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DEPARTMENT OF MATHEMATICS

MILTON KEYNES -

AN OUTLINE COST-BENEFIT STUDY

- by -

S.G. Lennox and Joan Tidbury

SUMMARY

This is a preliminary survey of some of the factors which would need to be investigated in the design and cost-benefit analysis of alternative transport systems for Milton Keynes. It outlines the framework within which further work can be developed and provides some order-of-magnitude estimates for basic elements in the transport cost-benefit equations.

Interim conclusions draw attention to the importance of the journey to work and the extent to which work journeys are localised within the various parts of the city or evenly distributed over the city as a whole. In addition, possible commuting into and out of the city will need to be considered. If excellent transport facilities are provided, facilitating work journeys over a wide area, then the amount of travel on work journeys will also increase. How desirable is this?

The case for public transport requires much more detailed study. This initial study confirms the high cost and space requirements of road systems for high car usage. For the assumed cost levels a segregated public transport system offers a cheaper solution but selection between high cost, high capacity rail systems and lower cost, lower capacity bus systems needs to be investigated more fully. Since this work was done more detailed information has come to hand on costings for urban rapid transit systems in the U.K., ref. 3. This indicates that the public transport system construction costs assumed in this report are minimal, and that the effects of higher cost levels should also be considered before definite conclusions are reached.

City Layout

A notional city layout has been assumed as a model for generating traffic flows, calculating journey times and estimating system costs for private and public transport. This layout, shown in Fig. 1 develops some of the principles discussed in previous studies for a North Bucks new city, ref. 1 and 2, but is in no sense a definitive or recommended layout. Other layouts merit study and eventually it is intended that representative city layouts proposed by the professional town planning consultants should be examined for their effects on traffic generation and transport costs.

A basic dumb-bell shaped residential unit for 15,000 persons is postulated. This is constructed from two overlapping circles of $^3/_8$ mile radius, at $\frac{1}{2}$ mile centres enclosing an area of 500 acres with a population density of 30 persons/acre. Public transport terminals at the centres of the circles are within $7\frac{1}{2}$ minutes walking distance of any point in the residential unit. Population for a 240,000 head conurbation is assumed to be housed in twelve of these residential units in addition to 40,000 people at Bletchley and 20,000 at Wolverton. Industry is assumed to be concentrated in four similarly sized units, employing 15,000 workers each, with an additional 6,000 at both Bletchley and Wolverton.

Each residential unit is assumed to contain its own local shops, offices and social facilities. Primary and secondary schools are located in open areas adjacent to each residential unit. Main business offices, shops and entertainment are in the city centre which is two miles long by one mile wide.

Outline layouts for the residential and industrial units are shown in Fig. 2, showing approximate location and penetration of feeder roads.

Traffic Generation

40% of the population are assumed to go out to work, 30% to industry, 5% to the city centre and 5% locally. Initially, an even distribution of workers from each residential area to each work area has been assumed, so that traffic demand between a pair or origin and destination points is proportioned to the product of their sizes.

Peak traffic flows are assumed to result from journeys to and from work, concentrated into one hour both morning and evening. For journeys by car an occupancy of 1.5 persons per car is assumed.

Journey to work traffic flows between origins and destinations are tabulated on next page.

Residence \ Employment	Industrial Unit 4 at 15,000	Bletchley 6,000	Wolverton 6,000	City Centre 12,000	Total
Residential Unit 12 at 15,000	938 x48=45,000	375 x12=4,500	375 x12=4,500	750 x12=9,000	63,000
Bletchley 40,000	2,500 x4=10,000	1,000	1,000	2,000	14,000
Wolverton 20,000	1,250 x4=5,000	500	500	1,000	7,000
Total	60,000	6,000	6,000	12,000	84,000

This traffic is assumed to be evenly distributed between multiple egress and access points at the areas of origin and destination; for instance, city centre traffic is distributed over six stations, one sixth to each.

Traffic Analysis

There are 28 home locations and 16 work locations in the model so that full traffic analysis requires summation of flows between 28x16 = 448 pairs. This is laborious. For this preliminary work a random sample of 50 pairs was selected for detailed study and total traffic estimates scaled up from the calculated flows between these 50 pairs. Fig. 3 shows the resulting peak hour traffic flows on the public transport loops for 75% journeys by public transport. Similar figures have been calculated for the road system.

Public Transport Layout

There are five continuous loops of segregated track, one serving the city centre alone and the other four linking residential and industrial areas to the city centre. A new main line rail station has been included which is also the largest interchange point for the public transport system. There are 43 stations, 11 of which serve more than one loop. The system is 42.8 miles long with an average distance between stations of 0.78 miles, a minimum of 0.27 miles and a maximum of 1.75 miles.

This layout has been examined for both one-way and two-way working. Two broad categories of public transport have been looked at, taking as representative vehicles a suburban train and an urban bus. The train represents a rapid, high capacity vehicle (60 m.p.h. cruising speed and up to 30,000 passengers per hour per track), with high capital cost. The bus represents a slow medium capacity vehicle (30 m.p.h. cruising speed and up to 6,000 passengers per hour per track), with lower capital cost.

Road System Layout

The primary road system consists of three inner ring roads, an outer ring road, a city centre spine road, a developed A.5 road and cross links totalling 52.4 miles with 15 major intersections including 10 T intersections and 5 multiway. There are 25 additional intersections with secondary feeder roads to residential and industrial areas. Feeds between car parks and the city centre spine road are assumed to be at frequent intervals and included in the car park costs.

The primary road system is designed for 40 m.p.h. average speeds with no congestion or halts at intersections. Road width is calculated from peak traffic flows on the critical segment of each of 11 sections linking major intersections, allowing 1200 cars per lane and 1.5 occupants per car. Results are shown in Table 2. It is immediately apparent that some of these road widths greater than 8 lanes are not feasible and that route intersections of 10 lane and 14 lane roads are not practicable For the purpose of this study these limits on feasibility have been ignored because it would not be too difficult to split the flows between parallel routes, although this might increase intersections costs above those quoted. Table 2 also shows the assumed sizes for intersections.

Secondary roads are split into feeder roads and collector roads which link the feeder and primary road systems. Fig. 2 shows some approximate layouts of the feeder and collector roads for the residential and industrial areas. In practice, less regular layouts would be used but these sketches serve to identify the length of roads as 4 miles of collector roads and 10 miles of feeder roads in each residential and industrial area.

Lane widths are 12 feet in residential areas and 14 feet in industrial areas. All feeder roads are 2-lane for all levels of car usage. Collectors are 2-lane for 25%, 3-lane for 50% and 2-lane dual carriageway for 75% car usage. The secondary road system is designed for 20 m.p.h. average speeds with grade intersections. Collector/Primary road intersections are of simple diamond or Y or trumpet type at two levels.

Car parks in industrial areas are assumed open site with space for 10,000 cars at 25%, 20,000 cars at 50% and 30,000 cars at 75% journeys by car. City centre parking is assumed to be part of a multi-storey building with space for 6,000 cars at 25%, 12,000 at 50% and 18,000 at 75% journeys by car. Two-thirds of this space is for shoppers. Home garage space and costs are listed but not included in the calculations. Ownership levels of 1.0, 1.5 and 2.0 cars per household are considered.

