HOUSEHOLD ACCESSIBILITY ANALYSIS IN DEVELOPING COUNTRIES USING TIME-SPACE PRISM

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ABSTRACT

Time geography approach provides quantifiable measures in the form of Time-space prisms which are used for analyzing individual activity spaces resulting from household activity-travel decisions. In the recent concerns to improve accessibility of rural households in developing countries, the need to develop a framework to study economics of household decision-making in the light of their time-space constraints has become profound. This paper presents a conceptual framework based on time geography approach which was used to study constraints limiting accessibility of work places. Data collected from rural locations in Pakistan was used to demonstrate how the economics of household decision-making formulates their accessibility to various activities duly transformed by the available transportation system, which includes both the vehicles as well as the network.

Keywords: Activity-travel patterns, developing countries, household economics, household decision-making, time geography, time-space prism

1. INTRODUCTION

Study of time budget constraints is a key to quantify economic deprivation of populations of developing countries. Time geography approach integrates time and space dimensions in order to study autonomy of an individual and is able to investigate individual activity-travel behaviour under constraints, [1]. Time is viewed both to overcome the spatial separation of activities as well as the constraints on the individual. Measures based on this approach conceive the activity programme of an individual in terms of probability of activity participation. This is closer to the definition of accessibility that concerns the opportunity an individual, placed at a given location, possesses in order to take part in activities [2].

Time-space paradigm is able to provide framework for analysis of activities 'accessible' to individuals under the economics of household decision-making. The objectives of this paper include (i) to explain the embedded concepts of time-space prism as a means to quantify accessibility measures and (ii) to demonstrate their applications in studying individual activity-travel patterns under household economic constraints.

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2. TIME-SPACE PRISM

The 'time-space prism' (TSP) of an individual considers time as a fixed constraint on the individual and 'delineates' the sequence of activities 'possible' during a time period (say a day). Two important elements of time used are (i) the minimum time required by the activity and (ii) the maximum time to be spent travelling. The TSP of a hypothetical rural individual is illustrated in **Figure 1**. The individual is free to move in all directions at a uniform speed v1. The horizontal axis represents space in linear dimensions (for example projected distances) and the vertical axis represents time. This simplified prism gives the total time budget available to the individual (e.g., between 8 a.m. and 1 p.m.). This general prism is then constrained on the basis of some further coupling constraints on the individual (i.e. to be present at certain places at certain times). An example is given below to define the basic concepts and terminology used [3].

Consider a school-going child selected from a hypothetical rural household. In **Figure 1** '2-D map' is shown along with time-space prism of this individual. A primary school at location A, having less facilities, is reachable in one hour. Another primary school, at location B, having a higher quality of education, is at a further hour's journey from location A. Both schools have the same 'opening hours' (9AM-4PM). The time-space prism of the child enables a transportation planner to assess the child's ability to reach to location A at 9AM and his inability to reach location B by 9AM. Thus the child's transport, temporal and spatial constraints define his capability to reach any of these activities. In other words, his TSP is able to define the accessibility of the activity, namely "attending school".

Time-space prism maps out the individual opportunities under effect of time-space constraints governing activity travel patterns of individuals in a developing as well as developed country context [4]. Significant differences have been reported to exist between workers and non-workers and between males and females, due to the more traditional gender and working status roles in a developing country context. The approach, therefore is able to address cultural constraints binding heavily on individuals in a developing country [5,6].

Description of salient points in TSP:
ac=Total time budget
ef,gh, ij = activity duration at locations A, B and Q, respectively
ae, ai, ag = travel from home to activity locations A, B and Q, respectively
fc, jc, hc = travel to home from activity locations A, B and Q, respectively

