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An Activity-Based Trip Generation Model

DISSERTATION

submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY
in
CIVIL AND ENVIRONMENTAL ENGINEERING

by

Ruey-Min Wang

Dissertation Committee:
Dr. Michael G. McNally, Chair
Dr. Will W. Recker
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1997

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The dissertation of Ruey-Min Wang is approved,
and is acceptable in quality and form
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Committee Chair

University of California, Irvine
1997

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ABSTRACT OF THE DISSERTATION

An Activity-Based Trip Generation Model

by

Ruey-Min Wang

for

Doctor of Philosophy in Civil and Environmental Engineering

University of California, Irvine, 1997

Dr. Michael G. McNally, Chair

The goal of this dissertation is to develop an activity-based trip generation model which addresses shortcomings of the conventional trip-based approach. Problems with conventional generation models resulted from a fundamental incapability to address the temporal and spatial characteristics of activities and the trips which they generated. The sequencing and scheduling of trips and activities, and interactions between household members, are ignored in the standard model. The proposed activity-based generation model was developed to estimate trip production from the analysis of complete travel/activity patterns. This approach classifies travel patterns with respect to activity, spatial, and temporal characteristics; standard trip rates can be also estimated from these representative activity patterns. In addition to a standard category production model, a stochastic logit-based pattern choice model and a deterministic discriminant analysis model were developed to simulate activity pattern choice and the associated trip production level. A variety of variables describing the socioeconomic and demographic attributes at the household or person level comprise the utility functions for choice prediction. Temporal

stability of activity patterns was evident in similar life cycle groups in the 1985 and 1994 Portland test data, supporting the conclusion that patterns are a viable structure on which to base future forecasts.

Chapter 1

Overview

1.1 Introduction

Transportation demand management has emerged as a component of several recent policy decisions in the United States including the 1990 Clean Air Act Amendments (CAAA) and the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Simultaneously, the conventional four-step forecasting process, the tool utilized to assess current and future travel demand and network performance, has been deemed insufficient to properly model the supply-demand equilibrium process (Pas *et al.*, 1994). Because of the limitations of the current modeling process, Metropolitan Planning Organizations (MPOs) are largely unable to either incorporate advances or improvements into the analysis procedures or adequately reflect any sensitivity to the majority of transportation policies currently being implemented (Harvey and Deakin, 1991).

Conventionally, the transportation planning process is focused on the prediction of trip segments rather than the choice of activity participation. That is, with the conventional approach, transportation planners imagine cars on specific roadways, but not that they are on the road to go to work or elsewhere. Thus, in each step of the conventional feed-forward demand modeling approach, the influence of activity characteristics decreases and that of trip characteristics increases. To combat this, the travel model improvement program (TMIP), has been launched to develop the next generation of methods for transportation modeling and includes an ongoing multi-million dollar project involving the development of an activity-based travel microsimulation model. A synthesis prepared for this program concludes that the direction of next generation transportation demand modeling will be activity-based rather than the conventional trip based approach and that a stochastic microsimulation will replace a deterministic aggregate extrapolation (Spear, 1994).

Despite the large amount of research done in the field of activity analysis, the application of activity-based modeling techniques has neither been fully developed nor empirically validated. Indeed, even the classification techniques for activity patterns have not been standardized, nor has the temporal stability of activity patterns been examined. Therefore, the intent of this research is to offer a potential modeling technique, which :

(1) is comparable to the conventional demand modeling technique, but with an activity-orientated modeling approach,

(2) has a household-oriented model structure that accounts for the effects of lifecycle stages and restraints due to the presence of children, and resultant impacts on household travel/activity patterns,

1.2 Activity-based Research Development

The travel model improvement program (TMIP) is supported by multiple agencies that include the U.S. Department of Transportation (US DOT), the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), and the Environmental Protection Agency (EPA). This program has four major research tracks (TMIP, 1995):

1. Track A- Outreach: Work to help practioners improve their existing planning procedures to be consistent with currently desirable practice. This outreach will be devoted to the research coordination, technical assistance and clearinghouse for research finding.
2. Track B- Near Term Improvements: This program will help MPOs and state DOTs elevate current practice to the state-of-the-art. These efforts will implement model improvements already developed but not widely included in current transportation, land use, and air quality planning activities.
3. Track C- Longer Term Improvements: Major research and development of fundamentally new approaches to travel and land use forecasting will be undertaken in this track. Issues and questions, and the roles of models in providing information to address them, will be determined. This research will advance the state-of-the-art of travel and land use modeling to meet these needs.
4. Track D- Data Collection: Efforts in this track will identify, design, and develop improved data collection procedures that will meet decision makers' current and future needs. Data will be collected for use in other tracks of this program.

The TRansportation Analysis and SIMulation System (TRANSIMS) is a set of integrated analytical and simulation models under development by the Los Alamos National Laboratory (LANL) under the support of Track C. The major components of the TRANSIMS include the Household and Commercial Activity Disaggregation Module, the Intermodal Route Planner, a Traffic Microsimulation module, and an Environmental Analysis module(see Figure 1.1). This model is a top-down formulation of the transportation demand forecasting approach that is based on an understanding of household travel needs and the interaction between household members. TRANSIMS deals with individual behavioral units and predicts trips for individual households, residents, and vehicles rather than for a zonal aggregation of households as done in conventional planning models.

The TRANSIMS model is an activity-based travel microsimulation model to simulate individual traveler's movement under a realistic environmental setting. A GIS (Geographic Information System) is suggested to serve as the operation platform. Beckman *et al.* (1996) use an iterative proportional fitting method to create synthetic baseline populations for activity microsimulation so that the socioeconomics and demographics of population can be simulated as well. Travel demand can be estimated from a simulation approach evolved from the development of travel behavior and activity theory. These efforts have been put together in order to design a model for the next generation travel demand modeling purpose.

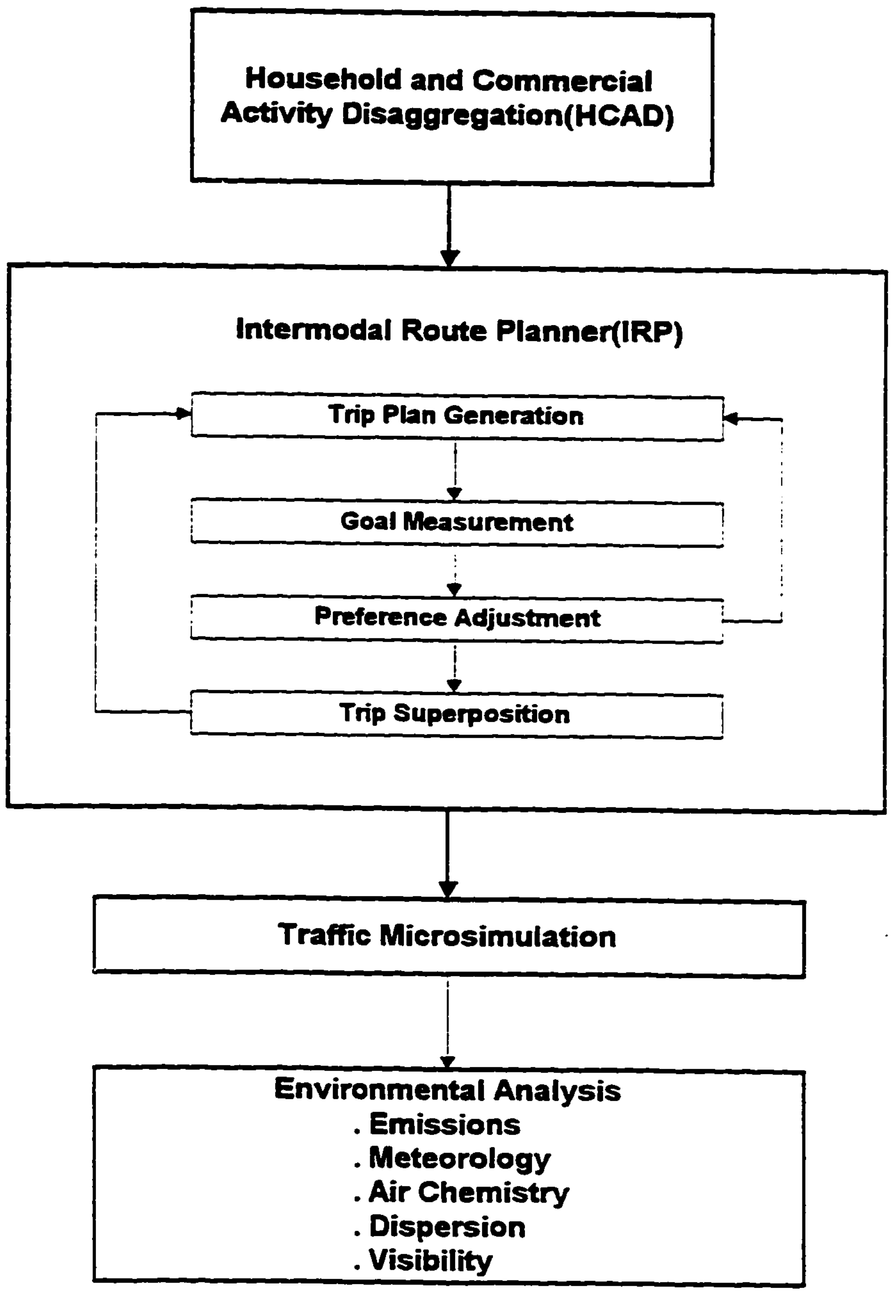


Figure 1.1 TRANSIMS Model Structure (TMIP, 1995)

1.3 Research Motivation

The traditional demand modeling approach is focused on finding a quantitative causal model for trips, yet it ignores the activity motivation for trips as well as the associated temporal and spatial characteristics of travel imposed by land use and transportation infrastructure. In the conventional method, trip production and distribution models are processed independently, thus the tenet that travel is derived from activity participation is ignored so that productions are not correctly estimated. The predicted trip flow between an origin-destination pair is computed primarily based on an aggregate general flow and network travel times instead of reflecting the actual distribution of trips towards a certain activity location.

An approach oriented from daily household activity patterns analysis should lead to a better estimation of household trips and should simultaneously more precisely reflect the spatial and temporal characteristics of household travel needs. The intent of this research is to develop an activity-based production model that utilizes the theory and methodology of travel-activity pattern classification to investigate household travel. Jones (1983) provided a good example of the alternate approaches of estimating household travel from investigating activity participation rather than simply trips (see Figure 1.2).

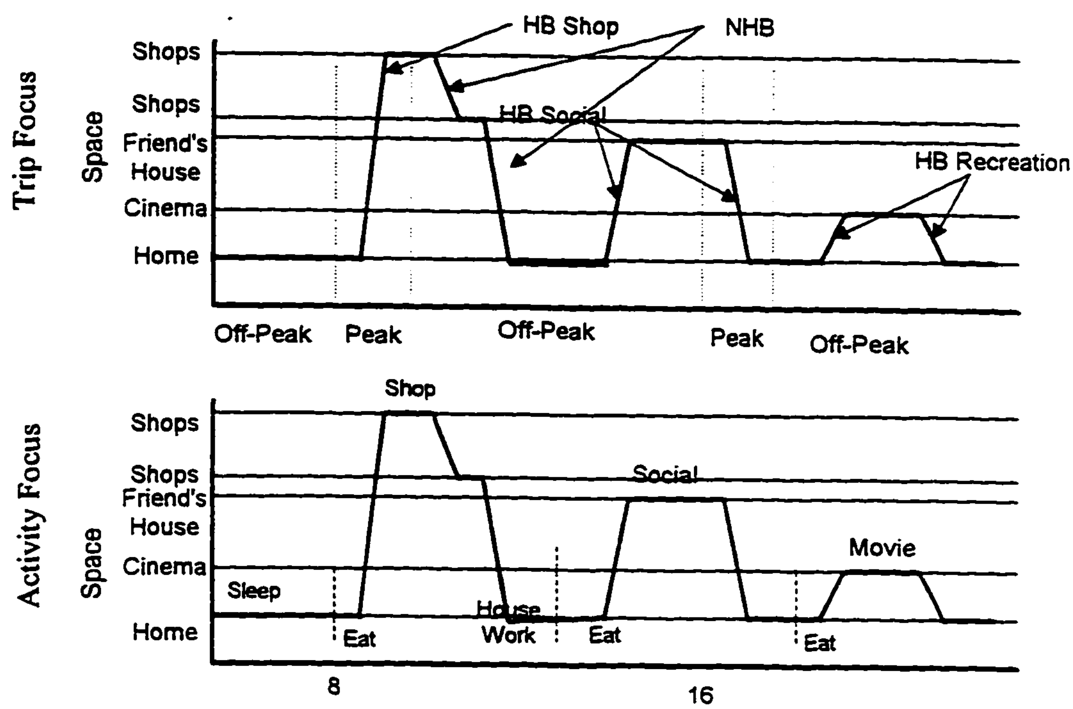


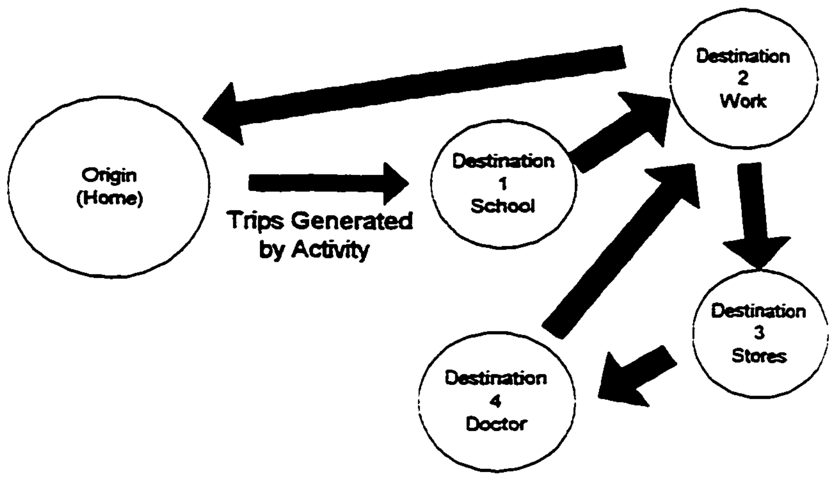
Fig 1.2 Relationship Between Trips and Activities

This activity oriented trip production approach is comparable to the traditional trip generation model, yet it can incorporate the interrelationship between trips for subsequent use in an activity-based transportation demand microsimulation model with this activity-based approach for household trip production, life cycle effects and temporal stability of household activity patterns can be examined to assure the practical applicability of activity research on demand modeling. Life cycle refers to changes in family structure and status as life evolves from childhood to single living to married status to parenthood, and so on. Different from past research endeavors, this research attempts to present household activity patterns maintaining both temporal and spatial aspects and to verify the effects of household life cycle on travel behavior. Presenting activity patterns with their temporal and spatial dimensions intact leads toward the understanding of the correlation of travel/activity sequences and of the relative spatial-temporal distribution of life cycle members over time.

