Urban safety project: The Bradford scheme

by R T Walker and M McFetridge
(Transport Operations Research Group, University of Newcastle upon Tyne)

The authors of this report are employed by the University of Newcastle upon Tyne. The work reported herein was carried out under a contract placed on them by the Transport and Road Research Laboratory.

The views expressed are not necessarily those of the Department of Transport.

This report, like others in the series, is reproduced with the authors' own text and illustrations. No attempt has been made to prepare a standardised format or style of presentation.

Traffic Safety Division
Traffic Group
Transport and Road Research Laboratory
Old Wokingham Road
Crowthorne, Berkshire RG11 6AU

1989

ISSN 0266-7045
Ownership of the Transport Research Laboratory was transferred from the Department of Transport to a subsidiary of the Transport Research Foundation on 1st April 1996.

This report has been reproduced by permission of the Controller of HMSO. Extracts from the text may be reproduced, except for commercial purposes, provided the source is acknowledged.
ABSTRACT

Bradford is one of five cities and towns involved in the Urban Safety Project, led by the Transport and Road Research Laboratory (TRRL) to demonstrate the effects on accidents and traffic patterns of combining a range of low-cost engineering measures on an area-wide basis.

The area of Bradford in which the scheme was implemented is situated to the south west of the city centre, containing a population of some 33,000 people in around 12,000 households, of which 65% have access to a car. It is mainly residential with a mixture of private and local authority housing.

The scheme consisted of a package of countermeasures that had been designed to achieve a safety strategy that had been formulated for the area. This strategy had been developed according to an analysis of the safety problems and was then modified in the course of extensive public consultation. The major feature of the strategy was the improvement of the main roads, particularly at their junctions with each other, to encourage most through traffic to use the arterial network in preference to local distributors and residential access roads. On one particular road with high traffic volumes, several measures were introduced to prevent its use by through traffic. Most of the traffic displaced from this route was contained on the arterial routes, but a small proportion transferred to a parallel local distribution route and access road. Additional traffic on the arterial routes due to the transfer from this and other access roads caused some additional delay in the peak hours at the two major (roundabout) junctions, but this additional traffic did not adversely affect their safety.

On average, about 110 injury accidents a year were reported before the introduction of the scheme. After two years of operation, the number of these accidents averaged 95 a year, which is estimated to be 14% lower than would be expected if no changes had taken place. This estimate is not quite statistically significant but there were significant reductions in those accidents occurring in day-light and in those in which the level of injury was slight, which support the overall reduction. Most of the measures were designed to reduce vehicle conflicts and it is accidents involving two-wheeled vehicles that have benefitted most from a greater level of safety. Although numbers of pedestrian accidents remained about the same in total, there were less involving children.

This report briefly describes the design and implementation of the scheme and the process of public consultation. Its main emphasis is the changes in traffic and accident pattern and the overall effectiveness of the Bradford scheme. The data (on these changes) were collected and analysed by the Transport Operations Research Group at the University of Newcastle upon Tyne under contract to TRRL.
Figure 1 Location of the Study and Comparison Area
1. INTRODUCTION

The Urban Safety Project is based upon the concept of the 'area-wide' approach to road safety (OECD, 1979 and Dalby, 1979) in residential areas, outside the central areas of towns and cities, using low cost accident countermeasures (Silcock and Walker, 1983). These are applied in a systematic way to reduce accidents by a strategy of preventing through movements on residential streets and by better provision for them on the main roads. This strategy is based upon the principle of strengthening a designated hierarchy of traffic routes and of concentrating through traffic on a few main routes so as to reduce conflicts and delays for local and access traffic, whilst ensuring adequate access to and from the main routes with greater safety.

The area-wide approach developed from earlier research work (Faulkner, 1975 and Chapman, 1978) which showed that, in urban areas outside the town centre, the majority of accidents are scattered and thus not amenable to site-specific remedial measures. Following the success of a pilot study in Swindon, five areas in different towns in England were selected for the development and implementation of safety schemes. These areas are in Bradford, Bristol, Nelson, Reading and Sheffield. Interim results for four of the towns have been published (Mackie et al, 1988), whilst each one is the subject of a separate final report. At the end of the project, all the five areas will be evaluated together, comparing and contrasting the effects of each scheme against the others.

Area-wide safety schemes are designed according to a defined planning method and so the procedure for dealing with the scheme in each town has been broadly similar (Lynam et al, 1988). In Bradford, the scheme was developed by representatives from the Transport and Road Research Laboratory (TRRL), West Yorkshire County Council (WYCC), Bradford Metropolitan District Council (BMDC), West Yorkshire Metropolitan Police (WYMP), West Yorkshire Passenger Transport Executive (WYPTE) and the Transport Operations Research Group (TORG) of the University of Newcastle upon Tyne, who were responsible for monitoring the scheme. Most of the detailed work was carried out by a small group from the County, TRRL and TORG. Responsibility for the scheme passed from the County to Bradford when the former Authority was abolished at the end of March 1986.

Initial investigations commenced in January 1983 and approval was given in April 1984 to a draft scheme to be presented for informal but detailed public consultation. Further rounds of public consultation were carried out before the final approved scheme was implemented between January and June 1986. This report examines the effect of the scheme after two years of operation.
FIGURE 2 The existing route hierarchy
2. THE BRADFORD SCHEME

2.1 Introduction

The area of Bradford in which the Urban Safety Project has been implemented is situated to the south west of the city centre, as shown in Figure 1. It covers an area of about 7 square kilometres, with a population of around 33,000 people in 12,000 households, 65% of which have access to a car. The area is mainly residential, where the majority of the houses date from the 1930s, mainly in private ownership in the east and north and local authority housing to the west and south. The main local shopping centre is the old village centre of Wibsey, with small parades of shops elsewhere and a large supermarket in Buttershaw.

The study area is bounded on the west and south by farmland and includes a small contiguous area beyond the City boundary in neighbouring Calderdale. On the eastern side, industrial land in Low Moor, together with a golf course form the boundary. The northern boundary consists of the A647 Great Horton Road and then, along the side of an escarpment which effectively forms a physical boundary. A "comparison area" of much the same size and character was selected on the opposite side of the City, as shown in Figure 1, with which to compare any changes in accident numbers and general traffic levels with those taking place in the study area.

2.2 Development of the Scheme

The planning process for implementing the Bradford Scheme consisted of:

(i) definition of the existing route hierarchy;
(ii) analysis of safety problems;
(iii) development of an initial safety strategy linked to a proposed route hierarchy;
(iv) public consultation and consequent modifications to the proposed hierarchy;
(v) re-definition of the strategy for the agreed scheme; and
(vi) development of a comprehensive package of countermeasures formulated to achieve the desired aims.

2.2.1 Definition of the existing route hierarchy (see Figure 2)

The function of arterial routes (primary and district distributors) is to provide safe and efficient traffic routes connecting different parts of the area and to link the area to the national road system. Four routes which traverse the area converge on Odsal Top Roundabout, which is just inside the eastern boundary. These are A6036 Halifax Road, A641 Huddersfield Road, A638 Cleckheaton Road and the B6380 route, which was considered as two individual sections, one being Wibsey High Street extending from Odsal Top Roundabout to Wibsey Roundabout and the other section being Beacon Road. Another arterial route, the unclassified St Enochs Road, also intersects at Wibsey Roundabout. The two remaining arterial routes form part of the study area boundary, namely A647 Great Horton Road on the northern edge and B6147 Cooper Lane on the West.

The function of local distributor routes is to provide a link between the surrounding arterial routes and the residential areas and to cater for the
traffic within them. Four such routes were identified, which all effectively intersect at Wibsey Roundabout, but they fell into two separate routes. Two of the routes connect directly to another arterial route, have a number of junctions with residential access roads and are routes used by buses, namely the Wibsey Park Avenue route and Moore Avenue, which joins St Enoch's Road immediately adjacent to Wibsey Roundabout. The other two routes cross arterial routes, have few junctions with access roads and have a common section, St Helena Road which is the only part that is a bus route. The priority route then continues as St Pauls Avenue to Halifax Road and, on the other side, as Netherlands Avenue across Huddersfield Road to Cleckheaton Road. The fourth route continues as Buttershaw Lane to Halifax Road, where there is a staggered T-junction, from where it continues to Huddersfield Road as Royds Hall Lane/Abb Scott Lane.

All other roads were categorised as access roads serving frontage properties. In some cases, where such a road serves a limited distributor function for several other access roads, then it was referred to as a "spine road".

2.2.2 Analysis of safety problems

Accidents which had been recorded in the previous four years were analysed on an area-wide basis, according to the type of conflicts or class of road-user involved (Walker 1985) with the following list of general problem areas being identified.

(1) Clusters of accidents on Halifax Road, Huddersfield Road and Cleckheaton Road at their junctions with the two local distributor routes running South from Wibsey Roundabout;

(2) a high proportion of night-time accidents on Halifax Road, Cleckheaton Road and Royds Hall Lane/Abb Scott Lane;

(3) powered 2-wheelers being involved on Beacon Road, St Enoch's Road and St Helena Road;

(4) danger to pedestrians crossing at the western end of Halifax Road, on the Wibsey High Street route and in the vicinity of Wibsey Roundabout;

(5) child pedestrians at risk in the Buttershaw Housing Estate, particularly along the central section of Reevy Road West;

(6) right-turning collisions on most arterial routes, in particular the manoeuvre out of the side roads;

(7) problems due to parking in the daytime on access and spine roads, in particular on Reevy Road West (a similar problem occurs on Halifax Road at night-time); and

(8) loss of control contributing to accidents on Great Horton Road, Huddersfield Road, Cleckheaton Road and also on the Wibsey Park Avenue route.
2.2.3 Development of initial safety strategy

Preliminary traffic flow information was gathered by the monitoring team early in the planning process (Walker 1987). This, together with a detailed route investigation and the accident analysis described in 2.2.2, formed the basis of a critical appraisal of the ability of the existing hierarchy to meet the demands made upon it. Where any section of route was found to be inadequate from a road safety, traffic or environmental standpoint, the options were:

(i) to alter its role in the hierarchy. This includes the possibility of transferring some or all of its functions to one or more other routes; or

(ii) to retain it, but to treat the accident problem(s) with specific safety measures.

This process was applied first to the arterial routes, then repeated for the local distributor roads and the spine roads.

It was concluded that several sections of the arterial and distributor network were unsatisfactory. A number of alternative proposals were considered by the Technical Working Group and eventually three options for changes to the hierarchy were formulated. These were then subject to a detailed evaluation, comparing each one with the other and with retention of the existing hierarchy.

The option that was finally adopted proposed the following changes:

(1) downgrading Wibsey High Street from an arterial route to a hybrid local distributor/spine road (by making a short section one-way only except for buses);

(2) promoting St Helena Road/St Pauls Avenue to an arterial route (effectively replacing Wibsey High Street in this role);

(3) downgrading Netherlands Avenue from a distributor to a spine road;

(4) downgrading Buttershaw Lane/Royds Hall Lane/Abb Scott Lane from a distributor to a spine road; and

(5) downgrading Beacon Road from an arterial to a local distributor route.

In the event, the original proposals for the first two were not proceeded with and the last two were substantially modified as a result of the extensive public consultation described below.

