Test of a time-geographic measure of accessibility: the effects of policies

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Test of a time-geographic accessibility measure. The effect of public policies

1. INTRODUCTION 2

2. MEASURES OF ACCESSIBILITY 2
   - 2.1. Types of measure (by reason for measure) 2
   - 2.2. The Activities Approach 3
   - 2.3. Preconditions for taking part in an activity 3
   - 2.4. Putting together preconditions to formulate measures 4
   - 2.5. Types of measure 4

3. METHODOLOGY USED IN WATFORD ANALYSIS 5
   - 3.1. Summary of measures used 5
   - 3.2. Data needs 5
   - 3.3. Constraints used in analysis 6
   - 3.4. The data available. 8
   - 3.5. Program descriptions. 8

4. ANALYSES AND RESULTS 9
   - 4.1. Time rings analysis 10
   - 4.2. Prototypical people 11
   - 4.3. Prototypical people - Altered constraints 13
   - 4.4. Real people 16
   - 4.5. Sensitivity tests 19

5. SUMMARY OF FINDINGS 21
   - 5.1. People with low accessibility. 21
   - 5.2. Effects of Transport changes. 21
   - 5.3. The Effect of Available Time. 21

6. CONCLUSIONS. 22
   - 6.1. Appraisal of the findings. 22
   - 6.2. Possible improvements to the measure. 23
   - 6.3. Usefulness of accessibility measures and analysis in real situations. 25

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1. INTRODUCTION

This paper presents the results of a test of a time-geographic measure of accessibility devised to show the effect that changes in the built environment and changes in policy will have on people living in a particular area.

The paper starts with a discussion of different types of accessibility measure in order to show why the one used was chosen (Section 2), and then goes on to describe its implementation and testing on Watford (a medium sized town on the edge of London (U.K.)). Section 3 describes the methodology, while Section 4 describes the ways in which the measure was used, and presents the results. Section 5 provides a summary of the more important findings. The paper finishes (Section 6) with a discussion of the advantages and disadvantages of such a measure as a tool in studying the social welfare aspects of transport planning.

2. MEASURES OF ACCESSIBILITY

A very large number of accessibility measures have been used in research and planning. There is not room here to review all these (see S.R. Jones, 1981; Ireland, 1972; and Cobley 1973 for reviews of measures), but it is important to describe the main different types of classification in order to explain why the measure used here was chosen in preference to others.

2.1. Types of measure (by reason for measure)

While there are obviously many reasons for wishing to find some measure or index of accessibility, the reason for the measure will affect the type of measure best suited to the purpose. The three most common purposes of measures are:-

a) **To measure the efficiency of the system:-** To measure the effectiveness of some aspect of society (usually the transport system) for the purpose of assessing that aspect's efficiency. For example one might wish to find out whether a transport plan would provide more efficient transport.

Such an approach will tend to favour a measure which looks at how easy it is to get from `A to B' for a number of journeys, taking the need for travel between points as given.

b) **To predict the viability of a facility:-** To assess the likely success of a plant, firm, fire station, shop, or other facility in terms of the number of people who could reach the place, or the ease with which `factors of production' would be able to reach a firm's premises. Here, the facility is the `base'.

This approach will tend to favour, for instance, a measure of the number of people who can reach a facility within a certain time limit

c) **To measure general welfare:-** To assess some aspect of social welfare related to some aspect of society (eg transport, or planning) for the purposes of assessing the overall success of plans, or indicating the needs for action to help solve people's problems.

The object of interest in this case is an indication of the ability of people to carry out activities. In this sense it is using a measure of accessibility as a measure of welfare.

In this case it is the third of these in which we are interested, as it is the effects that the environment and policies have on all people which is under study.

2.2. The Activities Approach

Having identified that we are concerned with the day to day activities that people make it is worth shifting the emphasis of study away from transport and the ease of travel to looking at the activities themselves and the ease of carrying them out.

Most activities do not require travel in order to be carried out, and in most senses the transport system has little or no effect on people's ability to carry them out. For those that do require travel, however, it is important to remember that it is the ease of carrying out the activity which is of importance, rather than simply the ease of getting to places. A person may have a very fast car and be close to many fast roads, but that is not of much use if all the shops are shut when they want to buy something.

2.3. Preconditions for taking part in an activity

Taking an activities approach to the study of accessibility it is useful (if at first sight a bit obvious) to look at what a person must do in order to carry out an activity.

In order for a person to carry out an activity in a place other than where that person is, the following preconditions must be fulfilled:-

a) Knowledge of facilities. The person must know of the activity and of a place where it can be done, which fulfils that person's expectations.

b) Personal motivation or need. He or she must have the motivation to go there and do the activity.

c) Lack of economic or social constraints. There must be no overriding social or economic constraints against going there and doing the activity (eg. age limits, or lack of money).

d) Mobility. The person must have access to the physical means of getting there.

e) Time available to the person. The person must have the time to get there, do the activity, and reach the next place where he or she is obliged to go; i.e. he or she must be able to fit the activity in between any other activities for which more important constraints apply.

f) Time availability of the facility. The facility must be open, or usable at a time when the person can use it.

Thus, in order to be accessible to an activity one must fulfil all these preconditions, unless the activity can be done without travel, in which case `d' does not apply.

Any complete assessment of personal access to activities should therefore take account of all these. It is evident that such a measure would be extremely complex.