1.4 Research Objective

In the last decade, Pas (1983) and Recker *et al.* (1983) have developed methods to classify household daily activity patterns. Their work has established the foundation for the quantitative measurement of household travel, though there have been no continuous development or application of their techniques for practical travel demand model design. The objective of this proposed research is to develop an activity-oriented trip generation model that predicts household trip production while maintaining trip linkages in time and space. Trips herein will be treated as the necessary movements of activity participants from one activity location to the next activity location, thus, the linkage between trip origin and destination is still maintained in the sequence.

The focus of this research is centered on trip production estimation using an activity-based approach, and trips generated by those activities are embedded with complete temporal and spatial information. In Figure 1.3, the number of trips motivated by activity execution can be estimated from an activity pattern that implicitly includes the sequencing information of trips.



Trip Focus

Type	Number
HBW	1
HBO	1
NHB	4

Activity Focus

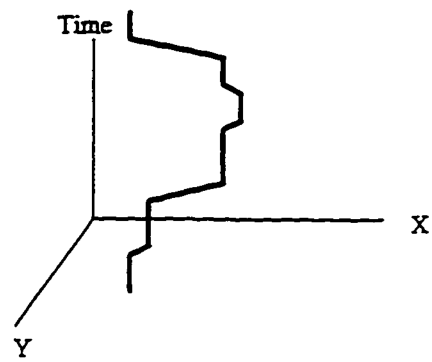


Fig 1.3 Deriving Trips from An Observed Activity Pattern

By introducing household travel-activity pattern classification as an add-on the conventional trip generation module, trip information can be obtained from the decomposition of daily travel-activity patterns. The resulting information will contain the daily trips, and implicitly the linkage from origin to destination by trip purpose. Hence, this proposed activity-based trip generation model is comparable to the traditional trip production approach, and can serve as a front end module for an activity microsimulation approach that requires more detailed pattern characteristics. In this proposed model, trips can be estimated with any variables embedded at the household or person level. This model is explicitly considered to have the following characteristics:

1. being comparable to the traditional trip generation model,
2. maintaining the linkage between trip ends in a temporal and spatial fashion,
3. more properly reflecting regional environment characteristics that result from land use patterns and transportation infrastructure.

1.5 Research Approach

The proposed research is to investigate household member activity patterns and to derive an activity-based trip production model by aggregating household activity participation and travel by household demographic and socioeconomic characteristics.

The approach involves a three level analysis process, which includes a level of analyzing individual activity patterns, a level of identifying the choice of patterns based on household or person characteristics, and a level of extracting trips from the patterns selected. Trip production then can be estimated by time-of-day or by purpose. The relationship between the levels of analysis is provided in Figure 1.4.

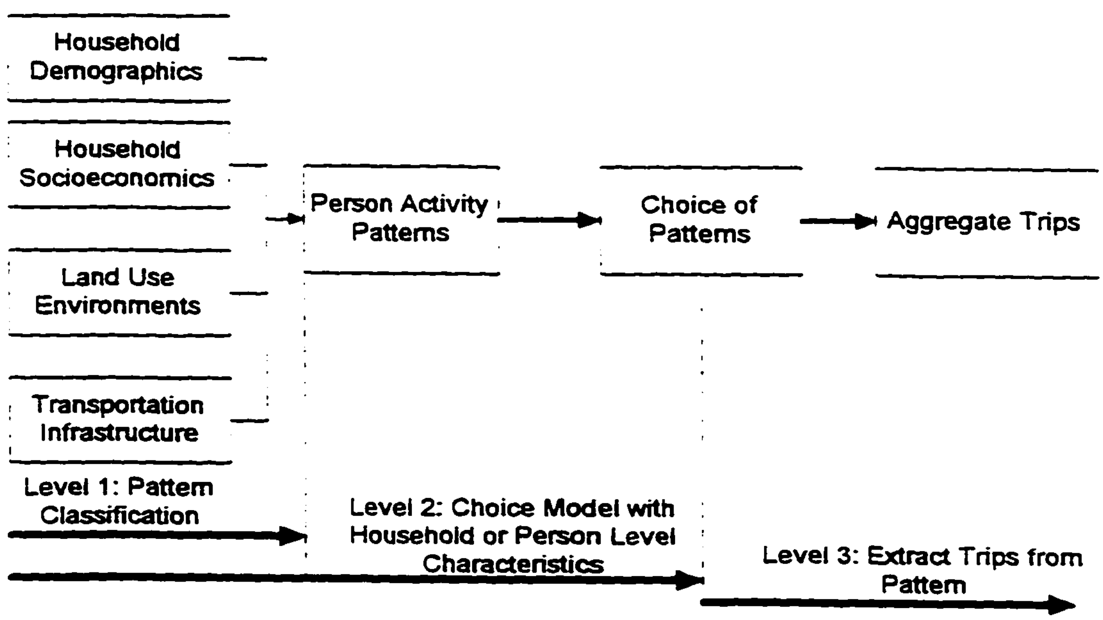


Fig 1.4 Proposed Research Approach

An activity pattern classification module to cluster activity patterns into homogeneous groups based on selected travel/activity variables will serve as the core of level one of this research. This module generates individual representative activity patterns (RAP) for all persons, each classified by combinations of household socioeconomics and demographics and residing in different resources environments and networks. A hypothetical activity generation process shown in Figure 1.5 illustrates the connection between observable travel behavior and complex household travel/activity decisions. Household characteristics are implicitly embedded within this connection.

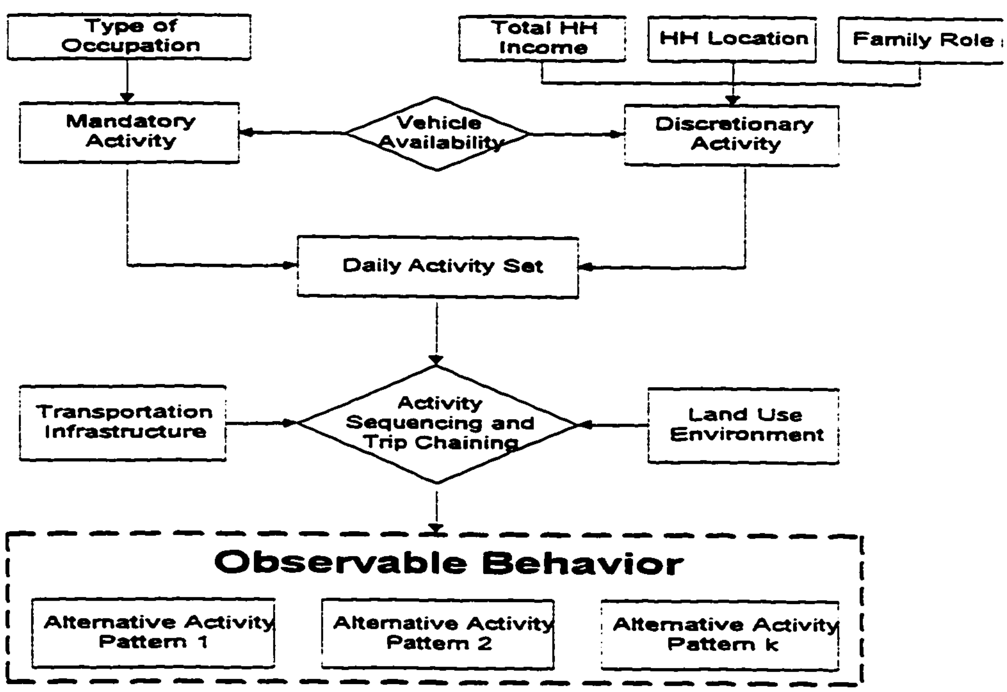


Fig 1.5 Hypothesized Activity Generation Process

The specific tasks and contributions of this dissertation can be summarized can be summarized as follows :

1. In order to examine the effect of family role on travel behavior as life cycle evolves, household samples are categorized by family type and working status.
2. Activity patterns are classified with respect to temporal and spatial characteristics, producing Representative Activity Patterns (RAPs) from which trip rates can be estimated.
3. Variables at the household or person level (such as car ownership, employment, and home type), are applied to derive trips from RAPs as an alternative to the conventional trip generation approach.
4. Several choice models for activity pattern selection are developed that explicitly predict the choice probability for a specific pattern based on the individual's and their household's socioeconomic and demographic characteristics.
5. The choice behavior of the selected pattern for each individual can be simulated, followed by the computation of conventional trip rates.

1.6 Organization

Before providing the details of the model developed in this dissertation, it is important to understand previous approaches to related research problems and how this dissertation resolves current problems and contributes to the study of the art. Previous research efforts are reported in Chapter 2, and two conventional models used by transportation agencies are presented in Chapter 3 and illustrate the reducible capability of the proposed model to the conventional trip generation model. The subsequent chapters of this dissertation will present the research methodology in Chapter 4, an empirical analysis of data in Chapter 5, and an operational trip generation model in Chapter 6. Finally, conclusions and future research are discussed in Chapter 7.

Chapter 2

Literature Review

2.1 Introduction

The objective of this chapter is to provide a conceptual framework for this research. The theory of activity-based travel behavior forms the basis of the research methodology that will be used to estimate individual trip/activity generation, which will also be used to derive an aggregate measure of household trip rates. Activity pattern classification methods will be discussed in this chapter, and conventional trip generation models will be reviewed as well. The organization of this literature review has been arranged as follows. First, recent papers of activity-based research in transportation are reviewed. Progress and recent advancements in activity pattern analysis are discussed. Well-known activity pattern prediction models and pattern analysis techniques are further compared in detail. These research efforts have been reflected in the development of activity-based approaches to travel analysis, but the areas of household life cycle and household interactions still need to be further addressed. Therefore, the relevant literature of household structure studies are reviewed in order to provide insight into the dynamics of household interactions.

Second, the literature review will focus in the investigation of conventional linear regression methods and cross classification trip generation estimation methods. After reviewing all this published research work, drawbacks and limitations of current models are discussed.

2.2 Scope of Activity Research

The activity-base approach for travel demand analysis evolves from the idea of observing routine travel patterns under stable conditions of supply and demand environments. Hagerstrand (1970) first presented the time-space ideology of human activity patterns that has greatly influenced the design of next generation transportation demand models. Activity theory was initially viewed from a physical perspective, that an individual's daily activity pattern is restrained by three factors: capability, coupling and authority (Hagerstrand, 1970). In this time-geography approach, travel is viewed as one of the various daily activities that individuals do and is considered as a demand derived from pursuing social needs and goods.

A broad definition of activity-based travel analysis was summarized by Pas (1985) which characterizes the application areas in activity research :

1. Demand for activity participation.
2. Activity scheduling in time and space.
3. Spatial-temporal, interpersonal, and other constraints.
4. Interaction in travel decisions over time.
5. Interaction among individuals.
6. Household structure and roles.

It should be noted that activity-based analysis is useful for transportation planning purposes as well as making an advancement in studying the travel supply-demand relationship. Jones (1983) suggests that the activity-based approach promises to be superior in that it can potentially address a wider range of policy issues and planning problems. Based on the theoretical appeal and practical sense, the development of the activity-based approach invokes the rethinking of the whole process of conventional transportation planning methods. Recently, the activity-based transportation modeling approach has attracted great attention, and its attractiveness is due to its potential superiority over the conventional approach as well as its theoretical appeal.

2.2.1 Integrated Activity Simulation Models

The activity-based approach has been advanced as an option for overcoming inherent limitations of the prior trip-based, sequential, feed-forward transportation planning models. An activity-based analysis approaches transportation demand and supply problems through a deeper understanding of travel behavior and the "dynamic" between transportation infrastructure and land use development. Within the past decade, the development of transportation models has been changing from aggregate to disaggregate, trip-based to activity-based, and from static to dynamic.

Pas (1985) concludes that the emerging features of activity-based analysis for travel demand modeling are:

1. Explicit treatment of travel as a derived demand.
2. Focus on sequences or patterns of behavior rather than an analysis of discrete trips.
3. Emphasis on decision-making in a household context, taking into account linkages and interactions among household members.

4. Emphasis on the detailed timing as well as the duration of activity and travel, rather than just using the simple categorization of peak and off-peak events.
5. Explicit consideration of spatial, temporal, and interpersonal constraints on travel choice and resource allocation.
6. Recognition of the interdependencies among events that occur at different times, involve different people, and occur in different places.
7. Use of a household and person classification scheme.

