<td>4,300</td>
<td>1,080</td>
<td>4.0</td>
<td>1,000</td>
</tr>
<tr>
<td>26</td>
<td>5,300</td>
<td>1,370</td>
<td>3.9</td>
<td>500</td>
</tr>
<tr>
<td>27</td>
<td>3,500</td>
<td>850</td>
<td>4.1</td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>29</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>4,100</td>
<td>780</td>
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<td>400</td>
</tr>
<tr>
<td>31</td>
<td>4,500</td>
<td>720</td>
<td>6.25</td>
<td>1,400</td>
</tr>
<tr>
<td>32</td>
<td>5,300</td>
<td>850</td>
<td>6.2</td>
<td>400</td>
</tr>
<tr>
<td>33</td>
<td>7,800</td>
<td>1,350</td>
<td>5.8</td>
<td>1,300</td>
</tr>
<tr>
<td>34</td>
<td>100</td>
<td>30</td>
<td>3.3</td>
<td>2,300</td>
</tr>
<tr>
<td>35</td>
<td>2,500</td>
<td>300</td>
<td>8.3</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Rest of Prestbury: 4,100 cars; 1,050 residents; 3.9 cars per resident; 300 employment
Rest of Lechampton: 1,800 cars; 290 residents; 3.1 cars per resident; 100 employment
Shurdington: 1,800 cars; 500 residents; 3.6 cars per resident; 500 employment
Badgeworth (past): 1,300 cars; 560 residents; 2.3 cars per resident; 100 employment
Staverton: 600 cars; 170 residents; 3.5 cars per resident; 400 employment
Vckington: 1,500 cars; 480 residents; 3.1 cars per resident; 100 employment
Rest of Swindon: 5,300 cars; 6,900 residents; 4.0 cars per resident; 1,600 employment

Source: Calculations by Gloucestershire County Planning Office
CHELTENHAM AND CHARLTON KINGS. DEMOGRAPHIC

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 19</td>
<td>31%</td>
<td>51%</td>
</tr>
<tr>
<td>20- 59</td>
<td>49%</td>
<td>52%</td>
</tr>
<tr>
<td>60+</td>
<td>20%</td>
<td>72%</td>
</tr>
</tbody>
</table>

Source: 1966 10% Sample Census

HOUSEHOLD SIZE AND COMPOSITION (for sub-region and CCK)

<table>
<thead>
<tr>
<th>Year</th>
<th>Persons per household</th>
<th>Percentage of elderly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1931</td>
<td>3.60</td>
<td>10.30</td>
</tr>
<tr>
<td>1951</td>
<td>3.23</td>
<td>11.61</td>
</tr>
<tr>
<td>1961</td>
<td>3.11</td>
<td>12.05</td>
</tr>
<tr>
<td>1966</td>
<td>3.02</td>
<td>12.66</td>
</tr>
<tr>
<td>1966 (Cheltenham and Charlton Kings)</td>
<td>2.90</td>
<td>? estimate 13.50</td>
</tr>
</tbody>
</table>

Source: Sub-regional study, and U.K. Census 1931-1966

ETHNIC

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Cheltenham</th>
<th>Charlton Kings</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irish (N.Ireland &amp; Eire)</td>
<td>1,480</td>
<td>150</td>
<td>1,630</td>
</tr>
<tr>
<td>Australia, Canada, N.Z.</td>
<td>150</td>
<td>40</td>
<td>190</td>
</tr>
<tr>
<td>Commonwealth and Colonies</td>
<td>910</td>
<td>90</td>
<td>1,000</td>
</tr>
<tr>
<td>Foreign Countries and at sea</td>
<td>1,840</td>
<td>370</td>
<td>2,210</td>
</tr>
</tbody>
</table>

Source: 1966 10% Sample Census (figures grossed up)
Income zones, by income quintile

1 = highest income
5 = lowest income

Fig. 17
Diagram shows all stopping and through traffic 8am—6pm, two way flows, in PCUs. Information obtained from Origin and Destination Census October 1963.
CHELTENHAM AUTO TRAVEL TIMES

TIMED SATURDAY 12:30 P.M. 22 AUGUST 1970

(See route map fig. 22)

