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AN INTRODUCTION TO TIME-GEOGRAPHY

Nigel Thrift

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AN INTRODUCTION TO TIME GEOGRAPHY

by

Nigel Thrift
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Acknowledgement

I would like to thank Professor T. Hagerstrand (Lund) without whom this monograph would (literally) not have been possible. And I owe a tremendous intellectual debt to Tommy Carlstein (Lund) which I would like to acknowledge here. May they forgive me.

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TIME - GEOGRAPHY

I am looking for a way of finding conceptual coherence in the geographer's understanding of the human world all the way from home to globe and from day to lifetime.

Torsten Hagerstrand (1975b, p 29)

I THE FRAMEWORK

(i) Introduction

Consider a road accident. Looked at from the traditional statistical point of view it is a product of the growth of number of cars in space or the proliferation of the built environment. But such a view tells us almost nothing about the specific accident. Even examining the legal issues involved does not necessarily tell us much about the real cause of the accident. Can we search for another meaning? The answer is, of course, yes. By re-stating the problem of the accident in time-space terms, and specifically in time-geographic terms, the language we are able to use enables us to grapple with the larger problems we simultaneously uncover.

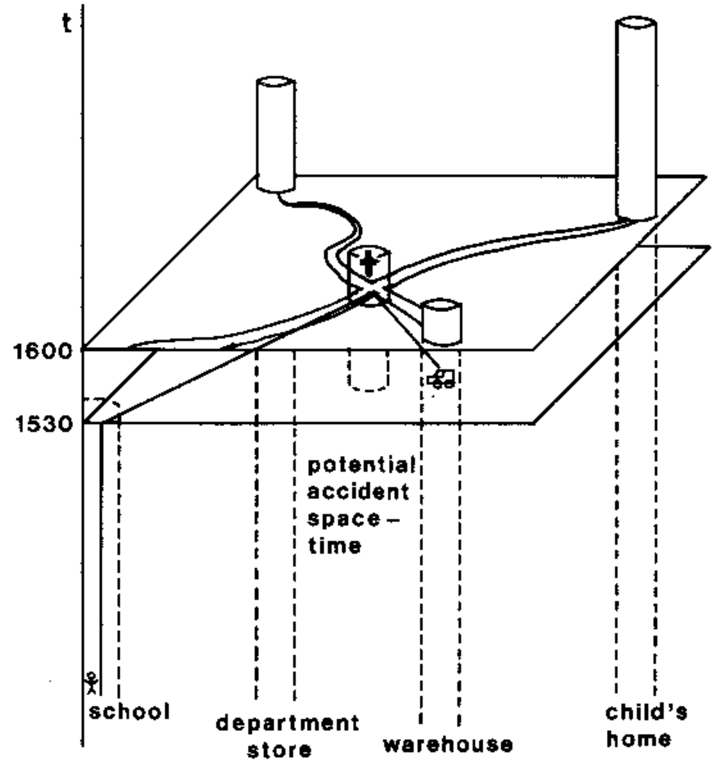


Fig. 1 An "accident" in time geographic terms

In time-geographic terms the individual accident is the focus of many components. But the reason for the accident (in the larger ecological sense) lies in the reason for their meeting in a specific location at a specific time. Take the example (see Figure 1) of an accident involving a school child and a delivery van. The van is involved in carrying goods from a warehouse to a department store at the same time as children are walking home from school. So the accident point is a point of high risk. The time-geographic framework examines the co-ordination of individuals' possibilities of action in time and space with existing objects and organisations in time and space. In this way the macro-scale becomes something more than the micro-scale. Thus the time-geographic model is an attempt to understand under what basic conditions linkages like "accidents" develop and how such conditions can be changed in order to improve the quality of life. The model allows for the fact that individuals, businesses and governments have their own conflicting projects and allows that a minor change in one can have a serious effect on the others. It is an intrinsically neutral model (of course the ends to which it is put need not be) which allows conclusions to be drawn about the school and delivery business within a wider framework than a series of separate boxes connected by arrows.

(ii) Space-Time and Environment

The physical environment we inhabit does not only consist of the readily observable spatial backcloth. Associated with it, indeed inseparable from it, is a temporal component which is just as important. It may not display itself in the same graphic manner but it is an essential ingredient of life - think only of times of lectures, shop-opening hours or work hours. To separate time from space is quite impossible. In theoretical terms we could think of such an abstraction of time from space as being like some future archaeologist trying to make deductions about the function of a car he has just dug up which has no engine in it. Just as a car with no engine has no movement (and so no rationale) so space with no time has no dynamic and is equally curious.

The simple act of moving from some point A to another point B in space will take a certain amount of time (depending on the mode of travel). This is a physical fact of life and essentially it is this "physicalist" approach which is the backbone of time-geography. It is a respect for the conditions which space, time and the environment impose on what the individual can do. Many geographic papers read in a way that seems to imply a complete lack of physical structure to the world, time-geography tries to rectify this.

In this brief monograph on time-geography it is intended to give only an outline of what is, by now, a very large body of work which incorporates a vigorous research frontier. The hope is to give the student some basic ideas and the vocabulary time-geography uses to describe time-space. So the monograph should be seen as a very simple ruler which should allow some steps to be made into time-space without too much confusion ensuing.

(iii) The Conceptual Base of Time-geography

Space and time are resources. We must realise that just as we use space as a resource, allocating particular portions to particular uses, so we use time as a resource allocating particular intervals to particular uses. Although these resources are not mined in quite the same way we shall explore the particular veins individually a little later on. For now we can regard them as roughly isomorphic.

The realisation that space and time should be treated as a corporate entity was probably the result of the work on space-time budgets (for a review of which see Anderson, 1971; Holly, 1975; Thrift, 1977). This work which is an extension of the classical time-budget approach, is based on the notion that human activities take time and this activity can be measured in physical time units. And since time is a limited resource it can be budgeted, allocated and so on. The time it takes to perform tasks is empirically observed in various social and environmental settings, usually by asking a selected sample of people to fill in diaries for some length of time. It is then possible to make all kinds of observations and calculations on how activities are and can be performed, on the impact of new innovations (television has been a favourite) and so on. These assessments are used as inputs to all kinds of planning decisions from the local (for instance the viability of flexible working hours) to the national (for instance in giving a more realistic figure for the gross national product).

The time-geographic approach, by contrast, does not derive from empirical observations which are in the final analysis just time-budgets with a spatial location tacked on. It takes as its base the population system, that is the system of human individuals inhabiting a given region. These two approaches might not seem at first sight very different but whereas the former is an inductive methodology the latter is deductive in character. It is this idea of the population as a point of departure that characterizes the time-geographic approach to socio-environmental modelling.

Often in geographical textbooks ideas are presented as having emerged from thin air so at this point a little history may be appropriate in order to show how this method of geographical analysis came about. The time-geographic model emerged as a product of Torsten Hagerstrand's studies of population movements in Sweden where the detailed population statistics kept since 1749 allow the movements of specific individuals to be followed over many decades. Of course Hagerstrand had also been looking at the problem of diffusion of innovations within this framework for some years but in a 1963 paper he first expressly addressed the problem in a broader framework and the history of time-geography from this point onwards is the history of trying to find concepts which might give geography the integration and degree at physical realism it had heretofore lacked. The decision was taken to go right back to the basic dimensions, to space and time, to start again from the beginning. And since 1966 Hagerstrand and his research team at Lund, Sweden (whose core is Tommy Carlstein, Bo Lenntorp and Solveig Martensson) have been developing this approach.

The physicalist approach to society - an appreciation of the biophysical, ecological and locational realities which impose constraints on the performance of the social system - is now generally known as time-geography. Its two main tenets are that time and space are seen as resources and that the constraints which operate on human beings particularly in the physical environment, are the primary dictates of human experience. This constraint or negative determinant approach should be contrasted with that of the space-time budget approach which until recently has relied on the stressing of choice in the environment. Here activities are seen as the outcome of choices reflecting values and the role of psychology is heavily emphasized (the reader should look at this opposing camp's productions in order to get some idea of the reason why time-geography is a necessary development, for example Chapin, 1974). As we shall see this choice-based view of the world (probably derived from cultural bias towards material consumption) is often non-viable. In everyday life, for instance, individuals often have only one way of getting from home to work.

The time-geographic approach is, first and foremost, a simple approach. There are a number of reasons for this. One is, of course, that it was felt necessary to go back to basics in order to establish a geography that did not jump into the middle of the phenomenological pool, but that started at the edge and made a logical progression from the pool's beginning to end. But other reasons should be mentioned:

(a) it is argued that a large part of the growth potential of human geography depends on the extent to which basic ideas and concepts can be understood by politicians and planners and with this in mind the emphasis at Lund has been on simple models from which substantive policy implications can be drawn. The success of this rationale is attested to by the fact that time-geography is now in general use as a policy-making aid in Sweden.

(b) it is argued that the use of an absolute space and time framework enables the relation of all kinds of substantively different phenomena. It acts as a common language. Thus the Lund group have tried to remove the imprecision and ambiguity attached to various terms by the use of a limited dimensionality in conjunction with a primary focus on the individual.

(c) perhaps most important of all the idea of simplicity allows the focus of study to be the individual. Usually in statistical aggregation in the social sciences the identity of the people a study is concerned with is lost. The population is treated as a mass of particles. Of course we cannot focus on every single individual in the aggregate but on a line with biography at one end and aggregate statistical populations at the other there is a twilight zone in between the two extremes which Hagerstrand has explored. Here one can at least be sure that the models conform to the same rules as the individuals. This sympathy for the individual is an integral part of the time-geographic approach; it is population geography in the true sense of the word. It is also a concerted attack on the kind of thought process which thinks time and space equals physics" rather than time and space equals society".

Before proceeding to the main body of the work we must list the eight fundamental conditions which Hagerstrand has identified as necessary to any "precise theoretical research" (Hägerstrand, 1975a, p 12). A useful exercise is to use these as a checklist against which to measure the degree of reality present in the geographic models encountered in the literature. The eight fundamental conditions, quoted here from Hägerstrand (1975a, p 12), are:

(1) the <u>indivisibility</u> of the human being (and of many other entities, living and non-living)'. This assumption is constantly broken in the social sciences, for instance in economics every time assumptions of convexity are made. Without recognising indivisibilities - in the human being, in residences, plants, equipment and in transportation - urban location problems, down to those of the smallest village, cannot be understood.