In recent years, several significant integrated activity-based transportation demand analysis approaches have been proposed. Kitamura *et al.* (1994) are trying to develop a new planning system comprised of a sequenced activity-mobility system (SAMS), a behavior adaptation module, and a geographical information system (GIS) platform. Focus on behavior adaptation and vehicle transactions are highlighted in the approach, and an activity mobility operation simulator (AMOS) was created to serve the aforementioned purposes. An explicit microsimulation of the interaction of traveler socio-demographics, land use, and activity scheduling is also found in the SMART model proposed by Stopher and Hartgen (1994). SMART (Simulation Model for Activities, Resources and Travel) utilizes a household activity simulator that determines that location and travel patterns of household members' daily activities in three categories, namely, mandatory, flexible, and optional activities.

These models have presented the possibility of implementing activity analysis into a full all-component operational transportation planning model. The integrated models allow simulations of the overall regional effects on household activities, and the effects of aggregate household activities on the region's development. These research frameworks have also shown the functional capability of introducing household decision interactions and land use effects as a level of research. Also, the TRANSIMS project underway at LANL (see Chapter 1) represents another comprehensive approach, and one that is being investigated from the bottom up.

2.2.2 Activity Scheduling

Activity scheduling can be regarded as the planning process preceding travel that determines what activities to perform and in what sequence, at which locations, at which starting and ending times, and using which route and travel modes (Ettema *et al.*, 1995). Recognizing that travel is not a simple behavior, travel patterns can not be properly examined without accounting for linkages to other people and other activities. An activity program is developed in the pre-travel stage. This program contains a list of planned activities for an individual or a household as well as as selected characteristics of those activities. It is assumed that this program reflects the activity needs as formulated prior to the program execution. However during execution, the activity program may be adjusted ahead on any of its defining dimensions.

Based on utility maximizing principles, Recker *et al.* (1986a) constructed a comprehensive framework to generate feasible activity patterns and to identify the optimal pattern. The utility gained from participation in activities is weighted against the disutility of travel needed for participation. In contrast to maximum utility approaches, Garling *et al.* (1989) develop a framework called SCHEDULER for household activity scheduling purposes. The sequencing task of this model is based on the theory of a nearest-neighbor heuristic optimization on the so-called long-term activity calendar. By mentally executing the initial program, other possibilities of replacement of an activity or changing the priority level are conducted. This approach is characterized as a stepwise, sub-optimal planning process of activity scheduling. However, there are currently no calibration methods to validate these models and, for most applications, it is not necessary for household trip scheduling to be optimal but rather to be satisficing.

2.2.3 Spatial-temporal Distribution of Activities

The importance of the temporal and spatial dimensions is evident in travel demand forecasting, and the restraints on the temporal and spatial dimensions are due to the activity opportunities available along these dimensions. Various research efforts have investigated trip length and trip purpose linkages, but few have focused on placing the linked trips in a spatial-temporal context (see Hanson, 1980; Kondo and Kitamura, 1987; Thill and Thomas, 1987).

Recker *et al.* (1980) utilized the Hagerstrand time-geography concept (Hagerstrand, 1970), and first successfully derived distinct activity travel patterns with 1976 Orange County, California household travel survey data. Individual trip makers in each distinct group reflect similar activity and distance from home profiles. McNally (1995) applies the same technique with the 1991 Southern California Association of Governments (SCAG) household survey for Orange County and has found evidence of temporal stability in the model results by comparing the 1976 and 1991 representative patterns.

Kitamura *et al.* (1990) investigate the trip chaining behavior in a time and space fashion using data from a 1980 origin-destination survey in the Kyoto-Osaka-Kobe metropolitan area of Japan. Their research hypothesizes that the decision of an activity location is made after the trade-offs between travel time and activity duration. It is found that intermediate stops in work/residence trips tend to distribute themselves around the work and residence locations. When additional travel distance is less than 20 km, activity durations are almost invariant irrespective of commuting distance.

2.2.4 Interaction of Household Members

Interaction among individuals in a household can occur with other household members or it can involve people external to the household (Shaw, 1990). The presence of young children affects the household demand for activity and is reflected in temporal and spatial constraints on adult travelers. For example, the presence of children leads to adults undertaking some serving passenger trips. Kitamura (1983) examined the correlation between travel patterns and serving passenger trips and found significant differences in the average number of sojourns and chains made when serving passengers trips are involved.

Van Wissen (1989) used a joint time allocation model for adults in two-adult households using a simultaneous linear equations approach to investigate the time spent individually and jointly, in various activity types. He found that different family roles and gender issues would lead to different levels of impact from one activity time allocation to another. For example, the effect of working time had a positive influence on the allocation of individual recreation time for males, but had the opposite effect for females.

Townsend (1987) developed an conceptual framework for classification and analysis of travel/activity patterns and used observed task assignments to analyze and classify household patterns using household structure and individual role characteristics. His work was directed toward the development of hierarchical relationships between the travel/activity patterns of the household and its individual members. Townsend first developed a theoretical household time allocation model where individuals participate in activities beyond or below the point of maximum individual satisfaction if household utility maximization is the goal. Using Dutch Panel Data, Townsend completed an empirical analysis of household interactions using a combination of trip, tour, and travel/activity pattern statistics. The effect of children's presence is found to be more significant on female than on male, and children tend to increase the amount of work activity for males and increase the amount of maintenance activity for females.

On the empirical application and analysis of the household interaction problem, Recker (1995) formulated the household activity pattern problem (HAPP) as a household ride-sharing and vehicle-switching problem by applying operation research techniques. Household activity pattern selection and interaction effects were formulated as a pickup and delivery problem with time window constraints and solved by the mathematical programming software GAMS.

2.2.5 Pattern Analysis and Classification

The use of activity patterns as a surrogate for travel behavior is consistent with the position that trip making can be better understood when trips and activities are linked and analyzed as a collection of individual actions and interactions (McNally and Recker, 1986) The relationships between activities, constraints, and the manner in which they are channeled into particular time-space paths can be assessed in terms of activity patterns.

Methods for pattern analysis and classification can be characterized by the terminology used in the analysis process, namely, the multiple measure approach, the event-based approach, and the time-based approach (Townsend, 1987). The multiple measurement approach describes patterns with a vector of attributes that includes a variety of travel and activity measures such as the number of activities and in-home and out-of-home times. The complexity of these vectors can be reduced by some variation of principal components analysis to locate them relative to a small set of principal axes; then the reduced patterns are used as dependent variables in multivariate regression against socio-demographics (Hanson, 1982; Tardiff and Allaman, 1982). However, the approach lacks a clear description of what the travel/activities are which involves the inevitable process of forming main pattern vector components with principal components analysis.

Pas (1980, 1982) uses a stop-based pattern descriptor and principle coordinate method to classify the deviation of daily travel/activity patterns. The n-dimensional space constructed by the coordinates of stops made over a day have the following attributes : stop existence, mode, time of day, and activity at the stop. A similarity measurement method is created (Pas, 1983) to differentiate between the patterns and then cluster them based on Euclidean distance (see Figure 2.1). As shown, the data is transformed, grouped and evaluated; these processes lead to the intermediate results for classification of daily travel/activity patterns. The approach is subjective due to a weighting scheme of the attributes which adds to the complexity of this method.

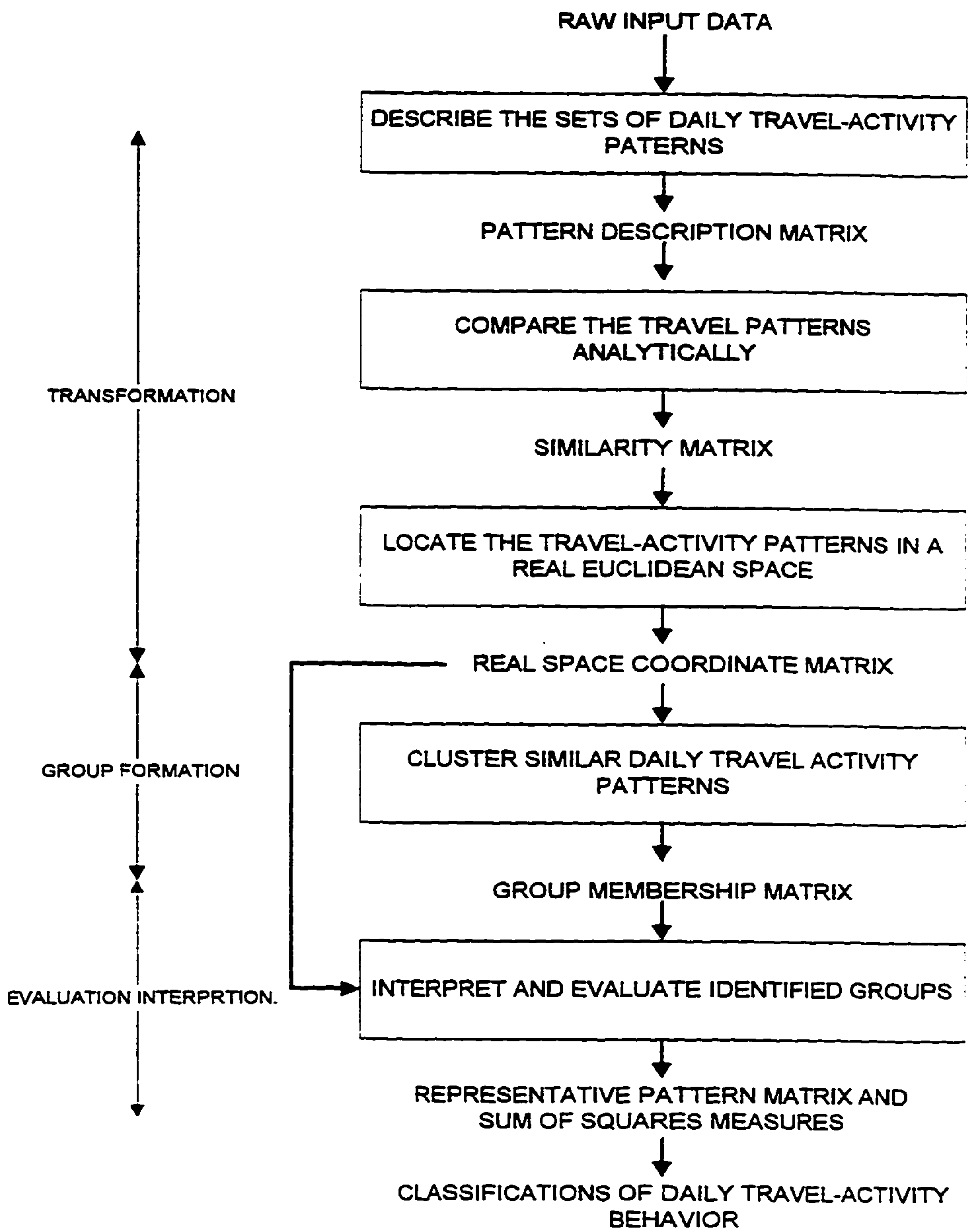


Fig 2.1 Activity Pattern Analysis Approach by Pas (Pas, 1983)

Recker *et al.* (1983) use a time-based method to identify individual travel/activity patterns with group representative activity patterns. Individual activity patterns were classified on the basis of spatial and activity indices derived from survey data.

The time period over which the patterns occur is divided into small time periods, and the pattern is then described in terms of activity type and distance to home in each of these time slices. The two-dimensional images were then clustered into 9 distinct groups that were classified based on the distributions of group members' distance from home and activity participation over the 19-hour analysis day. The representative patterns are then related to pattern group members with individual and household characteristics by discriminant analysis.

McNally and Recker (1986) later developed STARCHILD (Simulation of Travel/Activity Responses to Complex Household Interactive Logistic Decisions) an integrated activity simulator to predict an individual's choice of activity pattern. The modeling flow chart is shown in Fig. 2.2. This model focuses on the generation of an individual's choice for activity pattern rather than the classification of group activity patterns.

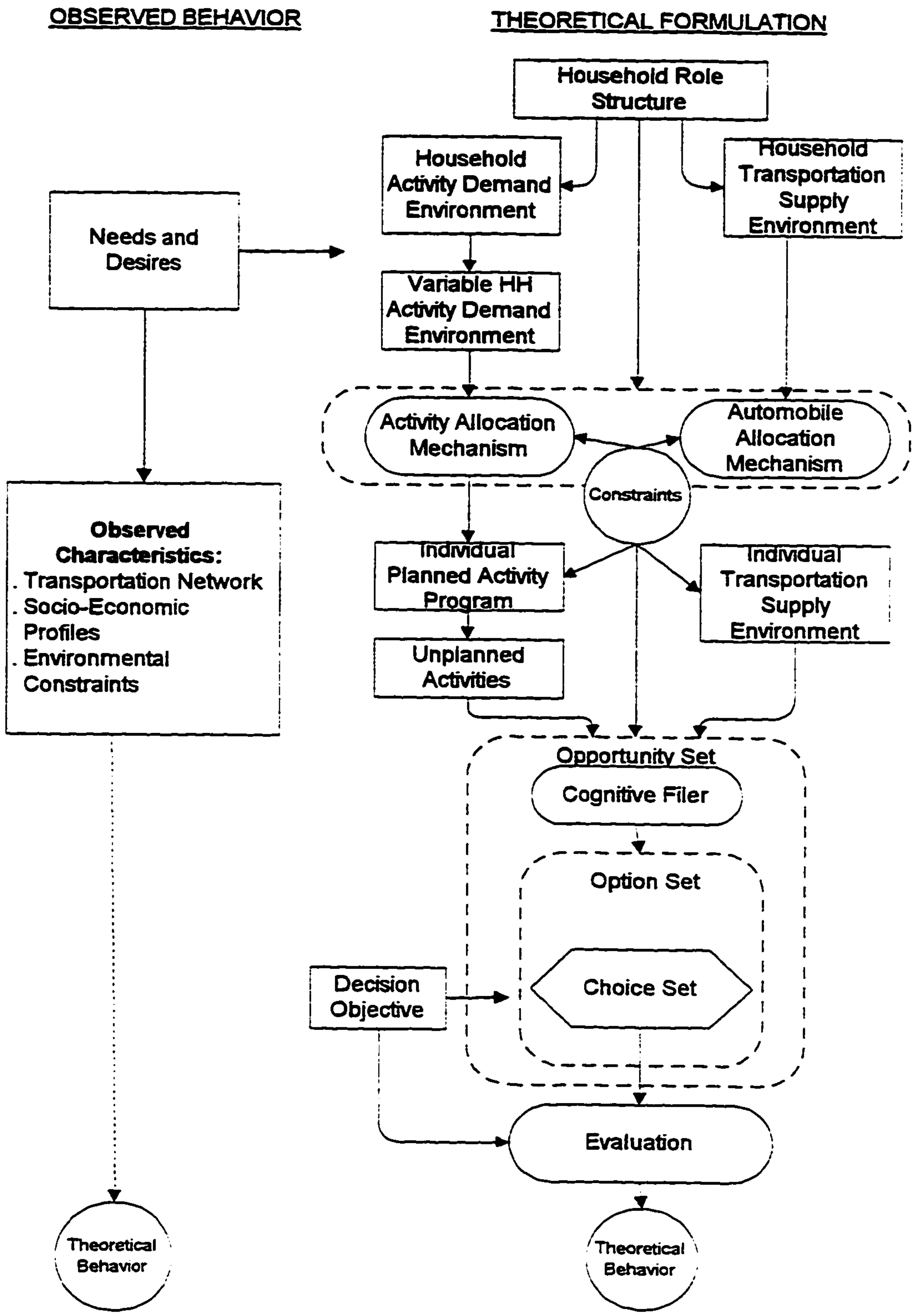


Fig 2.2A Overview of STARCHILD Theoretical Model
(McNally & Recker, 1986)