Costs

Rail system costs are assessed as:-

(a) All-in track construction costs, less land

£700,000 per twin track mile
£450,000 per single track mile

(b) Vehicle capital costs

£100,000 per 4-car train, carrying 400 passengers, enough trains for peak demand at 80% load factor.

(c) Annual charge for track amortisation
$^1/_{30}$th of construction cost

(d) Running costs including maintenance and depreciation, 2d. per passenger mile.

Bus system costs are assessed as:

(a) All-in track construction costs, less land
£100,000 per single track mile
number of tracks calculated for peak demand at 6,000 passengers/hour/track.

(b) Vehicle capital costs
£15,000 per 65 passenger bus,
enough buses for peak demand at 80% load factor

(c) Track maintenance annual cost
1% of construction cost

(d) Running costs including vehicle maintenance, and depreciation, 3d. per passenger mile

Road construction costs are assessed as:

(a) Basic road costs excluding intersections, per mile,

Single carriageway:	12' lane,	£20,000 + £50,000/lane
	14' lane,	£20,000 + £65,000/lane
Dual carriageway:	12' lane,	£60,000 + £50,000/lane
	14' lane,	£60,000 + £65,000/lane
Motorway:		£120,000 + £50,000/lane

(b) Intersections

Double diamond or Clover leaf X
£100,000 + £200,000/minor lane

Trumpet T
£80,000 + £60,000/minor lane

Single diamond or Y - £80,000 + £60,000/minor lane

(c) Car Parks:

Open Site - £50 per car space
Multi-storey - £500 per car space
Home Garage - £150 per car space

Annual maintenance, lighting and cleaning:

Roads	1% capital cost
Multi-storey car park	£15 per car space
Open site car park	£10 per car space

Car operating costs are assessed as:

Marginal running costs	3d. per car mile
Total running costs	6d. per car mile

These are divided by 1.5, the average car occupancy to produce passenger mile costs.

Accident costs are assessed as:

£700 per personal injury accident
1 personal injury accident in 10^6 passenger miles by car
5 personal injry accidents in 10^8 passenger miles by public transport

Land Use

Land use for public transport is assessed as:

(a) Rail

Twin track, 3 acres/mile plus $^1/_3$ acre per station
Single track, 2 acres/mile plus $^1/_4$ acre per station
Sidings, 1 acre per 15, 4-car sets.

(b) Bus

$1\frac{1}{2}$ acres per track mile plus $^1/_4$ acre per station

Land use for roads is assessed as:

(a) Basic roads excluding intersections, per mile

Single carriageway	primary	$2\frac{1}{2}$ acres + $2\frac{1}{2}$ acres/lane
12'	secondary	$1\frac{1}{2}$ acres + $1\frac{1}{2}$ acres/lane
14'	secondary	2 acres + 2 acres/lane
Dual carriageway	primary	5 acres + $2\frac{1}{2}$ acres/lane
12'	secondary	3 acres + $1\frac{1}{2}$ acres/lane
14'	secondary	4 acres + 2 acres/lane
Motorway		10 acres + $2\frac{1}{2}$ acres/lane

(b) Intersections

Double diamond or cloverleaf X	8 acres + 3 acres/minor lane
Single diamond or Y	8 acres + 3 acres/minor lane
Trumpet T	8 acres + 1 acre/minor lane

(c) Car Parks

Multi-storey	50 ft² per car space
Open site	260 ft² per car space
Home garage	325 ft² per car space

Journey Times

Journey times have been estimated under the following assumptions:

(a) Rail - 1 minute per mile distance + 1 minute per stop + 3 minutes per change of train. This is based on 60 m.p.h. cruise speed, 3 m.p.h./sec. acceleration and braking and 40 secs. station transit time. Add 14 minutes per journey, including 5 minutes walk to station, 3 minutes to embark, 1 minute to disembark and 5 minutes to walk to work.

(b) Bus - 2 minutes per mile distance + $\frac{1}{2}$ minute per stop + 3 minutes per change of bus. This is based on a cruising speed of 30 m.p.h., 3 m.p.h./sec. braking and acceleration and 20 secs. stop transit time. Add 14 minutes per journey.

(c) Car - $1\frac{1}{2}$ minutes/mile on primary roads and 3 mins/mile on secondary roads. 1 minute for changing from a primary to a secondary road or vice versa. $\frac{1}{2}$ minute per main road intersection to the left and 1 minute to the right. Add 9 minutes per journey, 2 minutes walk to garage and drive out, 2 minutes drive in to car park and disembark, 5 minutes walk to work.

Journey time has been valued at 5s. 0d. per hour for work journeys and 2s. 6d. per hour for shopping journeys. In reality the value that people put on their time is variable, so that a distribution of value for percentages of total journeys should be considered. In this preliminary investigation, average values have been assumed. Similarly, modal split will be the result of an accumulation of individual choice, based on subjective assessments of factors such as journey cost and valuation of journey time. In this study average values of modal split have been assumed evenly distributed over all journeys.

Method

Stages in the investigation were:

(a) Define the city layout and the location of transport links.

(b) Select a random sample of origin and destination pairs.

(c) Compute the traffic generated between each O-D pair for work and shopping journeys.

(d) Compute the shortest distance for each available mode of transport.

(e) Allocate traffic to the shortest routes of each transport mode in turn and sum the resultant traffic on each segment of each transport system for the total sample of O-D pairs.

(f) Factor these traffic flows by the modal split assumed, and by the ratio of total to sample traffic.

(g) Calculate the required capacity of each transport segment and hence the capital costs and land use requirements.

(h) Calculate the annual running costs, accident costs and journey time costs.

(i) Assess cost-benefit rates of return for alternative transport system proposals, excluding and including social costs and benefits.

Results

These are summarised in the attached tables. Table 1 lists the expected number of work and shopping journeys beyond the local neighbourhood, and the average length and duration of these journeys by the different modes of transport. Tables 2 to 7 list the cost implications of these journeys for three assumed percentage levels of journeys by private car at 1.5 occupants per car. The lower 25% level corresponds to a minimum expected level of people who will need or prefer to use their cars, however good the public transport service which is offered. The upper 75% levels correspond to a near maximum expected level, because there will always be some people who do not have access to a private car or would always prefer to use public transport. The 50% level is included as a mid-point estimate. Figures 4, 5 and 6 shows these results in bar chart form.

Table 7 brings together the cost estimates for capital expenditure and annual costs and evaluates alternative proposals in terms of rate of return on capital investment for the fully developed city. Both direct and social costs are considered. In this assessment, social costs include journey time and accidents. Environmental standards have not been costed other than to include in the final assessment an annual rent for land used by transport.

Discussion

For the assumed system costs the lowest capital cost is £92 million, equivalent to £1540 per household. This is for roads to carry 25% of peak travel by car and a segregated bus system to carry the remaining traffic. At off-peak times higher proportions of journeys could be by car without congestion.

The lowest annual cost, including both direct and social costs, is £10 million per annum for 75% of peak journeys by car and the remainder by bus; but this involves a capital cost of £120 million. Alternatives which provide the best rate of return on capital expenditure above the minimum are 1-way rail with 25% car journeys, if journey time costs are excluded, and 2-way rail with 25% car journeys if journey time costs are included.

