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Life Cycle and Household Time-Space Paths: Empirical Investigation

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The results of a research effort that explored some of the effects of stage in life cycle on the evening paths of urban households are summarized. The stage in life cycle was used as a descriptor of microscopic household factors, such as interpersonal linkage constraints and needs and propensities for evening activities, that affect activity and travel behavior. A statistical investigation that used trip records of husband and wife couples from a conventional origin-destination data set was carried out. The large sample allowed the spatial analysis of a geographic subsample and the analysis of interaction effects by means of multiway contingency-table analysis. Travel patterns of husband and wife couples were collectively represented as paths in time and space, and the associations between various path characteristics and life-cycle stages, as well as the interactive effects of other factors such as household work-trip status and individuals' household roles, were examined. The results indicate that the life-cycle stage of the household is related to many aspects of the evening path: engagement in evening out-of-home activities, type of path, participation of the spouse in the evening out-of-home activities, number of sojourns, and time of returning home. The presence of children in the household was found to have substantial impacts on the adult members' activities and travel. The stage in household life cycle was not found to be directly related to the spatial distributions of sojourns in the evening paths.

The formulation of the existing frameworks of travel-behavior analysis has involved various simplifying assumptions. Although these assumptions have made the models developed within such frameworks operational and immediately applicable to practical forecasting, at the same time they have placed the subject of analysis--travel behavior--somewhat out of context. For example, the effects of interpersonal interactions on household tripmaking (1), interdependencies among the decisions for respective trips and activities (2), and spatial and temporal dependence of travel behavior (3) have been, at best, only remotely represented. The recognition of such limitations in the existing approaches has led to recent proposals and research efforts for the development of more relevant analytical frameworks of activity and travel analysis (4-7). It is now well acknowledged that viewing urban travel as a linkage between activities offers a way to gain a better understanding of travel behavior, especially of how people modify their activity and travel when faced with changes in the general transportation and activity environment. It has also been recognized that activity scheduling and tripmaking are subject to various constraints and travel patterns developed within this constrained framework (1,8,9).

When travel is viewed as a linkage between activities, it is logical to examine the factors that have important effects on individuals' and households' activity patterns. As such a factor, life cycle has received extensive attention (9-14). It has been found that the presence of children in a household has significant effects on the adult members' travel behavior (9,10,15,16). Many empirical observations indicate strong correlations between the life-cycle stage and simple measurements of travel patterns (3,9,11,17). These results suggest that life cycle is strongly correlated with the types and frequencies of activities pursued and hence with travel patterns. Particularly important are the needs for additional activities such as child care and the interpersonal linkage constraints (1,8) that are brought about by the presence of children in the household. Who takes the responsibility of child care and chauffeuring will largely prescribe the household members' activity and travel patterns (16-17). In light of the rapidly changing life-cycle-stage composition and labor force participation by women in the United States, a thorough understanding of the association between life cycle and travel behavior appears to be of extreme importance.

The objective of this study is to identify the effects that household life cycle has on travel patterns in time and space of adult members of households. The life-cycle stage is viewed as a variable that is relatively easy to forecast but at the same time can be expected to be closely correlated with microscopic factors that affect activity and travel behavior (e.g., interpersonal linkages and other household contraints, needs and propensities toward out-of-home and in-home activities, time use, and attitude). It can be expected that a better understanding of travel behavior can be obtained by inferring the effects of these factors from the observed correlations between life cycle and travel patterns. Knowing the distinctiveness in travel patterns across life-cycle stages will assist in making long-term travel forecasting more robust. The spatial and temporal characteristics of household travel identified in this study will also provide basic information for future model-building efforts.

In exploring the effect of life cycle on travel behavior, this study treats the travel patterns of adult household members as trajectories (or paths) in time and space. This representation is based on the work of Hagerstrand (8), who has provided a comprehensive paradigm for the analysis of travel behavior. Representing an individual's activities and travel as a path within a prism defined by a set of constraints offers a legitimate framework for studying travel behavior. This prism of feasible activity space is a particularly useful concept in investigating spatial and temporal characteristics of the path.

Earlier efforts by Kostyniuk and Kitamura developed an analytical framework by which the time-space path was analyzed within a constrained framework (3) and showed that life cycle was a promising variable for examining characteristics of household time-space paths (18). The present study extends these efforts and attempts to explain the differences in path characteristics by using the life-cycle stage and several additional variables. The present study also extends the earlier effort by analyzing the paths of adult members in a household collectively and emphasizing the interactions among the household members that are closely related to the life-cycle stage.

This study considers the effect of such interactions on households' time-space paths while focusing on two aspects: First, the effects of the constraints that children impose on adults' activity and travel (e.g., when a small child stays at home, an adult usually must also stay home), and second, the differences in the spatiotemporal characteristics between the paths that are made jointly by adult household members and those that are made individually. Although the importance of interdependence of tripmaking among household members has been noted and several studies have offered valuable insights (1,9,10), most of the empirical work in the past has been concerned with the behavior of individuals (3,19). Accordingly, the spatial and temporal characteristics of household paths largely remain unexplored. This study may be viewed as an effort to statistically infer the nature and magnitude of this interdependence by using the life-cycle stage as a key descriptor of household characteristics.

Because there is no standard terminology on the subject (20,21), we define some key terms used in this study. A "time-space path" is defined as an individual's trajectory in the time-space dimensions over a study period. This study deals with only those paths that originate and terminate at the home within the study period (a day). Now, consider a site where a tripmaker can pursue one or more out-of-home activities. A site may be a complex of more than one facility in close proximity. A stop made at such a site is called a "sojourn", and the site where a sojourn is made is called a "sojourn location". A "trip" is defined as the movement between two successive sojourn locations or between a sojourn location and home.