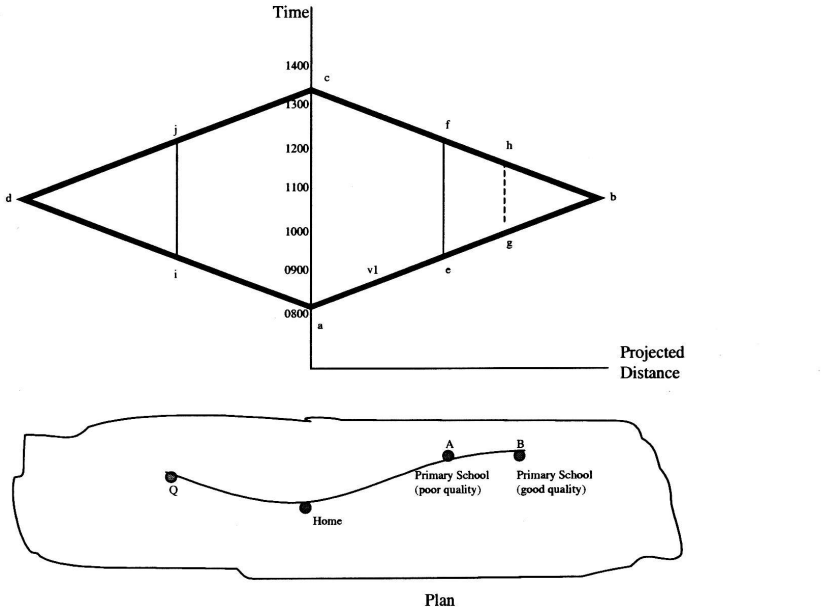

Figure 1. Time-Space autonomy of individuals

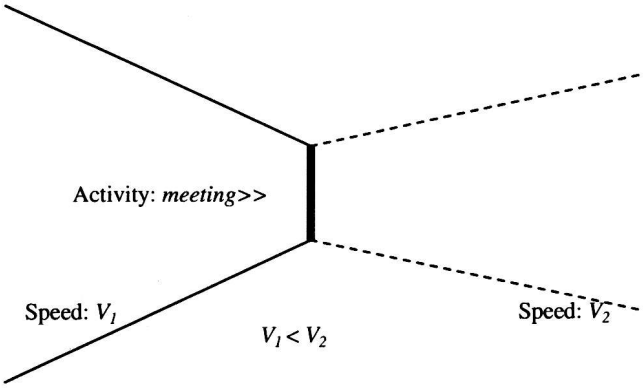

Figure 2. Explanation of coupling constraints

2.1 Accessibility Measures based on Time Geography Approach

Time geography measures view the activity programme of an individual in terms of taking part in activities. Burns [7] developed an analytical formulation to incorporate all the components of accessibility, the transportation, temporal and spatial components, in a single framework. He added temporal dimensions to the conventional 'spatial-accessibility' approach, which treated the ability of individual to reach the activities independent of his time constraints, both on the activity and the individual. The underlying assumption is that individuals value opportunities available to them in relation to the time budget at their disposal. He defined an opportunity through three non-negative numbers; the distance to travel (x), the attributes of the opportunity (a) and the duration of time (T). Burns [7] represented an opportunity by means of an ordered triad (x,a,T). The accessibility benefit measure developed by Burns [7] was improved by Odoki [8,9] and adapted for application for rural accessibility planning in developing countries [10]. The salient features of his model have been:

a) The transport component is weighted by a generalised cost function, which not only incorporates the deterrent effect of travel on the individual's perception of the utility of opportunity, but also weighted on the basis of his income,
b) The household perception is added as a factor in weighting the attributes of the spatially separated activities typical of rural areas of developing countries,
c) Contrary to the population weighted opportunities, this approach caters for value weighted opportunities conforming to the individual's space-time autonomy.

Jones, et al. [11] provided a framework whereby travel is traced in two dimensions, i.e. space and time; as a result sequencing becomes the key element of activities, hence trips. Ben-Akiva [12] indicated a change in perspective on the travel demand modelling approach, from purely a transportation system oriented approach to the activity-behaviour approach. The basic theme is that the demand for travel is derived from demand for activities. Wu et al [13] explored dynamics of time-space prism and developed network-based TSP's. They applied these concepts to evaluate accessibility of travellers under different congestion scenarios, alternative network flow control strategies, and activity scheduling policies. An example of coupling constraints is given in **Figure 2** which depicts the need of two individuals to be at one place (for example for a meeting) while both arrive there at their own pace (v1 and v2).

All the above studies put stress on analysis of individual activity-travel pattern while prime concern is on time-budget constraints and to devise measures for alleviating these constraints. The following sections of the paper deliberate this task further on.

2.2 Time-space distribution of activities and travel

Participation in the spatially distributed activities defines travel pattern of an individual in a given period of time. The activities which can be 'placed' within the TSP of an individual are termed as opportunities [9]. The sequence of this activity participation is studied in a two-dimensional time-space plane which provides insight of the individual time budget constraints. It therefore helps in devising planning strategies relieving these constraints.

Time-space prism of **Figure 3**, shows the activity-travel sequence of an individual starting and ending at times A & B, respectively. The inclined lines show the instantaneous positions of the time-space prism available to the individual after he decides to participate in any activity (the vertical

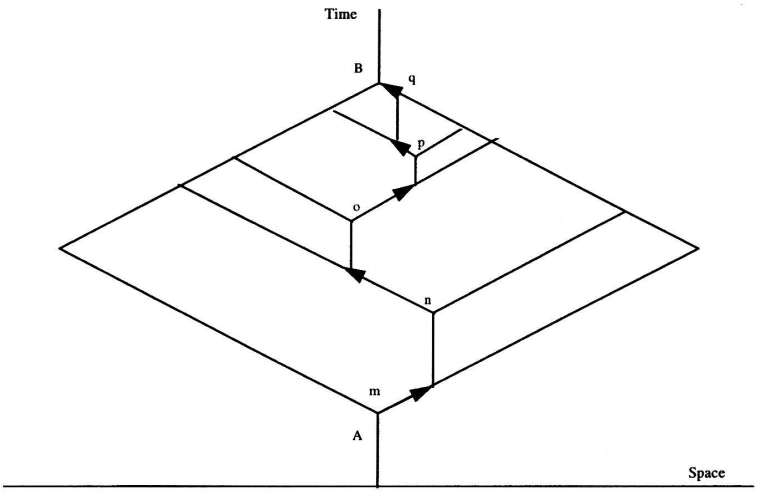

Figure 3. Time-space distribution of activities and travel

lines). The arrows show trips at the maximum uniform velocity. It is clear that the activity-space is rearranged after the individual participates in an activity. Four 'successive' positions of the activity space are generated in the figure as a result of three activities. The travel between activities defines trips; their sum defines total trips of the individual in one day.