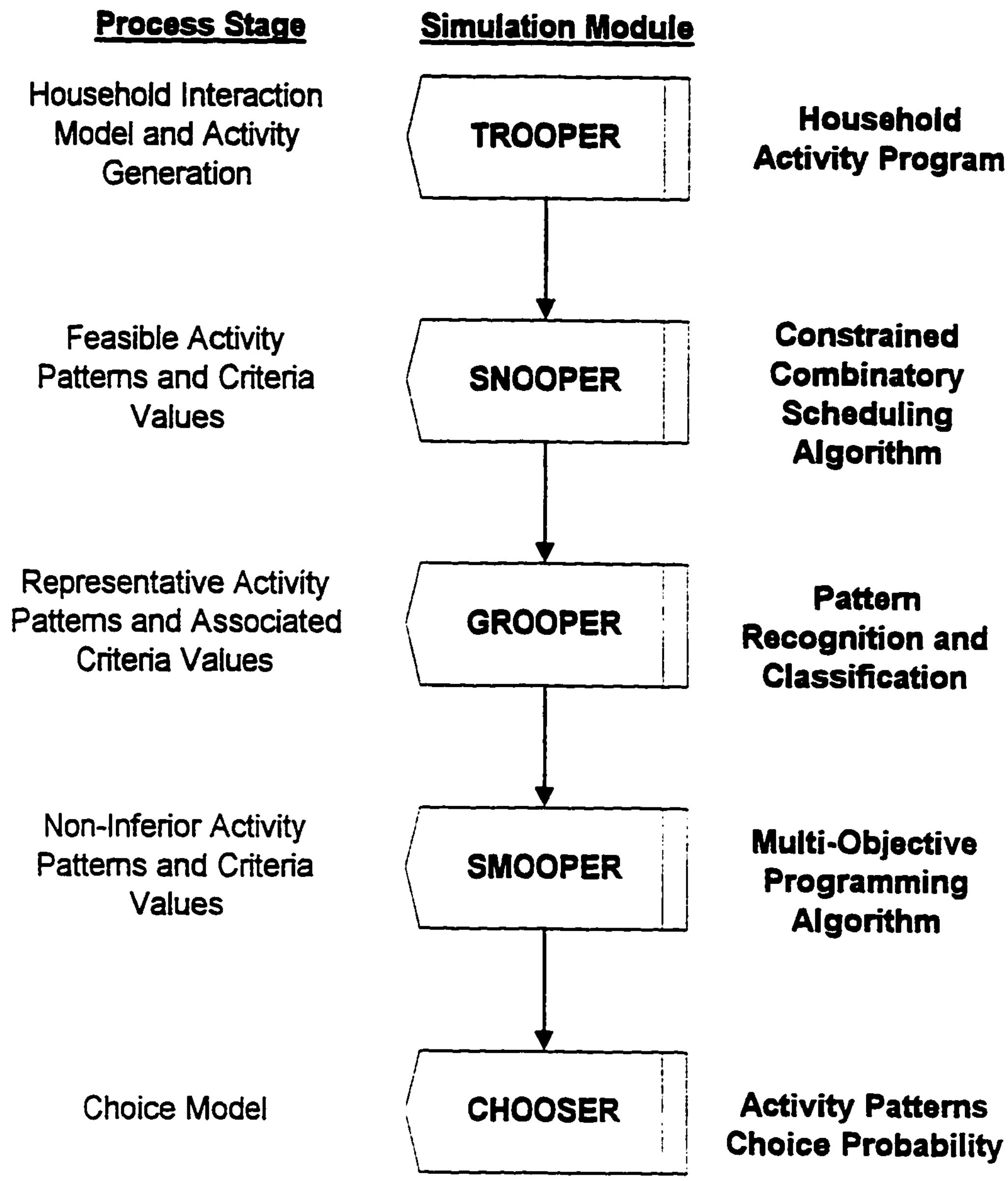


Fig 2.2B Overview of STARCHILD Operational Model
(McNally & Recker., 1986)

Pas (1983) criticized the time-based approach and identified the potential drawback in that two patterns with the same activities slightly displaced in time may appear to be very different in the time-slice representation. To amend the shortcoming of the time-based approach in the pattern classification process, STARCHILD model uses an extensive descriptive vector based on activities in the individual activity program instead of using temporal distributions of distance from home and activity participation. The descriptive vector includes characteristics of waiting time, starting time, sequence, duration and other associated features that can be related to the occurrence of the activity.

The research present later in this dissertation is based on activity pattern classification technique used by Recker *et al.* (1983), but the focus is to investigate the choice of patterns at the decision maker's level instead of basing it solely on the sequence of the trips. A variety of socioeconomic and demographic variables will be used to identify the likelihood of choosing a specific travel/activity pattern which generally describes the distribution of activity types and associated distances at different time, so that trips related to these activities can be estimated accurately according to their times and locations.

2.2.6 Travel Behavior and Life Cycle

Substantial analysis has been conducted at the household level for pragmatic and theoretical reasons (Salomon and Ben-Akiva, 1983). The understanding of complex travel behavior requires not only the understanding of individual behavior but also the household interactions that influence activity behavior. Clarke and Dix (1983) suggest that the activity behavioral reality is that decisions are made by individuals in the context of their respective households. The effect of stage in the family life cycle upon both behaviour patterns and underlying decision-rules has been recognized as a potentially important factor in activity-travel patterns analysis.

The households' life cycle stage and observed trip patterns are defined as exogenous and endogenous, respectively, and household life cycle stage motivates household individuals to pursue certain activities in order to satisfy household needs. In the conventional trip generation model, some variables of household life cycle have been used in trip production models, but no causal effects have been captured. This shortcoming leads to a deficiency of traditional trip estimation methods in reflecting the nature of the dynamics of household members' interaction.

Allaman and Tardiff (1982) hypothesized that household structure and life cycle has influence in travel /activity choice and time allocation. Their research did not find statistically significant differences in time allocations of men and working women without children (by holding the other socio-economic variables constant), however, for employed women, the transition to having a young child does make a difference in travel /activity choice. The break points used in their study are listed as follows:

1. A single person living alone, or living with (married to) another adult
2. The appearance of pre-school children
3. The youngest child reaches school age
4. All children have left home, but the couple have not yet retired
5. All members of a household have reached retirement age

McDonald and Stopher (1983) use household structure as a level of analysis for trip generation. Their result showed contrary indications for the use of life cycle in trip generation analysis because of less satisfactory performance in comparison with the multiple classification analysis (MCA) method (Supernak *et al.*, 1983). However, the difference was defined relative to the difference in methodology of holding constant the number of vehicles and household size at various household life cycle stages. Age 20 was used as the cutoff to distinguish between children and adults, and their life cycle categories were defined as follows:

1. Male and female single person households
2. Single parent households
3. Couples
4. Nuclear families (parents and their children; two generations only)
5. Adult families with children
6. Adult families without children
7. Unrelated individuals

The Transport Studies Unit (TSU) at Oxford University conducted a large-scale activity research project in 1983, a portion of which identified differences in behavioral patterns which are related to households differences in type and structure. The eight lifecycle stages used in their analysis are:

1. Young adults without children, and the youngest is under 35 years old
2. Families with pre-school children, and all children are under 5 years old
3. Families with pre-school children and young school children, and the youngest is under 5 years old
4. Families with young school children, and the youngest is at least 5 but under 12 years old
5. Families with older school children, and the youngest is at least 12 but under 16 years old
6. Families of adults at working age, and the youngest is at least 16 years old
7. Older adults without children, and the youngest is at least 35 years old
8. Retired persons, and all persons are at least 65 years old without jobs

An activity-based trip production model not only derives the trip generation rates of different households, but also finds the characteristics associated with the households or individuals contributing to the interactions of household member travel decisions. The interdependencies among household members vary by their current life status and household life cycle. Townsend (1987) developed a conceptual framework for classification and analysis of travel/activity patterns and used observed task assignments to analyze and classify household patterns using household structure and individual characteristics. Townsend's research was developed based on a theoretical household time allocation model where individuals participate in activities beyond or below the point of maximum individual satisfaction if household utility maximization is the goal. Substitution, companion, and complementary effects were postulated between individuals. Activities were categorized by purpose (subsistence, maintenance, serve passenger, and leisure) and by performer (single, couple, and multi-person). For couples, several key interactions were identified. With respect to the female's employment status, the partners of working females do not significantly increase their maintenance activities. There was also a shifting of joint maintenance trips to weekends. Townsend also found that working females made less maintenance trips than non-working females. He also found that the presence of children reflects more prominently on females. Maintenance trips are greater for mothers and lower for fathers when compared to their childless counterparts. Children tend to increase the amount of work activity for males and the amount of maintenance activity for females, but decrease the amount of leisure activity for females.

Golob and McNally (1995) also has shown that household attributes from life cycle status would be important in their travel-activity choice. Some promising factors have been pointed out, such as the number of members in the household, numbers of children of school and pre-school age, and numbers of employees related to the household structure.

2.3 Conventional Trip Generation Research

Travel is a spatial movement of human behavior performed to satisfy certain needs and desires. Individuals generally operate in the context of the household routine, and in turn, this routine is driven by all family members. The deviation in household demographics, socioeconomics, and life cycle stage contribute to different intensities of travel demand for activities. Three techniques are frequently utilized. Regression method is often used at the zonal or household level to model trip productions and attractions. Cross-classification analysis, a tabulation of trip rates by two or more explanatory variables, is frequently used as a disaggregate approach to estimating trip production at person or household levels. Land use-based trip rates are also utilized for both production and attraction models.

There have been several alternates to introduce activity-based approaches into trip generation analysis. Goulias *et al.* (1990) used a multivariate regression approach to estimate trip generation and trip chaining for which the trip rate is calculated in terms of the number of trip chains by household and by trip type. Variables used to estimate trip chaining and trip generation include household demographics, household life cycle stage, household head description, household income, residence location, dwelling density and car ownership.

Supernak *et al.* (1983) presented a person category model of trip generation as an alternative to household based trip generation models. A homogeneous group of persons is used as an analysis unit, and final description of the person categories is from the multistage, multivariate analysis of many potentially significant variables. The sample size necessary for developing a person-category model is drastically reduced compared to that to estimate a household category model. In the case of forecasting in market segment approaches, it is much easier to predict the population within some age category rather than predicting the number of households with certain formation and size twenty years later. Therefore, using a person category model has these advantages (Supernak *et al.*, 1983):

1. Person-level trip generation is compatible with other components of the classical transport demand modeling system, which is based on tripmakers rather than on households.
2. It allows a cross-classification scheme to be devised that uses all important variables and yields a manageable number of classes; this in turn allows class representation to be forecasted more easily.
3. Sample size required to develop a person-category model can be several times smaller than that required to estimate a household category model.
4. Demographic changes can be more easily accounted for in a person-category model as, for example, certain key demographic variables are virtually impossible to define at the household level (such as age).

The difficulty of introducing a person-based category model to replace a household-based one is the desire to include household interaction effects and household money budget constraints. A household level model may implicitly contain these considerations.

Trip generation rates reflect the demand for travel, and they are influenced by a variety of factors representing the trip maker's attributes and accessibility to opportunities (Sheppard, 1986). A household trip generation model was proposed by Allaman and Tardiff (1982), which was developed by adding variables describing household structure, age structure, and location characteristics to standard trip generation models. Daniels and Warnes (1980) concluded that family structure, income, mobility, and life cycle stage contribute to the effect of households to generate additional trips as certain demand has been accumulated.

Kitamura (1983) found significant differences in the average number of sojourns and chains made for the purpose of serving passengers among workers and nonworkers. This analysis revealed that the location characteristics of certain trips are correlated with some household life cycle status, such as household role and the presence of children.

2.4 Summary

Based on the cited literature, the purpose of this research is to create an activity-based household trip production estimation procedure which maintains comparability to conventional approaches. In addition to household characteristics (car ownership, dwelling type) which are frequently used in conventional trip production estimation models, life cycle, in terms of household type and the number of workers, will be considered. The proposed research is directed toward the development of a person level activity-based trip generation model which explicitly reflects associated household information that may affect individual's travel decision. The goal is to develop an activity pattern generation table at the person level, that incorporates information on trip rates and temporal distributions.