Ratios of road distance to direct distance for the assumed road system, average 1.48 for the journey to work and 1.28 for shopping journeys. This is higher than ratios of 1.15 to 1.20 which apply to grid road layouts.

A provisional estimate of minimum costs for such a grid layout has been derived by assuming a 20% reduction in average road distance for the same capital expenditure on roads. In fact, a congestion-free grid road layout would almost certainly be much more costly to build. This reduces the lowest annual cost to £9.5 million for 75% by car and bus public transport. The best rate of return on the nominal additional capital is still the 25% by car, 2-way rail at 7.5% per annum.

These preliminary results and the ranking of alternative possibilities may change with more detailed studies. These results show a case for a good public transport system but heavy capital expenditure on an extensive 2-way rail system can only be justified if a high utilisation of public transport facilities can be ensured. The Manchester studies, ref. 3, indicate that the rail system costs used in this report are at the lowest limit of possible costs. These costs may be feasible if entensive cuttings, overhead track and junctions can be avoided, but increases of 50% might be incurred otherwise. A less capital intensive system of segregated bus routes merits more detailed study and may well be better suited to the development time-scale anticipated for Milton Keynes.

These results depend on very liberal assumptions for journeys to work being uninfluenced by journey distance or time within the city region. Further tests should be made of more restrictive and more likely assumptions that people will tend to live near their work and work near their homes. Other city layouts could influence traffic generation very considerably by breaking down further the aggregations of industrial and business employment, e.g. a town cluster with several business centres.

At this stage no allowances have been made for regional commuting and traffic other than to provide good access to regional rail and road links. Further studies would need to investigate likely regional traffic flows.

Further Work

Profitable lines of investigation are:

(a) the effect of alternative city layouts on traffic generation and transport cost-benefit.

(b) analysis of alternative traffic generation models which take into account length of journey and intervening opportunities.

(c) investigation of modal split as an aggregate of individual modal choice dependent on income, journey cost and journey time.

(d) estimation of regional traffic flows for commuting to work and the requirements for regional transport links.

(e) the effect of sample size on accuracy for important traffic parameters.

(f) more detailed analysis of feasible road layouts including junctions and intersections.

(g) more detailed analysis of feasible public transport systems and likely construction and operating costs.

(h) consideration of novel public transport schemes, such as monorails, automatic buses, automatic taxis, and hovertrains.

(i) co-ordination with planning consultants on possible rates of growth for the city and region and the effect of growth rates on transport system development.

Refinements to analysis methods would be worth while to computerise laborious calculations and apply discounted cash flows to rates of return calculations.

References

1. Northampton, Bedford and North Bucks Study. H.M.S.O. 1965.

2. North Bucks New City - C.D.A. and Designation Report Bucks County Council 1965.

3. Manchester Rapid Transit Study - Manchester City Transport 1967.

TABLE 1

JOURNEY DISTANCE AND TIME

Total work journeys 166,666 per day

$\equiv 4 \times 10^7$ journeys per year

Total shopping journeys 96,000 per day

$\equiv 2.88 \times 10^7$ journeys per year

	Direct	Road	1-way Rail	2-way Rail	Bus
Avge. distance (work) miles	3.27	4.85	6.38	4.81	4.81
Ratio/direct	-	1.48	1.95	1.47	1.47
Avge. distance (shopping) miles	2.75	3.52	5.91	4.13	4.13
Ratio/direct	-	1.28	2.15	1.52	1.52
Avge. journey time (work) mins.	-	20	32	28	30
Avge. journey time (shopping) mins.	-	19	31	27	28

TABLE 2

PRIMARY ROAD SYSTEM

ROADS	LENGTH MILES	NUMBER OF LANES Percentage by Private Car 25	50	75
Central Spine	4.70	4	7	10
A.5. Development	6.80	5	10	14
N. Inner loop	4.52	3	4	5
S.E. Inner loop	5.87	2	4	5
S.W. Inner loop	4.12	2	3	5
N.E. Outer loop	7.18	3	5	8
S.E. Outer loop	5.67	3	5	7
S.W. Outer loop	7.65	3	5	7
N.W. Outer loop	2.95	4	7	10
N.E. Crosslink	1.18	3	4	5
N.W. Crosslink	1.73	2	3	3
INTERSECTIONS	**TYPE**	**NUMBER OF CROSSING LANES ON THE SMALLER ROAD**		
Centre Spine/S.E.Outer/M.1.	X	4	6	6
Centre Spine/N.E.Outer/(1)	T	3	5	8
Centre Spine/N.E. Crosslink	X	3	4	5
Centre Spine/N.E.Outer (2)	T	3	5	8
Centre Spine/S.W. Inner	T	2	3	5
Centre Spine/A.5.	X	4	8	10
A.5./S.E. Outer	X	3	5	7
A.5./S.W. Outer	T	3	5	7
A.5./N.W. Outer	T	4	7	10
A.5./N.W. Crosslink	T	2	3	3
N.W. Crosslink/N.E. Outer	X	2	3	3
N.W. Crosslink/N. Inner	T	2	3	3
N.E. Crosslink/N. Inner	T	3	4	5
N.E. Crosslink/S.E. Inner	T	3	4	5
N.E. Outer/N.W. Outer	T	3	5	8

TABLE 3

CAPITAL COSTS

CAPITAL COSTS 1967 £ million	Percentage by Private Car 25	50	75
1. Primary roads			
roads (52.4 miles)	10.2	17.2	23.2
X intersections (5)	3.7	5.7	6.7
T intersections (10)	2.5	3.4	4.5
collector junctions (34)	6.8	8.8	10.9
bridges (35)	1.8	2.6	3.5
	25.0	37.7	48.8
2. Secondary roads			
residential collecters (56m)	6.7	9.5	14.6
residential feeders (140m)	16.8	16.8	16.8
res. feeder junctions (448)	2.2	2.7	3.1
industrial collectors (16m)	2.4	3.4	5.1
industrial feeders (40m)	6.0	6.0	6.0
ind. feeder junctions (128)	0.8	0.9	1.0
bridges at 5%	1.7	1.9	2.3
	36.6	41.2	48.9
3. Parking			
city centre (multistory)	3.0	6.0	9.0
industrial areas (open site)	0.5	1.0	1.5
	3.5	7.0	10.5
4. Total Road System	65.1	85.9	108.2
* Cost per household £	1090	1430	1800
* Cost per head £	330	410	510
5. Public transport			
a) Bus - track	17.5	10.5	8.6
- vehicles	9.6	6.4	3.2
	27.1	16.9	11.8
b) 2 Way Rail - track	30.0	30.0	30.0
- vehicles	8.7	6.1	3.1
	38.7	36.1	33.1
c) 1 Way Rail - track	19.3	19.3	19.3
- vehicles	8.6	5.7	3.0
	27.9	25.0	22.3
6. Total Transport System			
a) Bus and Road	92.2	102.8	120.0
* cost per household £	1540	1710	2000
b) 2 Way Rail and Road	103.8	122.0	141.3
* cost per household £	1730	2030	2360
c) 1 Way Rail and Road	93.0	110.9	130.5
* cost per household £	1550	1850	2180
7. Home garage			
cars per household	1.0	1.5	2.0
cost at £150	9.0	13.5	18.0

* Costs per head and per household are for 210,000 new heads and 60,000 new households.