2.4. Putting together preconditions to formulate measures

In measures of personal accessibility some constraints or considerations have either been ignored or viewed as being predetermined for all individuals collectively, or for groups. This is most apparent in the cases of (a) `the knowledge of facilities' and (b) `motivation to carry out the activity'. In these cases (if one wished to account for personal differences) one could conduct questionnaires to elicit such information (and by doing so one would probably increase people's accessibility!), or one can make generalisations and assume that all people have perfect knowledge and a high level of motivation, or that different groups (by virtue of their education, income, or whatever) have specific different `knowledge levels of facilities' owing to their needs and requirements.

Each precondition may be interpreted as a `factor' which affects accessibility. In order to relate them as factors some restructuring of the concepts is needed. The knowledge of facilities could be redefined as `opportunities in space', and e) and f) may be combined together as `opportunities in time', while b) and c) become `personal characteristics reflecting needs and desires'.

In this way the preconditions can be viewed as four elements as:-

i) Needs and desires for activities.

ii) Opportunities in space

iii) Mobility

iv) Opportunities in time

2.5. Types of measure

The ways in which the various considerations (or factors) are related in a measure produces very different types of measure. Three basic conceptions can be identified by which measures can be classified.

a) Potential's approach (Factors treated as filters):- Accessibility is related to the potential a person has for reaching places, facilities, or activities.

Each precondition is viewed as a separate filter, and all filters must be open in order for the activity to be accessible. Measures of this type include Moseley (1978), Johnston (1966), West Yorkshire (1978b), and the various Swedish time-geographic analyses (esp Lenntorp 1974).

b) Generalised cost (Factors added together):- Accessibility is the generalised ease with which a person can reach places, facilities, or activities that they want to.

c) **Gravity measures (Factors related by multiplication):-** Accessibility is a product of the attractiveness of places, facilities, or activities, and the difficulty involved in reaching the place, or carrying out the activity.

In this study the potentials approach was used as it is closer to the way in people are likely to assess their own level of accessibility.

3. METHODOLOGY USED IN WATFORD ANALYSIS

3.1. Summary of measures used

For the analysis the following basic measure was used as an index for comparison of results.

> The total number of facilities where activities can be done that a person can reach in a specified time (in this case a day) given constraints on their mobility, time constraints, likely needs and desires, and by the constraints imposed by the opening hours, the transport system, and the location of facilities.

For some analyses a second measure was used which was:-

> The number of facility types where activities can be done, given the same constraints.

Both measures have shortcomings. The first measure can give a high value regardless of the types of facility that are accessible, while the second could give a high value regardless of the choice within each facility type.

3.2. Data needs

In order to calculate the measure accurately the following data are needed.

1. For measurement of external constraints

a) Location of facilities of different types.

b) Opening times of these facilities.

c) Minimum time needed to carry out activities at the facility.

d) The times needed for travel by different modes of transport between locations.

2. For measurement of personal constraints.

a) The times when the individual is not constrained to higher order constrained activities (ie work, household, and other commitments (eg escorting children and regular meetings).

b) The locations of the start and finish times of these activities.

c) The modes of travel available during these times and the ability of the person to use them (eg walking speed, and a maximum acceptable travel time).

3. For the measurement of personal needs.

a) The activities that a person may have need or desire to do.

3.3. Constraints used in analysis

The description of the measure given above implies that there is a large amount of information about people, their activity patterns, the transport system, and facilities in the area. In order to operationalise the measure it was necessary to simplify some of these aspects into numerical terms which could be implemented on a computer for the analysis.

Relevant activities

Different activities have different levels of constraints acting upon them. For instance, work is normally constrained in time and space, with fixed times. This analysis is concerned with activities which are not constrained to fixed times in this sense. Hence, work and school hours are excluded. It was also assumed that household activities such as eating and sleeping are not disrupted so these activities were also taken to be constrained, and not included. The analysis dealt generally with those activities which may be time or space constrained by the use of facilities which have set `opening hours' and those which are spatially constrained to facilities but which are not constrained to fixed times (eg games in parks).

Fifty five different types were used in the analysis. Those used are listed in Table 3.3.1.

Similar opening times were assumed for each facility of the same type; this was done for simplicity, and lack of data. Different opening times for different facilities of the same type could have been dealt with by adding a new facility type (eg. late opening grocery stores).

The minimum time needed to carry out the appropriate activity at a facility was assumed for each facility type, due to lack and impossibility of collecting data. Obviously the same activity at the same facility type could take different times for different people (eg. going for a drink at a bar), or different activities taking different amounts of time could be done at the same facility (eg, undergoing heart surgery or visiting a friend at a hospital). The times chosen were for typical activities taking a normal time at each facility.

Table 3.3.1 - Facilities used in the analysis.

Food Shops	Supermarket, Grocer, Butcher, Fishmonger, Fruit and Veg, Baker, Specialist food.
Durable shop	Hardware, Furniture, Wool and fabric, Shoes, Books, Records, Department store.
Other shops.	Newsagent, Tobacconist, Chemist, Off licence, General shop.
Cooked food	Cafe, Fish and chips, Restaurant.
Service	Dry cleaner, Estate agent, Employment agency, Building society, Turf accountant, Bank, Post Office, Ladies, and Gents hairdressing, Launderette.
Education	Primary school, Secondary modern, Grammar school, Library, College.
Recreation	Sports ground, Golf club, Pub, Swimming pool, Cinema, Old folks club, Allotment, Church.
Offices etc.	Police station.
Health.	Hospital visiting, Clinic, Doctor, Dentist, Optician.

Personal needs, desires, and constraints

It was assumed that a person might have need or desire for an activity unless there was some logical reason why they should not. Thus the only limitations were ones such as retired people having no wish to reach schools.