Chapter 3

Trip Generation Models

3.1 Introduction

Trip production estimation is the first step of the conventional four-step transportation demand forecasting process. Conventionally, trip generation models can be categorized into: aggregate or disaggregate approaches. The former is a direct estimation of trip frequency by zones; regression analysis methods are widely used in this approach. In contrast, the disaggregate approach estimates trip production from the household or person level, and category analysis is common methodology. An aggregate approach provides a very convenient zonal estimation of trip frequency with a few regression variables, and it is very economical in terms of data collection, calibration, and operation. In contrast, a household-based or a person-based disaggregate approach can require a significant amount of data for model calibration and testing. However, a disaggregate approach can provide a more precise estimation on trip frequency, and it can respond better to the different travel needs due to the different socioeconomic and demographic backgrounds of travelers.

Rather than completely replacing the current modeling approach to develop a truly activity-based technique, some useful aspects of the conventional approach should be maintained, thus, the proposed model will be designed to be fully reducible and comparable to the conventional model. Thus, the cost of designing a new modeling approach is minimized while simultaneously maintaining the applicability of the modified approach. In the next sections, an aggregate approach using a zonal trip estimation method and two metropolitan transportation planning models (Los Angeles and Portland) that use the disaggregate approach will be reviewed.

3.2 Trip Generation Model : Aggregate Approach

Multiple regression is the most common methodology used in the aggregate approach for trip generation, and it attempts to discover a (typically) linear relationship between the number of trips produced in a zone and the socioeconomic characteristics of the residents in the zone. A hypothetical regression form for a zonal trip generation model is (adopted from Ortuzar and Willumsen, 1990):

$$Y_i = \theta_0 + \theta_1 X_{1i} + \theta_2 X_{2i} + \cdots + \theta_k X_{ki} + E_i$$

where :

θ_k : coefficients to be estimated

X_{ki}: variable k for zone i

E_i: error term

This approach facilitates estimation of total trip production or attraction based on some common variables among residents of each zone. However, some zones that have extreme values of the common variables must be excluded from the analysis process, or they would increase the variation of the estimates. For example, an industrial zone which does not have any residential variables will not predict any home-based trips, and the inclusion of such a zone will arbitrarily influence the overall trip estimation accuracy.

Ortuzar and Willumsen (1990) suggest the use of trip rates instead of zonal total trips so the effect of the zone size can be eliminated (the error term will not depend on the size of the zone). Therefore, the original zonal total trip estimation can be changed into a zonal trip mean estimation, and the calibration process is implemented with zonal average characteristics attributes instead of residents in each zone. The original equation becomes:

Using trip rates instead of the number of trips:

$$y_i = \theta_0 + \theta_1 x_{1i} + \theta_2 x_{2i} + \cdots + \theta_k x_{ki} + e_i$$

where the Y_i, X_{ki}, and E_i are normalized by H_i,

$H_i =$ the number of households in zone i

$y_i = Y_i / H_i$, trips per household

$x_{ki} = X_{ki} / H_i$, attributes of household

$e_i = E_i / H_i$, error term

This approach suggests the development of a disaggregate trip generation model in which trips are directly estimated more precisely at the household or person level. The variation over households (or persons) in terms of socioeconomic or demographic characteristics is then used to reflect different intensities of travel demand.

3.3 Trip Generation Model: Disaggregate Approach

A disaggregate approach for a trip generation model is used to estimate trip frequencies at the household or person level instead of total trips by zones. The example models described are similar in that both use a multiple classification methodology and the trip frequencies are estimated at household level. Although regression analysis can be used to estimate trip rates for households or persons using socioeconomic or demographic variables, category analysis appears to be more widely applied and is less restrictive in terms of its assumptions.

A household level cross-classification approach is described first. The 1995 trip generation model used by the Los Angeles County Metropolitan Transportation Authority (MTA) is the trip generation model developed and utilized by Southern California Association of Governments (SCAG). The trip production rates are cross-tabulated by two housing types and three vehicle ownership levels, and the trip attraction end uses a regression equation of zonal population and employment to balance the trip attractions. The production and attraction relationship in the trip generation step is summarized in Table 3.1. There are five major trip types used in the MTA model: Home-to-Work (HBW), Home-to-Other (HBO), Home-to-Shopping (HBO), Other-to-Other (OTO) and Other-to-Work (OTW). Trips that do not have one trip end at home are identified as Non-Home-Base (NHB) trips. Trips produced from each zone are then estimated separately for each of the five trip purposes using a joint distribution of housing type and vehicle ownership; then trip attractions are adjusted proportionately to meet the zonal trip production.

Table 3.1 MTA and SCAG Trip Generation Model

Trip Generation	
Production	**Attraction**
Cross Classification with housing types and vehicle ownership where the following attributes are used: 1. Housing types: single, multiple 2. Car ownership: 0, 1, 2+ vehicle for each county in this region	$A = C_0 + C_1(P) + C_2(E) + C_3(RE)$ where: A = trip attraction P = zonal population E = total employment RE = retail employment C_i = regression coefficients

The Portland METRO model, which is also categorized as a disaggregate household level generation approach, uses a multiple classification analysis to derive home-based trip rates (Lawton *et al.*, 1994). However, the difference between METRO and MTA models is that the METRO model employs a regression approach to estimate the zonal total non-home-based trips, which makes the METRO model a mixture of aggregate and disaggregate approaches. The general flow of its trip production modeling is depicted in Figure 3.1, where a household level category approach is adopted with variables such as the number of workers and car ownership.

This disaggregate household level trip production estimation process requires some so called "re-generation" models to determine the portions of households with different numbers of workers, auto ownership and children (Lawton *et al.*, 1994).

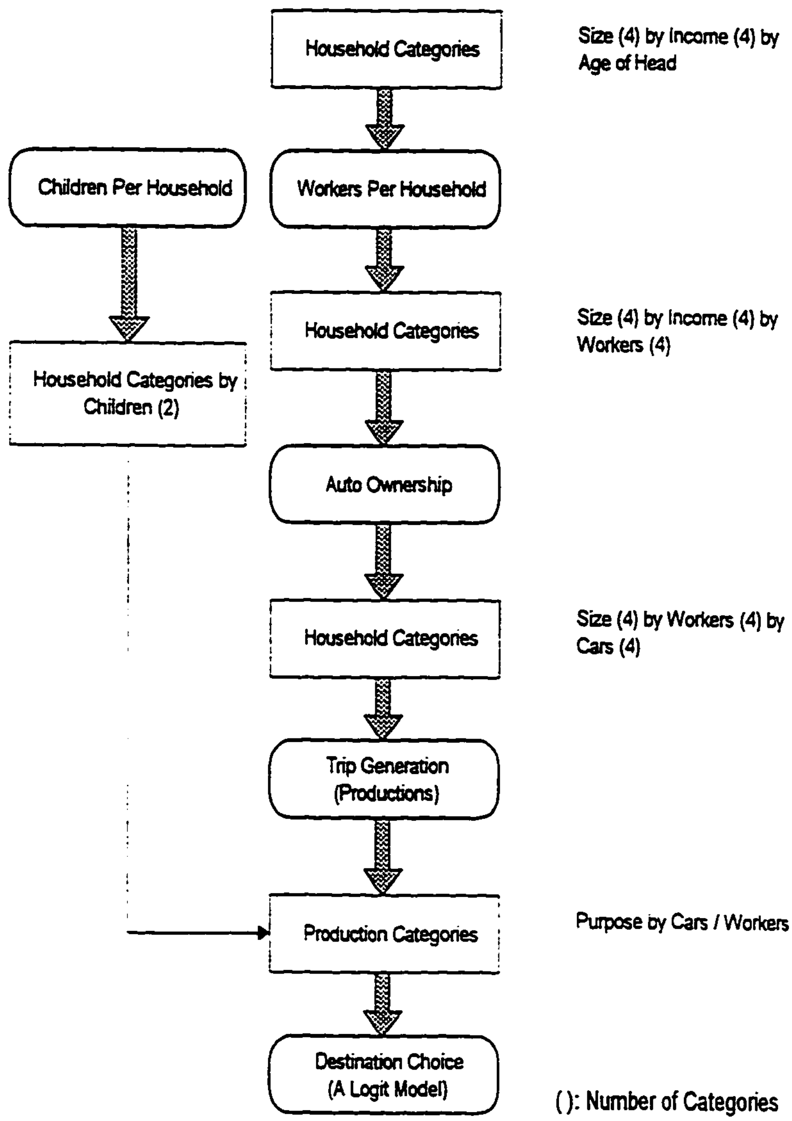


Figure 3.1 Portland, Oregon METRO Trip Generation Model Structure (Adopted from Lawton et al., 1994)

The METRO trip production and trip attraction models are shown in Table 3.3. A logit choice model has been employed to determine destination choice for this process (See the bottom of Figure 3.1)

Table 3.2 Summary of the METRO Trip Generation Model

	Trip Generation	
Trip Purpose	**Production**	**Attraction**
HBW	cross-classification by workers	1.32613*Total Employment
HBO	cross-classification by car ownership, number of workers and household size	5.309*Retail Employment +0.702*(CBD Attractions) or 5.47*Retail Employment +1.8899*Households +0.702*(Non-CBD Attractions)
NHBW	0.351106*Total Employment	0.3280779*Retail Employment + 0.114893*Other Employment
NHBNW	2.381122*Retail Employees + 0.239427*Households	same as Production
HBS	cross-classification with household size and number of children	same as Production
External	use Average Week Day Volume multiplied with the percents from travel survey	N/A

Different from the aggregate zonal average trip production approach, a disaggregate household (or person) level trip production model requires more detailed information regarding household (or person) socioeconomics and demographics. Hence, this approach will be expected to provide the advantages of investigation of specific market segments and policy sensitivity. Detailed household activity surveys have been credited with providing more realistic information in simulations of travel decisions and more evidence on behavior as it is affected by urban development patterns and transportation infrastructure.

3.4 Proposed Activity-Based Trip Generation Model

The proposed approach is an activity-based demand modeling method that is reducible to the conventional approach, thus ensuring compatibility with the remainder of the four-step process. Due to the treatment of household variables used in the modeling process, the proposed trip production model can estimate trip rates from a person level to a household level, or from a household level to a zonal aggregate level. Using clustering techniques to analyze household activity diaries, direct analysis of individual time-space activity patterns leads to a primary grouping of homogeneous travel/activity patterns over survey respondents. One of the characteristics of this proposed research is to employ life cycle concepts in the analysis procedure. This feature allows for the investigation of the interaction and interdependence among household members and to identify the changes in behavior attributable to the variance in household status.

The operational trip generation model based on the proposed method includes three stages. First, an initial activity pattern classification task is executed which leads to a primary estimation of trip rates based on travel/activity patterns, life cycle type, and household role. At this stage, representative activity patterns (RAPs) are identified that include distinct travel/activity patterns, and an average trip rate is computed for each RAP. Second, selected household characteristics (socioeconomic, demographic) are utilized to conduct a cross classification of household travel pattern types. In this stage, the model parallels the conventional model for trip production but also maintains complete temporal and spatial information about the trips, encoded into each RAP. Third, to advance to a full activity-based demand modeling approach, the estimated activities and trips in a household's activity pattern are simulated with an appropriate network and land use data to complete the spatial distribution of the pattern's activities.

A household activity program spawns individual activity programs that implicitly reflect the decision rules and constraints across the household and individual levels. An aggregation of the resulting from a household member activity patterns can lead to a more precise estimation of trip productions resulting household's interactions and their social needs (see Figure 3.2) compared to a model that simply aggregates total trips across entire zones.

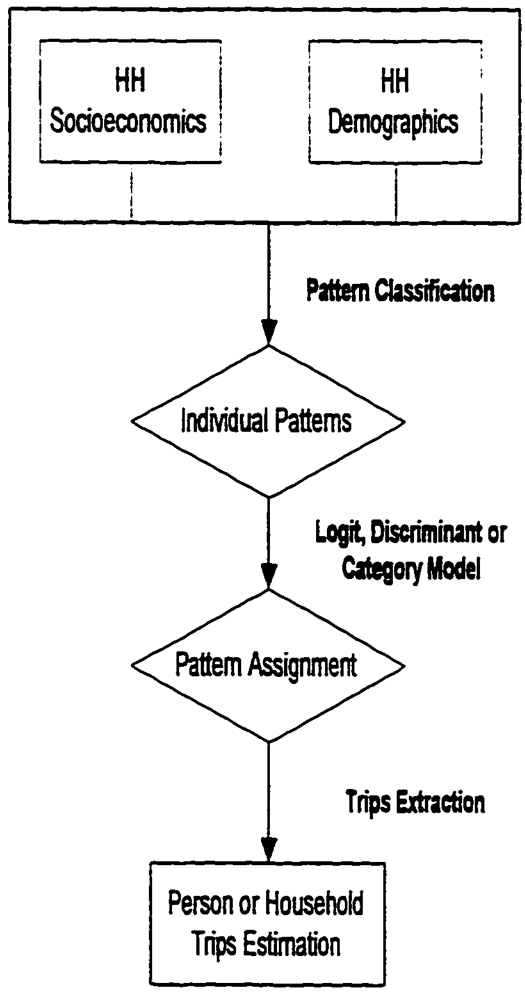


Fig 3.2 Proposed Activity-Based Household Trip Production Estimation Approach

In this research, the life cycle concept is used in the trip production phase as one of the category dimensions to capture the interdependence of household members. The household life cycle stage refers to the family structure and member composition through which a household evolves. The adopted concept takes into account structural changes in families such as number of family members or number of workers. For example, the interdependence between the adults and children in a family with one working parent will more likely affect the unemployed adult more than the other. In fact, the presence of children in the household is strongly correlated with the types and frequencies of activities pursued by the household and explicitly embedded in the activity patterns.