TABLE 4

LAND USE

LAND USE Acres	Percentage by Private Car 25	50	75
1. Primary roads			
roads (52.4 miles)	612	960	1269
X intersections (5)	88	118	133
T intersections (10)	108	124	142
collector junctions (34)	476	578	680
	1284	1780	2224
2. Secondary roads			
residential collectors (56m)	252	336	504
residential feeders (140m)	420	420	420
res. feeder junctions (448)	5	5	5
industrial collectors (16m)	96	128	192
industrial feeders (40m)	240	240	240
ind. feeder junctions (128)	3	3	3
	1016	1132	1364
3. Parking			
city centre (multi-storey)	7	14	21
industrial areas (open site)	60	120	180
	67	134	201
4. Total Road System	2367	3046	3789
* % designated area	10.8	13.9	17.2
5. Public Transport			
a) Bus	273	169	139
b) 2 Way Rail	151	149	147
c) 1 Way Rail	103	101	99
6. Total Transport System			
a) Bus and Road	2640	3215	3928
* % d.a.	12.0	14.6	17.9
b) 2 Way Rail and Road	2518	3195	3936
* % d.a.	11.4	14.1	17.9
c) 1 Way Rail and Road	2470	3147	3888
* % d.a.	11.2	14.3	17.7
7. Home garage			
cars per household	1	1.5	2.0
at 325 ft^2 per car	430	650	860

* Designated area 22,000 acres.

TABLE 5

ANNUAL FIXED COSTS

ANNUAL FIXED COSTS 1967 £ million	Percentage by Private Car 25	50	75
1. Road System			
Road upkeep	0.62	0.79	0.98
City Centre parking	0.09	0.18	0.27
Industrial parking	0.10	0.20	0.30
Total	0.81	1.17	1.55
2. Public transport			
a) Bus track amortisation	0.58	0.35	0.29
b) 2-Way Rail track amortisation	1.00	1.00	1.00
c) 1-Way Rail track amortisation	0.64	0.64	0.64
3. Interest on capital at 6%			
Road system	3.91	5.15	6.50
a) Bus track	0.53	0.32	0.26
b) 2-Way Rail track	0.90	0.90	0.90
c) 1-Way Rail track	0.58	0.58	0.58
4. Land rent at £1000/acre			
a) Bus and Road	2.64	3.22	3.93
b) 2-Way Rail and Road	2.51	3.20	3.94
c) 1-Way Rail and Road	2.47	3.15	3.89
5. Total System less interest			
a) Bus and Road	1.39	1.52	1.84
b) 2-Way Rail and Road	1.81	2.17	2.55
c) 1-Way Rail and Road	1.45	1.81	2.19
6. Total System including interest			
a) Bus and Road	5.83	6.99	8.60
b) 2-Way Rail and Road	6.62	8.22	9.95
c) 1-Way Rail and Road	5.94	7.54	9.27
7. Total System incl. interest and rent			
a) Bus and Road	8.47	10.21	12.53
b) 2-Way Rail and Road	9.13	11.42	13.89
c) 1-Way Rail and Road	8.41	10.69	13.16

Note:

1. Public transport tracks are amortised over a 30 year life and mid-life interest has been charged.
2. The road system is not amortised but carries interest on the full capital cost.
3. In a Discounted Cash Flow analysis over 30 years the public transport tracks would have nil residual value and the roads full residual value.
4. Public transport maintenance costs are included as running costs.

TABLE 6

ANNUAL RUNNING COSTS

ANNUAL RUNNING COSTS	Percentage by Private Car								
	25			50			75		
1967 £ million	Work	Shop	Total	Work	Shop	Total	Work	Shop	Total
1. Direct charges									
Car at 6d./mile	0.81	0.42	1.23	1.62	0.84	2.46	2.43	1.26	3.69
Car at 3d./mile	0.41	0.21	0.62	0.81	0.42	1.23	1.21	0.63	1.84
* Car at 3d./mile - 20%	0.33	0.26	0.59	0.65	0.52	1.17	0.97	0.78	1.75
Bus	1.80	1.12	2.92	1.20	0.75	1.95	0.60	0.37	0.97
2 Way Rail	1.20	0.73	1.93	0.80	0.49	1.29	0.40	0.25	0.65
1 Way Rail	1.60	1.06	2.66	1.07	0.71	1.78	0.53	0.36	0.89
2. Journey time costs									
Car	0.84	0.29	1.13	1.69	0.58	2.27	2.53	0.87	3.40
* Car - 20% distance	0.75	0.26	1.01	1.50	0.52	2.02	2.25	0.78	3.03
Bus	3.70	1.26	4.96	2.47	0.84	3.31	1.24	0.42	1.66
2 Way Rail	3.48	1.20	4.68	2.32	0.80	3.12	1.16	0.40	1.56
1 Way Rail	3.98	1.41	5.39	2.66	0.94	3.60	1.33	0.47	1.80
3. Accident costs									
Car	.034	.018	.052	.068	.036	.104	.102	.054	.166
Public transport	.005	.003	.008	.003	.002	.005	.002	.001	.003
4. Social costs (2) + (3)									
Car	0.88	0.31	1.19	1.76	0.62	2.38	2.63	0.93	3.57
* Car - 20% distance	0.79	0.28	1.07	1.57	0.56	2.13	2.35	0.84	3.20
Bus	3.74	1.28	5.02	2.54	0.88	3.42	1.34	0.48	1.83
2-Way Rail	3.52	1.22	4.74	2.39	0.84	3.23	1.26	0.46	1.73
1-Way Rail	4.02	1.43	5.45	2.73	0.98	3.71	1.43	0.53	1.97
5. Total costs (1) + (4)									
Car at 6d./mile	1.69	0.73	2.42	3.38	1.46	4.84	5.06	2.19	7.26
Car at 3d./mile	1.29	0.52	1.81	2.57	1.04	3.61	3.84	1.56	5.41
* Car at 3d./mile - 20% dist.	1.12	0.54	1.66	2.22	1.08	3.30	3.32	1.62	4.95
Bus	5.54	2.40	7.94	3.74	1.63	5.37	1.94	0.85	2.80
2-Way Rail	4.72	1.95	6.67	3.19	1.33	4.52	1.66	0.71	2.38
1-Way Rail	5.62	2.49	8.11	3.80	1.69	5.49	1.96	0.89	2.86

* Assumes a 20% saving in car journey distance to simulate a grid road system.