Personal constraints were a more tricky problem. There is no accepted operational definition of the dividing line between a personal constraint and an entrenched habit. In the event two approaches were used, the first using `prototypical' people with `typical' time constraints such as work hours, and meal times, which could be relaxed or tightened in a controlled manner, the second took week long travel diary data and analysed behaviour for that week, to look for recurrent patterns of behaviour, and times always spent at home or work, or other locations.

Mobility

Mobility is defined in terms of mode availability and the ease of travel by such modes in the travel system.

The speed of travel was defined by an assumed speed of travel for each mode through a network. For car, cycle and walk the networks were identical except for a few footpaths.

Times between locations were defined using a shortest path algorithm and the assumed speed for each mode.

For bus travel each route was coded with the locations of bus stops defined as the walk times needed to reach several adjacent rectangular 0.5km grid squares used as the analysis cell. For each stop a time was also recorded as the bus travel time from the start of the route, and all bus departures were recorded for the start of each route. Thus for a bus journey between two cells, the list of bus stops was scanned for a matched time to the cell. From the time of arrival at the stop the wait time till the next bus arrival was added, and the in bus travel time and walk time needed to reach the destination cell were also added. A routine was written into the program to allow for changing buses, and all routes serving both cells were timed to find the fastest at the given time of day.

3.4. The data available.

Data was made available from the Building Research Establishment (Urban Planning Division) in the form of travel diaries carried out in 1969 in Watford in connection with work on shopping patterns (Daws and Bruce, 1971, and Daws and McCulloch, 1974).

Further data on the locations of shopping centres and other facilities was also made available with the travel diary data. Other facilities were recorded in Kelly's Directory of Watford and District for 1969. Bus timetables were not available for 1969 so a 1975 timetable was used instead; no major alterations had been made in the meantime.

It is apparent that the dates of the survey render the study somewhat out of date, if one is interested in the results from a practical point of view. However, as the study was intended to study the effects of different constraints, this is not so important.

3.5. Program descriptions.

Two programs were written for the accessibility measures. These dealt with the two stages of the calculations of the measures.

Program to elicit personal constraints data. This program used data from the travel diaries to formulate the constraints used on times and locations of work, home based, regular meetings, and escort journey activities, and the modes of travel available to each person during the unconstrained time periods.

The general method was to split the day into units of one minute, calculate the times for which people were always at home, at work for five or more days, etc, and other times for which they were nearly always out of home. From this record `unconstrained time windows' were calculated for each individual.

Modes of travel available were defined in terms of the travel recorded during those `time windows'. Assumptions were made in this process that all people had access to walk and bus modes.

Program to measure accessibility. Using either hypothetical data on people's time and space constraints, or the output provided by the program to elicit constraints data, together with the environmental data on facilities and the transport system, this program calculated the measures for each individual.

For every period of unconstrained time a journey was simulated starting and ending at the set constrained locations, to each facility, by the modes available to the person, to evaluate if there was enough time available to reach the facility, carry out the activity normally associated with that facility (eg cashing a cheque at a bank), at the times when the facility was open or usable, and then to travel to the next constrained location for the next constrained time. The program was not capable of analysing multi purpose trips in any unconstrained period, although time between say, home and work, was regarded as unconstrained, so visits to facilities on the way to or from work or other fixed locations could be included.

For each `usable' facility that a person might have need or desire to use a score of 1 was added to a counter, and a record was made that the facility type was reachable. While the program allowed for four time periods, scores were not added twice if the facility could be used twice in the same day. Thus there was a maximum score of one per facility per day.

4. ANALYSES AND RESULTS

Four main types of analyses were carried out using the accessibility measures. Firstly the program was used in a simplified form to calculate `time rings' of accessibility for various locations and modes (Section 4.1). To test the effects of various different types of constraints hypothetical `prototypical' people were `invented', who lived in set locations with set constraints (4.2). These constraints could be altered (4.3) to test for differences in constraints. Using data from the Watford Travel Diary it was possible to test the accessibility for `real' people to see how this compared with that for the hypothetical people (4.4). Finally, sensitivity tests were carried out on some the assumed parameters such as speed of travel and parking time (4.5).

4.1. Time rings analysis

A fairly common measure of accessibility is known as time rings, a concept borrowed from cost rings in economics, where the index is the number of opportunities which can be reached in a given time period. This can be done for a variety of different time periods. Thus this index can be easily applied as a simplification of the methodology employed here.

`Time rings analysis' was carried out on the 10 sample areas used in the travel diary data (and also used in the prototypical cases). Rather than assuming that all facilities were usable at all times, runs were done for people starting at 10:00 am, and assuming that people would not be willing to travel for more than 50 minutes on any one leg of a journey. Runs were also done for a time period starting at 5pm to check look at the importance of time of day for facility opening hours. They were done for each mode.

Figure 4.1.1a to c show the results obtained for residents of three areas for various lengths of available time. It can be seen that mode availability had the greatest effect on accessibility

with people with cars having the best accessibility, followed by reasonably fit cyclists. The patterns for bus tend to be stepped as thresholds are reachable, while walk remains low. The maximum acceptable travel time applied to all modes except bus limits the facilities reachable after about 120 minutes.

Town centre located people have generally higher accessibility as measured by time rings than others.

Of interest are the circumstances which give rise to high and low accessibility. Table 4.1.2 summarises the results which gave an index of less than 0.3; these are the cases which imply a fairly low level of accessibility.