By knowing the life cycle status and associated household information, a representative travel/activity pattern can be easily assigned to each individual using a variety of techniques. By introducing life cycle as a level of analysis in the trip production process, the inter-dependencies between household members can be captured.

3.5 Summary

In this chapter, the trip generation methods developed with conventional approaches were discussed. Also, a new activity-based generation model is introduced. This new model maintains compatibility with the existent modeling process while also incorporating full temporal and spatial information lost in conventional approaches. The details of this model are presented in the following chapters.

Chapter 4

Research Methodology

4.1 Introduction

Travel is derived from the demand to participate in activities: it is a necessary complement for the performance of activities at different places and different times. In order to model travel behavior more completely, insight into the total activity pattern of individuals is necessary (Van Der Hoorn. 1979). Conventional trip production estimation is often based on observations aggregated in zones rather focused on individuals or households. consequently, the relationship between trip production and trip distribution is often based on aggregate concepts of gravity or entropy instead of individual traveling decisions. These zonal predictions do not realistically reflect the true interactions between demand and supply locations, and can lead to inaccurate transportation forecasts as well as non-efficient transportation investments.

Increasing attention has been drawn to the activity-based approach for transportation demand modeling. This approach allows for the use of a wider range of explanatory variables. The activity-based approach affords the chance to conduct demand modeling which provides an increased opportunity for more elaborate policy sensitivity tests given the increased utilization of data.

The approach proposed here is a synthesis of the conventional classification of economic variables and a life cycle stratification approach. This research not only addresses some of the deficiencies of conventional trip generation models. but also implicitly account for the complex interaction between individuals within a household revealed in their daily activity patterns. In Figure 4.1 (Jones, 1983), the spatial and temporal coordination among household members is illustrated; it is clear that the presence of a schoolchild may constrain the parent's mobility. The coordination of household member activities is not only constrained by temporal and spatial connectivity but also by transport mode availability and cost. An individual's activity pattern is a result of the interaction of household members instead of the utility an individual can gain.

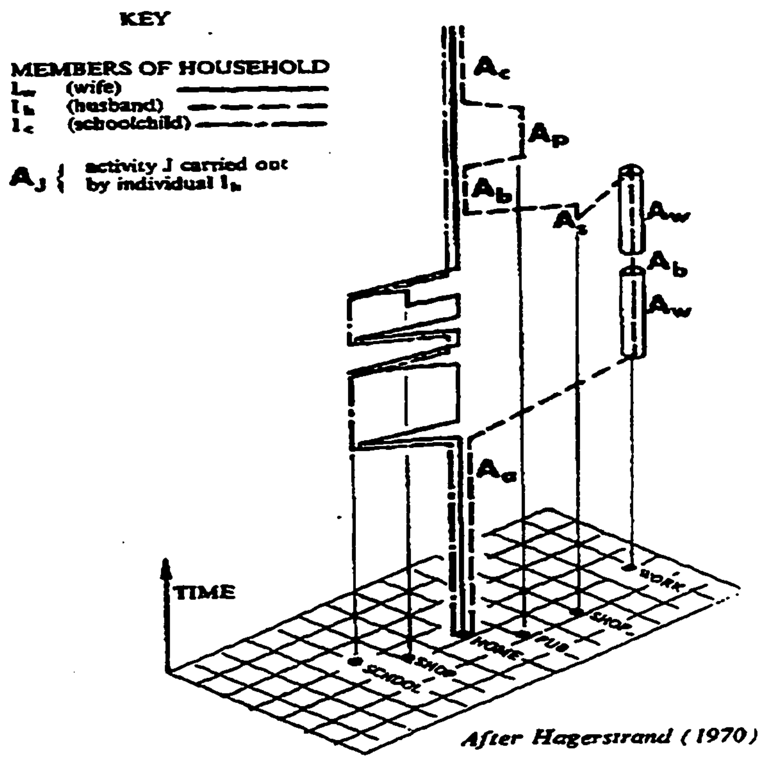


Fig 4.1 Household Member Travel/activity Interaction (Jones et al., 1983)

4.2 Research Framework and Methodology

The proposed framework is formulated as a two step process which is based on conventional data comprising a household travel/ activity survey and household characteristics. First, travel/activity patterns are classified by their temporal and spatial characteristics; each pattern denotes the general structure of behavior which its members, on average, reveal. A classification algorithm is used to generate distinct household travel/activity patterns for each life cycle group. Second, a variety of household and individual person characteristics are used to identify the choice of a specific pattern alternative, for example, category models or discriminant analysis.

4.2.1 Pattern Classification

Clustering is a means of grouping sets of objects to minimize intra-group differences and maximize inter-group differences. There are several clustering algorithms which heuristically cluster cases based on some measure of inter-object distances. These algorithms differ on the distance measures used and on the mechanisms for starting or splitting clusters, for updating them and for reassigning members to clusters.

The clustering algorithm used in this research is a k-means algorithm patterned after procedures developed after Ball and Hall (1965) and MacQueen (1967) to minimize the variance of within group dispersion and produce the most distinct group collections. The K-means algorithm was chosen over a hierarchical scheme since no explicit evolutionary development of pattern was assumed to exist.

The first step of this algorithm is to initiate K profiles as initial cluster centroids to form the staring representative activity patterns (RAPs) then to measure the score of each observed activity pattern. The scoring function utilizes an Euclidem metric for ordinal variables (type of activity and distance from home are treated as ordinal variables in this research), then a mean pattern distance relative to the selected centroids is calculated and the observed activity pattern is assigned to the most closest centroid. Second, the cluster new centroids are re-computed after each iteration of assignment, and the observed activity pattern are re-assigned to the new set of K-centroids. The process continues until memberships of each group become stable or no further improvement can be made.

However, the choice of the number of clusters is very subjective and the criteria to determine an optimal number of groups is described as follow:

1. The size of each cluster.
2. The diversion of patterns from a less number of groups to a higher number.
3. The membership stability through each number of groups.

The analysis of activity patterns is treated as a classification problem where a set of characteristic measurements is utilized to define the travel/ activity participation. In order to measure the similarity of activity/travel behavior, a time incremental measurement of distance and activity type were developed. Each individual's daily travel-activity pattern is divided into N slices, and each slice is coded with the information of time of day, activity type and the distance between home and concurrent activity location. For example, in Figure 4.2, the activity pattern can be divided into N time increments associated with activity type and distance from home, and the distance to a selected centroid is computed as Equation 4.1.

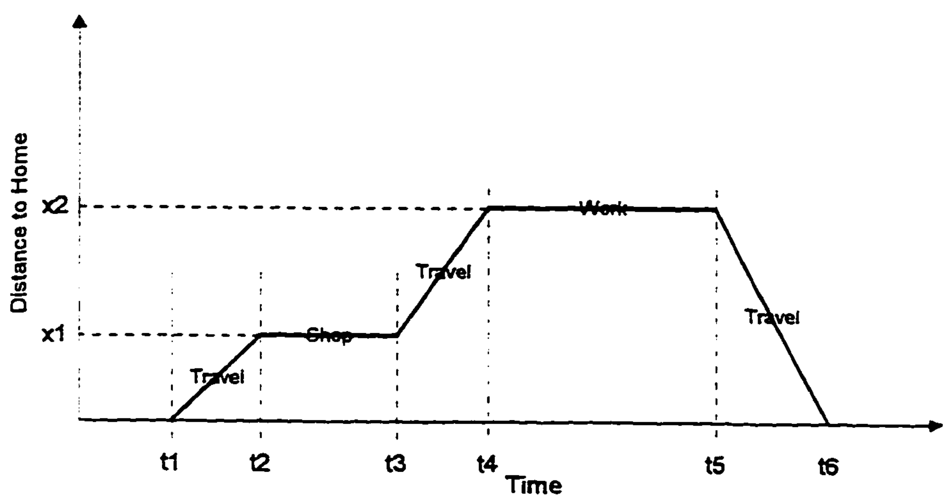


Figure 4.2 Distance and Activity Type

$$\text{Distance to Centroid k} = \sum_{i=1}^{N}\{\beta_1(g_i - \tilde{g}_{ik})^2 + \beta_2(f_i - \tilde{f}_{ik})^2\}$$

where:

k = selected centroid k

β_1, β_2 = arbitrary number (1 for this research) (4.1)

g_j = activity type $(j = 1, N)$

f_j = distance from home $(j = 1, N)$

g_{ik}, f_{ik} = values o activity type and distance from home for centroid k at time increment i

4.2.2 Linking Persons to Representative Activity Pattern

The coordination of household members' activity program resulted from combining household needs with the characteristics of trips in time and space dimensions. Therefore, some variables regarding household demographics (adult, child) and socioeconomics (car ownership, employed) should be also considered in the process of the RAPs identification. A discriminant analysis and a person category model are thought to be used for pattern choice purpose, and the prototype model of matching individuals with RAPs is shown in Figure 4.3.

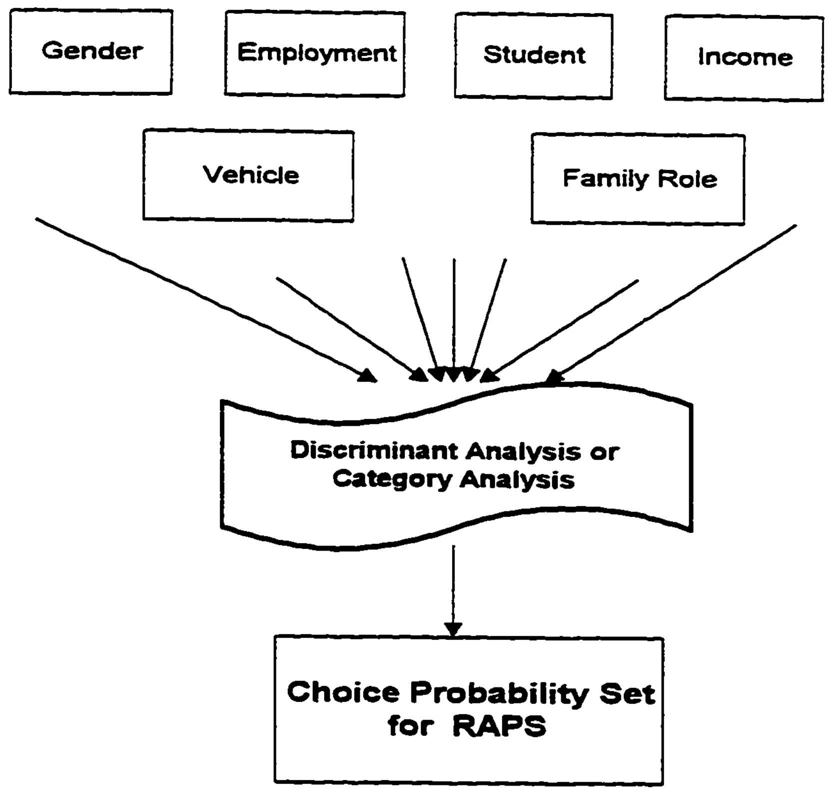


Fig. 4.3 Prototype Travel/activity Pattern Choice Model

4.3 Summary

Temporal and spatial characteristics of household activities are compared to classify activity patterns, which implicitly includes not only the trips/activities generation but also the directional information of activity locations. By clustering the one day activity pattern of individuals, the general structure of homogeneous travel/

activity patterns can be understood. A variety of household and person level variables in a discriminant analysis and a category model could be used to predict the choice of a representative pattern for each individual, and different socioeconomic status persons would be sensitive to the choice of activity patterns.

Based on the research framework above, the choice of pattern can be simulated and where trip rates can also be estimated. An empirical analysis with Portland area data has been applied with the proposed research framework, and further description of the analysis of activity patterns will be given in the next chapter.

Chapter 5

Empirical Analysis of Data

5.1 Introduction

In this chapter, an comprehensive empirical analysis of activity patterns is provided. First, the selection of the data source is made based on availability and the richness and completeness of the data regarding households as well as environmental information. The life cycle variable is used to capture the effects of household interaction. The details of constructing life cycle groups and tasks on data processing are described in section 5.3 and 5.4. respectively. An auxiliary product of this activity-based research is the derivation of trips from activity patterns that this will be introduced in section 5.5.

5.2 Data Selection

The proposed approach requires a comprehensive travel diary with detailed information on household demographics, activity scheduling, and activity locations. A compete database must include the following data:

1. Travel/activity diary

2. Household information

3. Person information

4. Network & land use data, etc..

Initially, two possible data sets were considered: the 1991 Southern California Association of Governments (SCAG) Origin/Destination Household Survey and the Portland Household Survey. The SCAG O/D Survey covers the majority of five counties in southern California, including Los Angeles, Orange, Riverside, Ventura and San Bernandino counties. The most recent 1991 SCAG data set includes approximately 13,000 one day out-of-home travel diaries. A sub-sample of the 1991 SCAG data set was used to investigate the temporal stability of activity patterns in comparison to similar work done by Recker *et al.* (1981) with 1976 data in the Orange County area. But this data set only provided the out-of-home activity records and does not provide any information of substitution between in-home and out-of-home activities. In addition, geocoding of trip locations has been problem and is incomplete.

The data used in this research include two independent sets of household travel/activity diaries collected in 1985 and 1994 in the Portland metropolitan area. The data adopted from the 1994 Portland Household survey is made up of a two day in-home and out-of-home activity diaries, only weekday records are utilized. The survey area covers Multnomah County, Clackamas County, Washington County, and sections of Columbia County and Yamhill County (see Figure 5.1). Technically, the data set is composed of a household file, a person file, an activity diary file, and a household vehicle file. External files of activity distances and network topology are also available.

In 1994, activity diaries were collected for all members of the sampled households: 4,451 households with 10,048 persons are collected in this database. After filtering incomplete records and inconsistent information, 1,652 households with 3,241 persons with complete location coordinates and weekday diary records were employed in the study. The specific activity diary records were then extracted using corresponding household and person identification numbers, where each out-of-home activity was associated with a shortest path travel distance.