2.2.4 Public Consultation and Modifications to the Scheme

A package of countermeasures (see below) was drawn up to support the proposed hierarchy and the Scheme was accepted by the elected members in April 1984, subject to detailed public consultation before any traffic orders were advertised. A mobile caravan exhibition was sited at six locations in the study area each day during the last week of June 1984. This was followed by four public meetings at different venues.
Most of the public who expressed an opinion were in favour of the scheme but certain of the measures received criticism. Accordingly, a number of modifications were made, as follows:

1. The proposed closure of Abb Scott Lane was deleted and alternative measures to discourage through traffic and speeds were adopted;

2. The proposed restrictions in Netherlands Avenue were modified to reduce the inconvenience for residents, whilst still preventing through movements;

3. The proposed one-way restriction in Wibsey High Street was resited; and

4. A proposed restriction on heavy goods vehicles using Wibsey High Street was adopted, due to strong local pressure, although it was not required on safety grounds.

The revised package of measures was approved by the elected members in December 1984, subject to a further round of public consultation, which was carried out early in 1985. The estimated cost of the Scheme was now £270,000, well above the £200,000 budget and so the need for some of the measures was reconsidered and less costly versions of others were devised. Also, early in 1985, the elected members separately approved an extensive series of waiting restrictions, designed to act in concert with the measures approved previously.

Following the successful second stage of public consultation, the scheme was formally advertised. This resulted in very strong protests against the restriction in Wibsey High Street, with a large petition and substantial adverse reporting of the issues in the local press. In April 1985, the elected members agreed further revisions in the light of the public consultation and the cost-reduction exercise. The main components remained unchanged, except that the one-way proposal in Wibsey High Street was to be held in abeyance, for re-consideration after the rest of the scheme had been implemented. Later, in September 1985, the waiting restrictions were approved with slight modifications in response to objections. Some further slight modifications were made to the package when tenders were received.

Implementation of the scheme commenced in January 1986, the work being scheduled to take three months. In the event, very severe weather conditions caused considerable delays and the work persisted into June (but see later). Halfway through the implementation period, West Yorkshire Metropolitan County Council was abolished and Bradford Metropolitan District took over responsibility for the Scheme.

Most of the measures have since operated satisfactorily and the few teething problems were quickly resolved by making minor modifications such as changes to waiting restrictions and reducing the severity of rumble strips. An initial appraisal of the Scheme was carried out in July 1986. The main point to emerge was the high level of non-compliance with a compulsory left-turn into Halifax Road from Buttershaw Lane, causing enforcement problems, so it was agreed to remove it and suspend the traffic order immediately.
The no-entry prohibition in Netherlands Avenue, however, was not implemented until August 1986. When it was, it resulted in a number of complaints and petitions from local residents regarding long detours and inconvenience, with a separate request to implement the rescinded closure of Abb Scott Lane. A petition was also raised to remove the Jer Lane road closure. In February 1987, the elected members turned down all the objections, except those relating to Netherlands Avenue and Abb Scott Lane, which were to be the subject of separate public consultation with local residents. The consensus regarding Netherlands Avenue was that the 'no entry' prohibition should be removed and a turning prohibition at Halifax Road should be relaxed, to be replaced by an "access only" prohibition for Netherlands Avenue (between Halifax Road and Huddersfield Road) and the roads leading off it. There was no consensus view regarding an optimum solution for Abb Scott Lane and so, in the end, no changes were proposed. The measures in Netherlands Avenue were implemented the following year, in February 1987.

In summary, extensive consultation was carried out with the public and in most cases, where there was strong criticism of measures, modifications were made. However, publication of the proposed traffic orders generated even stronger protests and further changes were made. It was probably somewhat over-optimistic to expect the shopkeepers to accept the quite radical proposals for Wibsey High Street given similar reactions that have arisen previously in traffic management schemes elsewhere (Hills and Walker 1980). This is clearly a matter, therefore, which needs to be taken into account when devising similar schemes in future, but the need to discuss the matter widely with the public and reach some form of compromise is a clear message from the Bradford Scheme.

2.2.5 The safety objectives of the agreed Scheme

On arterial routes, the principal aim was to provide safe and efficient traffic routes connecting different parts of the area. This required policies to smooth the traffic flow by reducing delays, together with improved right turn facilities at selected locations and assistance for pedestrians where appropriate. They are summarised below.

<table>
<thead>
<tr>
<th>Road</th>
<th>Safety objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleckheaton Road</td>
<td>Safety objectives - to reduce accidents at the junction with Netherlands Avenue and to influence the problem of 'loss of control'.</td>
</tr>
<tr>
<td>Cooper Lane</td>
<td>Safety objective - to improve conditions at the junction with Beacon Road.</td>
</tr>
<tr>
<td>Great Horton Road</td>
<td>Safety objectives - to remedy the loss of control problem and to reduce vehicle speed and assist pedestrians.</td>
</tr>
<tr>
<td>Halifax Road</td>
<td>Safety objectives - to reduce the high number of junction accidents and to improve conditions for pedestrians at the western end, together with a reduction in overtaking and restrictions on parking.</td>
</tr>
</tbody>
</table>
Huddersfield Road
Safety objectives - to reduce the high level of accidents at the main intersections and to influence the 'loss of control' problem apparent in accident reports.

Odsal Top Roundabout
Safety objectives - to accommodate any changes in the distribution of traffic flows, to improve conditions for two-wheeler vehicles and to deal with the 'loss of control' problem.

St Enoch's Road
Safety objective - to reduce accidents involving powered two-wheeler vehicles.

Wibsey Roundabout
Safety objectives - to accommodate redistribution of traffic and to assist pedestrians in the vicinity of the roundabout.

The two following routes were originally intended to be downgraded to local distributors. In the light of the public consultation, these proposals were not proceede with and so the routes remain as arterials.

Beacon Road
Safety objective - to reduce conflicts at junctions and with frontage activity on the eastern part of the route.

Wibsey High Street
Safety objective - to assist pedestrians.

The local distributor routes were intended to provide the link between the main arterial network and local access roads and disperse traffic within the residential areas. During peak hours however they are attractive for through traffic movements seeking savings in time and/or distance, which can also affect access roads depending upon circumstances. Scattered vehicle/vehicle and vehicle/pedestrian accidents were the common feature on these routes and their width and alignment encouraged higher speeds. The general safety objectives for these roads were: (i) to discourage through traffic; (ii) to prevent peak period traffic from using time-saving diversions via residential roads; and (iii) to assist pedestrians to cross streets where necessary.

Moore Avenue
Safety objectives - to make the route less attractive to through traffic, reduce conflicts at the arterial junctions and slow down the traffic along the route.

Wibsey Park Avenue
Safety objectives - to slow down the traffic, to aid pedestrians and to deal with scattered accidents.

St Helena Road/
St Pauls Avenue
Safety objectives - to reduce conflicts at major junctions and to assist pedestrians.

Buttershaw Lane/
Royds Hall Lane/
Abb Scott Lane
Safety objective - to decrease both the volume and speed or traffic.
On spine roads, greater safety has been sought by making the local environmental and residential function dominate that of traffic distribution. Measures to prevent through traffic, together with the control of on-street parking, have been used where necessary. All the spine roads identified in the existing route hierarchy were retained. In addition, Netherlands Avenue was downgraded from a local distributor to a spine road.

2.2.6 Development of the package of countermeasures

A package of complementary but interacting measures was selected to create the desired road hierarchy and to assist accident reduction generally. Most of these were agreed in April 1984, with additions, deletions or modifications (as necessary) in the light of public consultation and the cost-reduction evaluation.

3. THE EFFECTS OF THE SCHEME ON TRAFFIC AND PEDESTRIANS

3.1 Outline of the monitoring programme

To assess the changes in movement patterns of pedestrians and vehicles, associated with the countermeasures, an efficient monitoring programme was essential and this had been devised at an earlier stage of the project (Ward, 1983). It consisted of the four separate components, listed below, the information from which could be drawn together to identify changes according to the safety objectives.

(i) Automatic traffic counts on a sample of routes in both the study and comparison areas, to determine trends.
(ii) Classified movement counts at junctions to examine the particular traffic changes brought about by the scheme.
(iii) Moving car measurements to detect changes in manoeuvre times at junctions and journey times along main routes.
(iv) Observations of pedestrian movements to detect any overall changes as well as the effects of specific measures.

Preliminary surveys took place in July 1983. These were designed to provide information to assist the design of the scheme and to familiarise the monitoring team with the area and its traffic, in order to plan the full-scale monitoring. Issues examined were:

(a) variability in traffic flows by day of the week;
(b) the times and durations of the peak periods;
(c) the flows and turning movements on all the main roads and suspected "rat-runs"; and
(d) the most likely sources of delay.

The main monitoring programme commenced in October 1984, with six "before" surveys carried out up to the start of the implementation of the scheme in January 1986. The construction works took almost six months and so the first "after" survey took place in June 1987, with the final one almost at the end of the two-year period, i.e. in March 1988.
In addition to the standard monitoring surveys, three further types of survey were included when the need for supplementary information was recognised, as the countermeasures were being drawn up. These were:

(i) parking duration surveys at those locations where the control of on-street parking was a stated safety objective. These were carried out by the monitoring team;

(ii) speed surveys were also considered necessary, on roads where speed-reduction was a stated safety objective or where there was concern about possible changes in speed as a result of the scheme. These were carried out by West Yorkshire Metropolitan Police (Davies, 1987); and

(iii) overhead filming, which was carried out at the two roundabouts in the area. It was not possible directly to survey the turning movements of vehicles, due to the practical difficulties caused by the number of arms and the volume of traffic. Instead, filming was carried out by TRRL and the films were subsequently analysed by the monitoring team.

3.2 Summary of data collection and analysis

3.2.1 Data collection

The four original types of monitoring surveys and the two additional ones carried out by the monitoring team are outlined below.

(1) Automatic traffic counters were installed by TRRL at five permanent sites during March 1984. In the study area, there were three, located respectively on an arterial route, a local distributor and a spine road. There were two in the comparison area, both on local distributors. They yielded data, for one year before and two years after implementation. These data were analysed to provide mean hourly and daily flows for weekdays (Monday to Friday).

(2) Junction movement surveys were carried out at over 80 junctions, up to six times in the "before" period and up to eight times in the "after" period. Vehicles were classified into four groups; namely, cars and light vans, motorcycles and mopeds, buses and goods vehicles, and pedal cycles. The surveys were carried out at three separate times of day; 07.30-09.30, 12.00-14.00 and 16.00-18.00, with the actual counting taking place for 25 minutes from the start of each of the twelve half-hour periods. A Latin square experimental design was used for the 40 key junctions, dividing them into four groups to be monitored on different days of the week, during the four separate weeks that the surveys were carried out in the calendar year. Traffic flows quoted will, except where otherwise qualified, be an hourly flow, averaged over the six hours of survey, for all motorised vehicles for the period stated.

(3) Journey time surveys were carried out using the moving observer method (Wardrop and Charlesworth, 1954), where two vehicles travel in opposite directions over a specific route. Three routes were devised for the study area and one for the comparison area, each being surveyed three times in the "before" period and four times in the "after" period. A small lap-top microcomputer was used to record the
elapsed time and stationary periods at certain places on each route. This was later converted into journey times for each route section and manoeuvre times at junctions.