Table 4.1.2 - Time rings analyses giving accessibility indices of less than 0.3.

a) All analyses with a time limit of 30 minutes or less (for all areas by all modes)

b) Central area walk and bus analyses for up to 60 mins

c) Central area walk and bus analyses starting at 5pm up to 90 mins.

d) Garston area runs by walk for all travel times and all times of day (unless max travel constraint is relaxed)

e) Garston runs by bus up to 60 mins

f) Bushey Heath runs up to 60 mins by bus and walk

g) Suburban runs of any time by walk after 5 pm

4.2. Prototypical people

Using the measure outlined in the methodology section tests were carried out on 36 prototypical people for a variety of differing time constraints. The 36 cases were constructed to show differences in mode availability, home location, and work location. All people were assumed to want to reach all facilities. The characteristics were as follows:-

Mode availability -	Walk only Cycle only Bus and/ or walk Car only
Home location cell -	Cell no 1811 Inner Cell no 2214 Intermediate Cell no 1820 Outer
Work location cell -	Cell no 1812 Inner Cell no 1309 Intermediate

All combinations of the above were modelled making a total of 4 X 3 X 3 (=36) variations.

Using the sample of prototypical people and the `normal working' time constraints Table 4.2.1 shows the indices achieved for each of the 36 combinations of home and work location, and mode availability. The normal time constraints were for a full time worker who had the following temporal and spatial constraints.

Midnight - 8:30am	Constrained to home.
9:00am - 1:00pm	Constrained at work location
2:00pm - 5:00pm	Constrained at work location
5:30pm - 7:30pm	Constrained to home
11:00pm - Midnight	Constrained to home

Thus the constraints tended to be strict assuming that the full time worker had strong family commitments in terms of meal times etc. The effect of these was tested in the altered assumptions part of the work (Section 4.3).

Table 4.2.1 - Individual results obtained for `normal' `prototypical' results.

		INDEX 1 (Proportion of all single facilities visitable) Home location				INDEX 2 (Proportion of facility types visitable)			
		Inner	Mid	Outer	All	Inner	Mid	Outer	All
	Work	---	---	---	---	---	---	---	---
Car	Inner	.72	.72	.71	.71	.82	.82	.82	.82
	Middle.	63	.63	.63	.63	.82	.82	.82	.82
	Outer	.65	.65	.64	.65	.80	.80	.80	.80
	All	.67	.67	.66	.67	.82	.82	.82	.82
Cycle	Inner	.59	.59	.58	.59	.82	.82	.82	.82
	Middle.	43	.43	.42	.43	.80	.80	.80	.80
	Outer	.47	.47	.46	.47	.80	.80	.80	.80
	All	.50	.50	.49	.50	.80	.80	.80	.80
Walk	Inner	.32	.32	.30	.31	.80	.76	.82	.79
	Middle	.15	.14	.11	.13	.67	.64	.65	.65
	Outer	.10	.10	.07	.09	.58	.55	.56	.56
	All	.19	.19	.16	.18	.68	.65	.68	.67
Bus	Inner	.40	.35	.37	.37	.82	.82	.78	.81
	Middle	.22	.17	.18	.19	.64	.64	.64	.64
	Outer	.18	.13	.15	.15	.60	.60	.60	.60
	All	.27	.22	.24	.24	.69	.69	.67	.68

It can be seen that car gives good accessibility in all cases, while bicycle in general provides the second best. In many cases the difference between bus over walking is minimal, given the time constraints imposed. (It should be pointed out that some of the locations of home and work would not be possible by some modes given the travel modes available; eg a person could not walk from one side of Watford to the other in the 30 minutes allowed for the journey to work.) Home location has little effect in this situation as there is little time available for activities based from home, whereas work location has a much greater effect, as the lunch hour is of importance for a person with these constraints.

4.3. Prototypical people - Altered constraints

By altering the constraints it is possible to see the effects of the changes on people. Table 4.3.1 summarises the mean results for all home and work locations according to travel mode available, while Tables 4.3.2 and 4.3.3 hold the home and work location constant.

Table 4.3.1 - Prototypical results by mode available.

Mode	Car	Bike	Walk	Bus	AVE
1. Normal	.73	.53	.24	.29	.39
2. No free time in evening	.63	.46	.16	.16	.31
3. No lunch-break	.33	.27	.12	.21	.18
4. 30 mins extra for home trip	.73	.54	.24	.29	.40
5. 30 mins extra for work trip	.76	.61	.24	.29	.43
6. 90 minute lunch-break	.83	.63	.27	.64	.43
7. Morning work only	1.00	.89	.36	.82	.72
8. Afternoon work only	.90	.83	.36	.82	.68
9. No work, 9-5 free	1.00	.90	.50	.93	.79
10. No work, 9-5, 730-1030 free	1.00	.90	.50	.93	.79
11. No work, 9-12, 2-4, 730-1030 free	1.00	.90	.50	.90	.78

Table 4.3.2 - Prototypical results by **Home Location**

Home location	Inner	Mid	Outer
1. Normal	.47	.44	.44
2. No free time in evening	.35	.35	.35
3. No lunch-break	.27	.20	.22
4. 30 mins extra for home trip	.47	.44	.44
5. 30 mins extra for work trip	.50	.47	.47
6. 90 minute lunch-break	.59	.59	.59
7. Morning work only	.82	.74	.78
8. Afternoon work only	.77	.70	.72
9. No work, 9-5 free	.87	.77	.85
10. No work, 9-5, 730-1030 free	.87	.77	.85
11. No work, 9-12, 2-4, 730-1030 free	.87	.77	.82

Table 4.3.3 - Prototypical results by Work location

Work Location	Inner	Med	Outer
1. Normal	.56	.41	.38
2. No free time in evening	.47	.30	.30
3. No lunch-break	.28	.22	.20
4. 30 mins extra for home trip	.56	.41	.39
5. 30 mins extra for work trip	.59	.44	.41
6. 90 minute lunch-break	.70	.55	.52
7. Morning work only	.82	.78	.72
8. Afternoon work only	.78	.72	.68

It can be seen that the various changes had a large effect on the results, with extra time giving a higher index in all cases. As a person has more time available the importance of a faster mode of travel diminishes, although those with access only to walk are always at a disadvantage. Extra time on the trip home from work tends to make little difference, while that for the journey to work tends to make a greater difference, and a longer lunch break has a large effect for all people.