STUDY DESIGN AND STATISTICAL METHOD

In order to analyze the complex household paths in a practical yet meaningful manner, a decision was made to consider only the paths made by the husband and wife during the evening period (from 5:00 p.m. on). This period of day is selected for this study for several reasons. First, activities and travel of most workers during the daytime are almost completely determined. Second, it is expected that activities in the evening period are less obligatory; hence, the paths will be affected largely by desires, needs, and constraints arising within the household. Third, the weekday evening is a time when members of a family can act together. Hence, the effect of interpersonal linkages can be more frequently observed in the evening paths. Analysis of one specific time period of the day can be justified, since it has been found that people perceive a day as a set of time periods with distinct characteristics appropriate for particular sets of activities (1,2).

Although life cycle is expected to be a dominant factor that influences household paths, it is recognized that other factors must be simultaneously incorporated into the analysis or else erroneous conclusions may be obtained. As such additional factors, household work-trip status and household role (defined in the next section) are introduced into the analysis. It is expected that these factors interactively affect individuals' behavior. Even when faced with the same situation, individuals with different characteristics may behave differently; a particular combination of factor values may result in an effect that cannot be expressed as a sum of the independent effects of the respective factors. Such interaction effects are expected, especially for household role and responsibilities, and it is the intention of this study to identify them. Available travel data are usually categorical in nature and can be characterized by a lack of factorial design. Thus, the statistical techniques required for appropriate analysis of these data must be able to handle complex interactions in such data.

Contingency-table analyses have been a useful tool in this respect for years; however, as the number of variables and categories increases, the commonly used simple contingency-table methods lose their usefulness. Attempts to collapse multidimensional tables into simple ones can result in apparently paradoxical situations, a striking example of which has been noted by Simpson (22).

A particularly useful way of analyzing multiway tables and identifying significant interactions is through the use of log-linear models (23-25), where the logarithm of the expected cell frequency is expressed as a linear combination of main and interaction effects, as in this example from a simple two-way contingency table:

$$\log f_{ij} = \mu + \lambda_i^A + \lambda_j^B + \lambda_{ij}^{AB} \quad (1)$$

where

f_{ij} = expected cell frequency of cell i,j;
μ = grand mean;
λ_i^A = main effect of category i of variable A;
λ_j^B = main effect of category j of variable B; and
λ_{ij}^{AB} = two-way higher-order effect of category i of variable A and category j of variable B.

A particular model specifies a particular pattern of variation by the set of interaction terms included and can be used to state a particular hypothesis about the relations in a contingency table. Because the population probabilities are unknown, the observed cell frequencies are used to estimate them. The computer program ECTA (26) can be used to estimate the expected cell frequencies by the maximum-likelihood method and to test the goodness of fit of the model by using the likelihood ratio. ECTA also provides the estimates of the effect parameters. [One assumption of this method is that the model is hierarchical (i.e., if a higher-order interaction is included in the model, all lower-order effects involving the same variables are also included).]

The analysis of this study employs the log-linear models in a search for a model specification that, at the same time, involves an extensive examination of potential interaction effects (23,24). The analysis starts with the fitting of a saturated model that perfectly replicates the observation and exhausts all the degrees of freedom. The next step involves the fitting of a model with a single parameter (i.e., a set of interaction terms) removed. The contribution of this parameter is determined by comparing the log-likelihood statistic (Y^2) of the two models. The procedure continues with a forward-selection, backward-elimination process that establishes the significance of all possible parameters. This exhaustive examination of interaction parameters classifies all the effects as either important, unimportant, or in need of further study. The final choice of a best model is subjective, where complexity is balanced against the extent of explained variation. The effect parameters from the best model can be normalized and used to indicate the degree and significance of interactions that involve each category of each variable in the model. This procedure is used in this study in identifying intricate interaction effects that affect the household's evening paths.

DATA SET AND VARIABLE DEFINITION

A conventional origin-destination survey data set is used to statistically explore many spatiotemporal characteristics of household paths. Although the use of such a data set imposes a limitation on microscopic information available to the analysis (27,28), conventional large-scale data sets are the only existing ones that contain geographical subsamples whose sizes are adequate for spatial analyses of the paths. The intention of examining higher-order interaction effects also precludes the use of a small sample data set.

The data used in this analysis are from the 1965 Detroit Area Transportation and Land Use Study (TALUS) data set. The data set consists of a household sample of trip records that include information on the entire set of trips made by each member of the household on the survey day and of socioeconomic information of the individual and household. In this study, approximately 10 percent of the original trip records were sampled according to residential locations. This sampling employed nine geographic areas, which were selected to represent a wide spectrum of socioeconomic status.

The final sample used consists of 1884 households, each owning at least one car. These households are made up of 3612 adult individuals who were classified as either head of household or spouse. The household screening employed a number of criteria, including whether both the head of household and spouse, if there was one, had closed paths originating and terminating at home within the one-day study period; both made all trips by car; the head of household had a driver's license; neither made work trips after 5:00 p.m. and neither made trips from the work place after 7:00 p.m.; and all trips were made within a three-countywide study area. Households with missing data were eliminated.

The seven stages of life cycle defined in the TALUS data set and used in this study are given in Table 1. Because life-cycle stages 1 and 7 include mostly single-person households, most of the tabulations in this paper are made for 1728 households of life-cycle stages 2 through 6. Of these, 1476 individuals from 1005 households pursued evening activities. The original coding of this 1965 data set automatically assigned the category "head of household" to an adult male in the household, if there was one. Thus, in this study the head of household is referred to as husband and spouse as wife.