TABLE 7

COST BENEFIT

TOTAL COSTS 1967 £ million	25 Bus	25 2-Way Rail	25 1-Way Rail	50 Bus	50 2-Way Rail	50 1-Way Rail	75 Bus	75 2-Way Rail	75 1-Way Rail
	Percentage by Private Car								
1. Capital investment	92	104	93	103	122	111	120	141	131
increment on cheapest	0	12	1	11	30	19	28	49	39
2. Fixed annual cost									
basic	1.4	1.8	1.5	1.5	2.2	1.8	1.8	2.6	2.2
basic + land rent	3.9	4.3	4.0	4.7	5.4	5.0	5.9	6.5	6.1
3. Annual running costs									
direct, car at 6d/mile	4.2	3.2	3.9	4.4	3.8	4.2	4.7	4.3	4.6
direct, car at 6d/mile	3.5	2.6	3.3	3.2	2.5	3.0	2.8	2.5	2.7
direct, car at 3d - 20%	3.5	2.5	3.3	3.1	2.5	3.0	2.7	2.4	2.6
social, roads as shown	6.2	5.9	6.6	5.8	5.6	6.1	5.4	5.3	5.5
social - 20% car distance	6.1	5.8	6.5	5.6	5.4	5.8	5.0	4.9	5.2
4. Total annual costs									
a) Direct, car at 6d/mile + fixed basic	5.6	5.0	5.4	5.9	6.0	6.0	6.5	6.9	6.8
b) Direct, car at 3d/mile + fixed basic	4.9	4.4	4.8	4.7	4.7	4.8	4.6	5.1	4.9
c) Direct, car at 3d/mile - 20% + fixed basic	4.9	4.3	4.8	4.6	4.7	4.8	4.5	5.0	4.8
d) Social costs + b)	11.1	10.3	11.4	10.5	10.3	10.9	10.0	10.4	10.4
e) Social costs + c)	11.0	10.1	11.3	10.2	10.1	10.6	9.5	9.9	10.0
f) Land rent + d)	13.7	12.8	13.9	13.7	13.5	14.1	13.9	14.3	14.3
5. Total annual benefit over cheapest investment									
a) Direct, car at 6d.	0	0.6	0.2	-	-	-	-	-	-
b) Direct, car at 3d.	0	0.5	0.1	0.2	0.2	0.1	0.3	-	-
c) Direct, car at 3d. - 20%	0	0.6	0.1	0.3	0.2	0.1	0.4	-	0.1
d) Direct and Social, car at 3d	0	0.8	-	0.6	0.8	0.2	1.1	0.7	0.7
e) Direct and Social, car at 3d - 20%	0	0.9	-	0.8	0.9	0.4	1.5	1.1	1.0
f) Direct, Social and land, car at 3d.	0	0 9	-	-	0.2	-	-	-	-
6. Benefit rate of return over cheapest investment %									
a) Direct, car at 6d.	0	5.0	20.0	-	-	-	-	-	-
b) Direct, car at 3d.	0	4.2	10.0	1.8	0.7	0.5	1.1	-	-
c) Direct, car at 3d - 20%	0	5.0	10.0	2.7	0.7	0.5	1.4	-	0.3
d) Direct and Social, car at 3d	0	6.7	-	5.4	2.7	1.1	3.9	1.4	1.8
e) Direct and Social, car at 3d - 20%	0	7.5	-	7.3	3.0	2.1	5.4	2.2	2.6
f) Direct, Social and Land car at 3d.	0	7.5	-	-	0.7	-	-	-	-

TRANSPORT FOR MILTON KEYNES : LAYOUT A

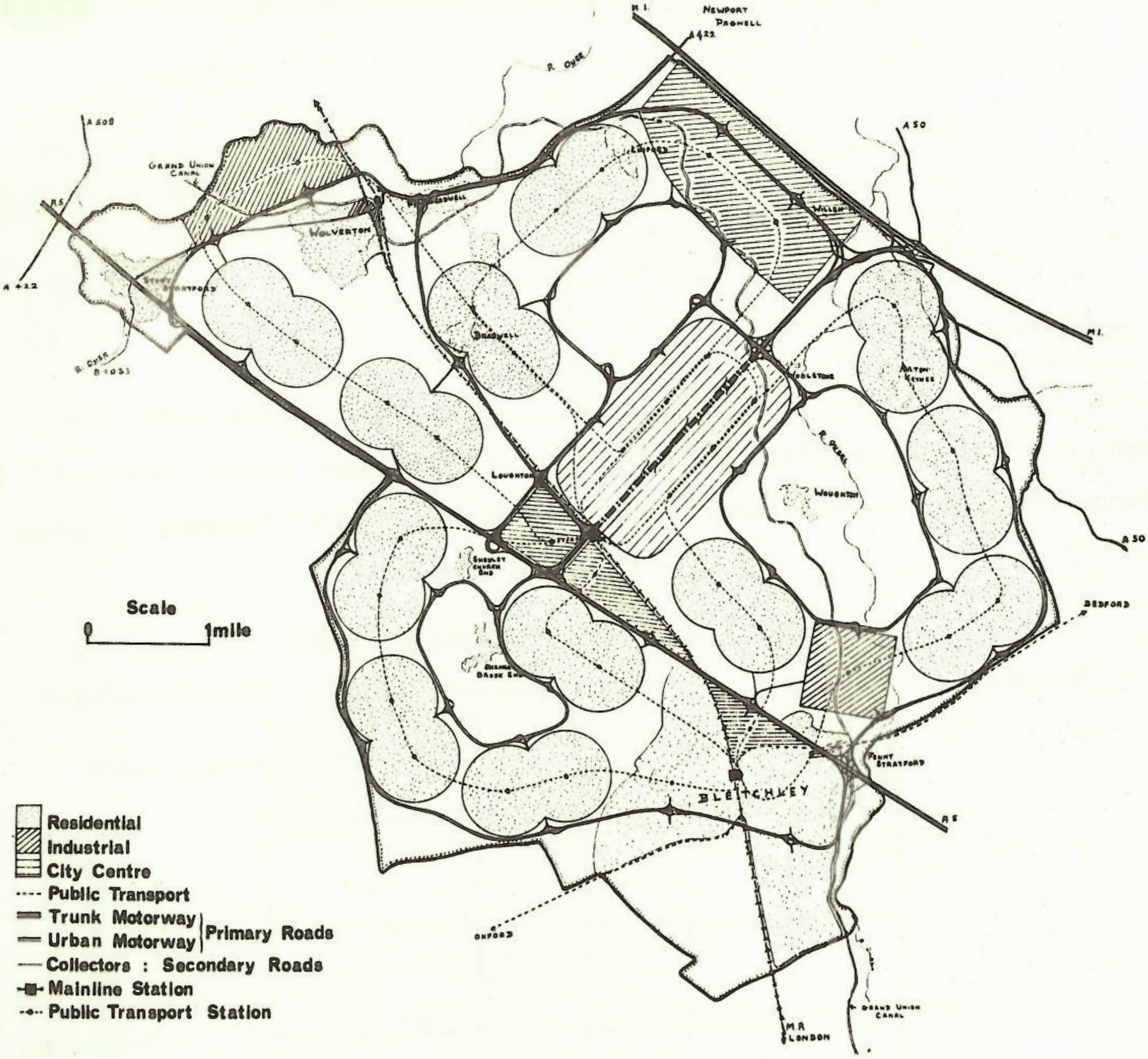
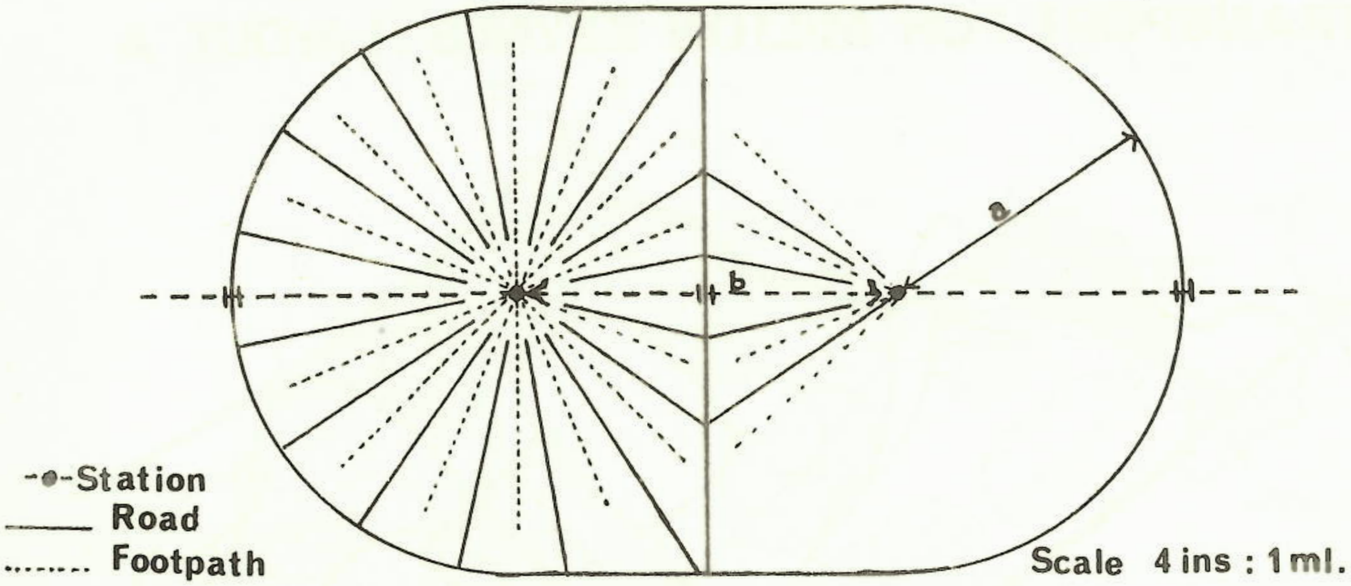