As was the case for the normal full time worker home location tends to have less effect than work location, even for those who do not have work constraints. Work location, however, has a greater effect, except where the person works part time, where its importance is diminished.

Table 4.3.4 shows the effects of the changes in time availability for people with only access to the walk mode. It can be seen that in this case home and work location are more important than time availability in many cases.

Table 4.3.4 - Walk runs for `prototypical people'.

	HOME AND WORK LOCATIONS								
Home	Inner	Med	Outer	Inner	Med	Outer	Inner	Med	Outer
Work	Inner	Inner	Inner	Med	Med	Med	Outer	Outer	Outer
1 `Normal'	.33	.32	.30	.15	.14	.11	.10	.10	.07
2 No free evening	.28	.28	.28	.08	.08	.08	.04	.04	.04
3 No lunch hour	.21	.07	.23	.07	.06	.05	.07	.06	.03
4 Long trip home	.33	.32	.31	.16	.14	.11	.12	.10	.07
5 Long work trip	.35	.33	.32	.18	.16	.12	.17	.10	.07
6 Long lunch break .	38	.38	.37	.18	.17	.14	.17	.17	.14
7 Work AM only	.54	.49	.44	.27	.27	.25	.33	.28	.12
8 Work PM only	.52	.46	.43	.26	.26	.24	.32	.28	.12
9 No work 1 **	.58	.51	.26						
10 " 2 ***	.58	.51	.26						
11 " 3 ****	.60	.51	.26						

** 9-00 - 5-00 Free

*** 9-00 - 5-00 and 7-30 - 10-30 Free

**** 10-00- 12-00, 2-00 - 4-00, and 7-30 - 10-30 Free

Only those who work in Central Watford with access to walk only have an index of more than 0.3 in general, even with the much relaxed time constraints.

4.4. Real people

Using the full accessibility measure, tests were done on all people from the Watford Shopping Survey, using the program to elicit personal constraint data, and then running the accessibility program on that data.

Runs were done firstly on these people with factors such as travel speeds as would be expected, and with the transport network as it was, to see how the index varied for different groups of people and to see how it compared with the prototypical people.

Figure 4.4.1 shows the cumulative distribution of index scores for the sample. The mean figure achieved was 0.71 although the median was 0.78. It can be seen from the distribution that the bulk of people had a accessibility score of over 0.6. This shows the prototypical sample as having on average low accessibility (0.39), but since the prototypical sample was for full time workers, with a variety of home and work locations and controlled access to modes of transport this is not surprising. The index achieved of 0.71 would be typical of people working part time (Table 4.3.2), which is probably nearer to the `real prototypical' person.

Table 4.4.2 shows the proportions of the population who were able to reach various selected facility types. For most, over 85 percent could reach a facility of each particular type given their assumed time constraints.

Table 4.4.2 - Percentage of sample able to use selected facility types.

Facility	% of all able to use facility	% of relevant groups able to use facility
Supermarket	91	91
Restaurant	85	85
Bank	80	80
Department store	95	95
Hospital visiting	78	78
Doctor	74	74
Dentist	92	92
Public house	92	92
Police station	97	97
Primary school	16	83
Library	89	89

Table 4.4.3 shows the indices calculated for various divisions of the sample.

Table 4.4.3 - Index achieved by different types of people.

		Mean	Sample	% with index under 0.3
All		0.71	1762	8.9
Mode availability.				
Car		0.79	682	9.0
Bike		0.68	81	10.7
Walk		0.60	98	25.2
Bus		0.69	867	7.5
Time availability				
Low (< 2hrs free per day)		0.14	83	84.3
Medium (2-4 hrs per day)		0.65	838	7.2
High (>4 hrs per day)		0.80	809	1.2
Life cycle group.				
Young unmarried		0.77	83	3.6
Married, no children		0.68	181	8.6
Married, Child <5		0.64	333	8.8
Married, Child 5-16		0.71	361	9.4
All adult household		0.71	530	9.3
Retired		0.72	242	3.6
Home location.				
Leavesden		0.76	181	7.3
Garston	Outer	0.66	179	7.0
Carpenders Park		0.78	186	9.5
Rickmansworth		0.73	134	10.5
Watford North		0.66	170	10.7
Bushey Mill Lane	Med	0.46	144	7.6
Bushey		0.62	182	8.0
Cassiobury		0.75	203	8.5
Harwoods	Inner	0.77	176	5.1
Kings		0.81	175	6.6

Time availability has the largest effect with those with little free time have very low accessibility. Mode also has a large effect while home location and stage in family life cycle generally have little effect.

In order to find out which groups suffer from low accessibility according to the accessibility measure Table 4.4.3 also shows the percentage in each group who recorded a score of less than 0.3. It can be seen that, again time availability is the most important, and mode availability.

Changed environmental parameters.