(4) Pedestrian movement was examined at 11 locations. People were classified as either adult or child and the number and location of crossing movements were observed. This was carried out three times in the "before" period and four times in the "after" period. The surveys were carried out at three separate times of the day, 07.30-09.30, 12.00-14.00 and 15.30-17.30 (or 16.00-18.00), with counts recorded in half-hourly intervals.

(5) Parking duration surveys were carried out on three road sections, three times before and four times after implementation. The surveys were carried out at three separate times of the day; 07.30-09.30, 12.00-14.00, and 15.30-17.30 (or 16.00-18.00), at half-hourly intervals, in conjunction with the pedestrian surveys. Parked vehicles were recorded by number and location.

(6) Overhead filming at roundabouts was carried out twice, once before and once after implementation of the scheme.

3.2.2 Analysis of data

Seven main types of analysis were carried out and, throughout this section of the report, all changes referred to are statistically significant at the 5% level, unless otherwise stated.

(1) Traffic flow data collected by the automatic traffic counter was intended to investigate and compare trends in traffic in the study and comparison areas. In the comparison area, however, one site was affected by a substantial redevelopment scheme adjacent to it, whilst the other has suffered double counting due to the narrowness of the road, accentuated by parked vehicles. In the study area two of the sites have been affected by the redistribution of traffic as a result of the scheme. Thus, it is not possible to examine trend changes in either the study or comparison area.

(2) The movement counts at junctions were subjected to analysis of variance, to test the general validity of the Latin square design used. This was carried out on the combined data from all the key junctions where the same movements had been counted in all the surveys. The results indicated that the data were sound and would not inhibit further analysis.

(3) The movement counts at junctions were then analysed for each junction, using generalised linear modelling (GLIM) techniques to determine if significant changes had occurred after the scheme was implemented.

(4) Journey time data were also analysed using generalised linear modelling techniques, to determine whether there were any significant changes in the study area, along the routes, or for particular movements at junctions. Delays at junctions were also examined when comparing total journey times. The route surveyed in the comparison area was used to determine any general changes that may be occurring.
(5) Pedestrian movements were analysed by comparing the proportion of people using the different zones at each location, to determine if there had been a significant change in the locations where people crossed the road.

(6) The surveys of duration of on-street parking were analysed by comparing the number and location of vehicles parked at the kerbsides at each location, to determine if there had been a significant change.

(7) The overhead films were analysed by comparing changes in the total flow and turning movements at each of the main roundabouts.

3.3 Results of the traffic measurements on the main roads

These are based on the junction counts and the journey time data.

3.3.1 Arterial routes

The measures on these routes were intended to smooth traffic flow, reduce conflicts and assist them to accommodate traffic displaced from other less satisfactory routes.

The overall effect on the arterial routes has been an increase in traffic on a number of them mainly as a result of the measures to prevent through movements on Netherlands Avenue. This has increased the volume of traffic using the largest junction, namely Odsal Roundabout. Wibsey Roundabout has also seen an increase in traffic as a result of the measures to prevent through traffic movements on nearby residential roads. This has led to additional queueing traffic on some of the arms of these two roundabouts, usually in the peak hours, and in some cases traffic has thus incurred additional delay. Movements along the routes have remained unaffected or improved where conflicts have been reduced.

The results for individual routes are described in Appendix A1.

3.3.2 Local distributor routes

The objective for these roads was to reduce through traffic on these and adjoining access roads, by introducing measures at their junctions with the arterial routes.

The overall impact of the scheme on the local distributor routes has been mixed. On Moore Avenue flows have not reduced significantly, despite extending journey times by measures at each end. Traffic on St. Helena Road and St Paul's Avenue has reduced as a result of the measures in Netherlands Avenue rather than acting to contain some of the displaced traffic in conjunction with the Halifax Road arterial route. Part of the Wibsey Park Avenue route and Royds Hall Lane/Abb Scott Lane carry more traffic, almost certainly displaced from Netherlands Avenue, with some additional delay to all traffic.

The results for individual roads are described in Appendix A2.
3.4 Results of the Traffic Measurements in Residential Areas

The overall effect of the scheme on the residential areas has been mixed. Where measures have been used specifically to reduce traffic on the residential roads they have been successful. In a few cases some of the measures have redistributed traffic onto a few of the more important residential roads, but very often this is related to a different pattern of usage of the residential roads by local traffic, with other adjacent roads showing a relative decrease in flow.

3.5 Pedestrian Movement

Improvement of pedestrian safety in the Bradford study area was mainly seen to be needed at certain places on the main traffic routes identified in the analysis of safety problems (section 2.2.2). In all cases, the number of people crossing at these places was small and so the pedestrian refuge was selected as the most appropriate measure. On some main roads, footway crossovers were also designed to help pedestrian movements along roads by inhibiting unnecessary turning movements and reducing the speed of turning vehicles. On others, the objective was to provide an overall reduction in traffic flow and/or speed in order to help pedestrians as well as other road users, and in these cases large refuges were used. In the residential areas, on the other hand, pedestrian movements tend to be dispersed and vehicle flows low. Here, safety improvement was based upon the strategy of reducing overall vehicle movements and speeds on all access roads throughout the area. One exception to this, however, was the West Buttershaw area where specific measures were introduced on one particular road (Reevy Road West) to reduce its width and assist visibility for children.

The monitoring of pedestrian movement was carried out at a total of 11 sites. These consisted of selected locations on the main routes, where refuges were installed, together with other places where it was anticipated that pedestrian movement could be affected by the original proposals to change vehicle flows. The site in the West Buttershaw area was also examined.

The pedestrian surveys indicate that child pedestrian movements at a number of places have decreased, resulting in a reduction overall, taking all the sites together, probably as a result of a change in school times which coincided with the scheme's implementation. As a result, some children were not being recorded in the after surveys compared with those before. Changes in the numbers of children lunching at school has also been commented on by local police. Even so, there have been noticeable effects at nearly all those sites where measures were introduced but with clear differences, depending upon the road type and thus most probably traffic volume too.

On the arterial routes with high traffic volumes, standard pedestrian refuges have attracted people to cross in that part of the road where they were installed rather than in adjacent lengths of road. Most people use the new refuge when crossing. On local distributors, where traffic flows are lower, a "chain" of refuges can attract people to their vicinity, but the refuges themselves are sometimes little used. Isolated refuges, on the other hand, appear to have no general effect on crossing location at these
lower traffic flows and usage of them depends on individual circumstances and on detailed siting.

The detailed results for the roads are described in Appendix A4.

3.6 On-street parking

A few places where the parked vehicles had been involved in accidents, warranted some form of remedial treatment. At two locations, where waiting restrictions were used, other measures to assist pedestrians were also implemented and it was possible to combine parking surveys there with those for pedestrians. The aim was to obtain a measure of the number and location of parked vehicles that could be recorded quickly and easily from static observation.

The surveys were carried out three times in the "before" period and four times in the "after" period, for three two-hour periods each day. Each site was divided into a number of zones, according to the location of the waiting restrictions and the other measures. The procedure was to count the initial number of parked vehicles, together with the numbers of arrivals and departures during each time period.

The waiting restrictions were well observed at the sites which were monitored, which suggests that overall compliance was good. The details of the two locations are described in Appendix A5.

3.7 Summary

The measures in Netherlands Avenue have prevented most of the through traffic using this route between Halifax Road and Huddersfield Road. This was achieved by using a directional 'no-entry' restriction together with an 'access only' restriction. Most of the displaced traffic has remained on the arterial routes with some additional delay at Odsal Roundabout, but a small proportion has transferred to a parallel local distribution and an access road, which showed a relatively large saving in journey distance. Although Rumble strips were installed with the intention of reducing traffic flows and speeds on these roads it was not possible to determine their particular effect. There is some evidence to suggest that through traffic has increased somewhat in the Buttershaw West area on the long spine road, Reevy Road West, which traverses the area. Some recent improvement works carried out in this area however may have caused an increase in access traffic which might account for some of the change. The relaxation of the restrictions in Netherlands towards the end of the after monitoring period has improved accessibility for local traffic, but prohibited turning movements have also increased. More worrying perhaps is the evidence that through traffic has returned in considerable numbers with the passage of time.

At some junctions additional delay has occurred as a result of the objective to reduce the speed and volume of turning traffic, or reducing the number of conflicting traffic movements. On some routes the objective of reducing traffic flows and speeds to make the routes less attractive to through traffic does not appear to have been always successful. However the additional time that has been incurred is not large, and is probably small relative to the overall total journey time.
Table 1:
Injury-accidents in the Bradford study area and comparison area for the periods 1981-1983

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Arterial Routes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1981</td>
<td>1982</td>
<td>1983</td>
<td></td>
</tr>
<tr>
<td>Beacon Road</td>
<td>6</td>
<td>11</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Clockheaton Road</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Cooper Lane</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Great Horton Road</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Halifax Road</td>
<td>23</td>
<td>11</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Huddersfield Road</td>
<td>11</td>
<td>11</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Odsal Roundabout</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>St. Enoch's Road</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Wibsey High Street</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Wibsey Roundabout</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison Area</th>
<th>Arterial Routes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1981</td>
<td>1982</td>
<td>1983</td>
<td></td>
</tr>
<tr>
<td></td>
<td>57</td>
<td>79</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Local Distributor Routes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Abb Scott Lane/Koys Hall Lane</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Buttershaw Lane</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Moore Moor Avenue</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>St. Helena Road</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>St. Paul's Avenue</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wibsey Park Ave/Farfield Ave/Carr House Lane</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison Area</th>
<th>Local Distributor Routes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>17</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Residential Areas</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wibsey Odsal</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Low Moor</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Woodside</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Buttershaw-South East</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Buttershaw-West</td>
<td>7</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Wibsey Horton Bank</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison Area</th>
<th>Residential Areas</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
<td>18</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

| Study Area Total Overall | | | | |
|--------------------------|---|---|---|
|                          | 106 | 114 | 105 |

| Comparison Area Total Overall | | | | |
|-------------------------------|---|---|---|
|                               | 115 | 135 | 125 |

Before, during and after implementation of the scheme

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B4</td>
<td>B5</td>
<td>B1 to B5</td>
<td>Average</td>
<td>Imp</td>
<td>A1</td>
<td>A2</td>
<td>A1-A2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>40</td>
<td>8.0</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>22</td>
<td>4.4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>19</td>
<td>3.8</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>38</td>
<td>7.6</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>9</td>
<td>90</td>
<td>18.0</td>
<td>5</td>
<td>18</td>
<td>18</td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>66</td>
<td>13.2</td>
<td>6</td>
<td>12</td>
<td>10</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>23</td>
<td>4.6</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>19</td>
<td>3.8</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>31</td>
<td>6.2</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>66</td>
<td>353</td>
<td>70.6</td>
<td>33</td>
<td>62</td>
<td>60</td>
<td>61.0</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>67</td>
<td>315</td>
<td>63.0</td>
<td>20</td>
<td>65</td>
<td>71</td>
<td>68.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>1.6</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>2.6</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>2.4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>7</td>
<td>41</td>
<td>8.2</td>
<td>2</td>
<td>10</td>
<td>4</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>14</td>
<td>81</td>
<td>16.2</td>
<td>2</td>
<td>14</td>
<td>10</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>32</td>
<td>176</td>
<td>35.2</td>
<td>18</td>
<td>29</td>
<td>27</td>
<td>33.0</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>4</td>
<td>21</td>
<td>4.2</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>14</td>
<td>2.8</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3</td>
<td>13</td>
<td>2.6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>12</td>
<td>2.4</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>1</td>
<td>47</td>
<td>9.4</td>
<td>5</td>
<td>14</td>
<td>12</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>2.0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>25</td>
<td>117</td>
<td>23.4</td>
<td>12</td>
<td>24</td>
<td>20</td>
<td>22.0</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>25</td>
<td>128</td>
<td>27.6</td>
<td>19</td>
<td>25</td>
<td>25</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>121</td>
<td>105</td>
<td>551</td>
<td>110.2</td>
<td>47</td>
<td>100</td>
<td>90</td>
<td>95.0</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>124</td>
<td>629</td>
<td>125.8</td>
<td>57</td>
<td>119</td>
<td>133</td>
<td>126.0</td>
</tr>
</tbody>
</table>