<table>
<thead>
<tr>
<th>Place</th>
<th>Time</th>
<th>Distance</th>
<th>Av. speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>JOURNEY 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prestbury/ Tatchley Lane</td>
<td>12.27</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pittville Circus</td>
<td>12.30</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Winchcombe St./Albion St.</td>
<td>12.32</td>
<td>1/6</td>
<td></td>
</tr>
<tr>
<td>Promenade/ St. Georges Rd.</td>
<td>12.37</td>
<td>3/4</td>
<td></td>
</tr>
<tr>
<td>Promenade/ Montpellier</td>
<td>12.39</td>
<td>3/4</td>
<td></td>
</tr>
<tr>
<td>Lansdown Rd./ Shelboure Rd.</td>
<td>12.41</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Queen Elizabeth Square</td>
<td>12.44</td>
<td>1/6</td>
<td>@13 m.p.h.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17 mins</td>
<td>3 5/6 miles</td>
<td></td>
</tr>
<tr>
<td><strong>JOURNEY 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lansdown Rd./Shelboure Rd.</td>
<td>12.51</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Suffolk Rd./ Bath Rd.</td>
<td>12.54</td>
<td>1 1/6</td>
<td></td>
</tr>
<tr>
<td>Old Bath Rd./ London Rd.</td>
<td>12.56</td>
<td>5/6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5 mins</td>
<td>2 miles</td>
<td>@24 m.p.h.</td>
</tr>
<tr>
<td><strong>JOURNEY 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>London Rd./Hearn Rd. (CK)</td>
<td>1.00</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Old Bath Rd./London Rd.</td>
<td>1.04</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>London Rd./ Hewlett Rd.</td>
<td>1.06</td>
<td>1/4</td>
<td></td>
</tr>
<tr>
<td>High St./ Promenade</td>
<td>1.08</td>
<td>1/4</td>
<td></td>
</tr>
<tr>
<td>L. High St./ New St.</td>
<td>1.10</td>
<td>1/3</td>
<td></td>
</tr>
<tr>
<td>L. High St./ Gloucester Rd.</td>
<td>1.12</td>
<td>1/3</td>
<td></td>
</tr>
<tr>
<td>Tewkesbury Rd./ Q.E.Way</td>
<td>1.17</td>
<td>5/6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17 mins</td>
<td>3 1/2 miles</td>
<td>@12 m.p.h.</td>
</tr>
<tr>
<td><strong>JOURNEY 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. High St./ Gloucester Rd.</td>
<td>1.22</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>L. High St./ Promenade</td>
<td>1.24</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>Winchcombe St./Albion St.</td>
<td>1.26</td>
<td>1/6</td>
<td></td>
</tr>
<tr>
<td>London Rd./ Hewlett Rd.</td>
<td>1.27</td>
<td>1/3</td>
<td></td>
</tr>
<tr>
<td>Bouncers Lane/ Prestbury Rd.</td>
<td>1.31</td>
<td>1 2/3</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9 mins</td>
<td>2 2/3 miles</td>
<td>@17 m.p.h.</td>
</tr>
</tbody>
</table>

- 218 -
CHELTENHAM CENTRAL AREA
TRAFFIC VOLUMES AND PEAKING CHARACTERISTICS

1963

Traffic to areas within cordon 61.1%
Traffic to suburbs from areas within cordon 26.8%
External traffic 12.1%

Source: Cheltenham Town Plan. Survey 1963 - 221 -
Diagram shows all stopping and through traffic 8am-6pm two way flows in PCUs
Projected from 1963 Census, allowing for expected population changes & motorway losses
### Table: C&K Journey to Work Matrix

10% Sample by Ward Zone

*Source: 1966 Sample Census*

<table>
<thead>
<tr>
<th>FROM TO</th>
<th>ABCDE</th>
<th>FGHI</th>
<th>ABCDEFGHJKL</th>
<th>MNOPQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Fig. 27**