Following the analysis of the main sample under normal circumstances changes were made to the assumptions about the transport system and other environmental factors to assess the likely impact of various policies or changes on people's accessibility. Table 4.4.4 shows the results of these various runs.

Table 4.4.4 - Summary of environmental change runs.

Run no	Name	Change	Mean Index 1	Mean Index 2
1	Normal	None	.71	.83
2	Faster cars	Car speed increased from 30 to 40 kph	.73	.83
3	Universal car availability	All people assumed to have access to a car	.77	.85
4	5 min bus frequency	Bus runs every 5 minutes on all routes	.72	.83
5	20 min bus frequency	Bus runs every 20 minutes on all routes	.70	.83
6	All buses	All people assumed to have access to buses	.72	.83
7	No buses	Bus users become walkers	.52	.81
8	No cars	Car users have no car but may use bus	.65	.82
9	Bias to bus	Bus frequency doubled; car speed reduced to 20 kph.	.68	.82
10	New centres	Two new large shopping centres opened on outskirts	.72	.83
11	Longer opening	All facilities increase opening times by 1hr either end of day	.78	.85

The highest accessibility of the tested scenarios was achieved by `longer opening hours', followed by `universal' car availability. It should be pointed out that the opening hour changes were somewhat arbitrary, but this result does point to opening hours being as important, or more so, than faster travel in accessibility.

In overall terms, changes to the bus service made little difference, partly as this only affects bus users. Similarly making car speeds faster did not increase accessibility enormously. The blanket abolishing of travel modes, forcing their users to use other modes had very large effects, with no buses having a very large effect.

4.5. Sensitivity tests

In order to test the sensitivity of the measure to the assumptions made in the travel system sensitivity tests were carried out varying the following factors:-

a) Travel speed - travel was normally assumed to be at an average of 4, 15, and 30 kph for walk, cycle, and car, respectively. For sensitivity tests these were multiplied and divided by 1.5. Table 4.5.1 shows the results of these changes on the accessibility index.

Table 4.5.1 - Effect of changing mode speeds.

Fast	Car= 45 kph Bike=22.5 kph Walk=6 kph	.77
Normal	Car= 30kph Bike=15 kph Walk=4 kph	.71
Slow	Car= 20 kph Bike= 10 kph Walk = 2.67 kph	.66

b) Minimum parking time - Two changes were tried, with increasing and reducing the `parking times' (the time needed to use a mode for travel). The effects on the accessibility measure are shown in Table 4.5.2 below.

Table 4.5.2 - Effect of changing `Parking time'

High	Car = 9 mins Bike = 4 mins Walk = 2 mins	.70
Normal	Car = 6 mins Bike = 2 mins Walk = 1 min	.71
Low	Car = 3 mins Bike = 1 min Walk = 0 mins	.72

c) Maximum travel time - For walk, car, and cycle modes a maximum acceptable travel time of 50 minutes was normally assumed. For the sensitivity tests others were also tested and the results are shown in Table 4.5.3.

Table 4.5.3 - Effect of changing Maximum acceptable travel time

Low	15 mins	.57
	25 mins	.64
Normal	50 mins	.71
	75 mins	.77
High	100 mins	.77

Average speed and maximum acceptable travel time had a very large effect on the index, while parking time had little effect, over the ranges tested. This is not surprising given the effects of each type of change.

5. SUMMARY OF FINDINGS

This section summarises the quantitative findings of the accessibility measure.

5.1. People with low accessibility

The main factors and characteristics leading to low accessibility may be roughly defined as follows:-

a) Small amounts of time available to the person for carrying out activities.

b) Lack of access to a mode of travel other than walking, and, especially, an inability to walk at speed, or for a long time.

c) Living at distance from facilities (combined with a lack of access to travel modes.

5.2. Effects of Transport changes.

a) Withdrawal of many buses would lead bus users to suffer considerably, unless such a withdrawal was accompanied by a pattern of universal car availability.

b) Universal car availability would improve accessibility for those currently without cars. (Such a policy would require lowering the driving age, and ensuring that all could afford cars for all family members). Since it is access to increased speed that is under consideration, it may be argued that increased use of bicycles by fit people, or a more enlightened attitude to lift giving by car drivers might have a similar effect.

c) Faster travel by existing cars would obviously only benefit those with access to cars, and somewhat marginally.

5.3. The Effect of Available Time.

By comparing the changes in access levels measured when environmental and transport characteristics are altered it is apparent that fairly small changes in time constraints can have significantly greater effects than transport and spatial alterations.

This is especially true for many of those suffering from poor accessibility. It should be pointed out that the samples used for these analyses were different, but it is apparent that the changes recorded are of a significantly different level to conclude that time changes are extremely important, and although generally considered outside the realm of transport initiatives, will affect transport more than most transport changes.

6. CONCLUSIONS.

What has been described and tested in this project has been a measure of accessibility that was intended to be more reflective of accessibility in terms of people's real levels of access to activities, but, at the same time, be fairly easy to implement without use of enormous amounts of data.

Thus this section on conclusions is written with this in mind.

6.1. Appraisal of the findings.

The importance of time.

It is apparent from the results that changes in people's time schedules and to opening times of facilities etc can have equal or greater impacts upon people's levels of accessibility to facilities than transport or locational changes.

Thus it is apparent that the temporal aspects which were incorporated in this measure are of great importance in any measure of accessibility (when the object of interest is people's welfare) so measures that do not take account of time are of limited use for such purposes.

Shortcomings of the time constraint definition process.