(2) "the limited length of each human life (and of many other indivisible entities, living and non-living)".

(3) "the limited ability of human beings (and many other indivisible entities) to take part in more than one task at a time". For a definition of "task" see over.

(4) "the fact that every task has a duration".

(5) "the fact that movement between points in space consumes time".

(6) "the limited packing capacity of space".

(7) spatial units of any scale must have a limited outer size, "the limited outer size of terrestrial space".

(8) "the fact that every situation is inevitably rooted in past situations".

<u>II THE CONCEPTS EXPLAINED</u>

(i) <u>Basic vocabulary</u>

We can now turn to a detailed examination of the Lund theoretical framework. All human beings have <u>goals.</u> To attain these they must have projects, series of tasks which act as a vehicle for goal attainment and which, when added up, form a <u>project.</u> (Hägerstrand (1974b) identifies five basic types of task-transportation and storage on the one hand and moulding, composition and decomposition of materials on the other. Whereas transportation is space-oriented, storage is time oriented).

So human action is composed of discrete units, of quanta, which form the activity sub-system. Projects involve people and their time, space and in many instances materials, tools, animals and plants - a series of interrelated living and non-living organisms. Time and space are resources of particular interest because projects can often not be completed due to the existence of <u>constraints</u> (Hägerstrand, 1970) which express themselves in these terms. There are three kinds of constraints: (a) <u>Capability</u> constraints limit the activities of the individual through both his own biological make-up (for instance, the need to sleep) and also the capacity of the tools he can command. (b) Cou lin constraints arise because it is necessary that individuals, tools and materials are bound together at given places at given times (for instance, during work hours). (c) <u>Authority</u> constraints which self-evidently refer to limitations and control of access. They occur at different levels to produce hierarchies of accessibility (Hagerstrand, 1970). The influence of such constraints on the Swedish wage-earner is shown in Figure 2.

The problem that the individual and society faces can therefore be seen as the ability to <u>pack</u> projects into the limited resources of time and space. The time-geographic model of society attempts to give a realistic picture of locational and situational relations both within and between society. The human population is conceived of as forming a web of paths which flow through a set of time-space locations or <u>stations.</u> In the "aquarium" (Hägerstrand, 1974a) of the relevant time-space unit (see Figure 3) anything having spatial and temporal extent can be described as <u>paths</u> (for instance, people, plants, animals, buildings and so forth). (See Figure 4) Each path has a different <u>life-span.</u> Here a distinction must be made between those objects which are indivisible such as human beings, animals and tools and those which are divisible, for instance, materials, energy and information (Hägerstrand, 1974a, 1975b). It can now be seen that each individual path will be visualised as a continuous line starting at the point of birth and ending at the point

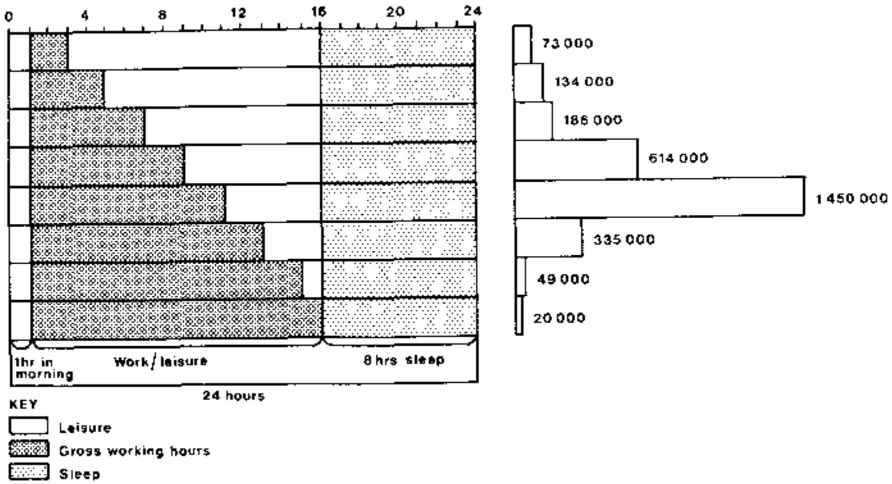


Fig. 2 Relation between leisure, gross working hours and sleep for a Swedish wage-earner in 1968. - After Lundahl

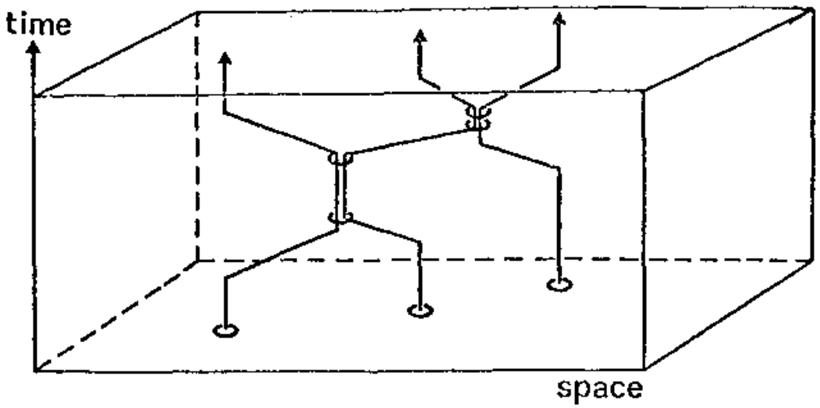


Fig. 3 The space-time "aquarium" in which entities generate trajectories, moving ahead inside and between stations. The graph extracts the space-time behaviour of three individuals over a 24 hour period.

-After Hagerstrand

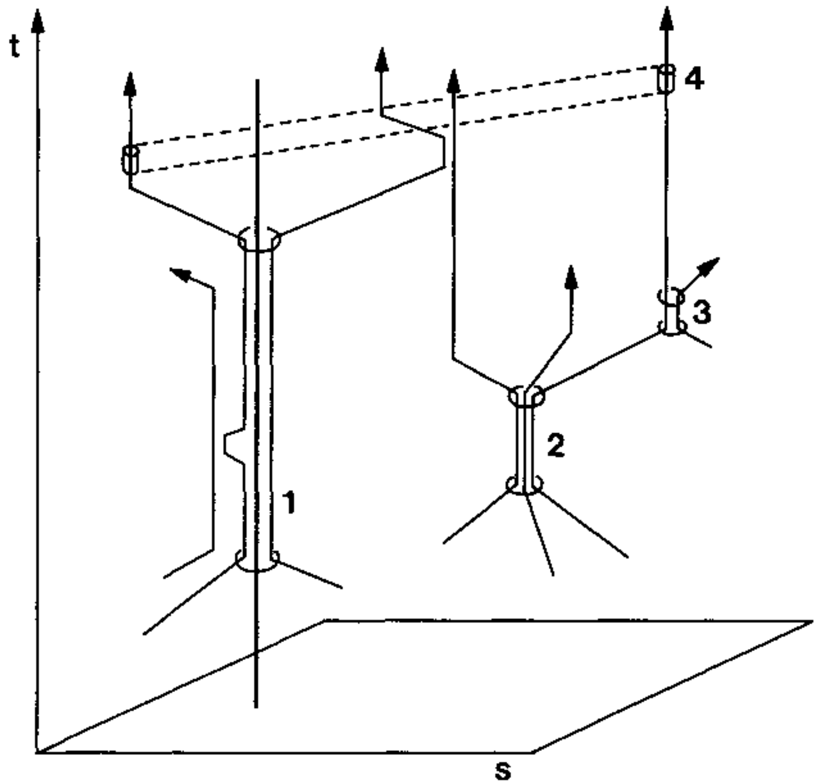


Fig. 4 The web of individual paths in a space/time representation. Activities 1, 2 and 3 are assumed to follow a regular time-table; 1 is attached to some fixed installation. 4 represents a telephone call, a coupling which needs no transportation by the person but takes away time from other activities. (from Hägerstrand 1970).
- After Hägerstrand

of death, according to the temporal units in use - be they days, years or some other period of observation (see Figures 5 and 6).

The paths of individuals are not isolated, they come into contact in accordance with the differential influence of the three constraints and the positioning of stations as <u>bundles.</u> Here it is crucial to remember that it is a time-consuming process to move about in space (see Figure 7). By collapsing metric space into functional category space life-path diagrams become useful analytical adjuncts with which to illustrate this point (see Figures 8, 9 and 10).

It must be remembered that stations have spatial extent and appear as "pillars" or "tubes" in time-space. These pillars will vary in size and even cease to exist over time, as in Figure 6. But it is not only biophysical bodies that have location and distribution, so have legal rules and other normative elements. An obvious case is the control areas or <u>domains</u> (Hägerstrand, 1973; 1975b; Carlstein, 1977) which are the physical manifestations of laws or norms, of authority constraints. A domain can be a favourite rocking chair or a nation - obviously there are hierarchies of domains (see Figure 11).

These are the elements which go to make up the time-geographic model of society. As can be seen the emphasis is on society as an organisation of co-ordinations in time (synchronisation), in space ("synchorization") and in time-space (see Figure 12). But how are these elements brought together to form a coherent whole?