Figure 1.

Fig. 2 : RESIDENTIAL UNIT : DIMENSIONS

Number of people 15,000 : Number of households 4,280

Population density 30 persons/acre



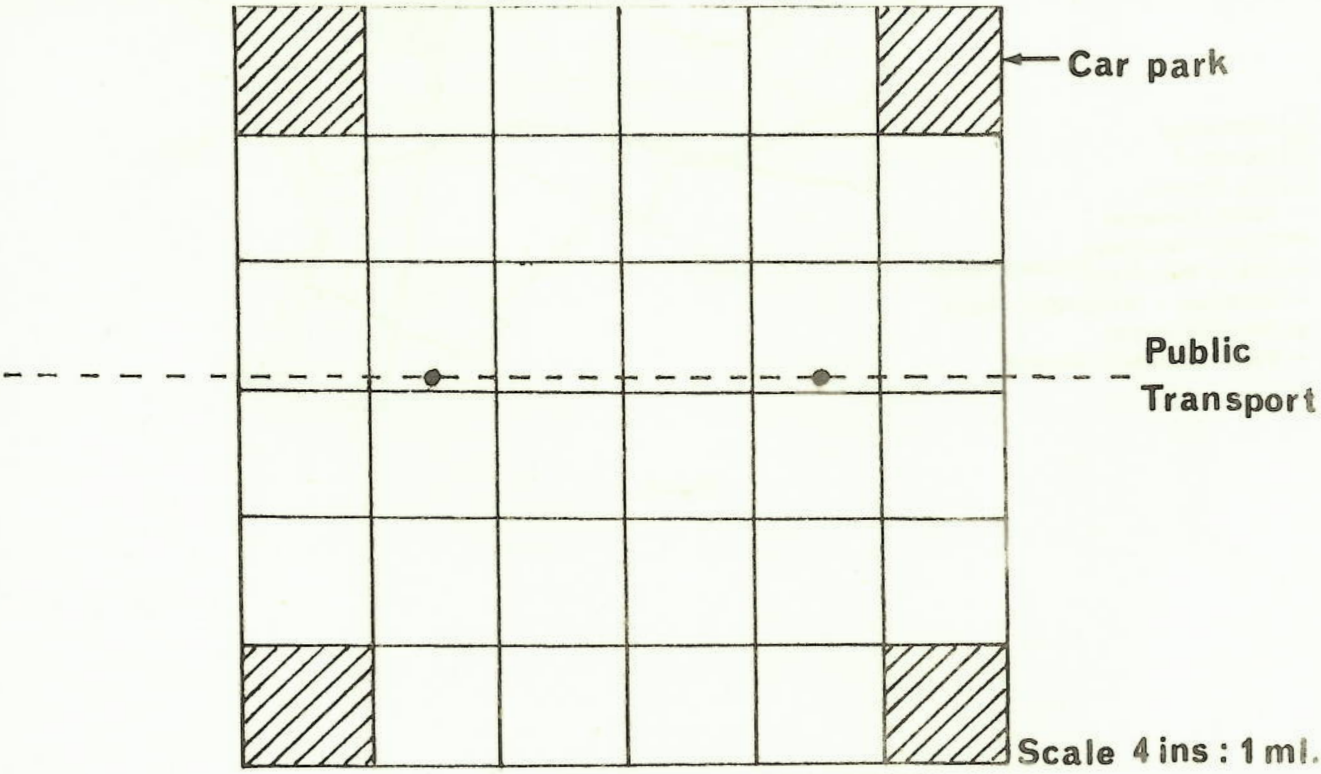
Minimum frontage 20ft : Minimum distance between radial roads 130 ft.