The employment status of household (i.e., how many and which members of the household are employed) has also been reported to be related to the travel behavior of households (29-31). It is generally accepted that employment status largely prescribes the time use of households and influences evening (after work) activity engagements. The employment status is also related to household role and responsibilities of individuals (10), which, in turn, influence evening activity and travel patterns. Work-trip engagement, or whether or not the person had a work trip on the survey date, is used in this study instead of the employment status. This variable is selected because it is more directly related with the time use of the household member on that day. The household role variable is defined in this study in terms of husband and wife designation and work-trip engagement of the individual, which results in four levels: husband with no work trip, husband with work trips, wife with no work trip, and wife with work trips. [A similar definition of household role can be found in Chapin (10).]

The most important descriptor that facilitated effective analysis of household evening paths and the interpersonal interactions is the path type. The evening time-space paths are classified by whether they were made jointly or independently by husband and wife. A path is considered joint if all or part of the path was common for both of these individuals. Joint paths are further classified by the location where they became joint: the work place, the activity location, or at home. Because the observed frequency of the paths with contact points at the activity locations is small, the first two are merged into one category--other contact points--in this study. The independent paths are classified by the individual who made the out-of-home evening paths: the husband alone, the wife alone, or both husband and wife but independently. Also considered are the no-activity paths in which no out-of-home activity is pursued by the husband or wife. Examples of typical paths are shown for the respective path types in Figure 1.

Other descriptors of the evening path used are number of sojourns in the evening path, both by the individual and by the husband-wife pair collectively; time of returning home for the day; total travel time; total out-of-home time; and sojourn locations, which are classified according to the same concentric rings used in a previous study (3) and shown in Figure 2.

RESULTS OF DATA ANALYSIS

Path Types

The first analysis examined the effects of life-cycle stage and household work-trip status on path type. A log-linear analysis that incorporated these three factors was performed on data from 1728 households of life-cycle stages 2 through 6, which treated path type as the dependent variable. The best model included main effects and interaction effects of all paired combinations of the three factors. Figure 3 shows the interactions from this model. The magnitude of each effect is presented in the figure by the standardized coefficient value, which is asymptotically t-distributed. A positive (upward) vertical line in the figure represents an effect's positive contribution to the expected cell frequency. A value of 1.96, which corresponds to $\alpha = 0.05$, is indicated on the vertical axis. The main effects of factors are not presented in the figure, since they represent only the marginal frequencies of the respective categories of the factors, and the interaction of life-cycle stage and household work-trip status are not presented in the figure.

Many interesting observations can be made from this figure. The life-cycle and path type interaction indicates that older couples (stage 6) have a higher-than-expected frequency of no evening out-of-home activities (path type 1; significant α = 0.01). Contrary to this, households of life-cycle stages 3 and 4 (married with preschool children and married with school-age children) can be characterized by their orientation toward evening out-of-home activities (both significant at $\alpha = 0.01$).

Young married couples without children (stage 2) are joint-activity oriented (path types 5 and 6) and their paths frequently involve contact points other than home (path type 5). This group of households and those with preschool and school-age children exhibit the interaction patterns that are complete reversals of each other. As opposed to the joint-activity orientation of the former group, the latter group with children is independent-activity oriented. Particularly notable are the significant interaction effects for the wife-alone paths (path type 3) of the households with school-age children and for the independent paths (path type 4) of the households with preschool children. Both effects are positive and significant at $\alpha = 0.05$. The couples with no children, on the other hand, show a negative interaction effect for the independent path. The result clearly demonstrates the substantial impact that children have on the adult household members' evening activities and travel. The result is consistent with intuition and previous results (8-10).

Table 1. Life-cycle stages in analysis.

Life-Cycle Stage	Marital Status	Age (years)	Children
1	Single	<45	-[a]
2	Married	<45	None
3	Married	-[a]	Youngest child aged 4 or younger
4	Married	-[a]	Youngest child between 5 and 18 years of age
5	Married	-[a]	Youngest child aged 18 or older
6	Married	≥45	None
7	Single	≥45	-[a]

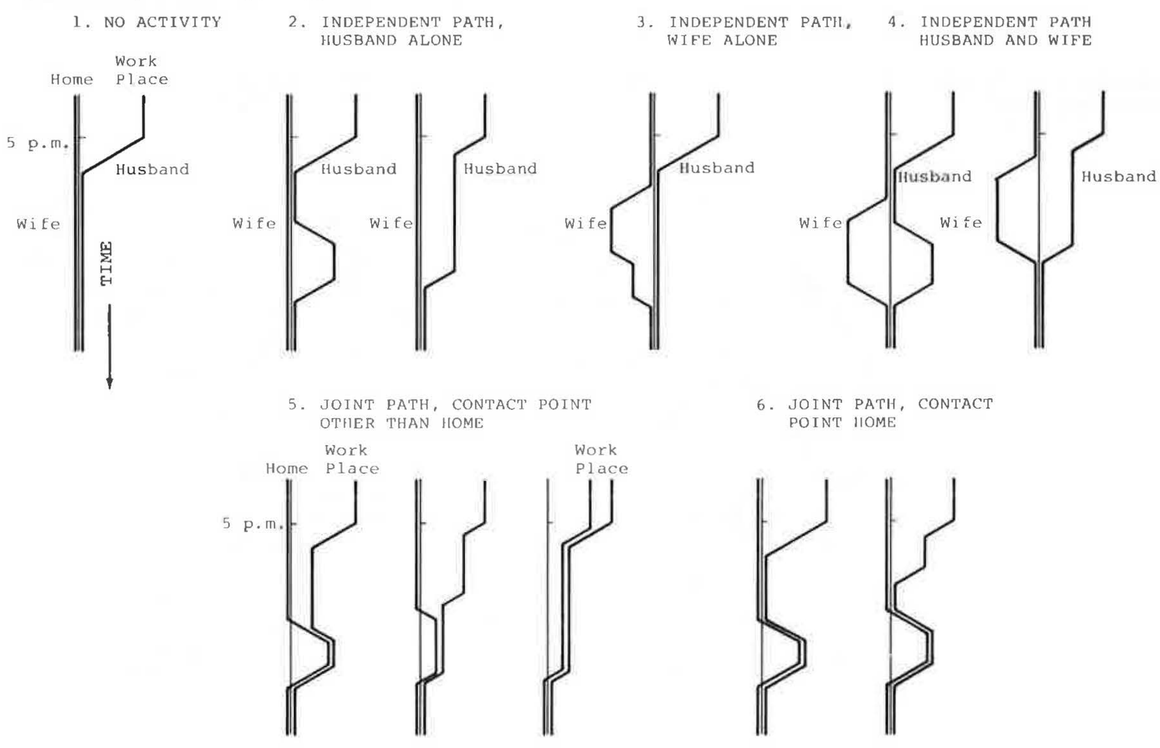
[a]Not used to define the stage.