Time-space prisms are used in analysis of activity-travel pattern of individuals and temporal vertices of time-space prisms are compared for various socio-economic and commute characteristics [14]. Kwan [15] suggested that modern spatial analysis tools embedded in a GIS environment would enable comprehensive representation of complex urban and cognitive environments more realistically by overcoming limitations of aggregate spatial data framework. Miller and Wu [16] argued that space-time accessibility measures (STAMs) reflect the benefits that individuals receive from the transportation system. They are easily interpreted, particularly with respect to changes in accessibility. This is critical as (in their opinion) transportation systems exist to improve individual accessibility.

3. RELEVANVE TO RURAL ACTIVITY-TRAVEL PATTERNS IN DEVELOPING COUNTRIES

The rural travel pattern in developing countries is dominated by travel required to access basic needs and services [17]. It has been reported that the time spent on such travel is relatively constant throughout the year [18]. Rural individuals (especially women and children) spend approximately 0.3-1.5 hours daily in acquiring basic needs like water and firewood. Poor access is also responsible for critical problems like high mortality rates, inadequate food security, and improper education [17]. It is therefore important to understand this issue in order to ascertain productivity of new infrastructure investments.

A common conclusion of a number of studies is that the wastage of time in acquiring access to basic needs and services is responsible for non-achievement of development objectives [18, 19]. These studies also emphasize that transport should be considered in its facilitating role of providing access at household level, [18]. Bryceson and Howe [19] strongly suggested the need to understand women transport logistics relating agricultural needs, household essential services and childcare, in multitasking (all in one) trip strategies.

Ellis [20] studied the mobility aspects of rural accessibility. He analyzed the effects of the provision of transport services for a given infrastructure in reducing operating costs and enhancing mobility. Howe [21] found that non-availability of low-cost transport modes was a major source of decreased mobility and increased poverty of rural population in Sub Saharan Africa. Both these works addressed personal mobility as an important determinant of rural accessibility in least developed countries.

It is important to recognize that a major part of rural travel in developing countries comprises of access to activities or services fulfilling basic needs. These needs are emanated at the household level where individual members are assigned specific roles of activity participation. The distribution of responsibilities of individuals carrying out these activities is very much dependant on the cultural binding rather than on an equal sharing of the workload. For example, in rural areas of Pakistan, women do not go out for shopping daily consumables, simply because of cultural constraints.

Therefore the male members of the household have to schedule these activities into their time frame. The household role allocation is an important consideration in defining the purpose and frequency of rural personal travel.

The current focus is on the link between accessibility and rural development in developing countries. This requires an understanding of travel patterns within the framework of accessibility of activities. The proposed framework should enhance existing rural transportation planning methodologies. In rural areas of Pakistan, the major household activity-travel distribution is such that the main burden of 'travel-related-economic' activities (for example work, shopping for essentials) rests on adult male members while the main 'non-travel' activities (for example household chores) as well as some specific 'daily need' activities (water and firewood collection) rest on the adult female members [3]. In the above backdrop a study area was selected from rural settlements of Pakistan such that villages were selected from five clusters of varying distance from major market centre [3]. Details are presented in sections to follow.

4. HOUSEHOLD ACTIVITY-TRAVEL PATTERN ANALYSIS

Household level data was collected from selected two rural locations in Pakistan [3]. These rural areas belonged to Hala, Sindh, a province situated in the south-most part of Pakistan. Its rural areas are predominantly agricultural based. The experiment design was based on the premise that individual activity-travel pattern is a result of the role of the individual within the household. It assumes that household needs are transformed into activities performed by household individuals. A variable called Life Cycle Stage (LCS) was introduced to capture household role allocation dynamics, (**Figure 4**).

4.1 Experiment design and sampling

The cluster method of design was adopted in this research to address spatial dispersion of population more effectively. The area set up is such that a district level administration is the centre of all major activities (for example market, high schools, etc) and fulfils the requirements of several villages in the adjoining areas, under its administrative control. Moreover, these villages being culturally and geographically homogeneous units, serve an adequate setting to be considered as clusters. In survey design five clusters were formed on the basis of distance from the market centre. From each cluster one village was sampled at random to constitute the first level stratum. The sampling of twenty households within the selected village was also done on a random selection basis. **Table-1** summarises the general characteristics of villages where household surveys were carried out.

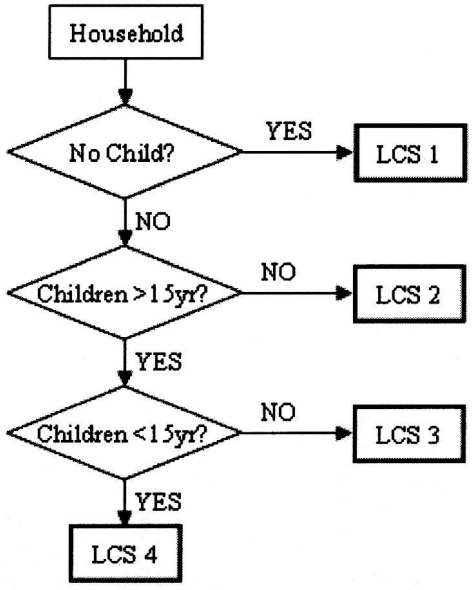

Figure 4. Life Cycle Stages Concept

Table 1. Sampled population

Cluster	Village	No.of Households	No.of Individuals	Male	Female	Indiv. Per HH
1	Hala Old	20	93	52	41	4.7
2	Khandu	20	69	34	35	3.5
3	Saeed Khan Leghari	20	94	55	39	4.7
4	Mansoora	20	70	40	30	3.5
5	Wngheri	20	47	23	24	2.4
		100	373	204	169	3.7