In comparison to the 1994 data set, the 1985 travel/activity diary has less complete household observations and less spatial information about activity locations. To obtain the traveling distances and distances from home for this study, the 1994 (1260 TAZs -Traffic Analysis Zones) network was reduced to the 1985 (400 TAZs) network for distance estimation. A TAZs equivalence table was created by visual examination on the 1994 and 1985 network maps, and distance was measured utilizing the shortest path algorithm in TRANPLAN.

A subsample of 1,500 households was drawn from the 4,910 households in the 1985 study; the rest of households were discarded due to inconsistent household data or missing person trip records, but the resulting subsample for the two years are similar.

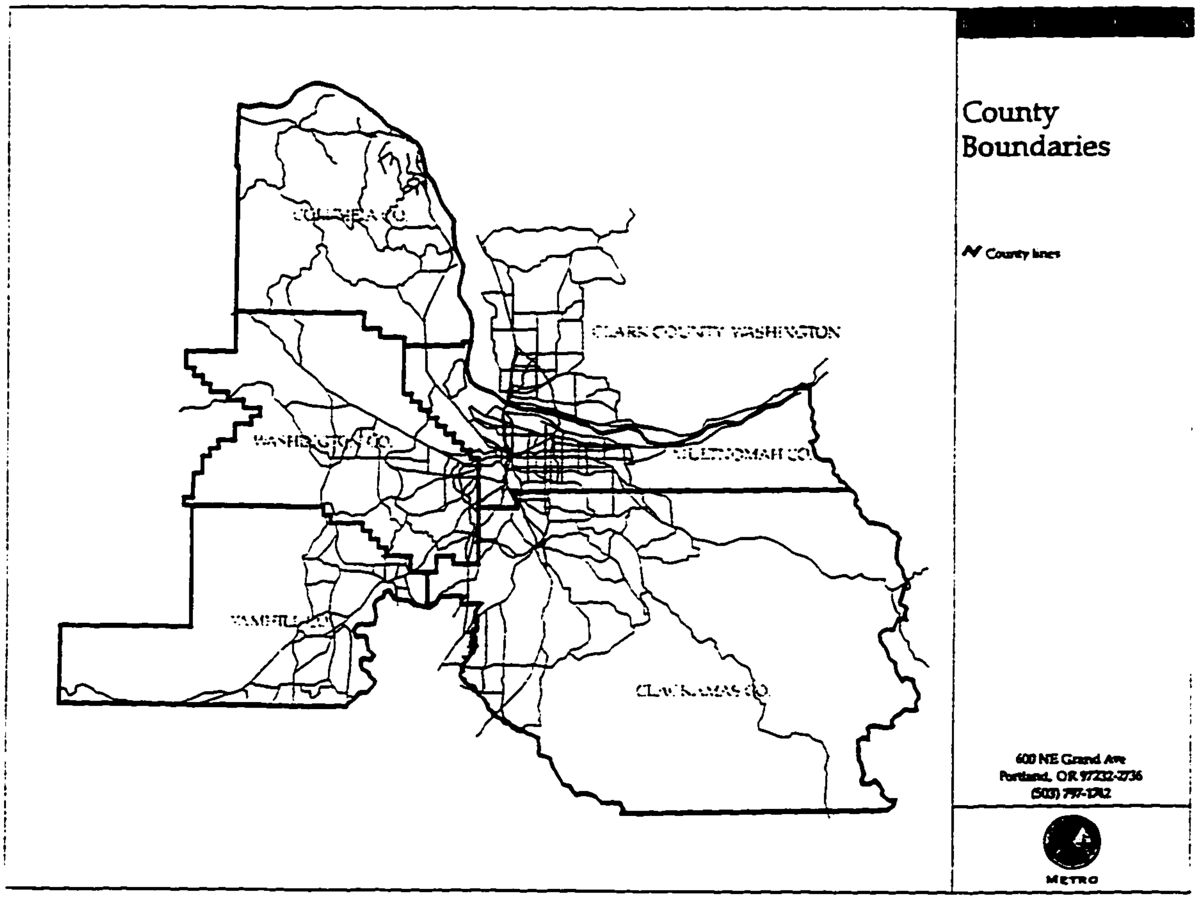


Fig 5.1 Portland Metropolitan Map (Source: Portland METRO)

5.3 Construction of Life Cycle Groups

The extracted 1985 and 1994 Portland household weekday activity/travel diaries contain the necessary information of household activity and travel demand. This specific data set includes a comprehensive, travel activity diary for each household member in addition to a basic socioeconomic profile. The concept of life cycle is used to divide this subsample to six major groups to represent six defined life stages, and the definition of life cycle groups as well as the resulting number of participants are provided in Table 5.1 and Table 5.2 respectively. It is believed (Jones, 1983; Stopher, 1995) that person's travel pattern would be modified as his (her) life stage advances to the others as the constraints coming from the family role and responsibility.

In this research, children's travel/activity patterns are processed separatedly from their adult family members. Since one of the hypotheses of this research is that life cycle may affect household travel-activity patterns. The interdependence between the adult family members and the under-age children will result in spatial and temporal constraints on each other's travel decisions.

It should be noted that the 1985 survey data used in this research only includes out of home trip records, and the duration of activity is estimated by subtracting an estimated waiting time from the time between previous trip end time and next trip start time. Similar oriented activities are collected into the same category for the convenience of summarization, and four major types of activity are chosen arbitrarily. The correspondence tables to categorize activities into four major groups (maintenance, discretionary, work/school and travel/activity/pick-up/drop-off) for the 1985 and 1994 data are given in Table 5.3 and 5.4, respectively.

Table 5.1 Life Cycle Group Hierarchy

Description of Group	Feature
Type 1. Male or female single person household	Single person and age > 14
Type 2 Single parent household	Single parent Any child's age below 18 years old
Type 3 Couples without children	Married or unmarried couples No children
Type 4 One working parent family	Only one worker (part or full time) Any child's age below 18 years old
Type 5 Both working parents family	Two workers (part or full time) Any child's age below 18 years old
Type 6 Others	Any type not in the above categories

Table 5.2 Sample Distribution of Different Life cycle Groups

Life Cycle Type	1985 Survey		1994 Survey	
	Persons	Households	Persons	Households
1. Single person	414	414	667	667
2. Single parent	231	99	196	75
3. Couples w/o children	908	454	852	426
4. One working parent	466	136	393	104
5. Both working parents	684	170	709	192
6. Others	510	227	424	188
Total	3213	1500	3241	1652

Table 5.3 Summary of 1985 Survey Activity Classification

Code	Original Activity	Activity Classification
0	Home	N/A
1	Work	Work/School
2	Shopping-grocery	Maintenance
3	Shopping -other	Maintenance
4	Personal Business	Maintenance
5	Social Recreation	Discretionary
6	Dine Out	Discretionary
7	School	Work/School
8	Serve Passengers	Travel
9	Change Travel	Travel

Table 5.4 Summary of 1994 Survey Activity Classification

Code	Original Activity	Activity Classification
11	Meals	Maintenance
12	Work	Work
13	Work-related	Work
14	Shopping (general)	Maintenance
15	Shopping (major)	Maintenance
16	Personal services	Maintenance
17	Medical care	Maintenance
18	Professional services	Maintenance
19	HH or Personal business	Maintenance
20	HH maintenance	Maintenance
21	HH Obligation	Maintenance
22	Pick-up/Drop-Off	Activity/Travel
31	Visiting	Discretionary
32	Casual entertaining	Discretionary
33	Formal entertaining	Discretionary
41	School	Maintenance
42	Culture	Discretionary
43	Religion/Civil Service	Maintenance
44	Civil	Discretionary
45	Volunteer work	Discretionary
51	Amusements (at home)	Discretionary
52	Amusements (out of home)	Discretionary
53	Hobbies	Discretionary
54	Exercise/Athletics	Discretionary
55	Rest and relaxation	Discretionary
56	Spectator athletic events	Discretionary
90	Incidental trip	Activity/Travel
91	Tag along trip	Activity/Travel

In this empirical analysis, data were classified by household structure and divided into the six major life cycle groups as described in Table 5.1. The 1652 households (3241 persons) in the 1994 data set and 1500 households (3223 persons) in the 1985 data set, each with complete activity site geocoding information, are classified into six groups of (1) single persons, (2) single parents with children, (3) couples without children, (4) one working parent family with children, (5) two working parents family with children, and (6) households not in the previous categories. The distribution of reported activities (both in-home and out-of-home) is provided in Table 5.4 for the 1994 data (no in-home activities were reported in the 1985 data). However, some household members did not perform any out-of-home activities during the survey period; the breakdowns between those with and without reported travel, are shown by life cycle group in Table 5.6 and Table 5.7 for the 1985 and 1994 surveys, respectively.

Table 5.5 1994Portland Survey Activity Distribution

Activity	Frequency			Percent	
	In-Home	Out-of-Home	Total	In-Home	Out-of-Home
Work/School	1557	4913	6470	5.75%	18.13%
Maintenance	6468	2977	9445	23.87%	10.99%
Discretionary	6976	2885	9861	25.75%	10.65%
Travel/Activity/ Pick-up/Drop-off	0	1316	1316	0.00%	4.85%
Total	15001	12091	27092	55.37%	44.63%

Table 5.6 Number of Household Participants in 1985 Survey

Life Cycle	Adult		Child (Age ≤ 18)	
	Person Making No Trips	Person Making Trips	Person Making No Trips	Person Making Trips
1. Single Person	40	374	N.A.	N.A.
2. Single Parent	5	94	25	107
3. Couples w/o Kids	216	692	N.A.	N.A.
4. One Working Parent	96	176	41	153
5. Both Working Parents	28	312	73	271
6. Others	168	342	N.A.	N.A.

Table 5.7 Number of Household Participants in 1994 Survey

Life Cycle	Adult		Child (Age ≤ 18)	
	Person Making No Trips	Person Making Trips	Person Making No Trips	Person Making Trips
1. Single Person	112	555	N.A.	N.A.
2. Single Parent	9	66	24	97
3. Couples w/o Kids	158	694	N.A.	N.A.
4. One Working Parent	30	178	34	151
5. Both Working Parents	32	352	44	281
6. Others	96	342	N.A.	N.A.

5.4 Analysis of Trips, Activities and Patterns

To process the raw trip diaries, several FORTRAN computer programs were written to test for data consistency and to extract appropriate attributes. The selected household activity records were identified and their daily patterns were divided into 10 minutes segments which specify activity type and distance from home. Given the information about activity type and distance from home, a selected time period from 5:00 AM to 24:00 AM (midnight) is used in this study.

The following analysis stage were executed:

1. Identification of sampled household by life cycle group.
2. Construction of activity and travel temporal distributions.
3. Insertion of transition points for trip chains (if appropriate).
4. Segmentation of the diary into 10 minute slices (only 5 to 24 AM is used).
5. Cluster Analysis by life cycle group and the distribution of group centroids.

The selection of the number of clusters is based on the distribution of group centroid points, and some subjective judgment may be made to exclude the outlier points for a more reasonable clustering result. In each clustering process, the size of distinct patterns is also an important factor for judging whether an optimal result is obtained. Then, the clustering process is repeated at least five times with different starting points to find the best result. By repeating the above process for each life cycle group, various numbers of distinct travel/activity pattern groups have been obtained.

Based on the household selected from the 1985 and 1994 data (see Table 5.6 and Table 5.7 for household distribution in each life cycle), the general description of each pattern is provided in Table 5.8A, Table 5.8B and Table 5.9A, Table 5.9B for the 1985 and 1994 data, respectively, but pattern of person reporting no trips made is not included in these tables. Also, a comparison table of these representative activity patterns of the 1985 and 1994 data is provided in Table 5.10A and Table 5.10B.