Another interesting point to note is the similarity between the two sets of interaction effects for young and old married couples without children (stages 2 and 6). Although the magnitude of corresponding interaction effects are different, they completely coincide in terms of their signs. The interaction effects for households in life-cycle stages 3 and 4 (those with preschool or school-age children) are completely different from these, as noted above, and those of life-cycle stage 5 (couples with youngest child over 18 years of age) show a pattern that may be characterized as a transitional pattern from stages 3 and 4 to stage 6. This statistical result quite dramatically illustrates the evolution of evening path types through the stages of life cycle.

The interaction terms of household work-trip status and path type (shown in Figure 3b) indicate that those households with no workers tend not to pursue evening activities ($\alpha = 0.01$), and also that when both the husband and wife work, they tend to pursue evening activities after getting together at a location other than home (path type 5, $\alpha = 0.02$). Joint paths with home contact are less frequent for this group, but the group also shows less frequent no-activity paths (path type 1); i.e., this group has a higher propensity toward evening out-of-home activities ($\alpha = 0.01$). Households where only one person works have a significantly less-than-expected frequency of joint paths with contact points other than home (path type 5, $\alpha = 0.1$).

Similar analyses were repeated with factors such as household car ownership and household size. The results showed that car ownership and the frequency of independent paths both by the husband and wife are positively correlated, and also that the frequency of no-activity paths by the husband and wife is negatively correlated with household size. The latter indicates the increased needs or desires for evening out-of-home activities that larger households have. Overall, this analysis of path types has shown the strong and meaningful correlations the

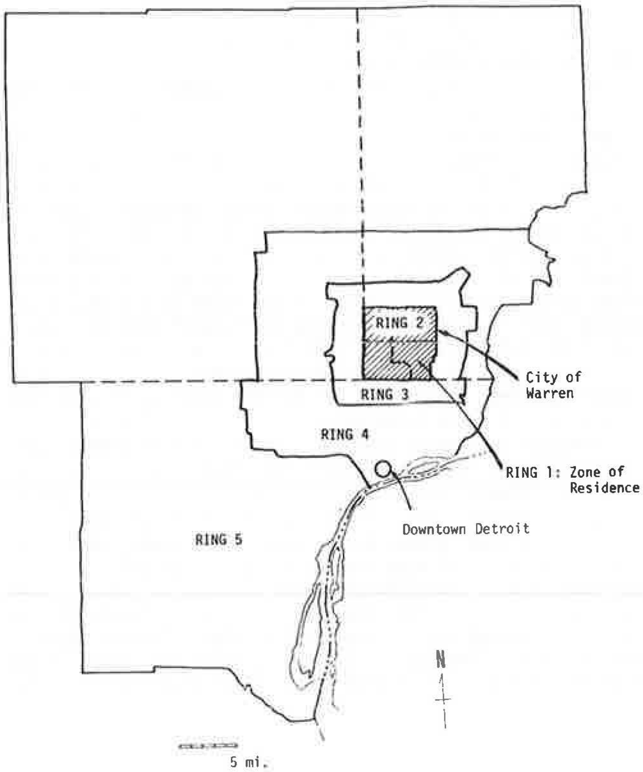
Figure 1. Examples of evening path types.



path type has with several factors that characterize households. The presence of children in the household results in dramatic changes in the evening paths. This may be seen as evidence of the constraints imposed by the children on the adult household members' activity and travel patterns.

A log-linear analysis of path type by household role (Figure 4) showed that both working and nonworking husbands tended to pursue independent (spouse at home) evening paths (path type 2 or 3, significant at $\alpha = 0.05$ and $\alpha = 0.02$, respectively). The wives, on the other hand, were more likely to have joint paths, with the path of the working wife becoming joint at a nonhome location ($\alpha = 0.01$) and that of the nonworking wife becoming joint at home ($\alpha = 0.01$). The wives also showed a clear tendency not to pursue independent (husbands at home) paths ($\alpha = 0.05$ for working wives, $\alpha = 0.02$ for nonworking wives), but the nonworking wife was likely to have an independent path if her husband was also out of the house (path type 4, $\alpha = 0.1$).

Figure 2. Concentric rings for spatial distribution of sojourn locations for Warren subsample.