In this study the method of defining people's unconstrained time was open to a large amount of error, being based on people's behaviour during one week. Having studied people's behaviour in terms of the times they were at home, or at work, these were taken as fixed constraints, which could not be changed. This is obviously not always the case, and sheds doubt on such a method of analysing time constraints.

The use of `prototypical people'

The use of `prototypical' people proved very useful, and was easier to analyse since it provided an easy way of testing the accessibility of different types of people. Using a potentials approach to the measurement of accessibility it used that framework, since one can define possible situations more freely, and thus define groups of people who are likely to have low accessibility, or to suffer or gain most from a change in the environment, or policy. It thus makes analysis of results much easier, and it also saves data preparation time.

6.2. Possible improvements to the measure.

One can see the measure as being improved in two different and generally opposing ways. Firstly it can be argued that accuracy needs to be improved (implying a more complex measure, or more data. Secondly one could argue that it would be improved by simpler operation, and a smaller data requirement.

a) Complicative changes.

The main drawbacks of the index in terms of accurate measurement of accessibility may be seen as:-

a) The inability to accurately measure accessibility for people who walk, especially for people who cannot walk fast, or cover long distances.

   This could only be improved by a more accurate network for walk, with more accurate locational information for facilities. Runs could also be done using different walking speeds, and different upper limits on maximum acceptable walking times.

b) The inability to account for complex (or multi purpose) activity schedules.

   Sequencing of activities has been studied in this way using PESASP (Lenntorp, 1976), and could be incorporated, but the definition of multi-purpose journeys to be tested by the measure could be very complex when one wants an overall index of accessibility.

   In a sense the model does deal with some of these problems in that unconstrained time can be defined as being between two time points at different places (eg between work and home). On could define a time period as being between a child care facility and work. The difference between this model and PESASP (in this respect) is that PESASP could choose which child care facilities a person could use and which other facilities could be used before getting to work at a fixed time, while this model has to look at one pre-chosen child care facility.

c) The inability to deal with non-rigidly fixed constraints.

   One major criticism of the time-space approach is that it has to assume that constraints are fixed, and inevitable, which is patently not always the case. If something is important enough people can `break' constraints. Stephens (1976) attempted to define the `relative fixity' of constraints for a simulation model of human behaviour within a time-space framework.

   Working with `real' people one could ascertain constrained time periods by means of a questionnaire, firstly asking about fixed constraints such as work hours (if there is no flexitime), before running it again in less rigid constraints such as eating, sleeping, etc.

   The problem with such an approach is that some amalgam of measures would have to be produced for any overall measure of accessibility, which might prove less useful than one measure which takes certain activities as fixed, and ignores others.

b) Simplicative modifications.

There are aspects in which the operation of the measure seemed very complex; the major ones being:-

a) The number of facility types.

In this study 55 facility types were used. This could have been reduced to 17 without much loss of accuracy, unless specific facilities are required to be tested. The program could be altered to deal with such cases.

b) The bus journey timing method.

Much of the data preparation time and much of the computing time was taken up in coding timetable data, and working out accurate journey times. For routes where buses are frequent (eg a headway of better than 15 minutes) one could assume that waiting time is say one half of the headway, which would reduce accuracy somewhat, but save time on coding bus departures. A matrix of estimated times could be produced with good local knowledge, without the need for the large coding and computing effort used in this study.

c) Other modifications.

a) One possible modification would be to stress activities rather than facilities to a greater extent using activities such as:-

- gaining everyday food

- gaining large amounts of food

- gaining money (through working, DSS, etc)

- gaining money (from bank, building society etc)

- an entertainment outing

- making a phone call

- washing clothes.

In this way activities which do not necessarily involve travel may be included, and the measure could become more like a true measure of ease of carrying out activities. This would, however, complicate the data needs.

6.3. Usefulness of accessibility measures and analysis in real situations.

An index such as this one is by definition a simplification of a complex qualitative notion into a single quantity, and is thus no substitute for sensitivity to other people's experience of their everyday lives and problems.

However, decisions are made in planning, (and other spheres of society) by people who have little time or energy to be interested in other people's real life problems. If such decision making is to be based on the available evidence that such a decision will have on people's lives, the evidence must be either very simplistic and hard hitting or be of a quantitative nature such that decision makers can understand it, and make a choice as the option which is best. IE that which maximises some measure (normally monetary return).

A successful index of accessibility must therefore be able to:-

a) Cover the relevant elements of accessibility,

b) Be simple to understand (in terms of what a particular index level means in reality), and,

c) Be sensitive to changes in the environment and people's situations.

The index used here fulfils all these requirements to a reasonable level, and thus could be of some use as a planning tool.

REFERENCES.

Cobley, B. (1973). **Accessibility in the Plan making process**. Unpublished MSc thesis; University of Reading, Geography Department.

Daws, L. and Bruce, A. (1971). **Shopping in Watford**. Building Research Establishment, Garston, Watford, U.K.

Daws, L. and McCulloch, M. (1974). **Shopping activity patterns: a travel diary study of Watford**. Building Research Establishment, BRE CP 31/74.

Department of the Environment (1976). **Development plan : evaluation and robustness: Application of an analytical program and a review of measures of performance**. LGORU Research Report 5.

Ireland, J (1971). **Accessibility and choice as quantitative variables in Land Use Planning**. SSRC Research Report.

Johnston R.J. (1966). **An index of accessibility and its use in the study of bus services and settlement patterns**. Tijdschrift vor Econ and Soc Geography, Jan/Feb 1966 pp33-38.

Jones P.M. (1975). **Accessibility, mobility, and travel need; some problems of definition and measurement**. Paper for presentation at the IBG Transport Geography Study Group Conference, University of Birmingham, Sept 1975.