*Implementation period
(1) 6 months from 1.1.86 to 30.6.86

AFTER YEARS
A1 : 1.7.86 to 10.6.87
A2 : 1.7.87 to 10.6.88
After allowing for a reduction in child pedestrian movement in the after survey periods, the installation of pedestrian refuges has in most cases still had an effect on the crossing movements. On the arterial routes, with high traffic flows, single refuges tend to be well used and pedestrians will divert to cross there. Where flows are lower, on the distribution routes, isolated refuges have little effect on pedestrian movement whereas a series of refuges have an attraction for pedestrians to cross nearby, but not to divert onto the refuge itself.

Where waiting restrictions have been introduced, both on arterial routes and within residential areas, the level of compliance has been very good where monitored.

4. ACCIDENTS

4.1 Outline of the Monitoring

In this report, accidents are taken as those involving personal injury which were reported to the police. Full details of these accidents, from January 1979 to June 1988, were transferred from the authority concerned via magnetic tapes to the monitoring team at University College London. These records were then loaded onto a computer data-base, to which the monitoring team at Newcastle University had access. The data was supplied originally by West Yorkshire Metropolitan County Council and, since April 1986, by West Yorkshire Highways, Engineering and Technical Services (HETS) Joint Committee. After a detailed checking procedure, the accident records were assigned to the appropriate geographical area (i.e. study or comparison).

The basic aim of area-wide safety schemes is to reduce the number of injury-accidents overall, in a pre-designated area. Changes can also be expected to occur in the distribution of accidents on the road network, with variations on individual roads and between types of roads depending upon the nature and extent of the measure adopted. Other effects may also occur, such as the severity of injury and the involvement of different road user groups.

To establish and maintain comparability between all five towns in the project, a five-year "before" period and a two-year "after" period was used for the main accident analyses. The implementation period for the measures in Bradford was six months, January to June 1986, so the "before" period covers the years 1981 to 1985 and the "after" period extends from July 1986 to June 1988. Table 1 shows the numbers of accidents in the study and comparison areas, in these three periods, allocated to the different types of road.

4.2 Introduction to the Statistical Analysis

A five year "before" period is used to detect trends and seasonal variation in the accident pattern and so to establish a range of accidents that might be expected in the "after" period had the project not taken place. Any differences in accident-rate between the "before" and "after" periods is taken to be due to a combination of system-wide secular effects, random effects and the effects of the scheme itself. Assuming the systematic
effects to be the same in both study and comparison areas, then the aim is to separate the two other effects in order to isolate the result attributable to the scheme.

Log-linear models were fitted to the two-monthly accident totals in the study and comparison areas. Use was made of the GLIM computer program (Barker and Nelder, 1978) to fit models by maximum likelihood methods, on the assumption that the accident totals are Poisson variates. Earlier work (Hutchinson and Mayne, 1977) had shown that this assumption could be relied upon, provided the accident frequencies are less than about 100 in the time period concerned. The models allow seasonal effects and long-term trends to be estimated, as well as the separation of the implementation period during which traffic was re-routed and accident occurrence could possibly vary accordingly. The model which was chosen and fitted to the Bradford accident data was:

\[ Y_{klm} = \exp \left[ a + c_k + d_l + e_m + (ce)_{km} \right] \]

where \( k \) is the area: \( k = 1 \) comparison, \( k = 2 \) study
\( l \) is the season: \( l = 1 \) being January/February and so on
\( m \) is the time period: \( m = 1 \) before, \( m = 2 \) implementation, \( m = 3 \) after

Similar models were also fitted to various categories of accident, such as those occurring on a particular road type or to a particular road-user group.

4.3 Changes in Accident Frequency

The objective of the Urban Safety Project was to reduce accidents by 10-15%. In Bradford, accidents were reduced from an average of 110 a year to 95 a year which is estimated to be an overall reduction of 14% by the basic log-linear model, with a 95% confidence interval of -31% to +8%. This estimate is based upon changes in the study area in relation to those in the comparison area, taking into account seasonal variations and time trends over the five "before" years and the two "after" years. The seasonal effect is very strong and, if this term is subtracted from the model, the increase in deviance is significant at a level better than 0.001. Nevertheless, this has no effect on the values of the estimated accident reduction in accidents or its confidence interval (i.e. the estimate and standard error have the same values). On the other hand, if a time term is added to the model, the reduction in deviance is negligible and again there is no change in the results.

Alternative assumptions for the before period ranging from 7 years down to 2 years made little difference to the estimates. In the latter case for example, with much less data, the confidence interval only widens by 7 percentage points. Varying the length of the seasonal factor, not surprisingly, made no difference to the estimates for any particular combination of before and after years data.

This consistency in the number of accidents in each area in the "before" period can be seen in Table 1, despite the large fluctuations that occur on individual roads. It can also be seen that the average number in the
"after" period, for the comparison area, is almost precisely equal to the average for the "before" period. This explains why there was no time term in the log-linear model shown above.

4.4 Changes by Light Conditions

Closer examination of the accident data between the day-light and night-time condition showed a marked difference in the study area after the scheme was implemented. The average number for the day-time reduced from 74 beforehand to 54.5 whilst the night-time accidents changed from 36 to 40.5, whereas in the comparison area there was little change in the respective figures. The log-linear model shows that there has thus been a reduction in day-light accidents in the study-area of 30% which is significant at the 95% level with the confidence interval being from -47% to -6%. The change in the night-time accidents is not significant.

Further analysis showed that the reduction in day-light accidents was concentrated on the main roads, whereas in the residential areas there was little change. This is discussed further below where observed changes in accident patterns of particular groups of road-users and on particular types of road. Given the smaller numbers of accidents that occur in these sub-sets and thus a greater difficulty in detecting changes that have taken place, the statistical significance in the respective analysis has been relaxed and a value of 10% has been used when referring to increases or reductions in the number of accidents on a particular road.

4.5 Changes by Category of Road

4.5.1 Arterial routes

Before the scheme was implemented, there were 71 accidents per year on these routes and afterwards the rate was 61 per year. This reduction contrasts with respective figures in the comparison area of 63 and 68, but the log-linear model shows that the change is not significant. However, the reduction in daylight accidents from about 44 a year to about 33 a year is significant. The number of accidents involving pedestrians, however, has remained constant overall, as can be seen in Table 2, despite an apparent improvement during the first year of operation of the scheme. Nearly all the change in accidents in the study area has occurred to users of two-wheeled vehicles, and most of these were in day-light conditions.

Evaluating the effect of the scheme on individual roads is more difficult because, as can be seen from Table 1, there is often a wide degree of variability in the "before" years. On-Beacon Road, however, there has been a marked reduction in accidents from 8 a year to 3 a year, and all this reduction has taken place in the day-time. Half of the saving has occurred at its junctions with Cooper Lane, converted from a cross-roads, (with sub-standard sight lines), to a T-junction, with the result that there have been no accidents there since the scheme was implemented. Elsewhere along the route, accidents involving right-turn manoeuvres or pedestrians are also less.

Cleckheaton Road has benefitted from the junction improvement at Netherlands Avenue/Brighouse Road, where there have been no accidents since the scheme was implemented compared with 7 in the five year "before" period. It has also helped to prevent the 'loss of control' accidents
which previously averaged 1 a year in this vicinity. On the rest of the route, accidents have not changed despite traffic flows having almost doubled.

Cooper Lane is the least important arterial route in the study area and along the route itself no measures were considered necessary. The average number of accidents has remained constant although there has been a general increase in traffic.

On Great Horton Road, the total number of accidents has remained relatively unchanged, although there have been changes in various categories of accidents. The closure of its junction with Beacon Road has removed this junction and with it those accidents which occurred here (1 a year), but some accidents may have transferred to the adjacent junction with Cooper Lane, because the average total for the two junctions has remained unchanged. On the other hand, the measures at the junction with Hollybank Road and Moore Avenue appear to have had little effect overall, despite having eliminated all accidents involving powered two-wheeled vehicles and/or a right-turn manoeuvre, which accounted for half of the former average of 2 accidents a year.

The average number of accidents on Halifax Road has remained the same, although the location and some categories of accident have changed. At the St Paul’s Avenue/Netherlands Avenue junction, the average number of accidents was over 5 a year before the modifications to reduce conflicts were made and 2 a year afterwards. Turning movements have increased at the Royds Hall Lane junction and here there was a total of 2 accidents in the five “before” years and 6 in the two year “after” period, all the latter occurred in the hours of darkness and half involved a powered two-wheeled vehicle entering Halifax Road. Elsewhere on Halifax Road, however, the average number of accidents involving powered two-wheeled vehicles averaged 4 a year beforehand and 1 a year after the scheme was introduced. On the section between Headway and Fenwick Drive there were about on average, 3 accidents a year before the refuges were installed and 1 a year afterwards. Accidents involving adult pedestrians averaged 2.5 a year beforehand and 5.5 a year after the scheme was implemented, half of those in the “after” period occurred between St Paul’s Avenue and Odsal Roundabout. (with most occurring in conditions of darkness) compared with just one in the five year “before” period. Overall, however, the number of accidents occurring on Halifax Road in the hours of darkness has remained unchanged.

Accidents on Huddersfield Road averaged 13 a year before the scheme and 11 a year afterwards. The measures to prevent through-traffic on Netherlands Avenue have resulted in a fall in accidents at this junction, from an average of 5 a year to 1.5 a year afterwards with greater effect on daylight accidents than night-time. However, at the Common Road junction accidents previously averaged 1 a year compared with 5 in the two-year “after” period the predominant feature throughout being the crossing manoeuvre over the main road. Accidents at Abb Scott Lane and New Works Road have remained relatively constant.

At Odsal Top Roundabout, where carriageway markings now delineate the traffic lanes, cyclists were previously involved in half of the accidents and averaged 2 a year compared with only 1 in the two-year “after” period. But vehicle/vehicle collisions on the immediate approach at the entrances
to the roundabout totalled 4 afterwards whereas there was only 1 in the five year "before" period.

St Enoch's Road is a very short arterial route with few accidents. It does appear however from the number and location of pedestrian accidents, that pedestrian safety has improved following installation of the refuges.