Table 2. Legends used in activity diary

Travel	Non Home Activities	Home-based Activities
0 Walk	9 Work/school	16 Home
1 Animal cart	10 Shop	17 Handicraft/ business
2 Bicycle	11 Hospital	18 House-chores
3 Tractor trailer	12 Leisure	
4 Motor cycle	13 Firewood collection	
5 Private car / jeep	14 Water collection	
6 Hired car/jeep	15 Other	
7 Bus		
8 Other		

4.2 Daily activity analysis

It is worth mentioning that in this research the Work was defined as the primary earning-related activity for any household individual. The following earning-related categories were used to define activity Work (as a part of detailed field survey):

(1) Waged Agricultural Labour
(2) Own Farm Agricultural Labour
(3) Waged Non- Agricultural Labour
    a) Office / indoor work
    b) Outdoor / field work
(4) Self Employed Non- Agricultural works
    a) Office / indoor work
    b) Outdoor / field work
(5) Other (specify)

The individual activity-travel patterns, therefore, provide information regarding the household role allocation and subsequently the fulfilment of household needs. The activity-travel pattern of an individual is, therefore, a function of (a) the individual category (for example Head, Wife, Child etc.) and (b) the activity type (for example Work, Shopping, School, etc.)

Individual activity-diaries were processed to divide total daily time (0600 to 2100) into 15-minute time slots (64 in total). All of these slots were non-blank and contained one number, between 0 and 18, on the basis of information derived from individual's activity diary. The description of the legends for these numbers is given in **Table 2**.

The legends given in **Table 2** were used to place each individual in one of the three states, namely, Travelling (0-8); Non-home activities (9-15); Home-based activities (16-18) **Figure 5** illustrates the daily activity-travel pattern of the Household Head. The percentage of the sample, within the individual category, carrying out a certain activity (or travel) at each time slot for the whole day (0600 to 2100) is plotted against the time.

The graphs in **Figure 5** provide the aggregate distribution of the population in the three states (home-based activities, non-home activities, or travel) at a given time. Most of the household heads leave home around 8:00am. The return journeys are spread between 13:00 to 21:00. The presence of these individuals at home is almost negligible within the working hours, i.e. 09:00 to 13:00. A peak for return journeys was formed around 14:30.

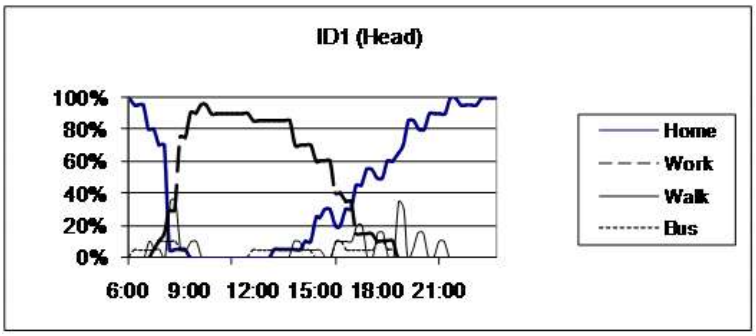

Figure 5. Daily activity travel pattern of household head

4.3 Cultural and gender effects

Similar analysis was performed for all household individuals. For the purpose of this analysis, individuals named “child>15 years” and “child<15 years” were further divided into male and female categories to highlight the discreteness in their activity-travel patterns. **Figures 5-7** show the activity-travel pattern of male and female individuals (respectively). Each of the individual category exhibits a discrete activity-travel pattern.

In general the graphs provide insight into overall time-budget of various individual categories. The state of home-based activities approaches 100% near the two ends of the day (around 0600 and 2000), when most of the individuals are at home. In the mid-day period most individual are at 'non-home' locations, (except for a few individual categories). The maximum percentage travelling was around 60%, (even in the case of the household head), explaining the role of travel in accessing daily activities.

On the aggregate basis, the household heads have involvement in 'non-home' activities for a longer part of the day, in comparison to any other individual category. The activity-travel pattern of the household wife and the female child (>15 years) were found to be similar. This explains the cultural effects on access to activities. A small percentage of housewives have been involved in travelling. The probable reason is for carrying out household chores like water collection, etc.

It is worth mentioning here that **Figures 5 - 6** only contain either of the two non-home activities, i.e. Work or School. At any particular instance of time, therefore, the total of the vertical axis may not sum to 100%. This indicates involvement of individual category in activities other than Work or School.