Jones S. R. (1981). **Accessibility measures: a literature review**. Transport and Road Research Laboratory Report LR967. Crowthorne, England.

Lenntorp, B. (1976). **Paths in Space-time environments; a time geographic study of movement possibilities of individuals**. Lund Studies in Geography no 44.

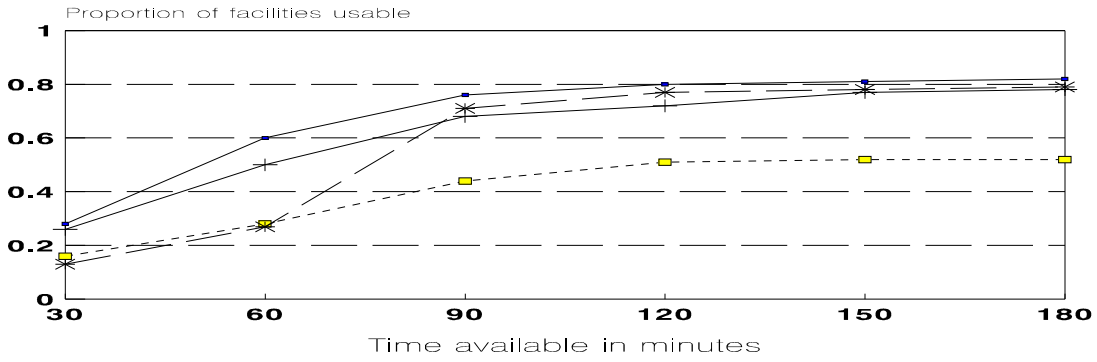
Moseley M.J. et al (1976). **Rural transport and accessibility** - Final report to the Department of Environment, Dec 1976, University of East Anglia.

Stephens J.D. (1976). **Daily activity sequences and time-space constraints**. In Holly B.P. (ed), 1976).

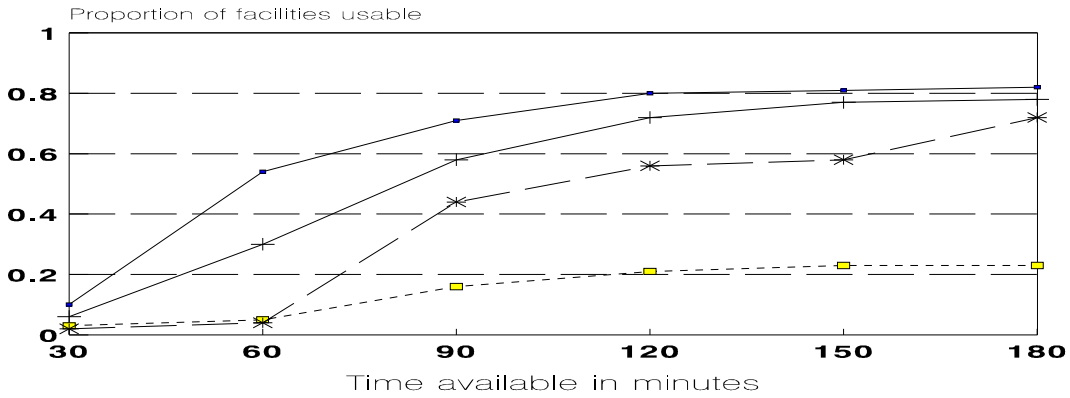
W.Y.T. Consult (1977) **The analysis of personal accessibility,** Document 431, May 1977.

W.Y.T. Consult (1977) **Analysis of accessibility in the free standing towns**. Doc 407, April 1977.

Fig 4.1.1 - Time rings for
a) Watford Town Centre Residents



b) Garston Residents



c) Bushey Heath Residents

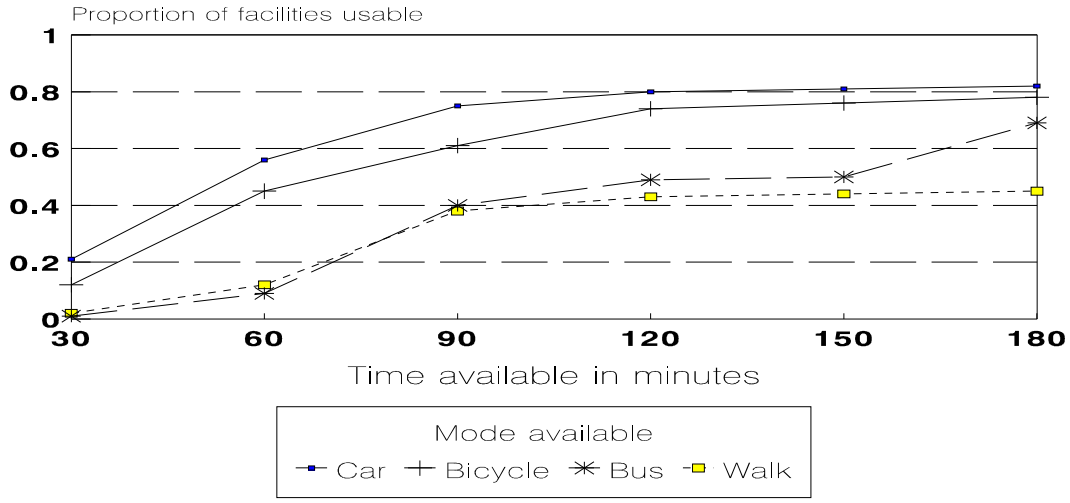


Fig 4.4.1
Distribution of accessibility index for `real' people