C&K Journey to Work Matrix

10% Sample by Ward Zone

*Source: 1966 Sample Census*
<table>
<thead>
<tr>
<th>Description</th>
<th>Week 4 1970</th>
<th>% Change</th>
<th>Total 28 Weeks</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Services</td>
<td>403,184</td>
<td>42.24</td>
<td>37,810</td>
<td>1.23</td>
</tr>
<tr>
<td>Express Services</td>
<td>25,713</td>
<td>36.16</td>
<td>707</td>
<td>1.17</td>
</tr>
<tr>
<td>Excursions and Tours</td>
<td>1,648</td>
<td>42.31</td>
<td>576</td>
<td>3.37</td>
</tr>
<tr>
<td>Contract Carriage</td>
<td>22,297</td>
<td>32.17</td>
<td>1,550</td>
<td>3.04</td>
</tr>
<tr>
<td><strong>Total Passenger Revenue</strong></td>
<td>452,842</td>
<td>40.67</td>
<td>34,777</td>
<td>2.42</td>
</tr>
<tr>
<td>Miscellaneous Revenue (Sheet 4)</td>
<td>4,148</td>
<td>.36</td>
<td>5,524</td>
<td>.51</td>
</tr>
<tr>
<td><strong>TOTAL REVENUE</strong></td>
<td>456,990</td>
<td>41.35</td>
<td>29,453</td>
<td>1.91</td>
</tr>
<tr>
<td><strong>VEHICLE LICENCE DUTIES</strong></td>
<td>E1</td>
<td>2,700</td>
<td>2.67</td>
<td>30</td>
</tr>
<tr>
<td><strong>TOTAL EXPENSES</strong></td>
<td>455,757</td>
<td>44.07</td>
<td>79,269</td>
<td>6.79</td>
</tr>
<tr>
<td><strong>HIRE CHARGES FOR VEHICLES</strong></td>
<td>G1</td>
<td>10,638</td>
<td>25.43</td>
<td>+ 473</td>
</tr>
<tr>
<td><strong>TOTAL WORKING EXPENSES</strong></td>
<td>473,025</td>
<td>42.67</td>
<td>87,747</td>
<td>6.51</td>
</tr>
<tr>
<td><strong>NET REVENUE</strong></td>
<td>8,537</td>
<td>(-)</td>
<td>56,724</td>
<td>+ 4,600</td>
</tr>
</tbody>
</table>

Note: Figures are rounded to the nearest whole number.
**ANALYSIS OF BUS SERVICE FROM TIME TABLES**

<table>
<thead>
<tr>
<th>Bus route nos.</th>
<th>Service frequency (Weekday &amp; Saturday)</th>
<th>Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>590* &amp; 591*</td>
<td>12 min.</td>
<td>7 a.m. - 7 p.m.</td>
</tr>
<tr>
<td></td>
<td>15 min.</td>
<td>7 p.m. - 11 p.m.</td>
</tr>
<tr>
<td>588</td>
<td>12 min.</td>
<td>7 a.m. - 7 p.m.</td>
</tr>
<tr>
<td>589</td>
<td>30 min.</td>
<td>7 p.m. - 11 p.m.</td>
</tr>
<tr>
<td>592</td>
<td>15 min.</td>
<td>7 a.m. - 11 p.m.</td>
</tr>
<tr>
<td>594</td>
<td>30 min.</td>
<td>6 p.m. - 11 p.m.</td>
</tr>
<tr>
<td>595</td>
<td>30 min.</td>
<td>7 a.m. - 11 p.m.</td>
</tr>
<tr>
<td>597</td>
<td>60 min.</td>
<td>7 a.m. - 11 p.m.</td>
</tr>
<tr>
<td>598</td>
<td>60 min.</td>
<td>7.30 a.m. - 11.30 p.m.</td>
</tr>
</tbody>
</table>

* from 8 a.m. - 9 a.m. duplicate busses run on this route

(for 5 duplicate journeys). Busses 90% full.

Bus routes listed in rough order of frequency of service.

Sunday busses run on all routes with average frequencies of 1 hour.