Road distances :- Peripheral collectors 4 miles, Radial feeders 10 miles

a = $\frac{3}{8}$ mile, b = $\frac{1}{2}$ mile

INDUSTRIAL UNIT : DIMENSIONS

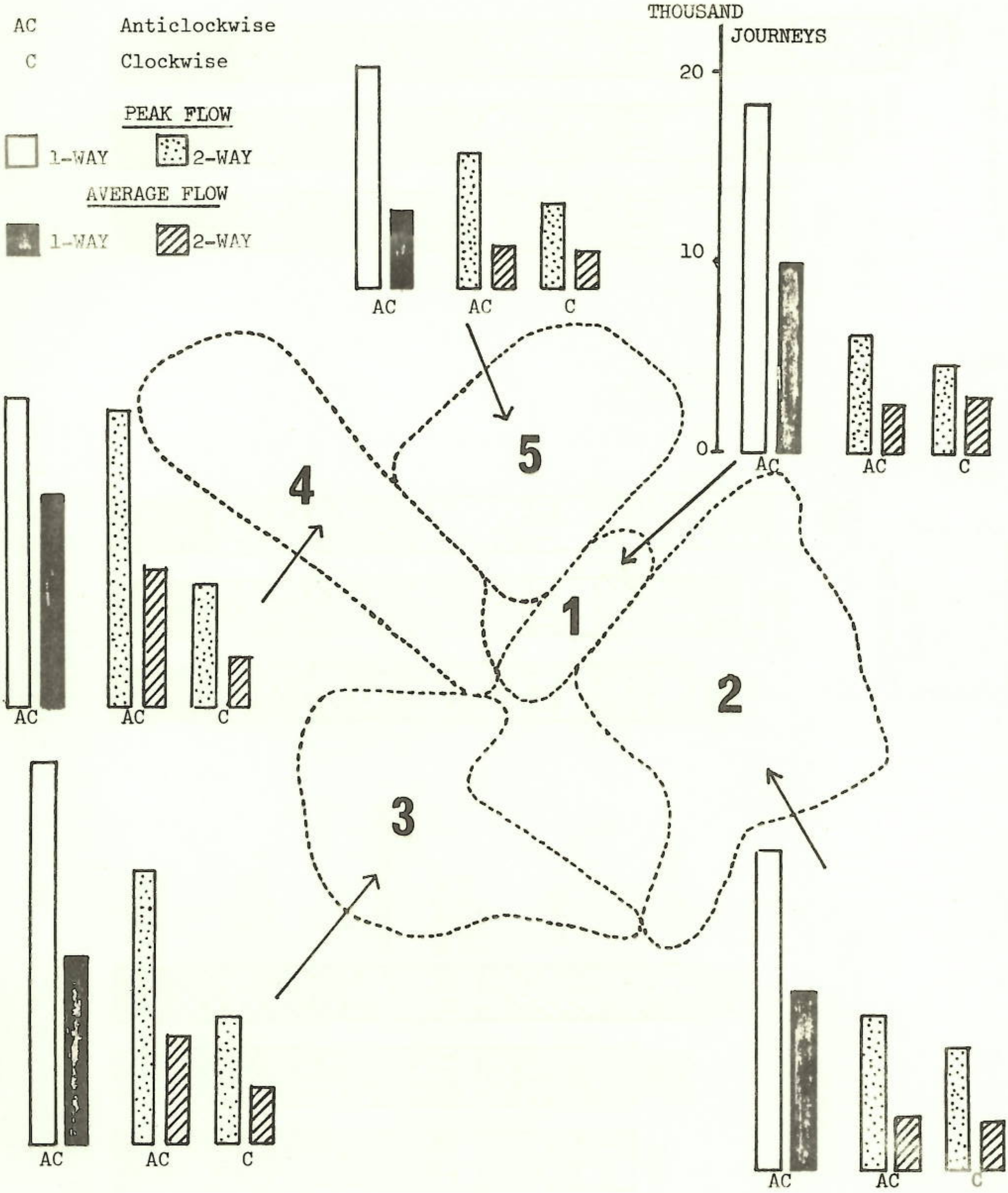
Number of workers 15,000 : Worker density 25 workers/acre