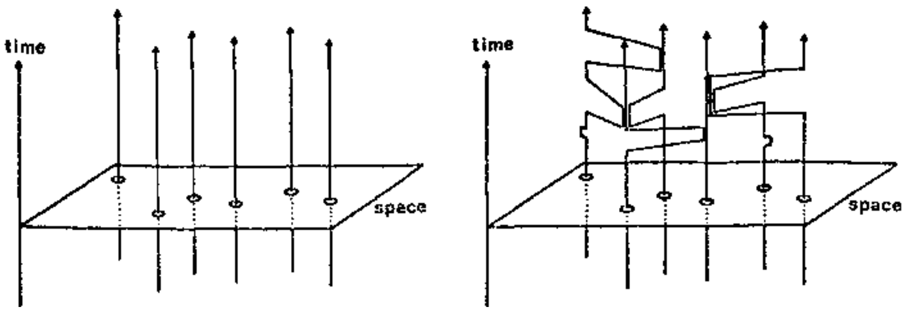
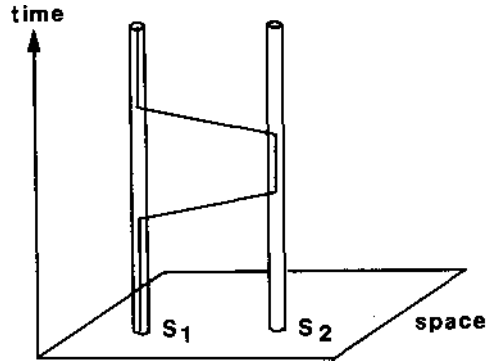
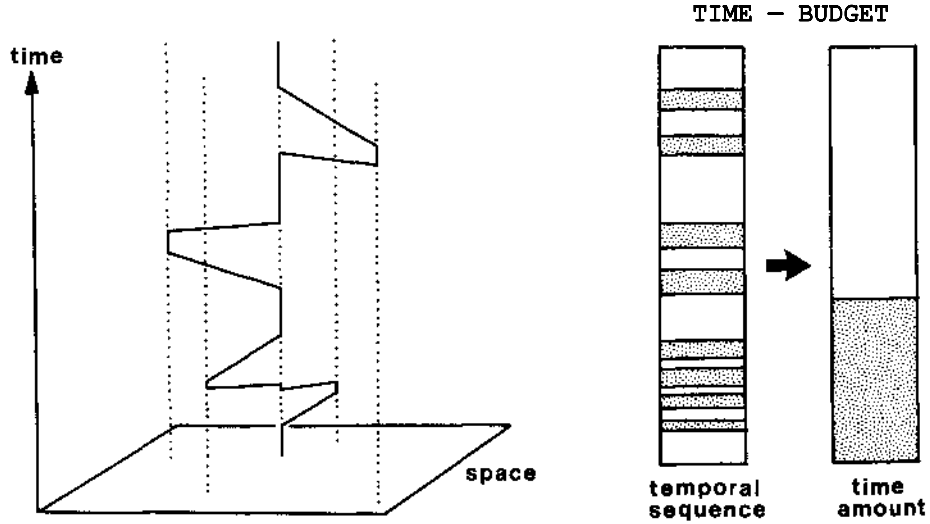


Fig. 5 Life Paths in isotropic time-space and when constraints exist
- After Carlstein



One individual (line) moving from one station (tube) to another and back again. The slope of the individual's path in relation to plane indicates the time it takes to travel.



The relation between a) an individual's path moving among four stations, left, and b) time spent on stationary versus mobile activities in a 24 hour period, right. The figure thus shows the relation between time-space path and "time-budget".

Fig. 6 Path and Budget because of Station
- After Carlstein

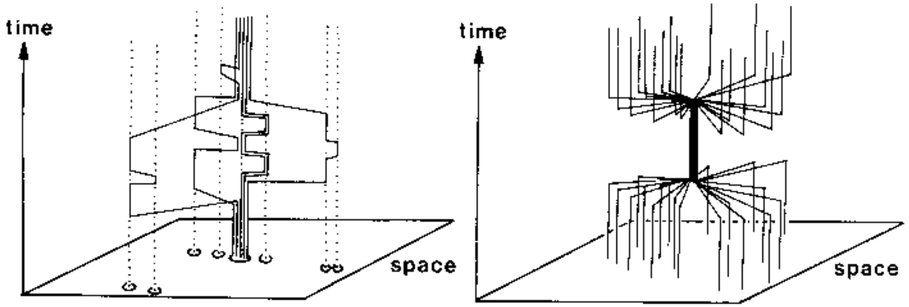


Fig. 7 Bundles: on the left a household as a bundle, on the right a school - After Carlstein

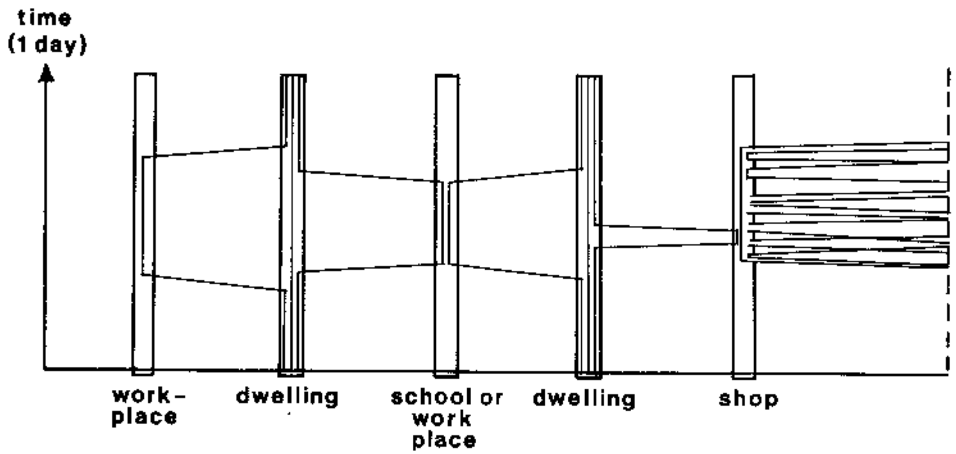


Fig. 8 Category Space - metric distance is collapsed into functional distance - After Carlstein

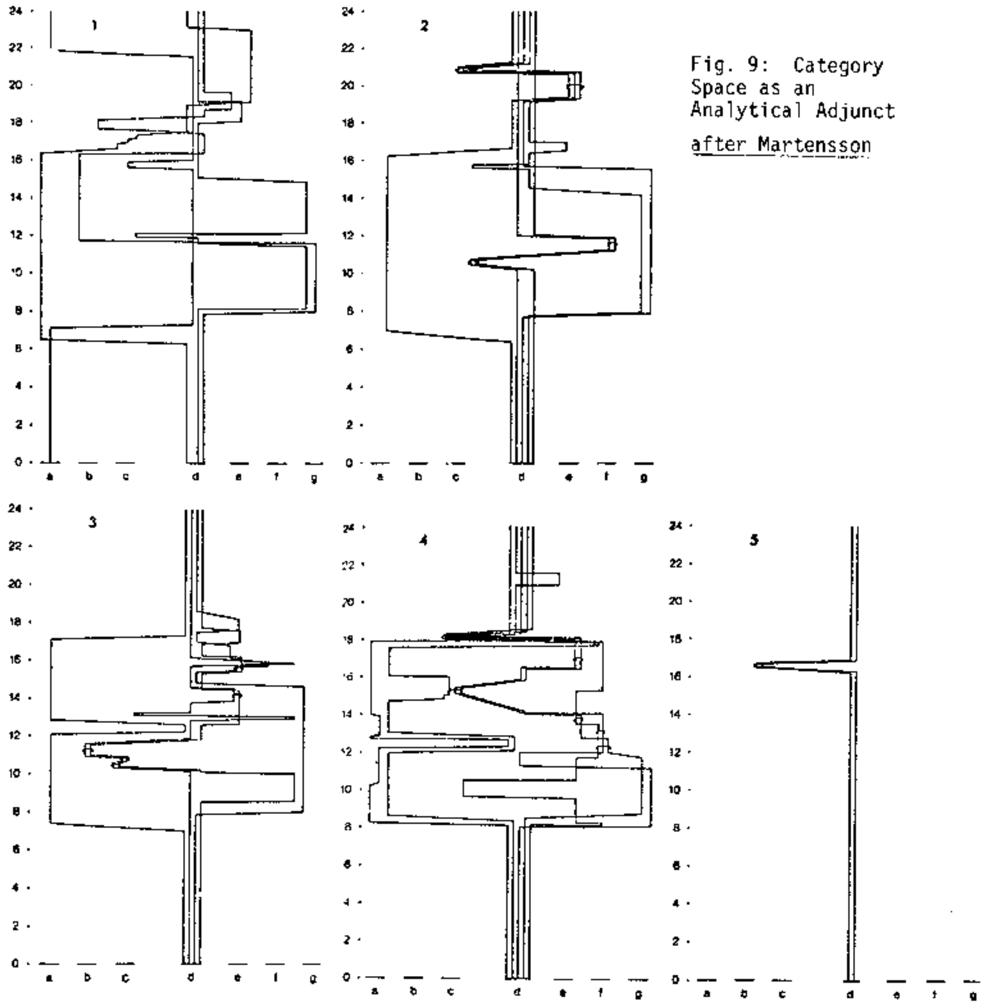


Fig. 9: Category Space as an Analytical Adjunct

after Martensson

The daily path of each member of five households. Seven categories are recognised: a) place of work b) place of services other than commercial c) commercial services d) home e) recreational space f) other houses g) schools. Members of each household are considered by age with the oldest one to the left.

1. Man 43, car; wife 38; boy 10; boy 8
2. Man 36, car; wife 36; boy 12; girl 10; boy 3.
3. Man 44, car; wife 38, car; boy 11; boy 7.
4. Man 37, car; wife 34, car; boy 9; girl 7; boy 5.
5. Man 81; wife 76.