Source: Bristol Bus Co., Cheltenham Office.
### BUS RECEIPTS FOR TYPICAL WEEK

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>£</td>
<td></td>
</tr>
<tr>
<td>2453</td>
<td>2646</td>
<td>587</td>
</tr>
<tr>
<td>3695</td>
<td>4181</td>
<td>588/9</td>
</tr>
<tr>
<td>5120</td>
<td>5706</td>
<td>590/1</td>
</tr>
<tr>
<td>3026</td>
<td>3281</td>
<td>592</td>
</tr>
<tr>
<td>3473</td>
<td>3840</td>
<td>594</td>
</tr>
<tr>
<td>1580</td>
<td>1833</td>
<td>596</td>
</tr>
<tr>
<td>527</td>
<td>586</td>
<td>597</td>
</tr>
<tr>
<td>191</td>
<td>211</td>
<td>598</td>
</tr>
<tr>
<td>56</td>
<td>57</td>
<td>- GCHQ services</td>
</tr>
<tr>
<td>143</td>
<td>69</td>
<td>- Dowty's</td>
</tr>
<tr>
<td>106</td>
<td>84</td>
<td>- GCHQ</td>
</tr>
</tbody>
</table>

N.B. Bus miles approx. equal over these last 3 years.

Ridership approx. same over these last 3 years.

---

### FARES in 1970 (since 28 June rise)

Passanger pays over one mile of ride approx 7d
- " " " two " " " " 1/-
- " " " three " " " " 1/5

Children up to 14 and scholars up to pay 1/2 fare
Proportion 1/2 fare riders of total ridership. 14% approx.

Source: Bristol Bus Co., Cheltenham Office
CCK BUS OPERATIONS
PERSONNEL, PAY RATES, WORKING HOURS, NO. OF BUSES

Drivers of one man busses 19
Drivers of two man busses 45
Conductors 45

Hourly pay rate for bus drivers (one man bus) 11:2 27/40d
" " " " " " (two man bus) 9:7 1/4d
" " " " " conductors 9:1 1/4d

Total hours per 6 day week worked by drivers (one man bus) 40
" " " " " " " " (two man bus) 40
" " " " " " " conductors 40

Total hours Sunday worked by drivers (one man bus) 6 hrs. 40 mins.
" " " " " " " (two man bus) 6 hrs. 40 mins.
" " " " " " conductors 6 hrs. 40 mins.

Passenger capacity of 1 double decker bus (seated) 58 and 70
" " " " " " (seated & standing) 66 and 78
" " " " " single decker bus (seated) 44
" " " " " (seated & standing) 52
No. of double decker busses in use per day in CCK 24
" " single " " " " " 8

Source: Bristol Bus Co., Cheltenham Office
FIG. 33

CAR OWNERSHIP BY COUNTY ZONE

Each circle represents approx. 500 cars.

No. of cars per person indicated.

eg. Cheltenham 0.190

Source: Gloucestershire County Surveyor's Office
CCK AUTO OWNERSHIP

<table>
<thead>
<tr>
<th>Year</th>
<th>Auto ownership per 1000 persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>75</td>
</tr>
<tr>
<td>1966</td>
<td>200</td>
</tr>
<tr>
<td>1985</td>
<td>400</td>
</tr>
</tbody>
</table>

Source: Cheltenham Town Plan. 1963 survey.

The 1966 figures are confirmed by the 10% sample census which yeilds a figure of 16,502 cars for 83,640 people.

The 1967 County Automobile survey yeilded .190 cars per person for CCK, or 5.1 person/car.
LONDON TRAFFIC SURVEY 1964

Average household size 2.87 persons
Mean annual income per household in 1962 £1,160
    of which 14% up to £500
    54% up to £1000
No. of households with cars 38%

Car owners make more than 2 times the number of trips as non-car owning population ie. 6.46 trips/day, instead of 3.38 per household.

7.4 trips/day at 14 miles from city centre.

Households earning £2000 make 40% more trips than households earning £1000.

88% of all trips are home-based.
DAILY TRIP MOVEMENTS IN CCK 1966
(Source: 1966 Sample Census)

A. Daily Residence to Workplace. One way moves by wards.
(refer also to ward map, fig.13) CB and all CC's developed from fig.13

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>1336</td>
<td>3120</td>
<td>3038</td>
<td>2130</td>
<td>7598</td>
<td>836</td>
<td>3274</td>
<td>3018</td>
<td>2274</td>
<td>2968</td>
</tr>
</tbody>
</table>

Source: Developed from Cheltenham Traffic Survey (1969), from 1966 Sample Census grossed up.