Road distances :- Peripheral collectors 4 miles, Internal feeders 10 miles

Parking 250 sq.ft./car Maximum number of cars 7,500

Figure 3 PUBLIC TRANSPORT TRAFFIC GENERATION - JOURNEY TO WORK



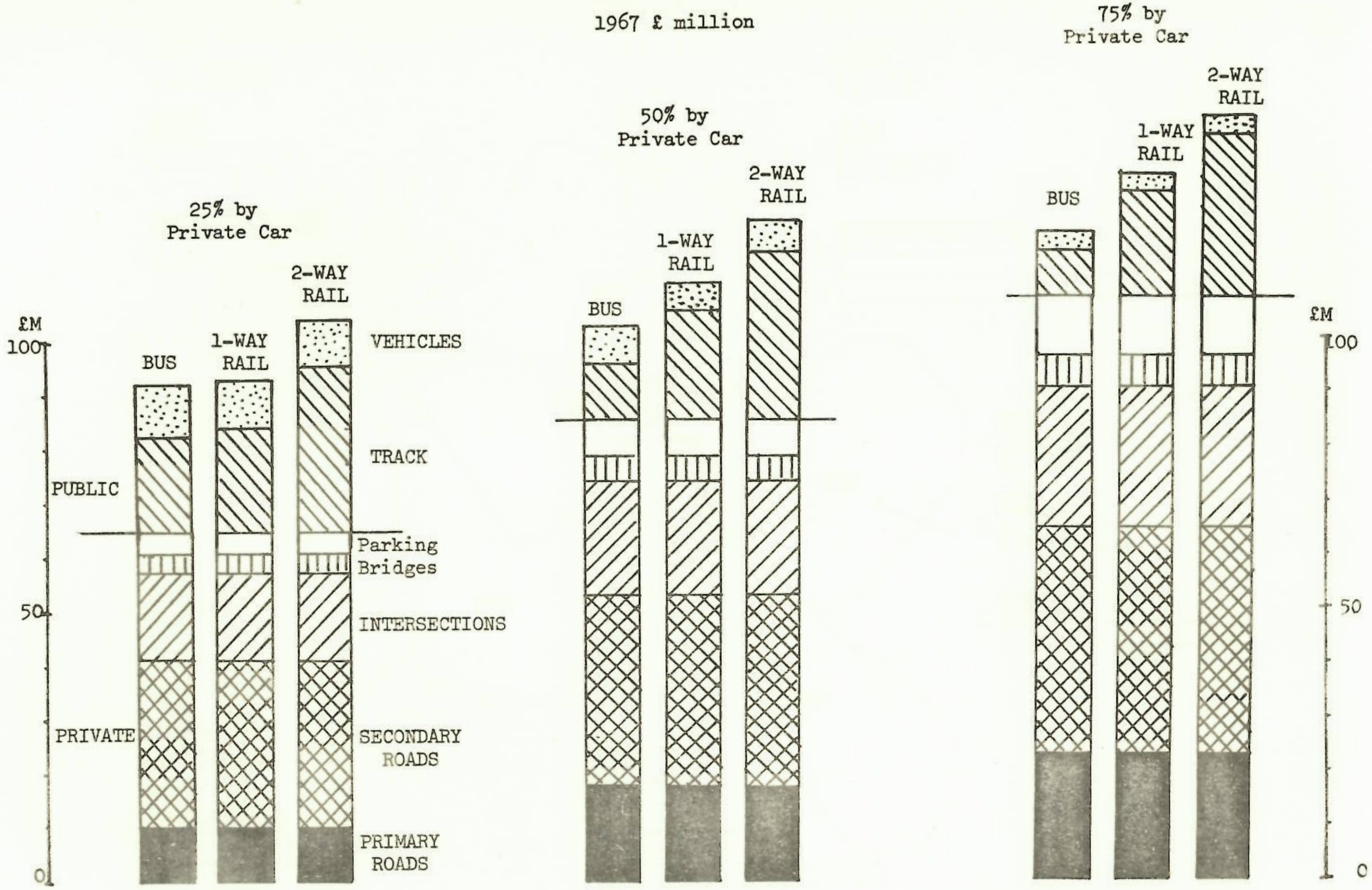


Figure 4 CAPITAL COSTS

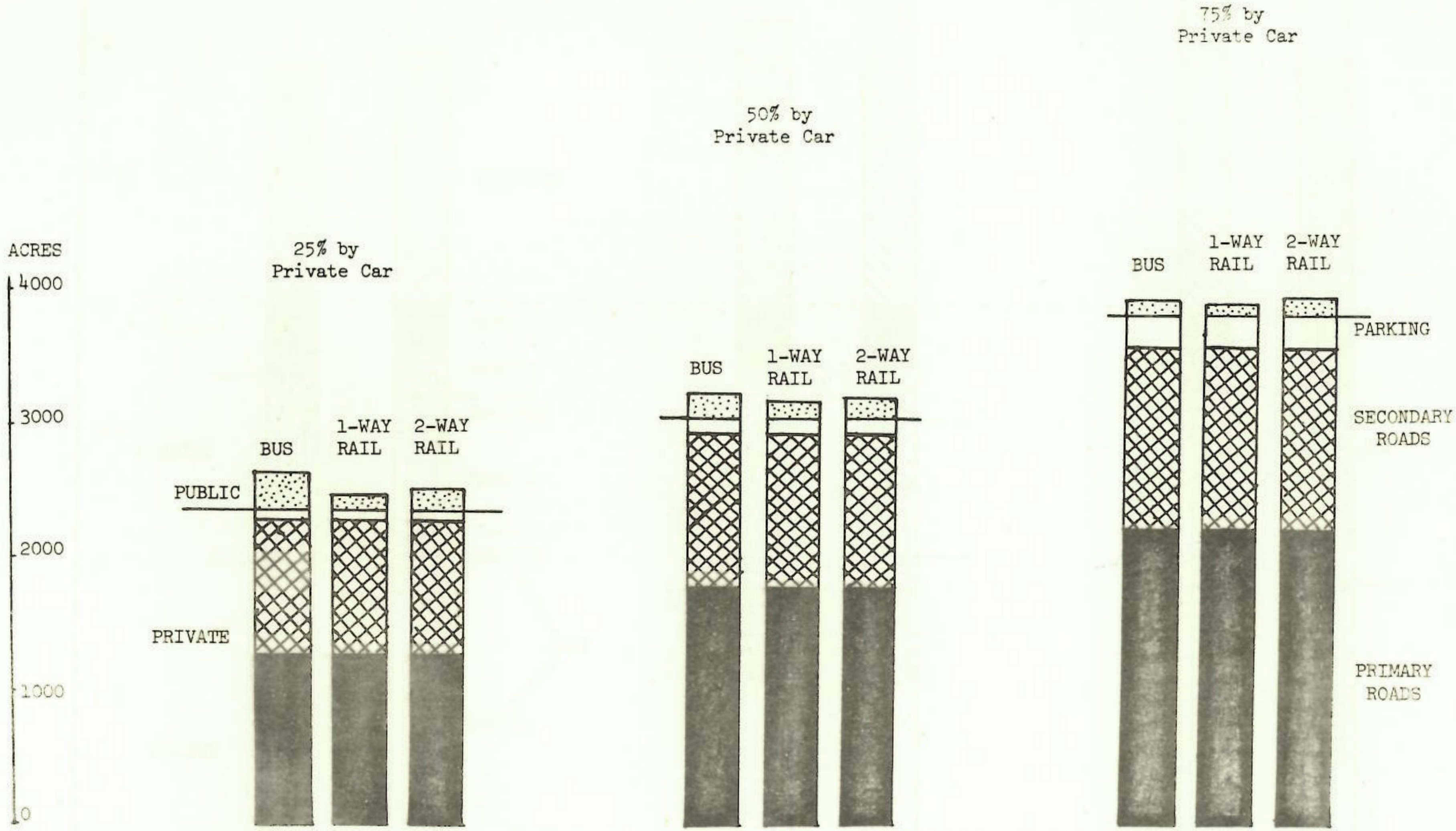


Figure 5 LAND USE

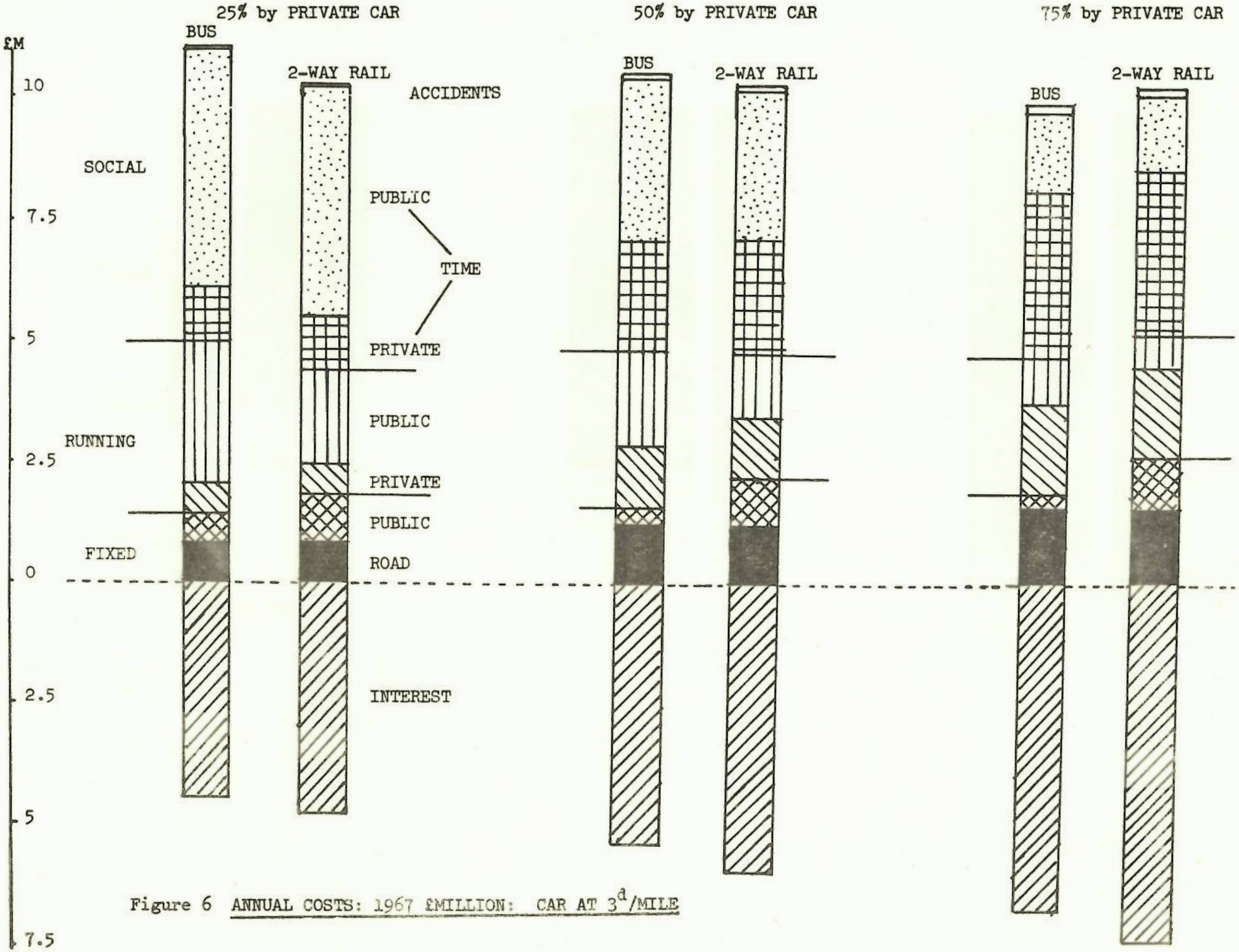


Figure 6 ANNUAL COSTS: 1967 £MILLION: CAR AT 3^d/MILE