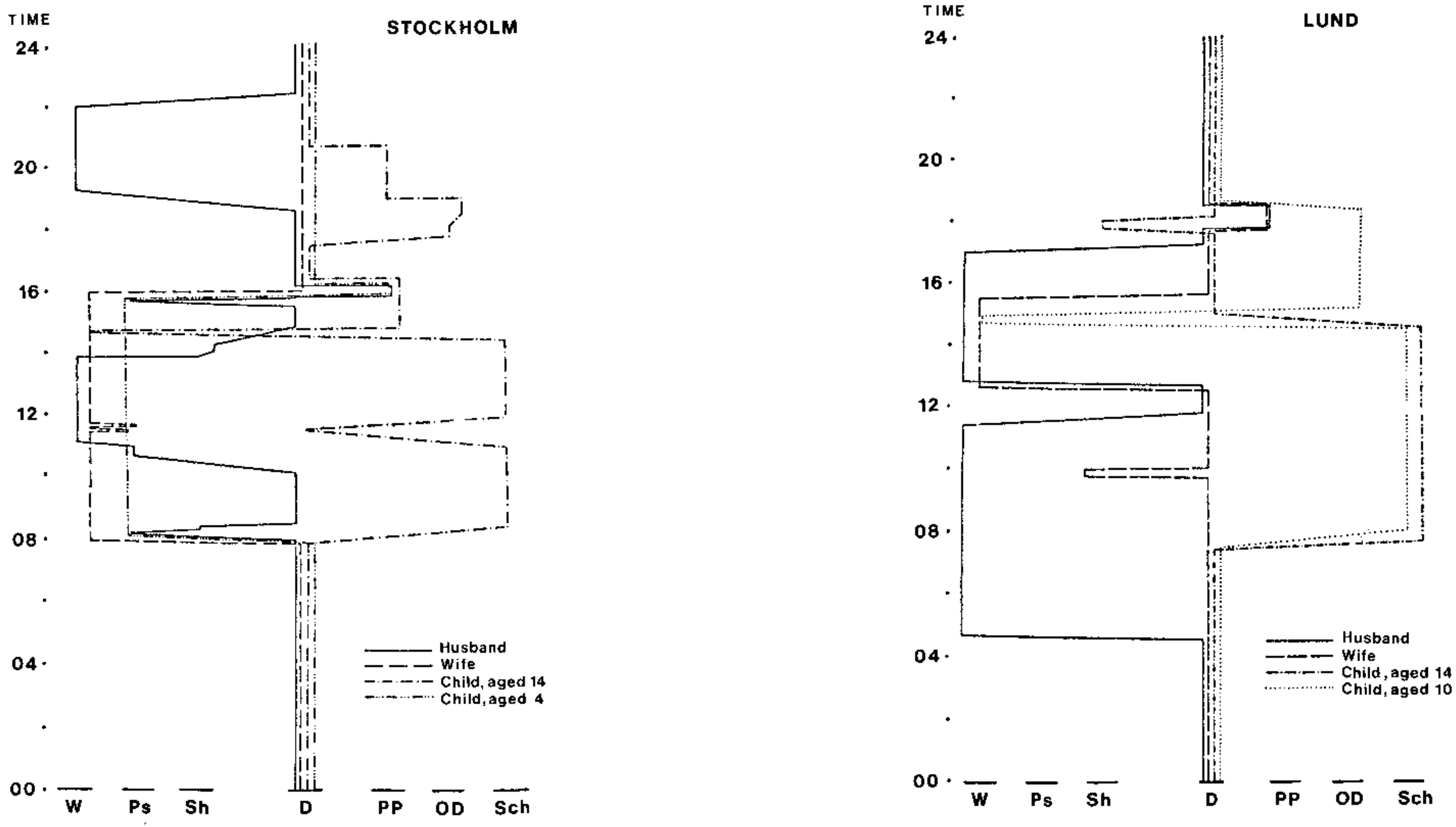


Fig. 10 Lifelines: graphic diaries for two 4-person familes, one in Lund and one in Stockholm - After Hägerstrand

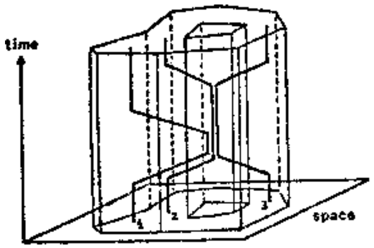


Fig. 11 Domains and 3 individual's paths - After Carlstein

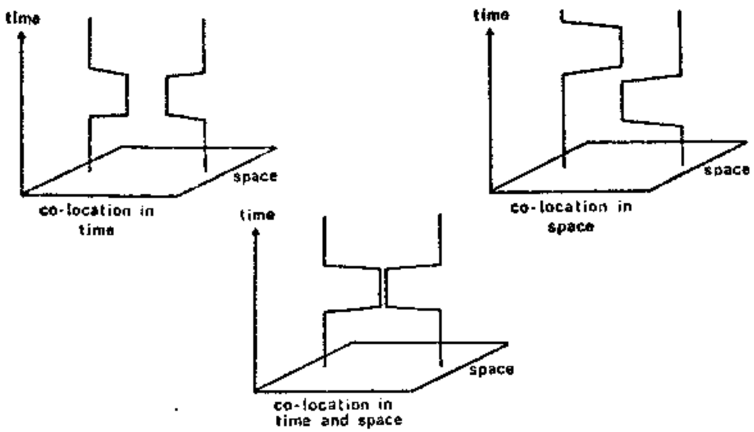


Fig. 12 Co-ordination in Time and Space - After Carlstein

(ii) <u>The Three Types of Model</u>

Essentially the model of society operates at three levels - that of the individual, the station and bundle, and at the societal "aggregate". Each successive level subsumes the ones before it and implies the existence of the other levels but not necessarily the analysis of other levels.

(a) The Individual Level

At the individual level the simple graphical device of drawing life-paths can prove very revealing, for these life-paths are the products of joint location in time and space according to the vagaries of the three constraints and location of stations (the reader is advised to see just how revealing these can be by agreeing on some category space and drawing one's own lifeline in this space; comparison of it with other people's is a worthwhile exercise). It is crucial to emphasise at this juncture that choice of one activity by one individual not only implies that time is then unavailable for alternate activities, but also that there will be a blocking effect for those individuals who might wish to interact with this individual, which leads to a <u>displacement</u> of the activities of these other individuals. But these displacement effects are not only crucial at the small scale (for instance, "someone is talking to the professor already") but equally at a large scale, specifically in terms of migration where Hägerstrand (1963, 1969, 1974b, 1975b) has concerned himself, amongst other things, with the "knock-on" effects that individual displacements inevitably have and, importantly, without losing sight of the individual.

(b) The Station Level

What of the station, the usual location of the bundle? Just as life-paths are used to describe the movement of individuals graphically so the Lund group has developed time-space <u>prisms</u> to depict the situational determinants of the individual's paths through the environment using the stations as referents. The shape of the prism is circumscribed by the individual's speed of travel and whether the station of origin is the same as the station of destination (if it is the prism is symmetric, otherwise asymmetric). Several determinants act as limits to the size and shape of the prism - the maximum speed of travel to destination, the distance to destination (the greater it is the larger the prism) and the spatial distance to destination. Size and shape of an individual's prism also varies according to activity and station character which impose coupling constraints in some given time period (see Figure 13). During a day a person can act within several sets of prisms centred around particular stations. These sets of prisms overlap to form a joint outcome for one day which is a greatly reduced volume of time-space (see Figures 14 and 15). Thus an individual's prism is an analgam of point of departure, a speed constraint, the projects and activities to be performed and the coupling constraints the time-space destinations impose (such as hours of opening). Prisms are not only of use at the individual level, but also to analyse time allocation and spatial occupation, conventionally and fuzzily referred to as "land-use". They can be very useful as analytical tools (e.g. Palm and Pred, 1976).

(c) The Time Supply and Demand Level - Time as Money?

The third level at which time-geography operates revolves around the concept of time supply and demand. The old adage time is money" can however be seen to be only partially true. We cannot assume that human time has the same properties that money has. Whereas money is a store of wealth, divisible,

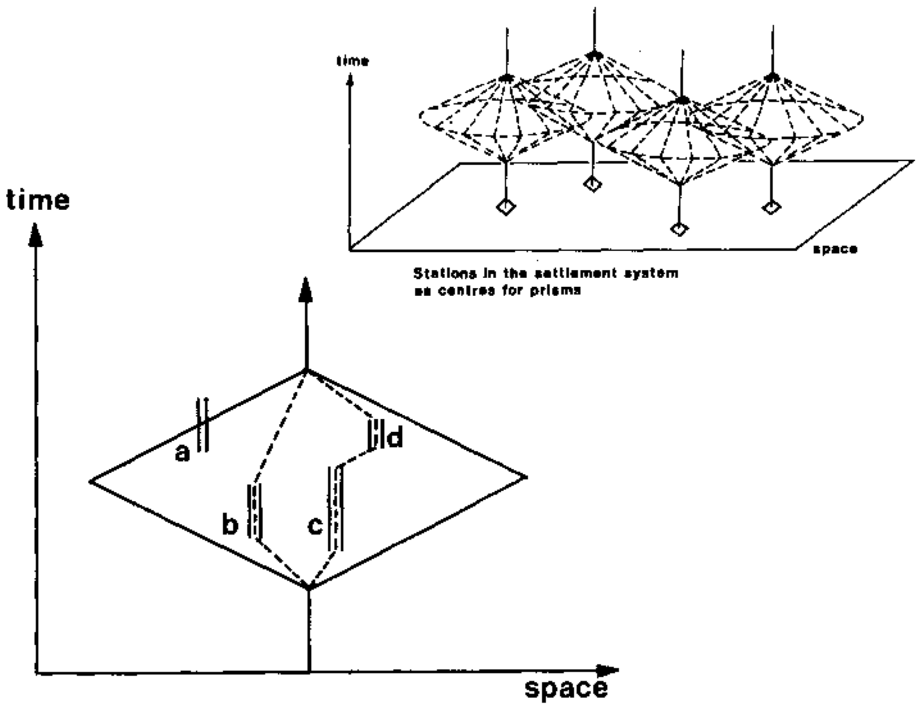


Fig. 13 Prisms

Some fundamental constraints determining the possible trajectories of indivisible entities, for example human individuals.
Given: (1) a base-point (say the dwelling) which the individual cannot leave before a certain time and which he has to return to before a certain later time;
(2) a maximum speed at which he or she can move out from the base-point and back again. These conditions determine the outer limits of the space-time "prism" available for visits. If we now assume that a,b,c and d represent tasks which have a predetermined location and duration then the individual will not be free to participate in all the combinations although the tasks all start inside the prism. a must be excluded because of its duration. If b is chosen, c and d get beyond reach. If c is chosen, b gets beyond reach, c and d can be combined. Obviously, only d can be chosen whereby both b and c are given up. Clearly, the choices finally made affect the trajectories of other entities sharing the same space-time region.
- After Hägerstrand