B. Daily Residence to Workplace. One way moves by 3 way Modal split.

<table>
<thead>
<tr>
<th></th>
<th>Public Transport</th>
<th>Auto and other private transp.</th>
<th>Foot and pedal cycle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chelt.MB</td>
<td>4,446</td>
<td>10,414</td>
<td>11,658</td>
<td>26,520</td>
</tr>
<tr>
<td>C.K. UD</td>
<td>632</td>
<td>2,538</td>
<td>856</td>
<td>4,020</td>
</tr>
<tr>
<td>Total</td>
<td>5,078</td>
<td>12,952</td>
<td>12,514</td>
<td>30,540</td>
</tr>
</tbody>
</table>

Source: 1966 10% sample census grossed up. (NB total in table A is more accurate)

Resulting Modal Split for residence/workplace
Bus 16%. Cycle and walk 41%. Auto and private 43%.

C. Total no. of moves by activity and mode, per day.

<table>
<thead>
<tr>
<th></th>
<th>Recreational*</th>
<th>Work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. week day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto</td>
<td>25,800</td>
<td>25,800</td>
<td>51,600</td>
</tr>
<tr>
<td>Bus</td>
<td>12,160</td>
<td>3,840**</td>
<td>9,600</td>
</tr>
<tr>
<td>Foot &amp; cycle</td>
<td>24,600 (poss.less)</td>
<td>24,600</td>
<td>49,200</td>
</tr>
<tr>
<td>Total</td>
<td>66,400</td>
<td>60,000</td>
<td>126,400</td>
</tr>
</tbody>
</table>

* Recreational calculated as equal to work moves (ref. section 3.7)
** School ridership (estimated 14% of total)
*** Approx. daily ridership (from Bristol Bus Co. receipts)
### TELEPHONE EXCHANGE CONNECTIONS IN 1969

<table>
<thead>
<tr>
<th>TOWN</th>
<th>BUSINESS PHONES</th>
<th>BUSINESS SHARED SERVICE</th>
<th>COIN BOX</th>
<th>RESIDENTIAL RENTED PHONES</th>
<th>RESIDENTIAL SHARED PERCENTAGE</th>
<th>KIOSKS</th>
<th>TOTAL PHONE CONNECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheltenham &amp; Charlton Kings</td>
<td>3,981</td>
<td>69</td>
<td>250</td>
<td>6,229</td>
<td>4,975</td>
<td>114</td>
<td>15,704</td>
</tr>
<tr>
<td>Prestbury</td>
<td>93</td>
<td>6</td>
<td>406</td>
<td>250</td>
<td></td>
<td></td>
<td>755</td>
</tr>
<tr>
<td>Shurdington</td>
<td>65</td>
<td>8</td>
<td>165</td>
<td>147</td>
<td>3</td>
<td></td>
<td>392</td>
</tr>
<tr>
<td>Andoversford</td>
<td>75</td>
<td>3</td>
<td>152</td>
<td>144</td>
<td>8</td>
<td></td>
<td>288</td>
</tr>
<tr>
<td>Winchcombe</td>
<td>139</td>
<td>6</td>
<td>330</td>
<td>179</td>
<td>6</td>
<td></td>
<td>667</td>
</tr>
<tr>
<td>Churchdown</td>
<td>225</td>
<td>15</td>
<td>659</td>
<td>789</td>
<td>18</td>
<td></td>
<td>1,775</td>
</tr>
<tr>
<td><strong>Total for area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>19,681</strong></td>
</tr>
</tbody>
</table>
## TELEPHONE CONNECTIONS - PERCENTAGE COVERAGE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>London area</td>
<td>46%</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Eastern</td>
<td>33%</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>South East</td>
<td>41%</td>
<td>89%</td>
<td></td>
</tr>
<tr>
<td>Midlands</td>
<td>24%</td>
<td>74%</td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>19%</td>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>North West</td>
<td>25%</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>South West</td>
<td>29%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Wales and Marches</td>
<td>20%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>Scotland</td>
<td>31%</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>Northern Ireland</td>
<td>16%</td>
<td>46%</td>
<td></td>
</tr>
</tbody>
</table>

United Kingdom Average       | 77%  | 100% |
Mobile Unit

This is a move-it-where-you-want-it, portable version at no extra cost. In appearance, it's an eye-catching lacquer red, with the handset neatly built-in. It can always be where you and your customers want it most. Just plug its extra long cord into sockets placed where you choose on your premises. If necessary, you can lock it away at the end of the day.
Dear Mr. Williams,

I have received, through our Berkeley Square Offices, your letter dated 23rd June, together with enclosures. Unfortunately, due to holidays and the pressure of business just prior and immediately on my return, I have been unable to reply before now so therefore apologise for the delay. I did try to contact you by telephone on several occasions but unfortunately there was no reply.