Number of Sojourns

The data base of 1476 individuals in life-cyle stages 2 through 6 with evening activities is used to examine the number of sojourns made by individuals in the evening period. Other factors included in the analysis are life-cycle stage, path type (independent or joint), and household role. The best model selected includes the following interaction effects:

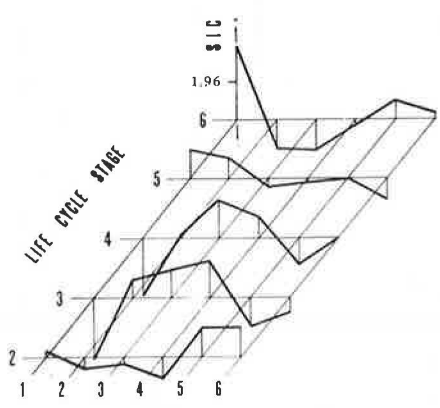
1. Life cycle, path type, and household role;
2. Number of sojourns and life cycle; and
3. Number of sojourns and path type.

The first higher-order interaction is automatically included in the model, since the number of sojourns is viewed in model specifications as the dependent variable. Because a hierarchical interaction structure is assumed, the interactions of all paired combinations of these three factors are also automatically included in the model (and therefore not listed above). Other higher-order interactions and the interaction of household role and number of sojourns are all not significant at $\alpha = 0.05$. The model is much simpler than the saturated one and effectively explains the variations in the sample by its simple structure.

The life cycle and number of sojourn interaction terms are presented in Figure 5. The tendency evident from the figure is that the older individuals

Figure 3. Interactions of path type with life-cycle stage and with household work-trip status.

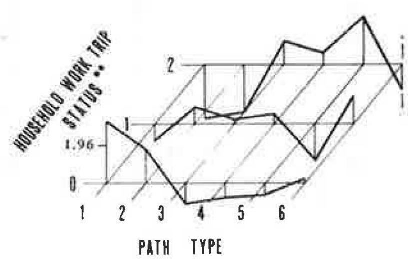
a. LIFE CYCLE-PATH TYPE INTERACTION



SIC: Standardized interaction coefficient

Sample: 1,728 households of life cycle stages 2 through 6.

b. HOUSEHOLD WORK TRIP STATUS-PATH TYPE INTERACTION



*PATH TYPE CATEGORIES:

1: No activity
2: Husband alone
3: Wife alone
4: Husband and wife independently
5: Joint, contact point other than home
6: Joint, contact point home

**HOUSEHOLD WORK TRIP STATUS:

0: None made a work trip
1: Either husband or wife made work trips
2: Both husband and wife made work trips

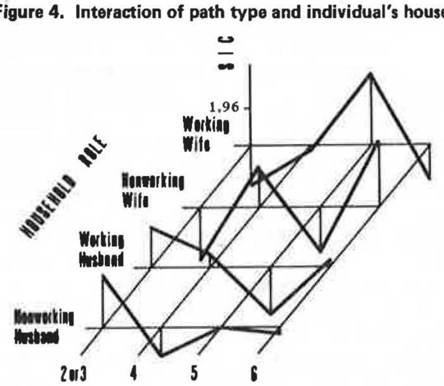
of stages 5 and 6 tend to have fewer sojourns while individuals of earlier stages of life cycle tend to make more sojourns. Individuals from households with preschool children (stage 3) have a higher-than-expected frequency of making three or more sojourns (α = 0.05), those from households with school-age children (stage 4) have a less-then-expected frequency of making only one sojourn (α = 0.05), and those older households with no children (stage 6) are likely to make only one sojourn (α = 0.01). The result reconfirms the difference in the orientation toward evening out-of-home activities across the life-cycle stages found in Figure 3, where the household path types were analyzed. Other interaction terms indicated that independent paths tend to involve only one sojourn (α = 0.05) and that nonworking wives tend to have joint paths (α = 0.02).

Out-of-Home Time and Travel Time

The first temporal aspect examined is the time spent by individuals outside the home together for activities and travel. Figure 6 presents the results of a two-way marginal analysis and shows that the total out-of-home time tends to be longer in the paths that involve joint activities for the same 1476 married individuals who pursued evening activities. Particularly notable are the much higher-than-expected frequency of short (less than 1 h) out-of-home durations in the independent paths by the husbands and the less-than-expected frequency of short durations in the joint paths with home contact points. Those individuals who had joint paths with contact points other than home stayed out frequently for a long period (4 h or more). Further analysis indicated that the individuals with work trips show this tendency, but not nonworkers. Individuals from younger households with no children (life-cycle stage 2) showed the same higher-than-expected frequency of spending a long time outside the home. The marginal two-way table presented in Figure 6 is significant at $\alpha = 0.005$ ($\chi^2 = 132.2$, df = 16).

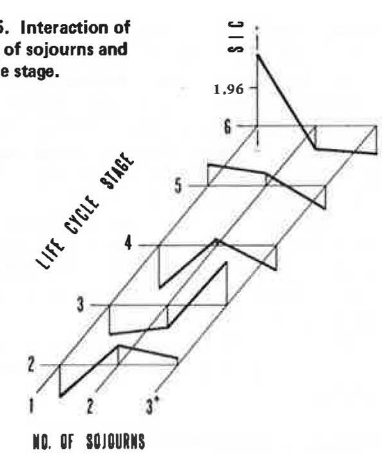
Whether or not a path involves a joint activity was found in the analysis to be most strongly correlated with the time spent out of home, while the correlations with the life-cycle stage, the individual's work-trip status, and the individual's household role were found to be relatively weak. The same statements can be made for the distribution of total travel times. Figure 7 shows that total travel time is longer when the paths are joint. Other factors are only weakly correlated with total travel time.