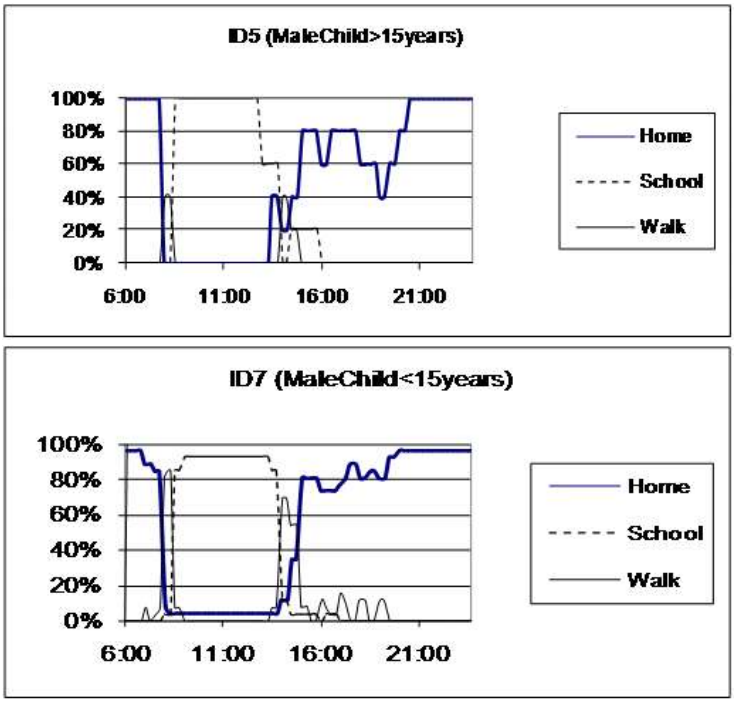

Figure 6. Daily activity-travel pattern by male individuals (all types)

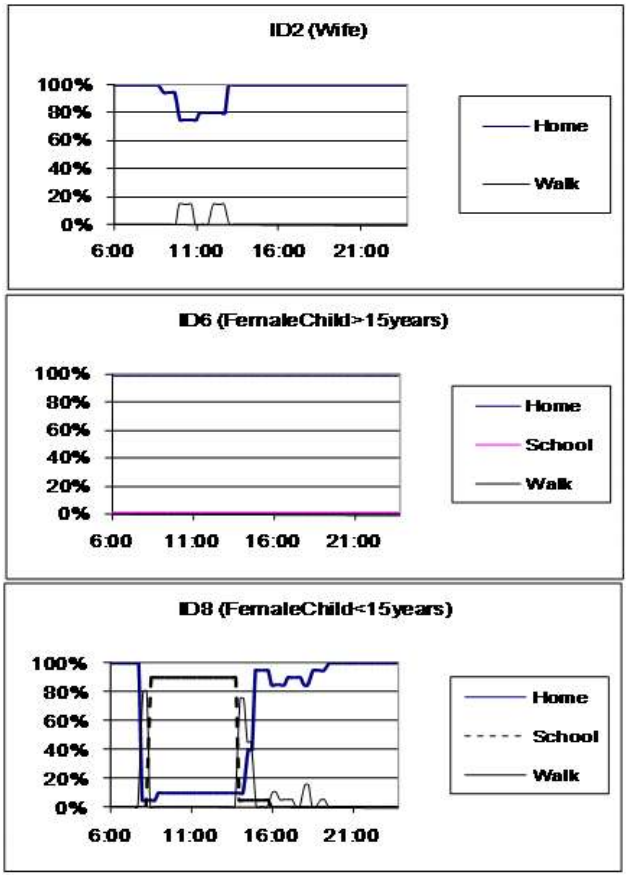

Figure 7. Daily activity-travel pattern by female individuals (all types)

4.4 Economics of household decision-making

The economics of rural household decision-making is derived on the basis of their involvement in earning-related activities. In a typical developing country context, Household Heads are the main individuals responsible for carrying out Work activities [3,5]. **Figures 5 - 7** support the derivation. This has become the basis of analyzing in detail the accessibility characteristics of household heads as presented in the sections to follow.

4.5 Vehicle ownership and time-space prisms

The transportation, temporal and spatial constraints binding upon individuals define their time-space prism (TSP). The TSP's of individuals provide information on the extent of the activities they can perform, and gives necessary leads to planners to seek ways to improve them. The analysis of work trips has been carried out to define the TSPs of individuals, their extents and various factors related to the households and the activity location. The household transport vehicle ownership and work travel mode were cross-classified. The results are presented in **Table 3**.

Table 3. Distribution of work trips

Work Travel Mode	No. of Work Trips by Household Head						All Vehicle Ownerships
	Household Vehicle Ownership						
	0	1	2	3	4	5	
0	45	1	10		3	1	60
2			1				1
3				1			1
4	2				5		7
5	2					1	3
6	1						1
7	21		3		3		27
All Modes	71	1	14	1	11	2	100

Table 4. Attributes of the activity work

Work Travel Mode	Average Distance to Work (km)						All Vehicle Ownerships
	Household Vehicle Ownership						
	0	1	2	3	4	5	
0	0.3		0.4				0.3
2			3.0				3.0
3				1.0			1.0
4	4.0				3.3		3.5
5	16.5					250.0	94.3
6	8.0						8.0
7	29.1		13.3		39.3		28.5
All Modes	9.5		3.4	1.0	12.2	125.0	11.1
Work Travel Mode	Average Travel Time to Work (min)						All Vehicle Ownerships
	Household Vehicle Ownership						
	0	1	2	3	4	5	
0	6		11				6
2			30				30
3				10			10
4	15				10		11
5	40					240	107
6	35						35
7	81		30		55		72
All Modes	30		16	10	20	120	28