It was interesting to learn of the research project you are conducting in regard to the "Dial-a-Bus" system, but in reply to your request for information on the development of small town buses I am afraid I have to disappoint you, because we have nothing available at the moment.

As you are no doubt aware, we, as British Leyland, have for many years produced double and single deck buses designed for heavy duty performance coupled with maximum passenger capacities, and we have never concentrated on the smaller lightweight vehicle with seating capacities of twenty or below. This, of course, has been the policy of Leyland Motors, AEC, Guy, Daimler and Bristol.

Now that we have merged with BMC and formed the British Leyland Corporation, with considerable interest in cars and lightweight commercial vehicles, there is a strong possibility that we may at some time in the future consider producing a specially designed lightweight bus or coach chassis. However, you will appreciate that before a decision of this nature is made, which would involve high capital investment, a detailed survey of the market is necessary to establish volumes etc., and this is currently being done.

At the moment we produce a range of light commercial vehicles which some bodybuilders have used for mounting 12 to 18 seater PSV bodies and in some instances seating capacities up to 22 can be covered.

For your information, I enclose herewith a leaflet describing a body which Sparshatt's have designed suitable for the British Leyland 420 FG and 550 FG range of chassis.

Yours sincerely,

(C R Brown)  
BUS MARKETING MANAGER  

ERB/JT  
11th August 1970
This body is designed for the British Leyland 420 FG 129" wheelbase chassis. It is also designed for the 550 FG chassis, depending on seating capacity.

It offers big bus comfort and space, scaled down to 20 to 22 seats retaining manoeuvrability, small turning circle and ease of handling associated only with lighter chassis.

Sturdy steel frame construction ensures a rigid body and long life whatever the conditions of operation.

Sparshatt custom built-serial construction with standardisation of major components offers a low cost basic body with a wide range of options.

It is available in Service Bus form, as a Semi Luxury Bus, Work’s or School Bus and in other variations to suit customer’s requirements.
CHASSIS:
The Sparshatt 22 seat body is designed specifically for the British Leyland 420 FG 10' 9" wheelbase chassis with an option of six cylinder 4.1 litre petrol engine or four cylinder 3.8 litre diesel engine. Chassis 550 FG is required for certain seating capacities.

INTERIOR:
Photograph on left shows spacious interior with very adequate window area. Seats are well spaced with more than usual leg room.

BODY REAR:
Photograph below illustrates wide swept window with optional luggage boot. Rear registration number is incorporated into an illuminated glass panel.

OPTIONS:
Body options include:
Full range of seating from timber slat service type to full upholstered seats with head rolls.
Large capacity luggage boot.
Luggage rack.
Saloon heater.
Wheel trims.
Radio.
Special paint finish.
Exterior decorative mouldings.
Available to full P.S.V. specification.

DIMENSIONS:
Overall length 19' 6" (5943.6 mm)
Overall width 7' 1" (2159.0 mm)
Overall height 8' 10" (2692.4 mm)
Inside length (saloon) 12' 4" (3752.2 mm)
Inside width 6' 11" (2108.2 mm)
Inside height 5' 11" (1828.0 mm)
Enterance width 2' 2½" (665.75 mm)
Enterance height 6' 3" (1905.0 mm)
Back rest to back rest 2' 1½" (647.7 mm)
Length of seat 2' 11½" (889.0 mm)
Width of gangway 1' 1" (330.2 mm)
Approximate weight unladen (Diesel) 6825lb. (3095 kg.)