Figure 4. Interaction of path type and individual's household role.



Sample: 1,476 individuals of life cycle stages 2 through 6 with evening out-of-home activities

Figure 5. Interaction of number of sojourns and life-cycle stage.



Sample: 1,476 individuals of life cycle stages 2 through 6 with evening out-of-home activities.

Figure 6. Relative frequency of total out-of-home time by path type.

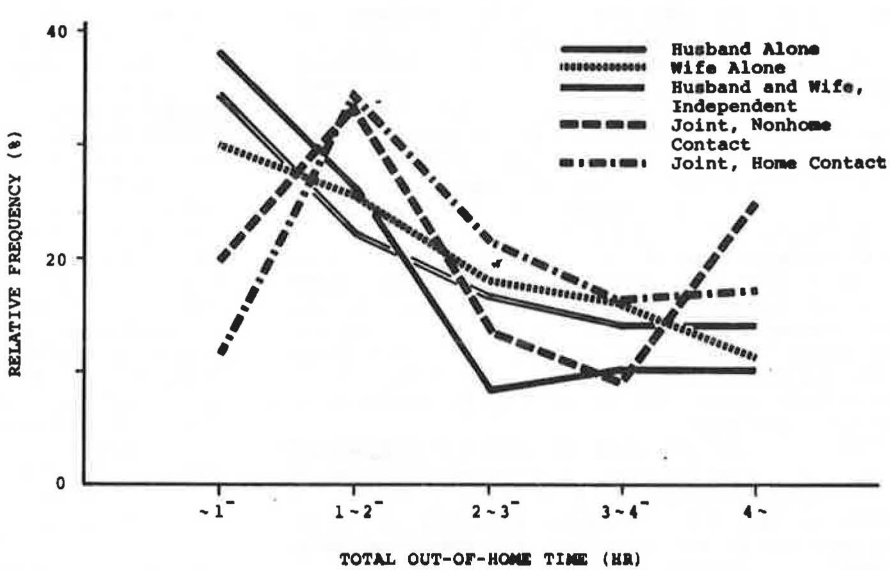
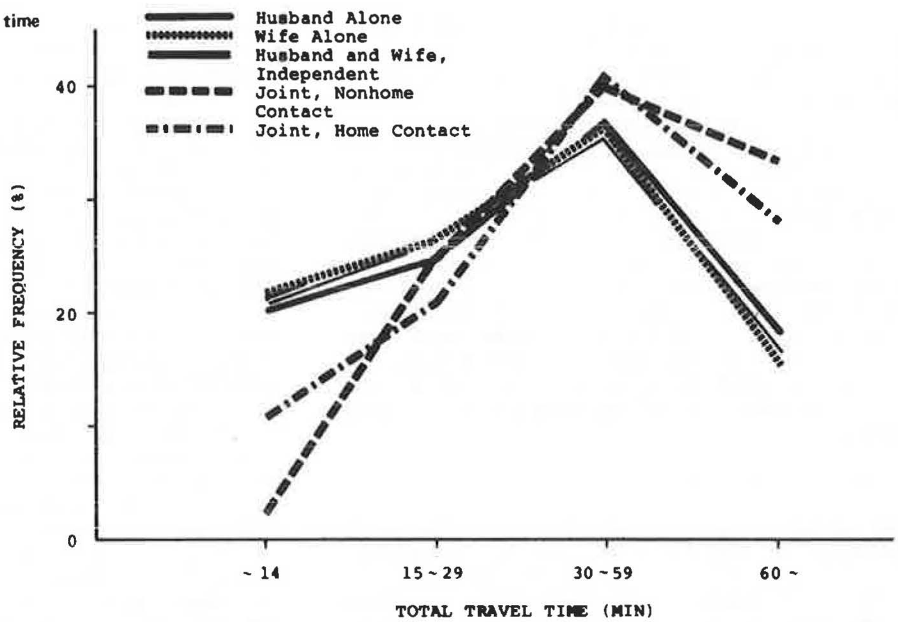


Figure 7. Relative frequency of total travel time by path type.



The marginal two-way table underlying Figure 7 is significant at $\alpha = 0.005$ ($\chi^2 = 66.2$, df = 12).

Quite notable is the surprising similarity in the distribution of travel times among the three path types that do not involve joint activities. Therefore, if an individual is pursuing evening activities without the spouse, the time spent for travel does not depend on whether the individual is a husband or wife or on whether the spouse is staying at home or not. The distribution of the total out-of-home times, on the other hand, shows certain differences among the three independent path types. Comparison of Figures 6 and 7 indicates that the wives tend to spend more time on activity participation relative to the time they spend in traveling than do the husbands.

Time and Probability of Returning Home

The above result suggests that the time of returning home for the day will be later if the path is joint, since both out-of-home and travel time tends to be longer in this case. The analysis of the return time on the same data base of 1476 individuals by using the log-linear model in fact showed this. The return time and path type interaction is significant with $Y^2 = 54$ and df = 3 ($\alpha = 0.005$). The other factors included in the analysis are life-cycle stage and household role. Other interaction term effects indicate that the older individuals of stage 6 tend to return home earlier if they go out at all ($\alpha = 0.05$), and that working husbands are more likely to return late ($\alpha = 0.01$).

The tendency that the return times of joint paths are later does not immediately imply that these paths are subjected to lesser constraints. A previous theoretical and empirical study of individuals' paths (3) indicated that as time constraints become tighter, the conditional probability of returning home, given that an activity is completed at that time, increases.