A general analysis of **Table 3** shows that, out of 100 households in Hala, a considerable proportion (71%) did not own any transportation vehicle, while about 60% of households used walking as the transport mode for their work trips. The remaining 40% of households used other modes for their work journeys. This provides the starting point of the analysis designed to answer the question "what is the 'basic' TSP of the individuals and how do they try to improve them?" Further analysis on average distance to work and average time for work trips was carried out and the results are presented in **Table 4**. Considering the overall average distance to work (**Table 4**), the average for the mode walking is around 0.3 km (0.186 miles). This means that on an average walking covered the work destinations which were about 0.3 km (0.186 miles) away. Similarly households that did not possess any transportation vehicle (vehicle ownership=0) travelled an average distance of 9.5 km (5.9 miles) for work. This was possible when they used other modes of transportation (modes 4-7). The trend for the average time taken for work trips was different from that for distance. The time taken by households not owning a transport vehicle was above the overall average of 28 min. (**Table 4**). This suggests that on an average these households spent more time than the overall average for the area but travelled a lesser distance. The reason was the availability of transport modes at their disposal. Not owning a transport vehicle forced them to either use public transport or to resort to localised trips. In both cases the overall travel time increased, i.e. the walking time in the case of "walking" as travel mode and the waiting time in the case of using public transport (travel mode 7). All vehicle ownerships codes in **Tables 3** and **4** are same as Travel modes in **Table 2**.

An important point worth mentioning is distance and time for work by households owning tractor trailer (mode 4). Usually these households also own farms and live on the farms so their travel pattern for work depicts a unique pattern. Similarly a different trend is found in distance and time for households owning and travelling by car (mode 5). The distinctive nature of the work trip suggests that the individual may be a driver.

4.6 Basic and Improved Time-Space Prism

The distance and time of travel to work may be used to define the individual time-space prism (TSP). The inclinations of the prism sides are defined on the basis of maximum speed of travel by the individual. The extent of the TSP depends both on the inclinations of prism sides as well as the total daily time budget. This time budget was defined as the overall time available to the individual

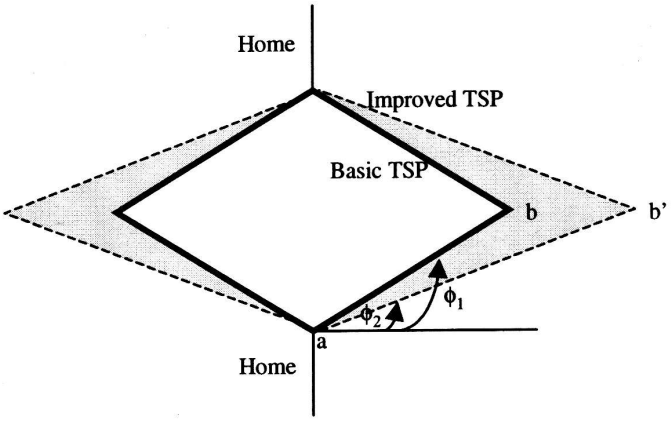

Figure 8. Configuration of individual TSP

between his home coupling constraints, for example fixed timings for leaving and returning home. (Salient elements of TSP of an individual are described in **Figure 1**.)

Figure 8 contains two circumscribed TSPs. The inner TSP is defined as the basic TSP. The inclination of side ab, i.e. the value of the angle 1, is defined on the basis of household vehicle ownership. This is computed using the speed of travel achieved by the individual from a household based on vehicle ownership at household level. The TSP obtained in this way is called basic TSP. The angle 2 defines the inclination of sides ab' of the improved TSP. The improved TSP is computed on the basis of the average speed achieved by the household with a given vehicle ownership using any faster mode of travel. Values of the two angles 1 and 2 in are computed using the following trigonometric relationship:

$$\phi = \tan^{-1}\left(\frac{\text{time}}{\text{distance}}\right) \quad (1)$$

where

ϕ = inclination of the prism boundaries

time = travel time

distance = distance to the activity

Table 5 was used to investigate the effect of various travel modes on the individual TSP. The table uses the data presented earlier in **Table 4** to compute the two values $_1$ and $_2$ using equation (1). For $_1$ (the basic TSP) the time and distance values corresponding to the vehicle ownership group were used (for example Walking for household not owning any transport vehicle). For $_2$ (the improved TSP) the time and distance values used were the overall average for the vehicle ownership group (bottom row in the relevant column). As the data revealed that only household heads are responsible to major source of earning, the data for this individual is only used for this analysis.

Table 5. Basic and improved values of angle phi

Work Travel Mode	Angle phi (degrees)						All Vehicle Ownerships
	Household Vehicle Ownership						
	0	1	2	3	4	5	
0	87.5		87.8				87.6
2			84.3				84.3
3				84.3			84.3
4	75.1				71.7		73.0
5	67.6					43.8	48.5
6	77.1						77.1
7	70.1		66.0		54.4		68.5
All Modes	72.2		78.2	84.3	58.0	43.8	68.4

In **Table 5**, the shaded values in the diagonals of the matrix are the values $_1$ and the shaded values in the 'all modes' row are the corresponding values of $_2$. The analysis of **Table 5** indicates how individuals tend to improve their TSP, as well as accessibility to Work, using the available transport modes. The households with no transport vehicle ownership, for example, would have the basic TSP having inclination of 87.5 degrees, while they improve it up to 72.2 degrees. Similarly, households with ownership of bicycle will improve their TSP from 84.3 degrees to 78.2 degrees. The households with ownership of vehicle types 3 and 5 (tractor trailer and private car, respectively) do not improve their TSP. This is possibly because they are at the maximum value of the inclinations. To generalise, it may be deduced that, all the individuals (belonging to any vehicle ownership category) would either tend to improve their TSP or would at least remain at their basic TSP by switching the mode which is the most feasible. On some higher note this points out the household economics. These findings were in line with the conclusions of Ellis and Hine (1995) that the rural households in Asian countries studied by them made use of the available transport services in order to improve accessibility of economic activities.