SPECIFICATION:
Frame: Heavy duty mild steel sections.
Panels: External: Main side panels 18 gauge aluminium alloy. Front and rear units one piece G.R.P. Mouldings including front screen and rear window frames.
Internal: Side panels plastic faced zinc coated mild steel with front and rear units one piece G.R.P. mouldings. Interior roof also a one-piece G.R.P. colour pigmented panel.
Roof: External roof fully shaped with centre section of 18 gauge aluminium alloy. Front and rear domes are glass fibre mouldings.
Floor: ½" resin bonded ply with heavy linoleum cemented to surface and aluminium treads to centre gangway and floor space between seats.
Windows: Glazed ½" plate safety glass in substantial moulded rubber frames. Windows include top sliding ventilation sections. Front windscreen and rear window are interchangeable curved safety glass units. Window in driver's/Emergency door has sliding hand signal section.
Doors: Passenger entry is by single hinged coach door at the forward end opening on to low stepwell. Alternative door arrangement can be a two-fold jack-knife door either hand or power operated. Emergency door is fitted opposite main door and serves as an access for the driver.
Interior: Seats for 20 to 22 persons. Standard seats have metal frames with cushions and back rests covered P.V.C. with foam rubber upholstery or to customer's requirements. Hand rails are fitted beside passenger entrance in plated steel tube and these include a modesty panel.
Polished mouldings with coloured plastic inserts are fitted to the interior roof full length of body above the window rails and across front and rear.
Driver's seat is bucket type, fully adjustable for height and length. A pull down night blind is fitted behind the driver's seat.
Electrical: Lighting is by means of strip lights mounted above window rails switched from driver's position.
Body rear incorporates tall light cluster.
Body interior fitted with an electric bell with bell pushers.
FOR EXPORT, all wiring is tropic proofed P.V.C. arranged in specially fused circuits with switch position adjacent to driver.
Finish: Steel and alloy components are anti-corrosion treated during building. Standard interior finish is in colour pigmented glass fibre and plastic faced panels, colour to customer's choice. Exterior is finished painted in one colour.

The manufacturers reserve the right to vary their specifications without notice and shall not be liable for any inaccuracy that may be contained in this leaflet.
Illustration of Mercedes Benz minibus.

FIG. 42
INTERIOR DIMENSIONS

Seating Capacity: 13 - 16 Persons
Aisle Height: 68 in. with Carpet and Rubber Mat
Aisle Width w/o Armrest: 18 1/2 in.
Aisle Width: 15 1/2 in.
Knee Space: 27 1/2 in.
Seat to Window: 14 1/2 in.
Seat Width: 18 1/4 in.
Step Well Steps:
  Step Depth 9 in.
  1st Step Width 19 1/2 in.
  2nd Step Width 21 in.
  2nd Step Height 10 in.

ENTRANCE DOOR
Opening Mechanism: Remote Manual
Figure III — Attractive appearance and auto-like operating characteristics make the Courier a highly suitable vehicle for residential streets.
Potential D.A.B. Service Areas

Within CCK

Outside CCK

CCK Ward Boundaries

Employment Generators
Ward areas for extended D.A.B. service

FIG. 42
RANKED CCK WARD POPULATION DENSITIES

<table>
<thead>
<tr>
<th>Ward</th>
<th>Area (sq.miles)</th>
<th>1966 Population</th>
<th>1970 estimated pop. (1966+8%)</th>
<th>Pop. density (1970 per sq.mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>2.69</td>
<td>9,802</td>
<td>10,586</td>
<td>4,430</td>
</tr>
<tr>
<td>CCA</td>
<td>0.81</td>
<td>5,579</td>
<td>6,019</td>
<td>7,440</td>
</tr>
<tr>
<td>CCC</td>
<td>1.56</td>
<td>11,903</td>
<td>12,855</td>
<td>8,348</td>
</tr>
<tr>
<td>CCI</td>
<td>0.94</td>
<td>7,772</td>
<td>8,388</td>
<td>8,357</td>
</tr>
<tr>
<td>CCG</td>
<td>1.50</td>
<td>13,331</td>
<td>14,395</td>
<td>9,556</td>
</tr>
<tr>
<td>CCE</td>
<td>0.87</td>
<td>7,884</td>
<td>8,508</td>
<td>9,780</td>
</tr>
<tr>
<td>CCB</td>
<td>0.50</td>
<td>4,794</td>
<td>5,178</td>
<td>10,356</td>
</tr>
<tr>
<td>CCD</td>
<td>0.62</td>
<td>6,018</td>
<td>6,498</td>
<td>10,450</td>
</tr>
<tr>
<td>CCH</td>
<td>0.37</td>
<td>5,640</td>
<td>6,088</td>
<td>16,430</td>
</tr>
<tr>
<td>CCF</td>
<td>0.69</td>
<td>10,914</td>
<td>11,786</td>
<td>17,080</td>
</tr>
</tbody>
</table>
highly significant expected, multi-car /le-car ownership. ing households is ld with two cars o) generates over at 10 per cent. of cent. of all the rather than use ore than one car. ids are made by for two- and for e, respectively.