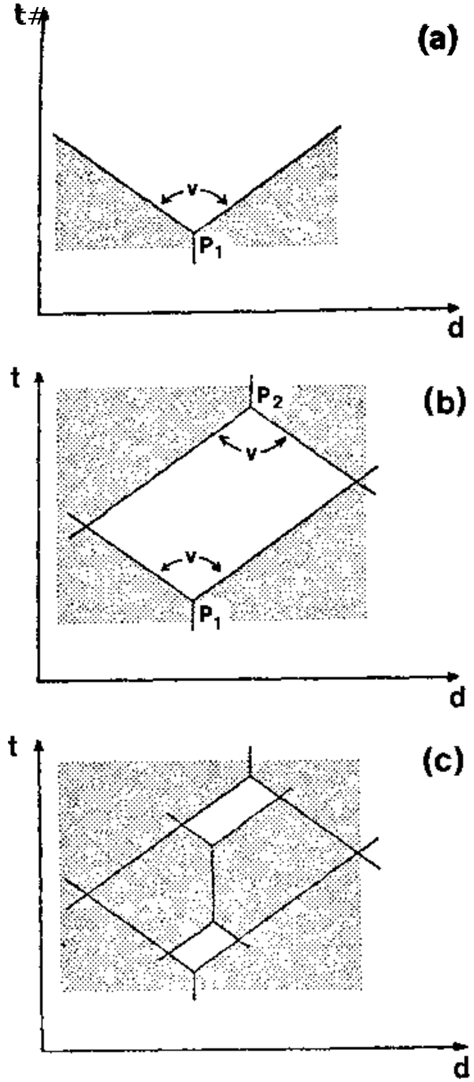


Fig. 14 Prisms and Constraints

A person's action space from a startpoint P_1 is delimited by: (a) some maximum speed of movement v (b), the destination P2 and (c) stops to engage in activities he makes on the way to P_2.
- After Hägerstrand

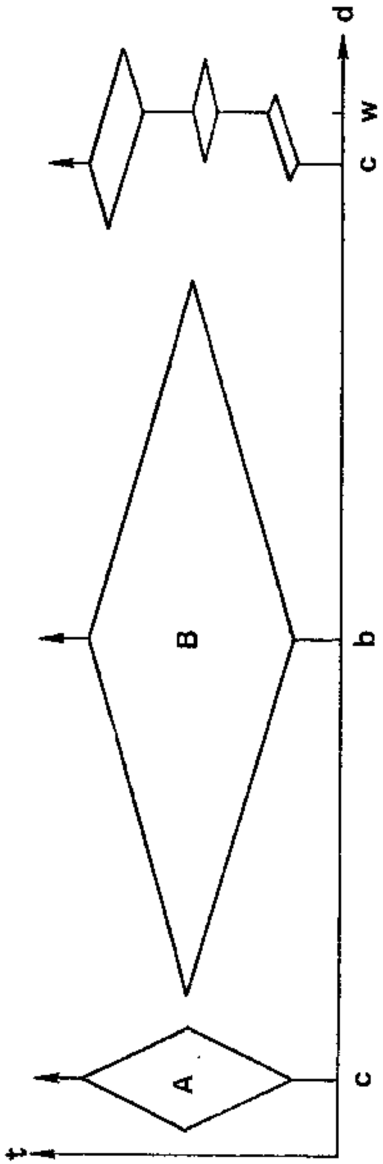


Fig. 15 Prisms

The range in "time-space" which the individual has in the course of a day (his "daily prism") illustrated in cross-section. d indicates distance and t time. a and b are residential bases which cannot be left before a certain time-point. The locations of the outer turning points of the prisms above a and b are determined by different means of transport available and thus vary considerably. Only those stations falling within the prisms above a and b may be chosen for a visit. Every stay at a station diminishes the range of the remaining prism(s). Thus, the person residing at c and having morning and afternoon work periods (vertical lines above W) has three smaller prisms (subprisms) within which he may choose stations to stop at, providing that none of the tasks or activities participated in is of such a duration that it prevents him from getting to his home or work-place on time. - After Palm and Pred

A = walking

B = car

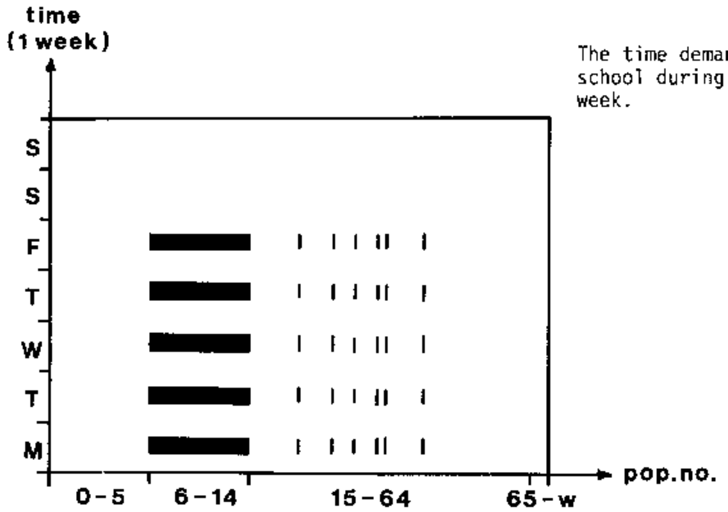
exchangeable, transportable, and additive (in the accounting sense) human population time has these quantities only in part. Time, for instance, cannot be stored. And crucially one of money's functions is as a medium of exchange to reduce the tensions of co-inciding wants, whereas the same does not hold true for time - if individuals wish to exchange information for instance they must wait for each other (thus perhaps causing a delay) or traverse space in order to match their time demands and supplies. Thus time allocation has a very definite s atial dimension through the need for access, every activity has a relative w en and where. This spatial dimension is too often ignored. Money can buy time (for instance in travel time savings) but time is not money.

So let us start from the basics. The individual has a time income to be used for activities which is equivalent to the time period to be observed (for instance 24 hours). Adding the postulate that the individual has a number of alternative activities open to him, and that the potential time "expenditure" of this would amount to more than the individual's time income there is a relation of scarcity which forces an individual to choose in some temporal order or sequence.

We can now obtain the following coherent definitions: the time cost of one activity is the time which is taken away from some alternative activities. If an individual's time is allocated to activities A and C then the opportunity cost becomes that of activity B which cannot be undertaken. The way in which this is measured, with all its pitfalls, is more reliable than the measures derived from standard definitions. The measure becomes more reliable the more aggregation is undertaken. Time budgeting then becomes a matter of assessing time supply and time demand of a population. The trade-off of time supply and demand, whether at individual or aggregate level will be in accord with what are considered societal priorities. Thus at an aggregate level the concept of opportunity cost can be replaced by that of time cost. So we see that time can be treated as a kind of money (measured in physical units). So what are time supply and time demand?

The supply side is reasonably obvious, it is the human population that supplies time and the volume supplied in a given period is a function of population size and population characteristics such as skill, age, sex and diverse other capability constraints on who can supply time to what kind of activity. But who then demands time? Obviously in an ultimate sense the population, but in effect the population does so through various intermediary mechanisms of time demand embodied in the multitude of human projects - for instance the workplace or the school (see Figure 16). It is therefore possible to analyse a population in terms of time supply and demand in order to calculate whether there are surpluses or deficits and how these mights influence the social structure (see Figures 17 and 18). Essentially here one is studying the capacity of the system.

Time use accounts describe the result of time allocation whereas the Lund group is interested in time allocation *per se*, its process and mechanisms, in terms of capacity and importantly the way in which that capacity has been arrived at - by packing in time and space (Carlstein, 1977). This packing must, of necessity, involve analysis of projects - especially in planning. As Carlstein has put it "the past is always product while the future is project".



The time demand of a school during one typical week.

The time demand of schooling for an average student or pupil throughout the day, week, year and life-time and its temporal location.