Accidents on the Wibsey High Street route have remained largely unchanged although there has been an improvement at North Road where footway crossovers were installed.

Wibsey Roundabout now carries somewhat more traffic but this has had no adverse effects on this noticeably 'safe' junction, given the volume of vehicles which use it.

In summary, most of the measures have had a positive effect in reducing accidents which occurred in the day-time. Some increases in accidents have occurred, virtually all at night-time. This suggests that further savings could possibly be made by selective improvement in street-lighting at appropriate locations.

4.5.2 Local distributor routes

Generally, accident problems on the local distributor routes tended to be scattered along each route, with speed being identified as a factor due to the width and/or the alignment of most of these routes. The majority of pedestrian accidents involved children. The various measures were aimed at making the routes less attractive to through-traffic and at reducing vehicle conflicts at the arterial junctions. Along the wide routes, measures such as refuges were installed to slow traffic down and assist pedestrians crossing. Accidents on the distributors averaged 15 a year before the scheme was introduced and 12 a year afterwards. This represents an estimated reduction similar to that on the arterial routes, but the 95% confidence interval is twice as wide. Thus even the almost halving of accidents occurring in daylight does not produce a significant result, even at the 90% confidence level, due to the much lower numbers of accidents on these roads.

Although Buttershaw Lane is not a particularly satisfactory traffic route, accidents were negligible. No measures, therefore, were installed in this short length of road. The remainder of the route, namely Royds Hall Lane/Abb Scott Lane was treated with two sets of rumble strips to reduce speeds. The average number of accidents appears to have increased, but accidents on this route were much higher in 1979 and 1980, i.e. the two years preceding the "before" period, and most occurred at night. As far as can be ascertained, there were no changes in the "before" period to explain the variation. The "after" period also shows a high proportion of such accidents, whereas the immediate two-year "before" period shows the opposite pattern. Thus, the situation in the "after" period falls within the pattern of previous years, albeit quite a bit further back in time.

The installation of refuges on the St Helena Road/St Pauls Avenue route and the improvement at the Reevy Road junction have helped to reduce accidents on this route from an average of 3.5 a year to 1 a year after implementation. About half this saving has occurred at the Reevy Road
junction, where accidents have been eliminated as a result of the minor realignment here.

Moore Avenue was also treated with a series of large refuges over much of its length. There was on average 1 pedestrian accident a year before they were installed and there have been none in the two-year "after" period. A common feature of the "after" period accidents is that they all involved a single moving car loosing control at night-time and colliding with a roadside object or parked car away from a junction.

Accidents on the Wibsey Park Avenue route, overall have remained about the same despite a cluster at the Reevy Road staggered T-junction, when, in the first three months of the "after" period, 4 accidents occurred. All involved cars turning first into and then out of the main road and being hit by a motorbike on the main road. Of these, 3 were due to lack of care by the car drivers turning left out of the eastern arm where the sub-standard sight-line (with stop sign) had been improved. On the section where the refuges were installed, the average number of accidents was over 2 a year beforehand and 1 a year afterwards.

Safety benefits appear to have resulted from the installation of the large refuges on these routes, with the more vulnerable road users being the main beneficiaries, but the low figures mean that the statistical confidence is lacking.

4.5.3 Residential areas

The study area has been divided into five separate areas, the boundaries of which are formed by major routes. These are broadly analogous with local place names and/or the predominate type of housing.

The Wibsey/Odsal area in the north east has Wibsey High Street running through it. No measures were installed within the area itself, but footway crossovers were installed on a number of roads at their junction with arterial routes. Accidents here were an average of 4 a year before the scheme was implemented and 3 over the two-year "after" period. Comparison of the locations of the accidents suggested that there was no apparent measureable effect of the scheme, and as can be seen in Table 1, there is a very large variability of the number of accidents year by year in this area.

The south east area, Low Moor, includes a park, cemetery, recreation ground and playing fields, so the number of houses is much less than its size would suggest. There were an average of 3 accidents a year beforehand and 1 a year afterwards in this area, with the respective figures for Netherlands Avenue being 2 a year and 1 in 2 years. In this area though, there were very few pedestrian accidents.

Woodside, the south western area, also had no measures installed within it. Accidents, since the scheme was implemented have remained about the same as before.

Buttershaw can be split into two separate areas by virtue of housing type, with Wibsey Park Avenue forming the divide. The smaller part to the south east, contains privately-owned housing, mostly semi-detached with off-street parking, and with few accidents involving pedestrians. No measures
Table 2:
Injury-accidents involving pedestrians in the Bradford study area and comparison

<table>
<thead>
<tr>
<th></th>
<th>1981</th>
<th>1982</th>
<th>1983</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td>STUDY AREA : ARTERIAL ROUTES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Becon Road</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Cleckheaton Road</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cooper Lane</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Great Horton Road</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Halifax Road</td>
<td>7</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Huddersfield Road</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Osbal Roundabout</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>St. Enoch's Road</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Wisbe High Street route</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Wisbe Roundabout</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>STUDY AREA : TOTAL ARTERIAL ROUTES</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>COMPARISON AREA : TOTAL ARTERIAL ROUTES</td>
<td>19</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>STUDY AREA : LOCAL DISTRIBUTOR ROUTES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abb Scott Lane/Boys Hall Lane</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Buttersh Lane</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Moore Avenue</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>St. Beelu Road</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>St. Paul's Avenue</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wisbe Park Ave/Fairfield Ave/Carr House Lane</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>STUDY AREA : TOTAL LOCAL DISTRIBUTOR ROUTES</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>COMPARISON AREA : TOTAL LOCAL DISTRIBUTOR ROUTES</td>
<td>9</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>STUDY AREA : RESIDENTIAL AREAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisbe/Osbal</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Low Moor</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Woodside</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Buttersh-South East</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Buttersh-West</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Wisbe/Horton Bank</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>STUDY AREA : TOTAL RESIDENTIAL AREAS</td>
<td>8</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>COMPARISON AREA : TOTAL RESIDENTIAL AREAS</td>
<td>14</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>STUDY AREA TOTAL OVERALL</td>
<td>33</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>COMPARISON AREA TOTAL OVERALL</td>
<td>42</td>
<td>46</td>
<td>54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
<td>to</td>
<td>R5</td>
<td>Imp</td>
<td>A1</td>
<td>A2</td>
<td>A1-A2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>14</td>
<td>2.8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0.6</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0.6</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>8</td>
<td>1.6</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>23</td>
<td>4.6</td>
<td>3</td>
<td>5</td>
<td>11</td>
<td>8</td>
<td>8</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>18</td>
<td>3.6</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1.4</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>20</td>
<td>4.0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>12</td>
<td>22</td>
<td>101</td>
<td>20.2</td>
<td>10</td>
<td>15</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>102</td>
<td>20.4</td>
<td>8</td>
<td>17</td>
<td>18</td>
<td>17.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0.6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
<td>1.6</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>22</td>
<td>4.6</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9.0</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>56</td>
<td>11.2</td>
<td>8</td>
<td>8</td>
<td>11</td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>13</td>
<td>2.6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0.8</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1.0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>28</td>
<td>4.8</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>3.0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>50</td>
<td>10.0</td>
<td>6</td>
<td>9</td>
<td>10</td>
<td>9.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>73</td>
<td>14.6</td>
<td>9</td>
<td>16</td>
<td>8</td>
<td>12.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>37</td>
<td>174</td>
<td>34.8</td>
<td>17</td>
<td>27</td>
<td>38</td>
<td>32.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>38</td>
<td>231</td>
<td>46.2</td>
<td>25</td>
<td>41</td>
<td>17</td>
<td>39.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Implementation period
(1) : 6 months from 1.1.86 to 30.6.86
(2) : 1.7.86 to 30.6.87
A1 - 1.7.86 to 30.6.87
A2 - 1.7.87 to 30.6.88
were installed within this area and the accident numbers are unchanged. By contrast, the much larger north western part of Buttershaw is mainly open-plan local authority housing, with no off-street parking, where the dominant feature was child pedestrian accidents. Measures were concentrated in the Reevy Road West spine road, in the vicinity of a shopping parade. Accidents in this residential area were on average 9 a year before and 13 a year since the scheme was implemented, and despite some improvement due to the measures in Reevy Road West, child pedestrians accidents have increased overall. As in the "before" period, over half of the accidents occurred on the spine roads, in particular Reevy Road West and Buttershaw Drive.

The northern area of Wibsey/Horton Bank also had no measures installed within it. This area contains semi-detached privately-owned housing and child pedestrian accidents were minimal. No measures were installed within the area and accidents have remained unchanged.

There appears to have been some safety benefit in the residential areas where through traffic has been removed, e.g. as the case of Netherlands Avenue. Elsewhere, accidents are generally few and there has been little change but in the western part of Buttershaw, child pedestrian accidents are still a predominant feature.

4.6 Accidents involving injury to particular road users

4.6.1 Pedestrian accidents

In the "before" period, there were about 35 accidents a year involving pedestrians with children being in a slight majority. For the two-year "after" period, the figure was 32.5 a year (see Table 2) and adult pedestrians formed a slight majority. There was a larger reduction in the comparison area so that when pedestrian accidents are substituted in the log-linear model, then a relative increase of 11% is suggested, but the 95 per cent confidence interval is very wide (+64% to -25%). If just child pedestrians are modelled a reduction is indicated but with even wider confidence limits.

On the arterial routes in the study area, the number of pedestrian accidents has not changed at around 20 a year, but there has been a small shift towards a lower involvement of children. On the distributor routes pedestrian accidents averaged 4.6 a year before the scheme with 3.0 a year afterwards, the numbers involving adults remained about the same so children benefitted. In the residential areas as a whole, there was no overall change in the number of pedestrian accidents or the proportion involving children.

The conclusion is that safety benefits for child pedestrians may have accrued on the local distributor routes where measures have been installed specifically for pedestrians. On the arterial routes and within the residential areas very few such measures were used and the number of pedestrian accidents has not changed.

4.6.2 Users of two-wheeled vehicles

This category of accidents excludes any in which a pedestrian was injured and is subdivided into two groups, pedal cyclists and powered two-wheelers. Cases where both vehicles were involved are classed as pedal cycle accidents.
Accidents involving pedal cyclists in the study area were on average 10 a year previous to the scheme being implemented and 6.5 a year afterward. Whereas in the comparison area the respective figures remained unchanged. Although the reduction is proportionately greater than for all accidents, it is not significant because the numbers are small and 95% confidence interval is very wide indeed (127 percentage points). The majority of pedal cycle accidents occurred in day-light and these figures have halved whereas those which occurred in night-time remained unchanged. The change has taken place on all the three types of road but most of that on the arterial routes has taken place at Odsal Top Roundabout.

Those accidents involving injury to only the driver or passenger of a powered two-wheeled vehicle averaged 27 a year before and less than 20 a year after the scheme was implemented. However, there has also been a similar reduction in the comparison area where accidents overall have remained unchanged. Nearly all the change in the study area has taken place on the arterial routes and virtually all in day-light.

In summary, accidents involving two-wheeled vehicles have shown proportionately the greatest change. Safety for pedal-cyclists has improved the most whereas for powered two-wheeled there has been a similar change in the comparison area.