creases in size, which are con-
proportion of uses from 52 per units. However, mains relatively the additional cran-
mparing single-

\[ \text{Cheltenham average household income level for 1970} \]

**7-1 Effects of household income on travel generation**

![Graph showing the effects of household income on travel generation.](image-url)
HOUSEHOLDS AND TRIPS PER WARD IN SELECTED WARDS PER 15 HR. DAY

Table A. Based on average of 2.90 persons/household (ref.4.1 and census)  
Based on average of 6.8 trips/household (ref.figures 35, 46)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Area</th>
<th>No.households</th>
<th>Total trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>2.69</td>
<td>3447</td>
<td>23,500</td>
</tr>
<tr>
<td>CCA</td>
<td>0.81</td>
<td>2345</td>
<td>16,000</td>
</tr>
<tr>
<td>CCG</td>
<td>0.50</td>
<td>4968</td>
<td>33,750</td>
</tr>
<tr>
<td>CCE</td>
<td>0.87</td>
<td>3071</td>
<td>20,840</td>
</tr>
<tr>
<td></td>
<td>5.87</td>
<td></td>
<td>94,090</td>
</tr>
</tbody>
</table>

average trips/sq.mile = 12,420

Table B. Based on average of 2.90 persons/household

Based on average of 4.5 trips/household (ref.figures 35, 46)

<table>
<thead>
<tr>
<th>Ward</th>
<th>Area</th>
<th>No.households</th>
<th>Total trips</th>
<th>0.03 of total trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC</td>
<td>1.56</td>
<td>3842</td>
<td>17,300</td>
<td></td>
</tr>
<tr>
<td>CCI</td>
<td>0.94</td>
<td>2819</td>
<td>12,680</td>
<td></td>
</tr>
<tr>
<td>CCB</td>
<td>0.50</td>
<td>1937</td>
<td>8,660</td>
<td></td>
</tr>
<tr>
<td>CCD</td>
<td>0.62</td>
<td>2874</td>
<td>12,930</td>
<td></td>
</tr>
<tr>
<td>CCH</td>
<td>0.37</td>
<td>2069</td>
<td>9,310</td>
<td></td>
</tr>
<tr>
<td>CCF</td>
<td>0.69</td>
<td>3821</td>
<td>17,200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.68</td>
<td></td>
<td>78,080</td>
<td>2640</td>
</tr>
</tbody>
</table>

N.B. 7 p.m.-11 p.m. of fraction of total daily trips (0.03) estimated from Fig. 24.

average trips/sq.mile over 7 p.m.-11 p.m. = 574
CCK STUDY WARDS. DEMAND FOR DAB

1. Home-based trips. 94,090 x 88% = 82,800
   Auto driver and passanger @4% of 80,285 = 3,211
   Bus passanger (15% m.s. x total service area x .3)
   @ 30% of 1840 = 522
   Taxi passanger (total 1500) @65% of 675 = 438
   \[ \text{Total} = 4,171 \]

2. Non home-based trips = 11,290
   Auto driver & auto passanger @2% of 11,003 = 220
   Bus passanger (15% ms) @10% of 212 = 21
   Taxi passanger @20% of 75 = 15
   \[ \text{Total} = 256 \]

Total week day demands for DAB in study area = 4427
Total demands per sq. mile = 754
  " " " " per hour (15 hr.day) = 50
  " " " " " " constrained
  by 60% phone coverage = 30
  " " per sq.mile at peak hr.(totalx110%) = 33