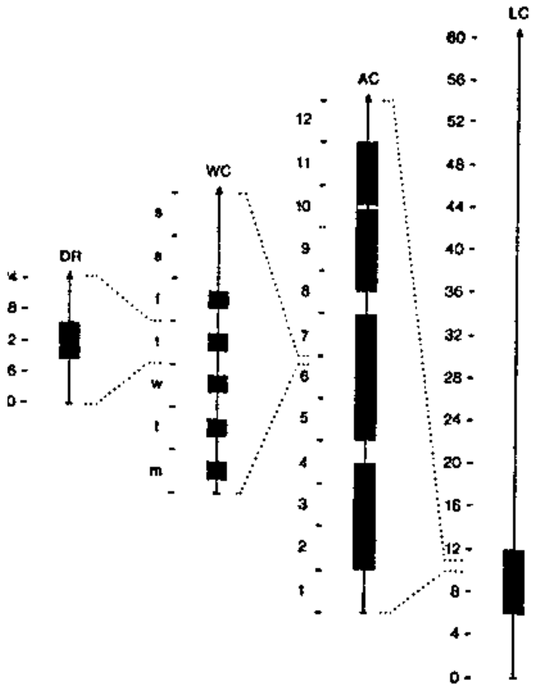


Fig. 16 The Realities of Time Demand - After Carlstein

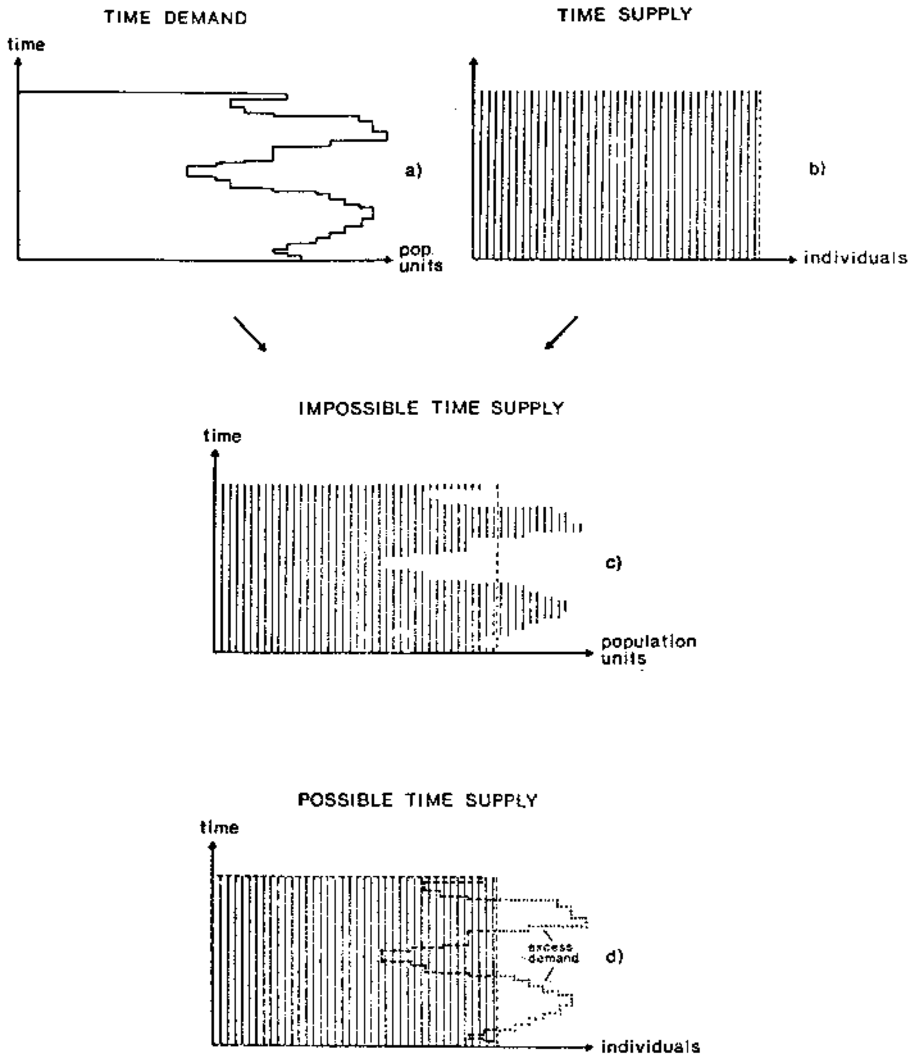


Fig. 17 Time Supply and Demand - the theoretical situation

Possible and impossible aggregate time supply in relation to demand

- After Carlstein

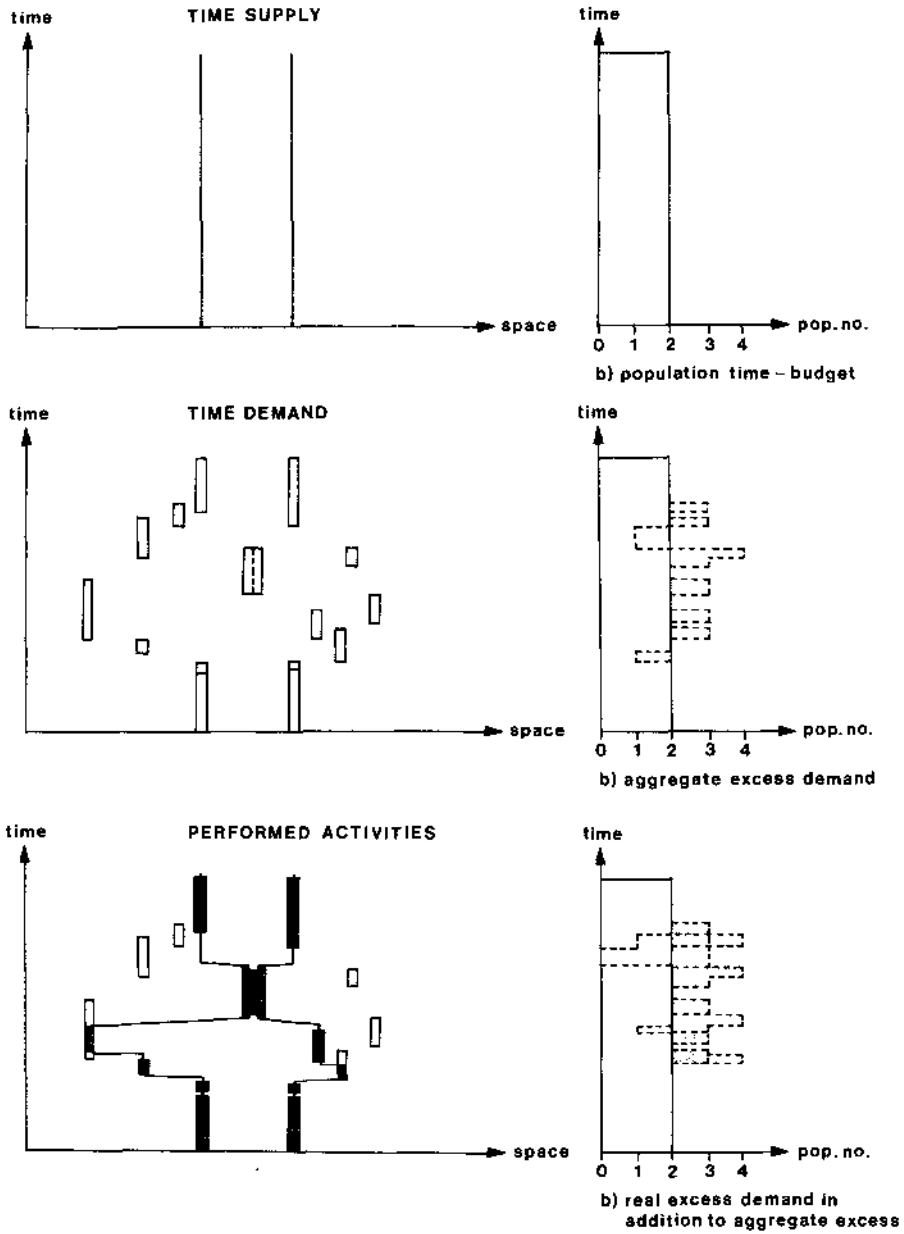


Fig. 18 Time Supply and Demand: the reality imposed by projects that need to be carried out and the limited time available
- After Carlstein

Obviously life-paths, prisms and time supply and demand are useful conceptually but how have these theoretical schemata been put into practice? The Lund Group immediately realised that to utilise the classic time-budget approach to analyse projects would be of limited use except, perhaps, as a check on model outputs. Collection of time use data would show only behaviour already adapted to the constraints and limitations of the setting. In the time-budget individuals have already chosen from the range of alternatives. So the question became how to collect empirical data on "non-behaviour". What people cannot do is just as important as what they are able to do, and often more revealing. Sampling would still give actual behaviour, and actual behaviour is often of little use in deciding policy, since it is already adapted to the constraints and limitations of the setting understudy in which there are as few "shadow" life-paths as are necessary. In fact the genuine policy parameters in urban and regional planning were seen to lie in the environment and the aim was to improve that environment in order to increase freedom of choice by removing unnecessary bottlenecks. In Sweden the aim has been to move towards an isotropic plane of choice (insofar as this is possible) reflected in an "equitable urban environment" (Hägerstrand, 1972). But it should be borne in mind that this is only one of many options that the time-geographic mode of description and analysis can help to realise.

III APPLIED TIME-GEOGRAPHY

Ina sense all time-geography is applied but here two real-life examples are given to whet the appetite.They are both very simple and are chosen purely for the sake of illustration. References to the numerous applications of these models can be found in the bibliography.

(i) PESASP - An Accessibility Model

The time-geographic approach with its starting point in the population and its possible paths in time-space has certain useful deductive properties. Series of basic, realistic postulates can be made concerning the population as a system of indivisible entities with paths in time-space. These paths can only be re-allocated under constraints related to capability or capacity, to couplings between paths and authority considerations. A very important set of capability and coupling constraints are those affecting spatial mobility, access (for instance, speed constraints), and the use of transportation facilities and it is this situation we shall look at.

Instead of beginning with time-budgets of actual behaviour as inputs to the analysis time-budgets of possible behaviour are the outputs of the simulations undertaken using a computer model called PESASP (Program for Evaluating Alternative Sample Paths) developed by Bo Lenntorp (see Lenntorp, 1977 for more detail). For each of the sample paths simulated in the model the time costs and time-space distances are evaluated as well as the deviations of one sample path from the shortest possible one. The inputs to the model are:

(a) daily activity programs.

(b) a model of the urban region considered in terms of the stations or spatial locations in which activities take place (residences, places of work, shops and so on).

(c) a model of the transportation system in the chosen region.

The activity programs are postulated programs of typical everyday activities as they are carried out in households of various compositions. These programs are only specified with regard to the set of activities to be carried out and the (often minimum) time it takes to perform them by average individuals. They are further specified as regards point of origin in space and point of destination.

The spatial locations of stations are mapped in time and space (an elaborate and time-consuming empirical exercise). The model of the transportation system (which of course includes time-tables) is also a major task and is usually simplified by correcting each station to certain nodes. Three modes of travel are usually tested - private transport, public transport and walking (although in this example cycling is added).

The raw output is in the form of tables for various locations in the city showing the number of possible ways in which a given activity program can be carried out. These tables can then be aggregated or processed in various ways depending on the problem at hand. A look at one very simple example will show the power of this technique (taken from work by Lenntorp reported in Hagerstrand, 1974b).

(1) activity program:- assume a sample person is prevented from leaving home until 1200 and has to return by 1800. He must spend 1300-1700 at work. He needs to go to a post office (a task which takes 12 minutes including waiting). He can only do this between 1200 and 1300 and 1600-1700. The question asked is: how many ways is it possible to carry out this sample program, given a set of dwellings/workplace/post-office locations and a choice between four modes of transport (car, bus, bicycle, walking)?

(2) model of the urban region:- the area chosen is Orebro (population 116,000) and is shown in Figure 19. Seventeen dwellings (D) are chosen, systematically spaced 1.5 kms. apart. In addition six places of work (W) are chosen, in central and extreme positions respectively. Nine post offices (P) are to be found at their correct locations. The situation defines a maximum number of alternatives in the following way. One can combine nine different post offices with each single place of work. Since the visit can be made before or after work there are (9 x 2 =) 18 possibilities per place of work. Since further each of the six places of work have to be combined with each of eighteen dwellings the total amounts to (6 x 18)   108 alternatives.