Figure 8 shows the observed relative frequencies of returning home by time intervals as estimates of this conditional probability. The observations are classified into two categories according to spouse participation in the activity. The estimated probability of returning home for the day after an independent activity starts out with a relatively large value in the early evening and increases slowly with time. Contrary to this, the probability of returning home after a joint activity starts out small but increases quickly. The difference (significant at $\alpha = 0.005$) indicates that the constraints on joint paths tighten more quickly than those on independent paths. It can be argued that joint paths are subject to tighter time constraints (e.g., baby-sitters must be released by a certain time). The result apparently supports this. It should be noted here, however, that the above difference may be due to the difference in the distribution of sojourn locations between independent and joint activities. The previous study (3) indicated that the conditional probability increases with the distance from home as well as with time. Unfortunately, the analysis here is inconclusive, since the spatial and temporal effects cannot be separated with the sample size available for this analysis.

Spatial Aspects of Evening Paths

The analyses thus far carried out, especially that of total travel time, suggest the possible correlations between spatial distribution of sojourn locations and other factors. A spatial distribution of sojourn locations by whether or not the activity was pursued jointly with one's spouse was obtained from 1421 sojourn records of 839 individuals from the City of Warren, a suburban industrial middle-class community. Each individual pursued at least one evening out-of-home activity on the survey day. Figure 2 defines the rings that are used in this analysis. Figure 9 shows that sojourn locations tend to be located farther from home if activities are jointly pursued and closer to home if they are pursued independently. This correlation is at least partly due to the correlation among activity types, spouse participation, and the distribution of opportunities by activity type.

The spatial distribution of household sojourn locations is further analyzed by estimating log-linear models with the following factors: number of household sojourns, household work-trip status, and path type (independent or joint). A sojourn made independently is weighted by 0.5 in this analysis.

The selected best model includes the following interaction terms:

1. Sojourn locations, number of sojourns, and path type;
2. Sojourn locations, work-trip status, and path type; and
3. Number of sojourns and work-trip status.

Figure 8. Relative frequency of returning home for the day by time and spouse involvement in activity.

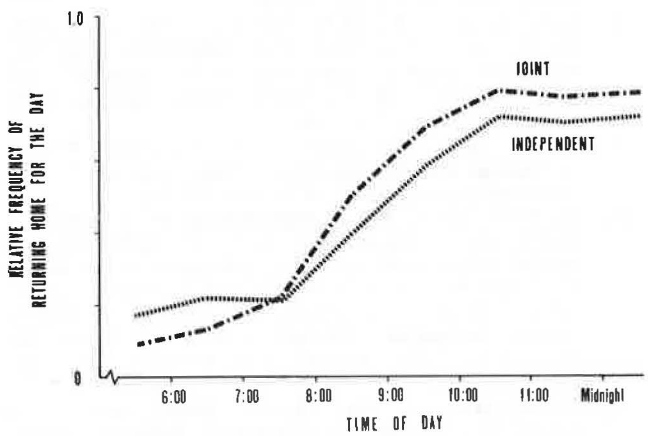
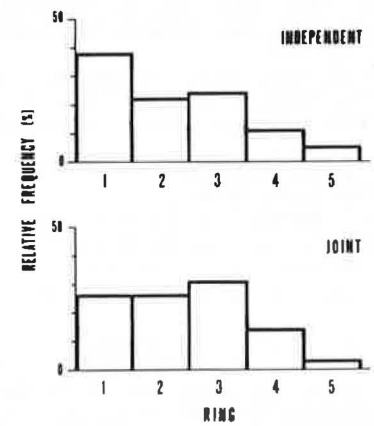
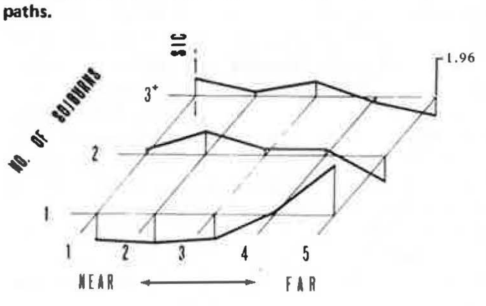


Figure 9. Distribution of sojourn locations by spouse involvement in evening activity.



Sample: 1,421 sojourns made by 839 individuals from Warren who pursued evening out-of-home activities.

Figure 10. Interaction of number of sojourns and sojourn locations for joint paths.



Sample: 1,373 sojourns made by 406 households from Warren whose members pursued evening out-of-home activities

This hierarchical model is applied to 1373 sojourn records of 406 households of life-cycle stages 2 through 6. As expected, the result confirms the association between sojourn locations and spouse involvement observed in Figure 9.

The interaction of household work-trip status and number of sojourns indicated that this geographical subsample has the same association between the two factors as found earlier (Figure 3). Figure 10 presents the interaction effects of sojourn locations, path types, and number of sojourns. The effects are shown for joint paths. Clearly indicated is the strong interrelation between the number of sojourns and the sojourn locations. If only one sojourn is made, its location tends to be farther from home, while when two or more sojourns are made in the joint paths, they tend to be located closer to home. This contraction in the sojourn-location distribution is consistent with the theoretical property of time-space paths derived earlier (3): Because a path is constrained by a prism, sojourn locations tend to be concentrated around the home when a large number of sojourns are pursued. It should be noted here that the interaction term effects for independent paths are just the opposite of those shown in the figure. Clearly, more effort is required for further investigation of these complex interaction effects of path characteristics and other factors.

Although sojourn locations in both households' and individuals' paths were also analyzed with several socioeconomic variables, including life-cycle stages, no clear tendency emerged. It seems appropriate to conclude that the distribution of sojourn locations is more strongly affected by the number of sojourns and the participation of spouse in activities, and that attributes of individuals or households affect sojourn locations only indirectly through their correlations with these path characteristics.