4.7 Utilization Index

In household accessibility analysis it may be useful to analyze how much the travel burden effects the overall activity participation, especially economic activity like work.

It means that if proportion of time spent in travelling would be reduced a person could spend the time saved in the economic activity. This leads to development of a time utilization index. Using individual activity participation information, it was possible to analyse the total daily time budget of the individuals as well as the real constraints shaping their TSP. From the individual activity diaries the following information was obtained:

a) start timings for work trips
b) timings for return trips
c) duration and mode for work trips
d) distance and duration of work

Table 6 summarizes the information on (a) and (b). It contains the average time of start of work trips, as well as the average time for start of journey to home. The clusters refer to various survey areas covered in detailed field survey carried out as part of this research. The column 'count' is the number of individuals observed in the given cell. It was found that the majority of the individuals left home for work at 08:00 (in the case of clusters 2, 4 and 5) or 08:30 (in the case of clusters 1 and 3). Similarly the majority of the individuals started the journey from work to home at 14:00 (in the case of cluster 2), 15:00 (in the case of clusters 1, 3 and 5), or 14:45 (in case of cluster 4). This leads to the conclusion that there is a set starting time for journeys to and from work. This pattern revealed that:

i) as far as work trips were concerned, the rural population either did not possess or did not exercise various varieties of work options (for example working from home)
ii) the mass out-going and in-coming timings showed some sort of dependency on external factors (for example connection to public transport).

Table 6. Work trip timings statistics

Cluster1			**Cluster2**			**Cluster3**			**Cluster4**			**Cluster5**		
Leaving hme for work			Leaving hme for work			Leaving hme for work			Leaving hme for work			Leaving hme for work		
Slot	Time	Count	Slot	Time	Count	Slot	Time	Count	Slot	Time	Count	Slot	Time	Count
10	8:30	62	8	8:00	18	9	8:15	1	4	7:00	4	8	8:00	21
11	8:45	2	9	8:15	2	10	8:30	52	8	8:00	18	12	9:00	2
28	13:00	3	10	8:30	7	22	11:30	6	9	8:15	2	29	13:15	2
Return hme for work			Return hme for work			Return hme for work			Return hme for work			Return hme for work		
Slot	Time	Count	Slot	Time	Count	Slot	Time	Count	Slot	Time	Count	Slot	Time	Count
36	15:00	66	32	14:00	25	9	8:15	5	2	6:30	2	6	7:30	3
40	16:00	3	48	18:00	3	35	14:45	5	35	14:45	23	32	14:00	1
52	19:00	21	49	18:15	6	36	15:00	59	56	20:00	10	36	15:00	23

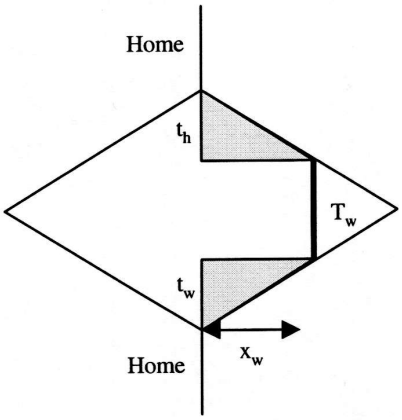

Figure 9. TSP of working individuals

Based on the above information it can be deduced that the individuals have a fixed time budget as far as work trips are concerned. This concept was used to define a simplified time-space prism for working individuals, as shown in **Figure 9**. It is assumed in **Figure 9** that.

a) the individual only takes part in the activity Work
b) the activity Work has a fixed duration of time Tw
c) trips to and from work have equal duration, such that tw=th
d) distance to work is given by xw, and
e) total time budget of the individual comprises of the above-mentioned three time durations

From the above conceptual setting, and considering that the individual needs to travel to access the activity work, a mathematical relationship can be developed as:

$$TW = t_w + T_w + t_h \tag{2}$$

where

TW = total time spent to access the activity work

t_w = travel time to work

t_h = travel time from work

T_w = actual work duration

Considering that the time for travel is unutilised, a utilisation index can be developed so as to analyse the effect of time of travel for work trips. From the utilisation index can be defined as the non-shaded area in the total time budget. Mathematically, it can be given as the proportion of the total access time spent in travelling, i.e.:

$$UI = \frac{T_w}{TW} \tag{3}$$

where

UI = utilisation index

The utilisation index gives the percentage of time utilised when an individual accesses the work location. This is based on the variation in the shaded area, which represents unutilised time. The above idea was explored using the data on distance to work from the five clusters of Hala. Considering that the distance people have to travel to reach Work locations was a major factor affecting the utilisation of time for activity participation, an analysis was carried out to study the relationship between distance to Work location and the UI. The average value of the travel distance to Work was found to be 11 km (6.84 miles). Two subgroups of household heads were formed on the basis of this threshold value; i.e. persons with travel distance to work below and above the average distance of 11 km (6.84 miles). Two graphs (**Figure 10**) show how the distance to Work affects the utilisation index, with respect to the average travel distance threshold of 11 km (6.84 miles). This was also confirmed by testing of relationship between Distance and Utilization Index by running correlation between the two variables (**Table 7a**).