(3) transportation model:- the movements ,are made to follow streets and bus routes as they actually occur in Orebro. A walker is assumed to move with a speed of 5 kms/hour, a car is given an average speed of 40 kms/hour. Walking to and from the car plus parking time is standardised to six minutes per trip. Cyclists are assumed to move at an average speed of 12 kms/hour. Buses follow the existing timetables.

The outcome of the exercise is shown in Figure 20a. Number of origins (dwellings) have been plotted against number of possible alternatives for each travel mode. Alternatives are grouped in classes.

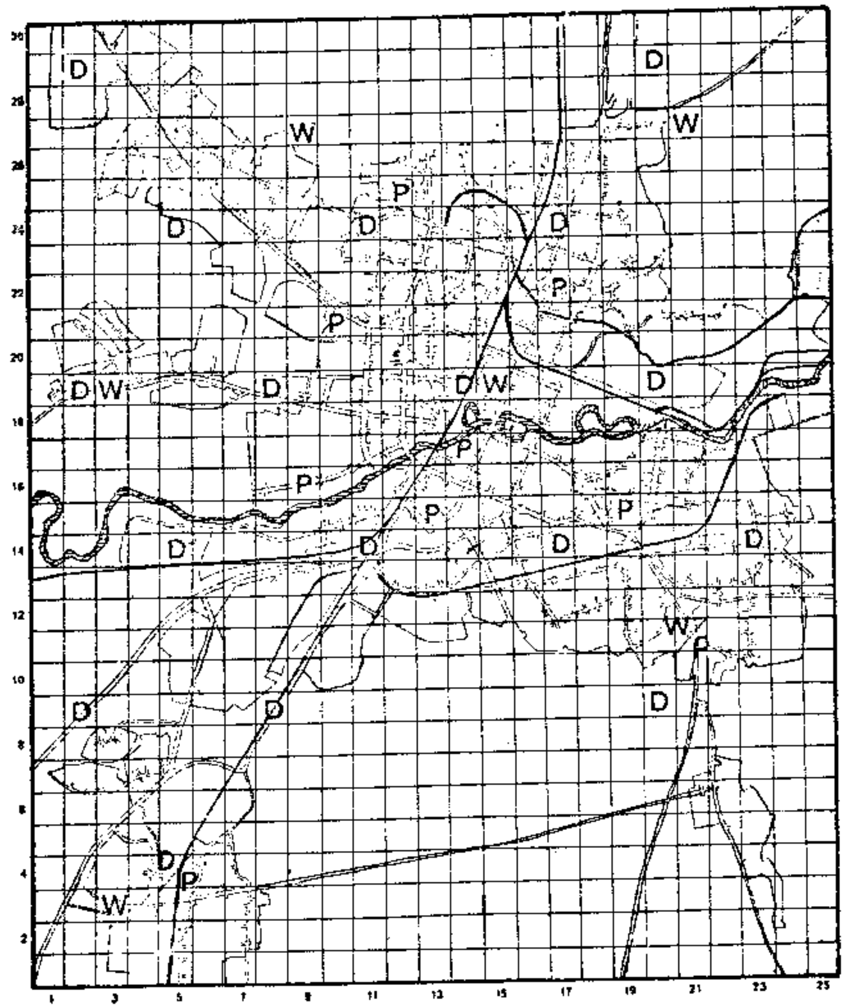


Fig. 19 Use of PESASP

The 17 dwellings (D) - all 1.5 kms apart, 6 workplaces (W) - in central and extreme locations - and 9 post offices (P) chosen.

- After Lenntorp

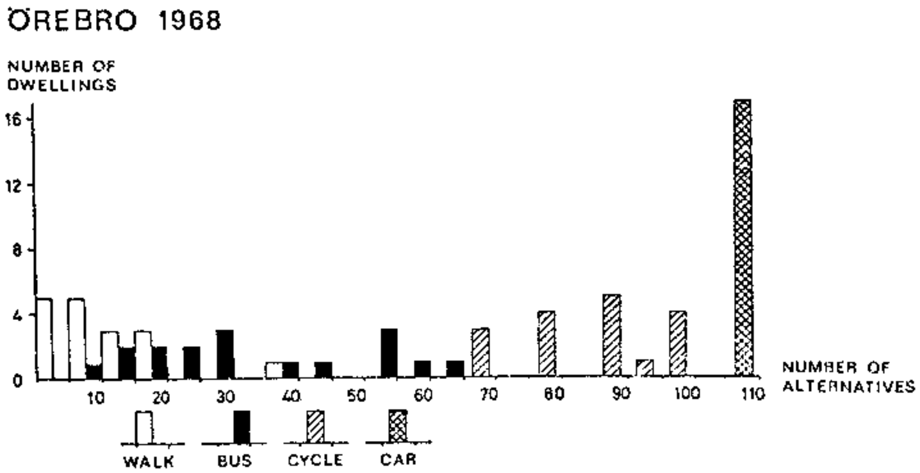


Fig. 20(a) Rank order of modes in terms of options for environment specified in 19

The rank-order of modes in terms of number of options is clear. Walking, then bus, then bicycle and then car became increasingly more efficient. The car driver is able to complete the whole set of alternatives from all origins. For the other modes there is more variance. Public transport is generally unreliable in the sense that some origins rank high and others low. The fact that the bicycle does so well in spite of its low speed indicates that the advantage of private transport lies above all in the fact that waiting times can be avoided. The same applies to the car, even though there is some loss of time for walking at both ends of the trip. Thus we can see that the main motivation for using a car in an environment where journey distance is rarely more than seven or eight kilometres is not in time saved, or flexibility given, but in the convenience offered.

Another question was then asked. How can public transport be brought into line with cycling and driving by manipulation of two variables - speed and trip frequency? Three average speeds were used (20, 30 and 40 kms/hour) and three trip intervals (20, 10 and 5 minutes). All other assumptions were held constant.

The outcome is illustrated in Figure 20b. With the longest trip interval public transport efficiency is nowhere near that of the bicycle and car (compare with Figure 20a). At this interval variation in speed is also entirely irrelevant. At the ten minute interval a great improvement takes place. The two higher speeds are singled out but there is little to choose between them. Performance is now the same as for cycling. It is only when the five minute interval (and the highest speed) are reached that public transport is able to compete with the car, and even here it is not very satisfactory.

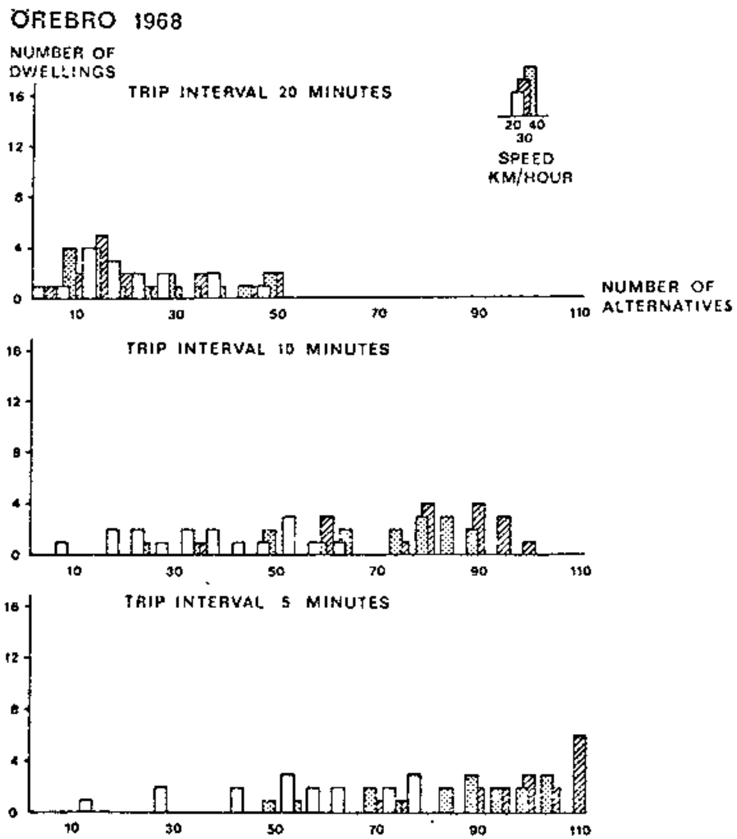


Fig. 20(b) Mode efficiency according to trip interval for environment specified in 19

- After Lenntorp

This is a very simple example of a time-geographic model in use and can be argued to be rather unrealistic. But the point is that this example also shows preparedness to deal with unexpected situations. If there are a large number of potential ways to get to a location then such situations are much more easily dealt with. If there are few ways the person is in trouble. Think of the post office as instead an urgent call from an ageing relative help and the point becomes clear. Access through mobility is paramount.

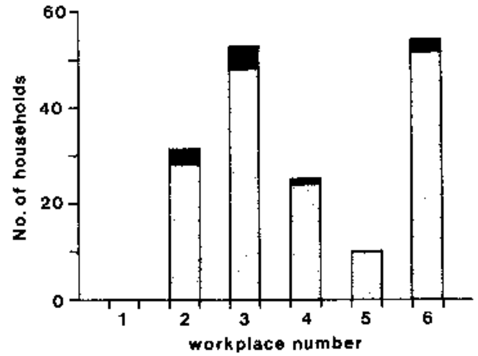
Obviously for the model outlined above to be of real value specific parts of the city and certain transport modes would be barred to certain people. When considerations such as these are taken into account it is not at all uncommon to find that only one way of completing an activity program is available to a person - so much for choice! And if someone who relies on public transport loses their job this often leaves only two options - to stay unemployed or migrate.

The PESASP model allows a series of options and many substantively different kinds of situation to be dealt with. To give some idea of its scope Figure 21 shows results from experiments carried out in Karlstad by Lenntorp (cf. Lenntorp, 1977). Here the most obvious way of using the model as a planning tool is shown - changing of the time-space environment is easily carried out and the multiple impact of such changes can then be examined.