CONCLUSION

It is accepted in this field that the key to the prediction of travel demand is in the understanding of travel behavior. Observation of travel behavior by hypotheses formulation and testing is one way in which theories of travel behavior are developed and eventually applied to prediction.

Time-space paths of travelers are observable indicators of travel behavior. If patterns exist in these paths, then they can be used to identify regularities and help detect underlying constraints. If a set of basic properties of time-space paths exists, then these properties should not be violated in models of travel behavior. As part of an ongoing effort to identify basic properties of time-space paths of urban travelers, this study explored the effect of life cycle on the evening travel behavior of adult household members. The life-cycle stage is used to represent the microscopic factors that affect activity and travel behavior of households, such as interpersonal linkage constraints and needs and propensities for evening activities. In this exploration, travel patterns of husband and wife couples were collectively represented as paths in time and space, and the associations between various path characteristics and life cycle were examined. Emphases were placed on the interactive effects of contributing factors, including household work-trip status and individuals' household roles.

This study used a conventional origin-destination survey data set in analyzing households' activities and travel. The large sample size allowed the spatial analysis of activities by using a geographic subsample and also the analysis of higher-order interaction effects by using multiway contingency tables. Use of appropriate variables such as life-cycle stages and household roles made it possible to statistically obtain many relations that are sufficient to infer the effects that interpersonal linkages and other constraints have on the paths. The results indicate that the life-cycle stage of the household is related to many aspects of the evening path: engagement in evening out-of-home activities, type of path, participation of the spouse in the out-of-home activity, number of sojourns, and time of returning home. The presence of children in the household was found to have substantial impacts on the adult members' activities and travel. For example, young couples without children jointly pursue evening activities more frequently than those with preschool or school-age children. The result indicates the constraints created by the children and provides additional empirical evidence of the constrained framework within which these household paths evolve.

Not all aspects of the evening path can be explained by the life cycle. Out-of-home time, travel time, and the distribution of sojourn locations were more directly correlated with the path type, especially whether the activities were pursued jointly or independently. Thus, life cycle is related to these aspects only indirectly through its correlations with the path types and spouse participation in the activity. This, however, is intuitively agreeable. When a husband and wife who are raising children decide to go out together at all, naturally a baby-sitter is arranged; therefore, the couple can behave like a couple without children, while whether they will go out together or not is strongly affected by the life-cycle stage.

Although this study confined its scope to the analysis of household time-space paths in the evening period, the study result has the following general implications. Travel behavior of urban residents is closely correlated with the life-cycle stage of households and household roles of individuals. The population distribution of life-cycle stages is continuously changing and household roles of individuals are shifting rapidly due to the increasing labor force participation of women. Travel-demand forecasting, therefore, cannot neglect these factors. The effect of children on travel behavior found in this study also suggests that an appropriate definition of life-cycle stages should incorporate the presence or absence of children in the household and their ages. Such refinements in travel-demand forecasting seem to be especially important in the current planning context, where the weight of nonwork trips has increased, compared with the time when the peak-period demand and the capacity of urban transportation facilities, and accordingly work trips, were of primary concern.

The findings of this study offer empirical evidence that substantiates the viewpoint that time-space paths of urban travelers evolve under the influence of many constraints. Moreover, the statistical indications of this study are consistent with the hypothesized association between these normally unobservable constraints and the household's stage in the life cycle. Validating the many properties of urban time-space paths found in this study with observations from different geographical areas and survey dates remains as a future task.

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Life-Style Segmentation in Travel-Demand Analysis

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Market segmentation, when used as a method for accounting for cross-sectional taste differences, is often applied in travel-demand analyses. This paper suggests the employment of the life-style concept as an improved basis for segmentation. Life-style is defined as the behavioral pattern that results from three major life decisions: the decision to form a household, the decision to participate in the labor force, and the orientation toward leisure. By using available socioeconomic variables, an attempt is made to identify life-style groups and to use them as market segments in a joint mode and destination choice model. Two tests are presented. One is the use of life-style-specific variables in the model specification and the other is the estimation of separate models for each market segment. Both approaches have shown an improvement in the model performance compared with either a pooled model or an income-based and a life-cycle/occupation-based segmentation. Further refinement of the ability to identify life-styles is suggested.

The shifting focus of travel-demand analysis to individual or household behavior has drawn attention to the problem of cross-sectional differences in individuals' tastes. A number of pragmatic solutions have been used over the past few years to account for taste differences. Generally, the approach entails the use of market segmentation, which creates some homogeneous groups that are likely to behave in a similar manner under changing conditions. Yet it seems that in many of these efforts there is a lack of a theoretical basis.

This paper presents an attempt to use a segmentation that is based on the concept of lifestyle. Life-style segmentation, as defined in this paper, offers a theoretical basis for differentiating between behavioral groups. It is integrated in the framework of the choice hierarchy that distinguishes between short- and long-run decisions in travel behavior. Although there still exists a serious gap between the conceptual definition of life-style and its empirical definition, an attempt to apply the concept is presented.

The concept of life-style is widely used in market research as a basis for segmentation (1,2). It is also regaining ground among sociologists who suggest that life-style differentiating among groups has greater behavioral relevance than differentiation along social or economic classes (3,4).

A segmentation based on life-style is compared with alternative market-segmentation schemes based on socioeconomic characteristics. The performance of a mode and destination choice model for shopping trips is used to evaluate the alternative schemes. The results of this analysis indicate that life-style segmentation is an improved approach compared with the others tested in this research.