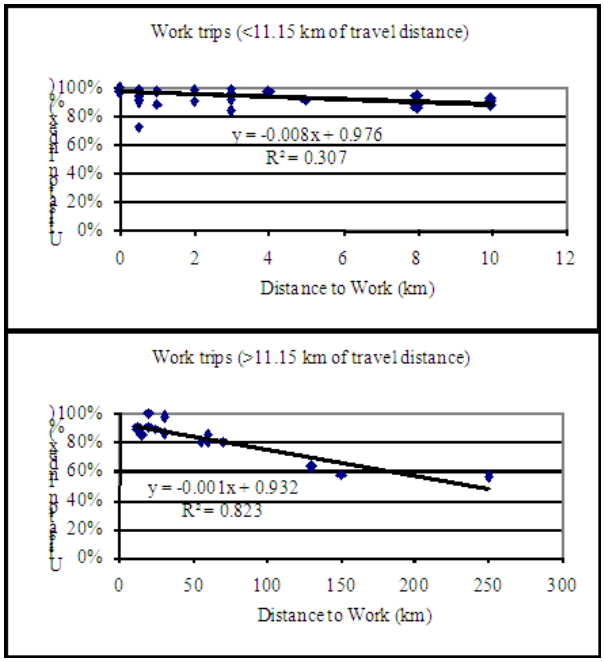

Figure 10. Effect of household income on utilization index

Table 7a. Testing of Relationship between Distance and Utilization Index

Correlation Coefficient Between Distance and Utilization Index	
Distance	**Corr.Coeff.**
<=11km	-0.55
>11km	-0.91

On the basis of **Figure 10** and **Table 7a** it can now be deduced that work trips within a distance of 11 km (6.84 miles) (average for the area) do not seem to affect the utilisation index. This is logical, as the average distance below certain values may not create a significant deterrence. Travel distances higher than 11 km (6.84 miles) (**Figure 10**) play an important role in affecting the time utilisation. This happens because the individuals spend a considerable time in travelling to reach the activity, which, in turn, decreases the overall time for participation in activity Work. When the relationship between household income and distance to work was studied, it was found that an increase in household income is not a direct result of travelling long distances. This was done by computing correlation coefficients between Distance to Work and Household Income. **Table 7b** depicts that no correlation exists between the two, for both subgroups of the population (less and greater than 11km (6.84 miles)). This indicates that in rural areas of Pakistan, Household Heads have to travel longer distance to earn their livings, irrespective of a direct increase in their income.

On the basis of the above analysis it can be deduced that the distance to work, beyond a certain threshold value, has as a profound effect in reducing utilisation of time for earning activities. The threshold may be defined as the average travel distance for the given area. The analysis is an example of the use of time geography to study household economics of decision-making. The decision to take part in distant work activities does not necessarily result in increasing the household income, it may just be the effect of the limited opportunities available within the village that the population has to travel longer distances at the cost of reduction in their overall time utilisation.

Table 7b. Testing of Relationship between Distance and Household Income

Correlation Coefficient Between Distance and Household Income	
Distance	**Corr.Coeff.**
<=11km	0.10
>11km	0.32

5. CONCLUSIONS

This paper demonstrated the application of time geography approach to rural transportation planning in developing countries. A concept of basic and improved time-space prism (TSP) has been developed. The spatial separation of activities defines the trip distribution for personal travel. In the case of rural areas of developing countries, there are discrete locations of activities fulfilling most needs and services and the choice of locations is therefore limited. For example in Pakistan, people from all villages within about 20 km (12.43 miles) travel to Hala (Sindh Province) for shopping, hospital, banking and postal services. This results in a multitasking environment for activity participation. In this case, trip distribution is not primarily based on the choice of location, but on the allocation of time for various activities. This becomes the basis of defining origin and destination of various travel decisions throughout the day.

In rural areas of many developing countries especially in Pakistan, personal travel is mostly carried out on public / community transport facilities. Most of the village access roads are un-engineered tracks. The transport service providers who operate on these tracks set-up their fares on the basis of their operating cost. In turn, the choice of travel mode is highly dependent on the ability of the household to use the available facilities. In quantifying travel mode choice it is important to consider the need for travel, the household socio-economics to afford a transport mode and the extent of the transportation infrastructure in place.

It was found that distance to work, beyond a certain threshold value, has as a profound effect in reducing utilisation of time for earning activities. The threshold may be defined as the average travel distance for the given area. The analysis is an example of the use of time geography to study household economics of decision-making. The decision to take part in distant work activities is not necessarily based on increasing the household income, it may just be the effect of the limited opportunities available within the village that the population has to travel longer distances at the cost of reduction in their overall time utilisation.

It can be deduced from the above analysis that in the limited time-budget situation, the distance to Work affects the overall time available for earning activities. The development policies designed to address the mobility problems of long distance commuters would therefore be expected to yield a high impact.

It was argued that households use a number of ways so as to improve their TSPs in order to bring more activities within their reach. The analysis confirmed that technological developments when trickled down to individuals may be able to enhance their mobility and, as a result, their accessibility to various opportunities.

The concepts developed provide a basis for development of travel demand models considering access to services as the primary utility while using the time geography approach for mathematical formulation of the problem. This may provide a way ahead for improved vision of transportation interventions in the overall context of improved accessibility to activities increasing earning/well being of the society.

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