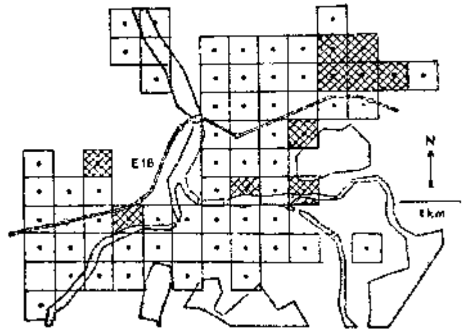
(ii) A Time Supply and Demand Model

What is most interest about time-geographic models is the way they overcome the scale problem in human geography. In the next model, again far too briefly described to be given full justice to, the concern is with time supply and demand concepts at the aggregate level but through the model's clever construction this level is easily linked to the life path and prism concepts.

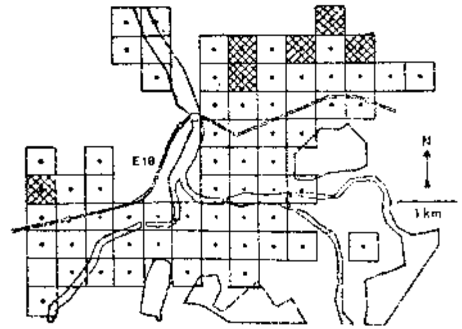
The model has been used to study large-scale policy change impact in three chosen areas. The model is in six stages (see Figure 22). In stage 1 the region to be studied is chosen, and the appropriate time interval (a day, month etc.). In stage 2 the choice of region gives a particular population to analyse and together with the appropriate time interval it enables the calculation of total time available to the population. In stage 3 the total time is divided between activities which are split into three groups - production time, consumption time and individually necessary activities and the population is divided into groups corresponding to this particular classification of activities. The next stage, 4, involves timing of selected activities in order to work out time demand and supply for the region. In stage 5 time supply and demand are reconciled to produce time devoted to various activities by the population and in stage 6 the number of travel occasions can then be calculated in order to investigate future transport needs. A number of sub-models are used at each stage (see Ellegard-Hagerstrand-Lenntorp (1975b) for a full description) including a modified PESASP program. In conjunction with a series of scenarios on future economic growth, population trends and so on it has been possible to work out what daily life will be like in the year 2000 and from this the different demands that will be made upon society. Thus starting from the concept of population time it is possible to calculate life paths of typical individuals at some future date and even the number of trips that will be made in the selected region for some representative day at that future date.



Activity programme:
Journey to work and visit to day nursery for children. The black portion of the pillars denotes for each of the 6 major work places in the region, the additional number of household locations (out of a total of 62) from which the programme is able to be carried out. This as a result of supplementing the existing transportation network by *a new route.*



Activity programme:
Journey to work and visit to day nursery for children. The figure shows the additional number of accessible work places from each dwelling location, when the *density of trips by bus* has been increased. The hatched cells show locations in which one additional work place has become accessible.



Activity programme:
Journey to work and post office visits. The figure shows the additional number of accessible work places from each dwelling location, when a *new route* has been added to the existing bus network. The hatched cells show the locations in which one additional work place has been made accessible.

Fig. 21 Some typical results from PESASP. Postulated activity programme and new environmental features are italicised.

- After Lenntorp

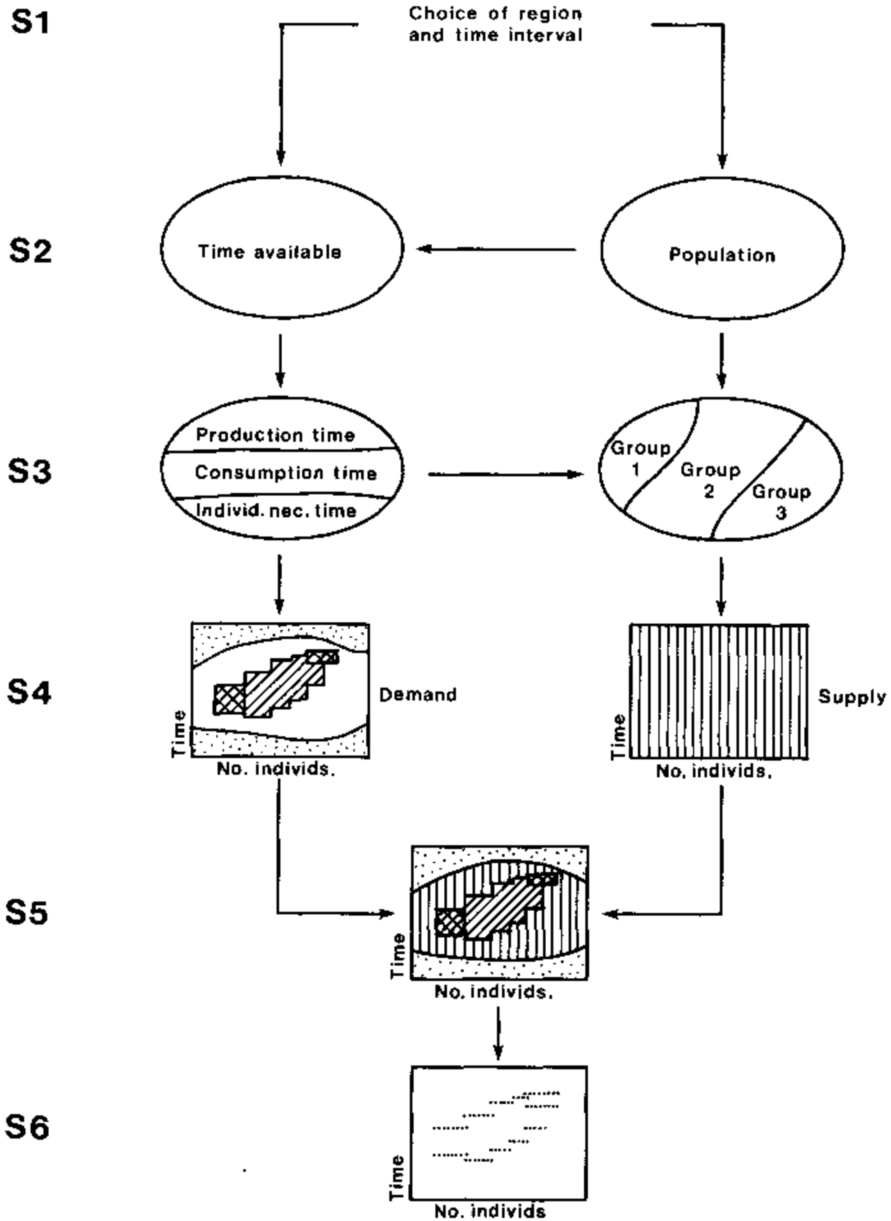


Fig. 22 Intermeshing of Time Supply and Time Demand Concepts to produce a theoretical approach able to forecast activity organisation and demand for travel.
(Note. Time interval = 1 day) - After Ellegard, Hägerstrand and Lenntorp

IV FURTHER EXTENSIONS AND CONCLUSIONS

It is important to at least point to advances made on the more general theoretical level by Hägerstrand and his research team. In particular Hagerstrand and Carlstein have been involved in a more general development of interaction theory in time-space terms. Thus Carlstein has looked more closely at the time and space allocation problems involved in multiple innovations (Carlstein, 1977) and in particular at "exnovations" (that is, those things which must be removed before an innovation can be slotted in) and other packing phenomena, in a Third World agrarian context.[1]

Hägerstrand has been working towards a general theory of socio-technical ecology and innovation impact. He has used an input-output formulation (not to be confused with its economic counterpart) in terms of an accounting framework which gives a score to the project according to the quantity of time and space quanta used and if a slot is available for these quanta. Essentially this includes calculation of the holding capacity for projects in a time-space unit. Man's basic physical existence and the consequences pertaining to it are again stressed in a series of papers (Hägerstrand, 1973; 1974a, 1974c, 1975b). Man is living in the intersection of two separate but in many ways similar worlds - the biological and technological (as Hägerstrand has pointed out techology too exhibits its own "food chains"). The approach taken is, as has been stressed, not rooted in the observable behaviour of subjects but rather in the constraints which circumscribe and describe that behaviour. As we can see from the example of behavioural geography conclusions are very hard to draw from data collected (often at considerable expense) about what has happened. The constraint view may be problematic, for instance in requiring that we pinpoint the reason for "non-events", but it is through such an approach that we can understand in the deeper sense the nature of ecological conditions. There are limits to the extent to which individuals and objects can be packed in time-space.

And so every living being has the problem of finding or creating small pockets in time-space with enough local order to allow the individual to exist in at least a basic fashion. The importance of domains now becomes clear. Space is first and foremost a provider of room and only secondarily a maker of distances. As Hägerstrand has said this is "practical political geography" (Hägerstrand, 1974c, p 275). Possession is nine points of time-space. Observed behaviour does not tell us much about the constant change in the potential of each pocket of space-time, or the inputs and outputs which sustain it. Perhaps we can redefine geography as the study of time-space units and how they are or can be packed" (Thrift, 1977b).

FOOTNOTE

1. Carlstein has pointed to an illustrative example of this multiple innovation approach. In studying adoption of a school it was found that this was only possible if fencing was also introduced because the children were needed to tend the cattle. Thus two innovations were needed in order for one to be effective.

In conclusion it should be stressed that time-geography is still very much a growing, expanding subject and one which still requires much work before the ends will be tied up. It is not possible or desirable to write a monograph which gives any other impression and this has not been attempted. This monograph gives the basic facts and some guidelines for the student to follow - the bibliography should be seen as of paramount importance. We conclude, as is only correct, with a quote from Torsten Hägerstrand (1975b,,p 10) which seems to sum up the role time geography can play, we need a geography today which helps us to see ourselves, our fellow passengers and our total environment in a more coherent way than we are presently capable of doing. To me the answer seems to lie in the study of the interwoven distribution of states and events in coherent blocks of space-time - in other words a regional synthesis with a time-depth".

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In many ways this bibliography is the most important part of the monograph, since in this area further reading is vital. Unfortunately much of the important work is available only in Swedish, especially the empirical applications, but hopefully these will appear in English in the next few years. The bibliography is annotated to help prospective readers. Particularly important papers are marked with an asterisk.

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