4.7 Severity of accidents

The severity of injury-accidents has been considered in order to determine if there are any instances where this has changed either on a particular road, for a particular more vulnerable user group (such as pedestrians) or at a particular location where changes in traffic flow have occurred as a result of the scheme. In this respect, severity is expressed as the proportion of fatal and serious accidents expressed as a percentage of all accidents. By that yardstick, there appears to have been a slight increase in severity since the scheme was implemented whereas in the comparison area, there has been a reduction. The reason for this is that there has been a reduction of 15 in the number of slight injury accidents in the study area, from approximately an average of 83 a year before the scheme to 67 a year afterwards which is equal to the reduction in all accidents. This is estimated to be a fall of 24% with a 95% confidence interval ranging from decreases of 2% to 42%. Fatal or serious accidents however remained the same averaging some 27 a year.

There has been a change in the number of severe accidents involving two-wheeled vehicles in line with the change in all such accidents, although there are differences between the different types of road. The number of pedestrian accidents involving fatal/serious injury was 10 a year before the scheme and 12 afterwards, whereas pedestrian accidents overall reduced somewhat, but not significantly. In the residential areas, the severity of pedestrian accidents has remained constant whilst, on the distributor routes, there has been an improvement in those cases involving children. On the arterial routes there has also been no change in severe pedestrian accidents except for Halifax Road, particularly the section from St Paul's Avenue to Odsal Top Roundabout (as discussed earlier).

The scheme has not, therefore, had a direct effect on the severity of accidents, but the increase in accidents on the eastern section of Halifax
Road has nearly all involved severe injury and must be a cause for concern even though the numbers are low.

4.8 Summary

There has been an overall reduction in the number of injury-accidents in the Bradford study area from 110 a year to 95 a year. This is estimated to be a fall of 14% when compared to a similar area on the other side of the city, but this reduction this is not quite significant at the 95% confidence level. However, there has been a slight, but insignificant increase in the average number of accidents occurring in darkness and so the fall of 19 accidents occurring in the daytime is estimated to be a significant reduction of 30%. This reduction in daytime accidents and small increase in night accidents has taken place on all the three categories of road, though not uniformly throughout.

Accidents involving cyclists and drivers and riders of powered two-wheeled vehicles have benefitted most. Pedestrian accidents overall have not benefitted much but those involving children have improved slightly, compared with those involving adults.

The decrease in accidents has wholly occurred within the slight injury category. The number of fatal and serious injury accidents has remained the same and so, as a proportion of all accidents, has increased.

The greatest relative effect on accidents appears to have been on the local distributor routes. However, when the comparison area accidents are taken into consideration, this has been about the same order on both arterials and distributors, with little change in the residential areas. On the arterial routes, most of the measures have showed varying degrees of accident-saving, but the night-time accidents at some locations suggest that remedial treatment is required, in particular the eastern section of Halifax Road where serious pedestrian accidents have occurred. On the local distributor routes safety benefits have accrued to child pedestrians and drivers and passengers of two-wheeled vehicles. On residential streets, as a whole, there has been no change; where through traffic has been eliminated, there has been a benefit, but the western part of Buttershaw remains a cause for concern regarding the continuing high level of child pedestrian accidents.

5. EVALUATION OF COSTS AND BENEFITS

5.1 Introduction

An evaluation of the economic benefits of the scheme has been carried out, assuming a useful economic life of five years. This has been based upon comparing the costs of designing and installing the scheme with the benefits that accrue from the reduction in injury accidents.

It is standard practice to apply different values to the avoidance of accidents depending upon their severity and to allow for increases in real values of accident savings with time in line with real income. Future costs and benefits are then discounted at a standard rate, currently 7% per annum for transport schemes. However, due to the large confidence range of the accident reductions, it is considered that incorporation of all these
factors would suggest an exaggerated level of accuracy. Thus, over the notional five year life of the scheme, all figures are calculated at constant 1986 prices, with no allowances for real increases in values or the discounting of future benefits.

5.2 Accident benefits and scheme costs

There are two components for the costs of the scheme which have been taken into account. These are the cost of all the works associated with implementing the scheme, which amounted to £249,000; and an assumed cost of staff for design and management, which has been taken as equal to the cost of implementation, giving a total of £498,000.

After two years' operation of the scheme, there has been an average accident reduction of 14%, which is 15 accidents a year. In the interim period, there was a decrease of 6% which gives an additional saving of 3 accidents.

The average cost of an injury accident in a built-up area is £12,560 (Department of Transport, 1987), thus interim period accident savings amounted to £37,680 and subsequent accident savings are £948,750 per year amounting to £948,750 over five years. This gives a payback period of two years on the total cost of £498,000.

5.3 Summary

Combining the above results yields the following:

<table>
<thead>
<tr>
<th></th>
<th>costs</th>
<th>benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>implementation and works</td>
<td>£249,000</td>
<td></td>
</tr>
<tr>
<td>design and management</td>
<td>£249,000</td>
<td></td>
</tr>
<tr>
<td>accident savings during interim period</td>
<td></td>
<td>£37,680</td>
</tr>
<tr>
<td>accident savings for 5 years afterwards</td>
<td></td>
<td>£948,750</td>
</tr>
<tr>
<td></td>
<td>£498,000</td>
<td>£986,430</td>
</tr>
</tbody>
</table>

On this extremely simplified basis, therefore, the benefit/cost ratio over an assumed life of five years is 2.0.

6. CONCLUSIONS

The area-wide strategy formulated to improve road safety in urban areas has been effective in reducing accidents in the Wibsey-Buttershaw area of Bradford when compared with a similar area on the opposite side of the town. The overall reduction, after two years operation of the 'counter-measures', is estimated to be 14%, with 95% confidence of -31% to +8%. There has been a significant reduction in those accidents occurring in conditions of day-light; estimated to have reduced by 30% and those involving only a slight casualty injury which were reduced by 24%. Where accidents have reduced as a result of a particular measure [or measures] one dominant feature of the 'before' accidents was for example a substantial preponderance of day-light accidents; rather than that measures have generally not been successful in reducing night-time accidents.
In Bradford, extensive public consultation lead to a re-shaping of the initial safety strategy although most of the individual components remained unchanged. Thus very few measures needed to be amended when the scheme was implemented.

The predominant problems that were identified were traffic conflicts at a number of junctions on the main roads, in particular where some local distributor routes intersected with arterial routes. Thus nearly all the counter-measures were installed on the main roads and so these roads have benefited most from the reduction in accidents. A further feature therefore is that there has been little change in pedestrian accidents; the main beneficiaries of the measures have been riders and passengers of two-wheeled vehicles.

One road, a section of Netherlands Avenue, had a number of measures installed to prevent through traffic in order to reduce its status from a local distributor to an access road. The measures were successful and the amount of non-compliance was relatively small. Most of the displaced traffic was contained in the arterial road network, with the particular routes being unaffected, but at the major roundabout junction there were longer queues on some of the arms in the peak hours, which in some cases led to additional delay. Some of the displaced traffic migrated to parallel routes, comprising a local distributor road and an access road, (although it must be noted that the number of frontaging properties is extremely low). The measures were relaxed towards the end of the scheme, following representation, from the local residents, but it appears that these 'access-only' restrictions, are being ignored by a growing volume of through traffic.

New pedestrian refuges have attracted pedestrians to cross at them on the arterial routes. On distribution roads, where traffic flows are much lower single refuges do not appear to have much effect, but a series of refuges does have an attraction for pedestrians who cross mainly in their shelter.

The total cost of the scheme was £498,000, of which half was estimated to amount for its design and construction. The estimated savings accruing from the scheme will recoup these costs within two years.

7. ACKNOWLEDGEMENTS

The Urban Safety Project is a collaborative project between the Department of Transport and local authorities. The project was managed by the Transport and Road Research Laboratory and the Bradford scheme was monitored by a team in the Transport Operations Research Group (TORG) at the University of Newcastle upon Tyne, led by Richard Walker, under the direction of Professor Peter Hills and Mr David Silcock, assisted by colleagues from the monitoring team at the Transport Studies Group at University College London, principally Heather Ward.

The authors acknowledge the assistance of officers and elected members of West Yorkshire Metropolitan County Council, the City of Bradford Metropolitan Council, West Yorkshire Metropolitan Police and West Yorkshire Highways, Engineering and Technical Services Joint Committee.
The authors wish to thank colleagues at TRRL for their assistance and helpful comments throughout the project: Miss B E Sabey and Mr E Dalby (both now retired), Mr D A Lynam, Mr A H Mackie and Mr C H Davies.

In particular, the authors wish to thank colleagues, past and present, in TORG especially Geoff Gardner, Andrew Beardmore, Stephanie Lane, Julie Middleton, Nigel Peacock and Bob Sharp, who all helped at various stages of the project in checking and analysing the very large amount of data. Thanks also go to colleagues at University College London, who maintained the accident data-base, wrote computer programs and assisted with the analyses.

The work described in this report forms part of the programme of the Transport and Road Research Laboratory and the report is published by permission of the Director.

3. REFERENCES


ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (1979)  

countermeasures for application in residential areas. Research Report  
39, Transport Operations Research Group, University of Newcastle upon  
Tyne.

their effectiveness. Symposium - Road safety and the road user,  
University of Salford.

flow of traffic from a moving vehicle. Proceedings, Institute of  
Civil Engineers, Pt. II, 3, 158-171.

WALKER, R.T. (1975) Route hierarchy and accident patterns in area-wide  
safety schemes. Symposium: - Road safety and the  
road user. University of Salford.

WALKER, R.T. (1987) Appraisal process leading to development of area  
safety in Bradford. Symposium: - Recent developments in research and  
road safety. University of Salford.
APPENDIX A1 : Results of the traffic surveys on arterial routes

Beacon Road

The traffic flow on this route gradually increases as it approaches Wibsey roundabout, due to local traffic. After the scheme was implemented, there have been changes in the numbers of turning manoeuvres at the junctions with several of the spine roads and access roads along this route. Overall, however, traffic flows along the route have hardly changed at all, ranging from about 470 vehicles per hour at the western end to almost 700 vehicles per hour at Wibsey roundabout. The time taken to traverse this route has consistently increased by between 13 and 23 seconds [about 10%], depending upon the time of day, due to the extra time needed to negotiate the modified junction at Cooper Lane/Beacon Road and some extra delay due to increased traffic on Wibsey Roundabout.

Cooper Lane

At its northern end, the changes in traffic at Great Horton Road and Beacon Road have resulted in increased traffic on Cooper Lane. Further south, it appears that this road is now also a more popular route for traffic from the adjacent residential area of Buttershaw. The two movements to and from the east have increased at Halifax Road, as has the total flow from 200 to 260 vehicles per hour. It must be concluded that Cooper Lane is carrying both more through and more local traffic than before.

Cleckheaton Road

There has been an increase on this route, between Odsal Roundabout and Common Road, from an average of 480 vehicles per hour to 800 per hour, as a result of the measures to prevent through traffic using Netherlands Avenue between Halifax Road and Huddersfield Road. However, it is clear that not all the displaced traffic has transferred to this route because at the boundary of the study area, the average flow on that section of Cleckheaton Road has decreased from around 880 vehicles per hour to the figure of 800 shown above. Due to the additional traffic on this route, the longer queues at Odsal Roundabout have resulted in longer journey times in the evening period of on average around a minute [about 40%] but there are very large variations in the times between the individual surveys and clear evidence for a strong seasonal effect with journeys taking upwards of half a minute longer in winter, when it is mostly dark, than in summer.

Great Horton Road

This route forms the north-west boundary of the study area and is unusual in that there is on average, consistently more traffic flowing in the easterly direction towards the city centre, whereas flows are typically about equal in each direction on the other main roads. After the scheme was introduced, there was a consistent but insignificant increase on this route. The closure of Beacon Road concentrated all the turning movements at the Cooper Lane junction did not reduce movements between Great Horton Road and Beacon Road, rather there was a general slight increase in movement overall.
Halifax Road

Traffic flows on Halifax Road gradually increase towards its eastern end, due to the city centre and areas served by the ring road being more important for local traffic than places to the west of the study area. Generally traffic has increased on Halifax Road since the scheme was implemented. Typically, from around 1000 to 1100 vehicles per hour at the western end and from 1100 to 1300 vehicles per hour at Odsal roundabout. At some locations however the change is not significant at 5% level, due to differences in turning movements at a particular junction. At the western end, additional traffic on Cooper Lane has resulted in an increase in the two turning movements at this junction, those to and from the east. This is matched by similar increases in the turning movements to and from the west at Abb Scott Lane. At the St Paul's Avenue/ Netherlands Avenue junction, there has been a reduction in all but one of the movements into and out of Netherlands Avenue, as a result of the measures to prevent through traffic on this route.

Huddersfield Road

There has been a general increase in the flow along this route as a result of the measures in Netherlands Avenue. Traffic has increased in both directions on the slip roads to and from Odsal Roundabout, rising from a total average flow of 450 to about 500 vehicles per hour. The additional flow into Odsal Roundabout, together with increased traffic on the roundabout from Cleckheaton Road, have resulted in some additional delay here in the morning and evening periods, but this has been offset by a reduction in journey times along the main section of Huddersfield Road. It also appears that there is more traffic using the underpass at Odsal but the change is not significant. At Netherlands Avenue the removal of the previous through movement on this route is shown by the reduction in the movements across Huddersfield Road and the two north-west/south-east turning movements. Some of the displaced traffic has transferred to the Royds Hall Lane/Abb Scott Lane distributor and Common Road, the connecting access road, with increases in turning movements observed at both junctions. At Abb Scott Lane, the increases in left turn (in) and the right turn (out) movements reflect reductions in these movements at Netherlands Avenue, whilst Common Road is clearly used as a through route to Cleckheaton Road. At the Abb Scott Lane junction, the flow on Huddersfield Road towards Odsal has not changed whereas, in the opposite direction, it has increased and so the total average flow has risen from about 1400 vehicles per hour to 1490 vehicles per hour.

St Enoch's Road

The section of St Enoch's Road between Mount Road and Moore Avenue carries more traffic towards Wibsey roundabout than previously, as a result of the measures which prohibited the right turn out of Moore Avenue and transferred this movement to Mount Road. Traffic on the remainder of the route has remained unchanged, although there have been changes in turning manoeuvres at access roads.
Wibsey High Street

There has been a general increase in traffic on the Wibsey High Street route but this is not quite significant over the section between Wibsey Roundabout and Folly Hall Road. The additional traffic from Folly Hall Road/Upper George Street is sufficient to ensure that the increase is significant for the remainder of the route to Odsal roundabout, there being no additional traffic exiting at Wibsey Bank. The average flow on the section between Folly Hall Road and Smith Avenue, where the original restrictions were proposed, has increased from 850 vehicles per hour to about 950 vehicles per hour. The additional traffic on this route has resulted in longer queues at the entry to the two roundabouts, with increased journey of on average some 12 to 18 seconds [about 10%].

Overhead filming at roundabouts

The two most important junctions in the study area are controlled by roundabouts. It was not possible to survey the turning movements of vehicles directly due to practical difficulties notably the number of arms, the volume of traffic. The data on the movements of traffic was collected by overhead filming carried out by TRRL, the films being subsequently analysed by the monitoring team using a variable-speed projector. Unfortunately, the size and disposition of Odsal Top roundabout was such that part of the roundabout was not revealed in the film and it was not possible to infer any of the movements concerned.

Filming took place at standard times as with the junction surveys. One survey was carried out in the "before" and one in the "after" period.

Wibsey roundabout is a medium-sized roundabout at the junction of St Enoch's Road, Fair Road (Wibsey High street), St Helena Road, Wibsey Park Avenue and Beacon Road. The junction of Moore Avenue with St Enoch's Road is very close to the roundabout and effectively constitutes a sixth arm. A number of measures were introduced nearby, with the intention of reducing traffic on Moore Avenue and a nearby residential road. The effect of this has been a small increase in the volume of traffic using the roundabout, over half of which can be directly attributed to the measures introduced. A median island provides the physical enforcement to prevent right-turns into Moore Avenue from St Enoch's Road, the alternative route involves a U-turn at the roundabout and then a left-turn into Moore Avenue. This movement has increased, as has the movement from St Enoch's Road to Beacon Road, due to the other nearby measures. St Enoch's Road contributes about one-third of the flow to the roundabout and the other changes in flow on this arm involve a shift in the predominant movement from St Helena Road, before the scheme was implemented, in favour of Wibsey High Street afterwards. Wibsey High Street, however, showed no change in flow overall as a result of the scheme. Flow into the roundabout from this arm remains at just over 20% of the total, with a slightly larger movement towards St Enoch's Road than towards Beacon Road.

The inflow from Beacon Road has increased as a result of nearby measures to prevent traffic bound for St Enoch's Road by-passing the roundabout though it is still slightly less than the flow from Wibsey High Street. Individual movements from Beacon Road have changed with a reduction in the movement to St Helena Road and an increase towards Wibsey High Street. On St Helena Road, there has been a small increase in traffic towards the
roundabout, but the larger reductions in traffic on this arm, especially from St Enoch's Road and Beacon Road, will have been due to the measures further south, on Netherlands Avenue, rather than those in the vicinity of the roundabout. Lastly, the flow from Wibsey Park Avenue has increased, but it is most unlikely that the nearby measures have caused this.

The conclusion is that the measures adjacent to the roundabout have had a noticeable effect on the three movements most directly affected. There have been other changes which can be attributed to measures farther away, demonstrating their area-wide effect. However, not all the measures on Netherlands Avenue were installed at the time of the filming in the "after" survey and so, some of the changes described above appear to have lasted for only a short period and thus, show differences to the results from the full-scale monitoring.

APPENDIX A2 : Results of the traffic surveys on distributor routes

Moore Avenue

At all the places where traffic along Moore Avenue was counted, there has been a reduction in flow but, in each case, this is small and not significant. For example, on the middle section, the total average flow has decreased by 30, from 550 to 520 vehicles per hour. At Great Horton Road, the right turn into Moore Avenue has increased, probably due to the prohibition of this manoeuvre at the nearby junction of Great Horton Road with the Pickles Lane spine road. The left turn flow out of Moore Avenue into Great Horton Road has decreased, probably due to the closure of the western arm of Moore Avenue. Both of these changes are reflected in changes in movements at the Moore Avenue/Poplar Grove junction. The changes at Great Horton Road have also had an effect on journey times, in particular the heavy right turn movements out of Moore Avenue has incurred additional delay of between 10 and 23 seconds, which is an increase of about 15% in the journey time from St Enoch's Road. At the other end of Moore Avenue the re-routing in the direction towards St Enoch's Road via Mount Road has increased the total distance by some 10%. This has resulted in the journey times in this direction increasing by the same proportion, which amounts to between 15 and 20 seconds depending upon the time of day.

St Helena Road/St Paul's Avenue/Buttershaw Lane

There has been a substantial reduction of traffic on the St Helena Road/St Paul's Avenue route, due to the measures prohibiting through movements on Netherlands Avenue. At the northern end, by Wibsey roundabout, the average flow on St Helena Road has fallen from 580 vehicles per hour to 440 vehicles per hour. On the southern part of the route, St Paul's Avenue, the reduction in traffic is more noticeable, as it has halved from 350 vehicles per hour to 170 vehs per hour. This is accounted for by the reduction in the crossing movement to and from Netherlands Avenue. Surprisingly, there has been no change here in the left turn out of St Paul's Avenue or the right turn in. So, there has been no obvious transfer of the previous crossover movement. Nor has there been any transfer of this north-south movement to Buttershaw Lane, (see below) as the flows on this route have remained unchanged.
Royds Hall Lane/Abb Scott Lane

Traffic has increased on this route. At Halifax Road, the left turn flow out and the right turn flow into Royds Hall Lane have both increased, with the total average hourly flow increasing from 290 to over 330 vehicles per hour but there has been no change in the movement to or from Buttershaw Lane. About half of this increased traffic continues along Abb Scott Lane to Huddersfield Road, where the two corresponding turns (the left turn in and the right turn out) have increased. The other half also travels to and from Huddersfield Road, via Common Road and thence to Cleckheaton Road. The additional traffic on Royds Hall Lane/Abb Scott Lane has resulted in longer queues waiting to exit at Huddersfield Road. The journey time from Halifax Road to Huddersfield Road has increased by between 24 and 57 seconds which is 16% and 37% respectively. In the opposite direction however, journey times have remained unchanged because the right turn into Halifax Road has been assisted by the new refuge at the zebra crossing, and also there is room at the junction for the left turn into Halifax Road, which has increased, not to be unduly delayed by vehicles waiting to perform the right turn movement.

Wibsey Park Avenue

This route is similar to Halifax Road, in that there is a general rise in the volume of traffic as the route progresses eastwards towards the city centre and so, at Wibsey roundabout, 80% of vehicles travel to and from St Enoch's Road. There has been an increase in the eastbound movement towards Wibsey roundabout, of around 20 to 30 vehicles per hour on the western section (where it is significant) but at the eastern end the increase is less and not significant. Westbound traffic has shown a similar but lower rise, which is not significant. Thus at Wibsey roundabout there has been little overall change in traffic on this route, with an average total flow of just over 400 vehicles per hour.

APPENDIX A3 : Results of the traffic surveys in the residential areas

Wibsey - Odsal

This area is bounded by St Enoch's Road, St Helena Road/Buttershaw Lane and Halifax Road and, through it runs Wibsey High Street between Wibsey and Odsal Roundabout. No measures were implemented on any of the spine or access roads and thus any changes will be due to measures on the main routes. There has apparently been no transfer of the through traffic displaced from Netherlands Avenue to the Smith Avenue spine road, where flows have remained at between 65 and 90 vehicles per hour.

On Reevy Road/Folly Hall Road there have been increases in traffic at each end of this spine road, reflecting a rise in the use of this route by traffic travelling to and from the central section of Wibsey High Street, where the right turn out of Folly Hall Road is now assisted by the new roundabout. The provision of this roundabout could also explain the increases in all of the movements out of Upper George Street whereas the in flow has remained unchanged.
Low Moor

Low Moor is bounded in the north by Halifax Road and on the west by Royds Hall Lane/Abb Scott Lane, whilst on the south and east there is the study area boundary itself. The measures in Netherlands Avenue have reduced the average traffic flow in the north-western section (between Halifax and Huddersfield Roads) from 380 vehicles per hour to less than 100. At Halifax Road, the only permitted movements for most of the time were the left turn into Netherlands Avenue and the left turn out, from which a right turn movement could then be carried out into St Paul's Avenue. Very few vehicles contravene the turning restrictions here, the prohibited right turn into Netherlands Avenue was made by only 1 vehicle per hour compared to the previous figure of 50 before the measures were introduced whilst the prohibited crossing movement from St Paul's Avenue averages less than 1 per hour compared with over 100 previously. Local access traffic is obviously affected by these measures, which is seen in the increase in the left turn in movement accompanied by a corresponding U-turn in Halifax Road at a number of places to the east of Netherlands Avenue. The directional No-Entry prohibition in Netherlands Avenue by Beech Avenue was much less well observed and infringements average about 16 vehicles per hour, although this should be compared with the previous figure of 180 vehicles per hour. This latter restriction resulted in more vehicles gaining access to the area via Larch Hill, where both of the turning flows in from Huddersfield Road have increased, whereas the flows out remained constant. Whilst some of this inbound traffic progressed through to Netherlands Avenue via Beech Avenue, it was roughly matched by a reduction in vehicles entering from the opposite direction.

When the turning restrictions at Netherlands were modified to allow further local access, then the U-turn movement in Halifax Road ceased and the left turn into Netherlands Avenue fell to about the same figure as before the scheme was implemented, but the prohibited right turn out has increased noticeably. At the same time that the turning restrictions in Netherlands Avenue were relaxed, the no-entry prohibition by Beech Avenue was replaced by an "access only" restriction at Huddersfield Road. This did not result in an immediate increase in illegal through movements, but a subsequent check a year later indicates that these have increased substantially. The other residential road in the area which has been affected is Common Road, between Abb Scott Lane and Huddersfield Road, which now carries some of the traffic displaced from Netherlands Avenue. Flows on this road have risen by an average of 45 vehicles per hour, from between 130 and 150 per hour to between 175 and 195 per hour.

Woodside

This area, which lies to the west of Royds Hall Lane/Abb Scott Lane and south of Halifax Road had no measures installed within it. The only measureable affect has been a greater use of Meadoway, with consistent increases on all the entering and leaving movements at Halifax Road, giving a rise in the total flow from 70 vehicles per hour to 100 vehicles per hour. This could be accounted for by the recent development of 200 properties off Meadoway.
Buttershaw South East

The boundaries of this area are Halifax Road, Wibsey Park Avenue and St Helena Road/Buttershaw Lane. Measures were installed in the area on two adjacent roads, at their junction with Halifax Road. One was made one-way towards Halifax Road and the other one-way from Halifax Road; in each case, full compliance with the restrictions has been observed. There was an increase in traffic on Reevy Road, crossing over St Helena Road, but there is no change in the turning traffic to and from the south at this junction (which is surprising in view of the measures in Netherlands Avenue). There have been no measures applied at the western end of Reevy Road, although it does now carry somewhat more traffic. No changes have occurred on Harbour Road, the other spine road.

Buttershaw West

This, the largest of the residential areas, is bounded by Beacon Road, Wibsey Park Avenue and Cooper Lane. There has been an increase in traffic on three of the four turning movements at the western end of Reevy Road West but the actual flows are low, with the total volume increasing from 120 vehicles per hour to 144 vehicles per hour. This increase of around 25 vehicles per hour is also found at the eastern end at Wibsey Park Avenue, but the only significant change here has been the right turn into Reevy Road. There have been changes in turning movements elsewhere on this spine road and some of the other spine roads, but in each case the numbers are very low.

Wibsey - Horton Bank

Great Horton Road, St Enoch's Road and Beacon Road form the boundaries for this area. The right turn prohibition into Pickles Lane from Great Horton Road has not been well observed, with infringements averaging three vehicles per hour compared to nine previously. There have been changes in traffic flows on a number of the roads as a result of various measures on the main roads. The measures on Great Horton Road have resulted in an increase of traffic on the Poplar Grove/Old Road route of about 15 to 20 vehicles per hour, due to a transfer of traffic into this route, to and from the east side of Moore Avenue, from the previous route of Moore Avenue/Great Horton Road. Greater use is now also being made of Watty Hall Road, as a result of the measures at St Enoch's Road/Mount Road/Moore Avenue, with increases in all the turning flows, resulting in an increase of 50% in the total flow from 70 vehicles per hour to 105 vehicles per hour.

APPENDIX A4 : Results of the pedestrian surveys

Arterial Routes

Great Horton Road

On Great Horton Road, between Old Road (east) and Moore Avenue, a number of measures were adopted. Those directly to assist pedestrians consisted of a refuge between two-side roads and the closure of the western arm of Moore Avenue. There appears to have been a decline in child pedestrian activity at this location, subsequently, so interpretation of some of the results is
difficult. Despite the closure of one arm of Moore Avenue, pedestrian movement across this side-road has decreased also. Movements across Great Horton Road, in the section containing the refuge, have risen (but not significantly). The majority of people are now using the refuge, which may account for some, but not all, of the decrease across the mouth of Moore Avenue.

Halifax Road

At the junction of Royd's Hall Lane and Buttershaw Lane, the safety objective was to assist pedestrians by providing a large refuge for the Zebra crossing in conjunction with right-turn bays. The effect has been to increase crossing movements within the zig-zag markings on the side of the zebra, where there were a few shops, but there has been a correspondingly greater decrease in movements on the adjacent section of road. Crossing movements at the Zebra crossing itself have remained constant. This transfer of crossing movements could be due to the shielding effect of the large refuge extending beyond the area of the crossing.

Between Beck Hill and Fleece Street, two conventional refuges were installed, to assist pedestrians as well as to deter vehicles from overtaking. One refuge has clearly attracted crossing movements from a considerable length of road on either side, extending to the area containing the second refuge. The more attractive refuge was observed to be very well used by pedestrians whereas the other one is little used.

St Enoch's Road

The safety measures for St Enoch's Road were to reduce the carriageway width and to assist pedestrians by means of refuges. Pedestrian crossing activity was observed on the section between Brown Royd Hill and Oakdale Avenue, where one of the refuges was installed. Crossing movements have increased on that part containing the refuge, which was used by the majority of people crossing on that length of the road.

Wibsey High Street

The original objective for this route was to prevent the eastbound movement, except for buses. Initially, this was to be done at Oakroyd Road and so, pedestrian movements were surveyed in its vicinity. This area is the focus of considerable pedestrian activity and included a Zebra crossing. Subsequently, the site suggested for the traffic restriction was moved eastwards and so, pedestrian movements were also observed at the new location. However, the proposed restrictions initially were held in abeyance and in fact have never been implemented. At the first site, a small roundabout was installed at Folly Hall Road, with a large splitter island extending along most of the zig-zag markings back to the Zebra crossing. Most people who cross within the zig-zag markings on the roundabout side of the Zebra used the splitter island and, although the proportion of people crossing has increased, the numbers averaging 15 in 6 hours are very low. On the other side of the crossing, there has been a decrease in people crossing (significant at the 10% level), both within the zig-zag markings and nearby. The more easterly site did not have any measures installed and pedestrian movement has remained constant.
Local Distributors

Moore Avenue

A number of large refuges were installed in Moore Avenue, to reduce the effective width of carriageway and, hopefully, vehicle speeds and also to provide direct assistance for pedestrians crossing. The vicinity of Kenley Avenue is the focus for pedestrian activity associated with two bus stops and a small shopping parade, opposite which one of the refuges was installed. There has been an increase in the number of pedestrians crossing on this section of Moore Avenue containing the refuge, with a decrease in the adjacent section across the mouth of Kenley Avenue, but less than 10% of people use the refuge itself. On the section of road on the other side of Kenley Avenue, not far from another refuge, there has been an increase in crossing movements (significant at the 10% level). Thus, the refuges appear to be acting as a form of median shelter, attracting crossing pedestrians to their vicinity.

Mount Road

As part of the objective to reduce traffic in Moore Avenue, Mount Road was made one-way from Moore Avenue to St Enoch's Road and a refuge was installed across the wide mouth of Mount Road itself. Despite the substantial increase in traffic on Mount Road, few pedestrians make the lengthy detour to use the refuge.

St Helena Road/St Paul's Avenue

One of the original objectives was to encourage the use of this route, to carry through traffic displaced from Wibsey High Street but these measures were never implemented. The other objectives were to reduce traffic speeds and to provide assistance for pedestrians by means of large refuges. On St Paul's Avenue, by two junior schools, a refuge was installed at the site of the school crossing patrol. Pedestrian movements in this area have remained unchanged and people have not been attracted to the refuge from nearby.

The junction of St Helena Road and St Paul's Avenue was realigned and a refuge was installed in the mouth of the minor road, together with another on the major road. Although the refuge in the main road is well used, movement across the road has remained unchanged after installation of the measures. However, there has been a clear change in movements along the main road, with people being attracted to that side with the refuge in the minor road.

Residential Areas

Reevy Road West

Reevy Road West is a spine road in the West Buttershaw residential area. The section between Brackenholme Royd and Bessingham Gardens is adjacent to a local shopping centre, for which the safety objective was to reduce conflicts between traffic and children near parked vehicles. The measures consisted of the closure of the two-side roads, introducing waiting restrictions along one side, with parking bays opposite, thereby reducing the width of the road and creating clear focal points where pedestrians can
cross. It was also proposed to install pedestrian guardrails along one side, but this was deleted in the cost-cutting exercise. There has been a reduction in the total number of children crossing at this site since the scheme was implemented, in particular at the site of the school crossing patrol. In March 1986, the times of the school crossing patrol were amended to take account of changes in the times of some of the local schools. This coincided with the construction period and so could account for the reduction in both adult and child pedestrian movements at the patrol site. Elsewhere along the road, there have been changes in crossing locations, generally away from the parking bays towards where the kerb has been extended.

APPENDIX A5 : Results of the parking survey

Halifax Road

The safety objectives pursued, on the section of Halifax Road from west of Beck Hill to Fenwick Drive, were to prevent overtaking, to assist pedestrians to cross and to reduce the numbers of parked vehicles. The measures consisted of pedestrian refuges, together with 'no waiting at any time' restrictions over almost the entire length of road. Following the first "before" survey, the waiting restrictions were revised, thus upsetting the relationship between the survey zones and the extent of the restrictions when they were implemented. The parking survey was focussed on the section of road between Beck Hill and Fleece Street, where pedestrian behaviour was being examined.

The overall level of parking has gone down during the "after" period. The level of non-compliance with parking regulations was low, considering the long lengths of road involved, and the displaced vehicles have not transferred to the adjacent sections of the road where waiting is not restricted.

Reevy Road West

The section of Reevy Road West between Bracken Holme Royd and Bessingham Gardens was identified as having an accident problem for child pedestrians crossing between parked vehicles. Although the level of on-street parking was low, it was scattered along both sides of the road. The safety measures adopted was to consolidate the parking, by forming two parking lay-bys in the south side of the road together with 'no waiting at any time' restrictions along the north side. In the "before" period, the majority of parking occurred on the north side of the road. In the "after" period, the total amount of parking has remained the same, with vehicles displaced by the waiting restrictions transferring to the south side of the road to park in the lay-bys.