Table 5.8A 1985 Representative Activity Pattern

Life Cycle (adult, child)	Pattern (%)	Description (only persons reported trips are described here)
Single Person (374,0)	1A (7%)	Typical 8 to 5 work schedule followed by discretionary activity in the evening outsides
	1B (59%)	Part-time workers with a lot of discretionary activities during the day
	1C (34%)	Typical 8 to 5 workers
Single Parent (94, 107)	2A (20%)	Maintenance activity (almost staying home) during the day and more evening discretionary activities outsides
	2B (22%)	Typical 8 to 5 workers
	2C (29%)	Typical 8 to 5 worker with evening discretionary activity outsides
	2D (29%)	Part-time workers with afternoon discretionary activity
	2KA (21%)	Typical 8 to 3 school children with evening discretionary activity outsides
	2KB (36%)	Typical 8 to 3 school children with rare out-of-home activity after school
	2KC (43%)	A mixed schooling and discretionary activities during the day
Couples w/o Children (692,0)	3A (7%)	A mixed work and discretionary activities during the day
	3B (5%)	Very little work activities with relatively high discretionary activities
	3C (5%)	Part-time worker with intensive discretionary activities during the day
	3D (40%)	Mainly discretionary and maintenance activities
	3E (43%)	Typical 8 to 5 workers

Table 5.8B 1985 Representative Activity Pattern

Life Cycle (adult, child)	Pattern (%)	Description (Only persons reported trips are described here)
One Working Parent (176, 153)	4A (9%)	Part-time workers with evening discretionary activity
	4B (43%)	Typical 8 to 5 workers
	4C (12%)	Mainly discretionary activity in mid-morning and evening
	4D (12%)	Workers with some evening discretionary activities
	4E (21%)	Part-time workers with very intensive discretionary activities throughout the day
	4KA (74%)	School children with some evening discretionary activities
	4KB (20%)	Very little schooling with intensive discretionary activity during the day
	4KC (6%)	Mixed school and discretionary activity before 4 PM
Both Working Parents (312, 271)	5A (76%)	Typical 8 to 5 workers
	5B (20%)	Part-time workers with intensive maintenance activity
	5C (19%)	Part-time and full-time workers with discretionary activity mixed during the day
	5D (31%)	Part-time worker with intensive traveling before and after work
	5KA (39%)	School children with evening discretionary activity
	5KB (21%)	School children with evening intensive discretionary activity in comparison to 5KA
	5KC (10%)	Mainly staying at home and evening discretionary activity
	5KD (30%)	Very little schooling but with late afternoon discretionary activity

(continued)

Others (342, NA)	6A (10%)	Part-time workers with intensive evening discretionary activity
	6B (33%)	Mixed work and discretionary activity in midday
	6C (39%)	Typical 8 to 5 workers
	6D (7%)	Rare activity in the day and discretionary activity starts from the evening
	6E (11%)	Typical workers or students during the day and with evening discretionary activity

Table 5.9A 1994 Representative Activity Pattern

Life Cycle (adult, child)	Pattern (%)	Description (Only persons reported trips are described here)
Single Person (555,0)	1A (23%)	Mixed activities at locations near home
	1B (5%)	Part-time workers with intensive traveling during the day
	1C (32%)	Typical 8 to 5 workers with evening discretionary activity
	1D (30%)	Mixed work, maintenance and discretion in mid day
	1E (10%)	Mainly staying home activities
Single Parent (66, 97)	2A (15%)	Possible night shift workers and rare activity during the day time hours
	2B (33%)	Part-time workers with maintenance activity during the day
	2C (52%)	Typical 8 to 5 worker with evening discretionary activity
	2KA (39%)	School children with evening discretionary activity
	2KB (37%)	Mainly staying home activities
	2KC (8%)	Mainly discretionary and maintenance activities
	2KD (15%)	Some school children and part-time workers with discretionary activity
Couples w/o Children (694, 0)	3A (43%)	Mainly staying home with maintenance activity in mid day
	3B (9%)	Mixed part-time and full-time workers with evening activities
	3C (36%)	Typical 8 to 5 worker with evening discretionary activity
	3D (12%)	Mainly maintenance mixed with some work and discretionary activities

Table 5.9B 1994 Representative Activity Pattern

Life Cycle (adult, child)	Pattern (%)	Description (only persons reported trips are described here)
One Working Parent (178, 151)	4A (44%)	Mixed maintenance and discretionary activities in the day
	4B (17%)	Mixed maintenance, discretionary activities associated with traveling
	4C (39%)	Typical 8 to 5 workers
	4KA (14%)	School children with afternoon discretionary activity
	4KB (27%)	Mixed maintenance, discretionary activities and traveling
	4KC (42%)	Typical 8 to 3 school children
	4KD (17%)	Only discretionary activity associated with traveling
Both Working Parents (352, 281)	5A (17%)	Part-time workers with mixed maintenance activity associated with traveling
	5B (29%)	Part-time workers with discretionary activity mixed during the day
	5C (54%)	Typical 8 to 5 workers with evening discretionary activity
	5KA (43%)	School children with a lot of evening discretionary activity
	5KB (57%)	Typical 8 to 3 school children
Others (342, NA)	6A (37%)	Typical 8 to 5 workers
	6B (25%)	Part-time workers with maintenance and discretionary activities during the day
	6C (34%)	Workers without fixed schedule during the day
	6D (4%)	Mainly staying at home activities and some part time workers

Table 5.10A Membership Correspondence Table

Life Cycle (% of '85 LC, % of '94 LC)	1985 Data (% of Sample)	1994 Data (% of Sample)
Single Person (27.6%, 40.4%)	1A(7.0%)	1B (4.9%)
	1B(59.4%)	1A(22.7%), 1D(30.1%), 1E(10.1%)
	1C(33.6%)	1C(32.3%)
Single Parent (6.6%, 4.5%)	2A(20.3%)	2B(33.3%)
	2B(22.3%)	
	2C(28.7%)	2C(51.5%)
	2D(28.7%)	2A(15.2%)
	2KA(20.6%)	2KB(37.1%)
	2KB(34.6%)	
	2KC(44.9%)	2KA(39.2%), 2KC(8.2%), 2KD(15.5%)
Couples without Children (30.3%, 25.8%)	3A(7.1%)	3B(9.1%)
	3B(4.8%)	
	3C(5.1%)	3D(12.1%)
	3D(40.2%)	3A(43.2%)
	3E(42.9%)	3C(35.6%)

LC: Life Cycle

Table 5.10B Membership Correspondence Table

Life Cycle (% of '85 LC, % of '94 LC)	1985 Data (% of Sample)	1994 Data (% of Sample)
One Working Parent (9.1%, 6.3%)	4A(7.4%)	
	4B(43.3%)	4C(39.3%)
	4C(12.4%)	4A(43.8%)
	4D(21.0%)	
	4E(16.2%)	4B(16.9%)
	4KA(65.4%)	4KA(13.9%), 4KC(41.7%)
	4KB(19.0%)	4KB(27.1%)
	4KC(15.6%)	4KD(17.2%)
Two Working Parents (11.3%, 11.6%)	5A(32.1%)	5C(54.0%)
	5B(17.9%)	
	5C(19.2%)	5A(17.0%), 5B(29.0%)
	5D(30.8%)	
	5KA(38.7%)	
	5KB(9.2%)	
	5KC(10.0%)	5KA(43.1%)
	5KD(42.1%)	5KB(56.9%)
Others (15.1%, 11.4%)	6A(10.2%)	
	6B(33.2%)	6B(25.4%), 6C(33.6%), 6D(4.1%)
	6C(38.6%)	6A(36.8%)
	6D(7.3%)	
	6E(10.5%)	

LC: Life Cycle

5.5 Trip Rates by Groups

This research uses traveler's trajectories in time and space (travel/ activity pattern) as a tool to analyze the temporal and spatial distributions of trips, and representative activity patterns are served as the typical structures of trip distribution. With the proposed methodology, several distinct travel/activity patterns are obtained for each life cycle group with the proposed methodology; and general summary tables of activities and trips for each life cycle group are provided in Table 5.11 and Table 5.12 for 1985 and 1994 data, respectively. The detailed break-down for representative travel/activity patterns for each life cycle category is provided in the appendix. The activity and trip rates are computed for the diary hours (5AM - 24 AM) arbitrarily selected in the research, thus, these rates underestimate daily rates and categorized into work/school, maintenance, and discretionary activity purposes.

All distinct non-home activities were recorded, as well as any travel needed to access any activity locations. The in-home activity for the return trip to home is also recorded, as are all other in-home activities with durations greater than 30 minutes. Most non-home activities typically are paired with a trip required to access the activity location (such as commuting to work). Some non-home activities, although distinct, occur at the same location as the prior activity and thus do not require travel (such as eating lunch at your desk while at work). Each non-home activity chain terminates with a return trip to home; the purpose of this trip is recorded as the in-home activity performed upon arrival. Depending on the degree of trip chainings, the value of trips to activities will vary (see Figure 5.2).

Example	Trips	Non-home Activity	Ratio
1. H-t-NH-t-H	2	1	2.0
2. H-t-NH-t-NH-t-H	3	2	1.5
3. H-t-NH-NH-t-H	2	2	1.0
H= Home; NH= Non-home; t= travel			

Fig. 5.2 Sample of Home-based Trip Chains

Table 5.11 Average 1985 Trip Rates for Life Cycle Groups
(trips per person)

Life Cycle N= Observations		Work/ School	Maintenance	Discretionary	Pick-up/ Drop-off	Total
1.Single Person N= 374	Trip	1.16 (0.55)	1.29 (0.92)	0.95 (0.78)	0.13 (0.07)	3.53 (1.92)
2.Single Parent N= 201	Trip	1.44 (0.68)	1.46 (0.98)	0.95 (0.63)	0.92 (0.85)	4.77 (2.18)
3.Couples w/o Children N= 692	Trip	1.24 (0.79)	1.21 (0.52)	0.87 (0.85)	0.65 (0.43)	3.97 (2.78)
4.One Working Parent N= 329	Trip	1.32 (0.68)	1.33 (0.83)	0.99 (0.75)	0.95 (0.85)	4.59 (2.16)
5.Both Working Parents N= 583	Trip	1.62 (0.74)	1.12 (0.86)	0.93 (0.69)	0.86 (0.44)	4.53 (2.11)
6.Others N= 342	Trip	1.33 (0.99)	1.17 (1.02)	0.94 (0.93)	0.58 (0.65)	4.02 (3.02)

( ): for Standard Deviation

Table 5.12A Average 1994 Activity/Trip Rates for Life Cycle Groups
(trips per person)

Life Cycle N= Observations		Work/ School	Maintenance	Discretionary	Pick-up/ Drop-off	Total
1.Single N= 555	Act.	1.15 (1.05)	1.88 (0.93)	2.14 (1.13)	0.29 (0.15)	6.60 (3.90)
	Trip	1.51 (0.63)	1.02 (0.32)	0.85 (0.28)	0.27 (0.17)	3.65 (1.44)
2.Single Parent N= 163	Act.	2.93 (1.32)	2.00 (1.11)	1.49 (0.97)	0.93 (0.44)	7.35 (3.49)
	Trip	1.72 (0.78)	1.47 (0.55)	1.01 (0.37)	0.84 (0.33)	5.04 (1.87)
3.Couples w/o Children N= 694	Act.	2.29 (1.53)	1.97 (0.93)	2.06 (0.88)	0.66 (0.34)	6.98 (3.77)
	Trip	1.57 (0.78)	0.92 (0.26)	0.89 (0.47)	0.63 (0.47)	4.01 (1.76)
4.One Working Parent N= 329	Act.	2.83 (1.91)	1.84 (1.03)	1.81 (0.96)	0.66 (0.37)	7.14 (4.57)
	Trip	1.6 (1.21)	1.33 (0.58)	1.15 (0.76)	0.62 (0.41)	4.70 (2.88)
5.Both Working Parents N= 633	Act.	2.68 (0.57)	1.63 (0.93)	1.49 (0.62)	0.69 (0.51)	6.49 (1.52)
	Trip	1.80 (0.22)	1.21 (0.65)	1.02 (0.48)	0.64 (0.43)	4.67 (1.53)
6.Others N= 342	Act.	2.08 (1.51)	1.72 (1.21)	1.84 (1.02)	0.28 (0.21)	5.92 (3.87)
	Trip	1.40 (1.13)	1.28 (0.85)	1.17 (0.92)	0.27 (0.26)	4.12 (2.83)

( ): for Standard Deviation Act. = Activity

Table 5.12B Average 1994 Non-home and To-home Activity/ Travel for Life Cycle Groups

Life Cycle N= Observations		Average Non-home	Average To-home	Total	Compared to 1985 Data
1.Single N= 555	Act.	2.21	4.39	6.6	N.A.
	Trip	2.01	1.64	3.65	+3.4%
2.Single Parent N= 163	Act.	2.74	4.61	7.35	N.A.
	Trip	2.61	2.43	5.04	+5.7%
3.Couples w/o Children N= 694	Act.	2.05	4.93	6.98	N.A.
	Trip	2.04	1.97	4.01	+1.0%
4.One Working Parent N= 329	Act.	2.71	4.43	7.14	N.A.
	Trip	2.47	2.23	4.70	+2.4%
5.Both Working Parents N= 633	Act.	2.89	3.60	6.49	N.A.
	Trip	2.58	2.09	4.67	+3.1%
6.Others N= 342	Act.	1.3	4.62	5.92	N.A.
	Trip	2.09	2.03	4.12	+2.5%

Because of the 1994 data is an activity/travel survey which records any activity lasting more than 30 minutes in-home and all out-of- home and activities (and trips), a greater number of trips compared to conventional trip diaries. From Table 5.11 and Table 5.12B, a slight increase (1.0%-5.7%) in overall trip rates at the person level has been observed in each life cycle group. It should be noted that income distribution and land use pattern may have changed between the two survey periods, change in trip generation should be expected. However, the goal of this dissertation research is to derive the travel/activity patterns where the trip rates can be estimated. Therefore, the temporal stability of activity patterns is essential for future year forecasting.

5.6 Temporal Stability of Activity/ Travel Patterns

Besides modeling travel needs by classifying travel/activity patterns, Recker *et al.* (1982) and Pas (1983) have found similar characteristics in the household activity/travel patterns from a temporal and spatial perspective. McNally and Wang (1995) utilized a data from the 1976 and 1991 SCAG Household Surveys to investigate the temporal stability among household travel/activity patterns. A goal of this research is to identify temporal stability of household travel/activity patterns in the 1985 and

1994 Portland household surveys, so this proposed research framework can be used for transportation demand forecasting purpose.

Temporal stability is interpreted in terms of the distributions of distance from home and activity type over time. Similarity was assessed via a two stage process: first, the representative patterns identified in the 1994 data were matched with those representative activity patterns identified in the 1985 data, with respect to activity types and distances from home at different times during the day. Second, those observed activity patterns from the 1994 data were matched with the identified representative activity patterns of the 1985 data with respect to the distance from home and activity type at different time. Third, a simple comparison of the time-space pattern for the closest matched patterns was made and the percentage distribution of activity types accessed.

Although a quantitative measure of a pattern's activity type and distance from home at different times is reliable when two representative activity patterns have similar activity (trip) starting times, an earlier or later activity (trip) starting time will possibly make the matching result total different. Therefore, visual examination will be applied to review their time-space image for a better adjustment. Though some patterns have been observed with a lag effect on activity starting (or ending) time, the whole pattern should be considered, and these patterns should be counted as similar if appropriate. In this circumstances, the visual examination helps to access which pattern fits better since both the effects of the type of activity and distance from home may all contribute to the measure. Besides the stability in pattern's time-space distribution, traveler's characteristics embedded in each pattern should also remain similar across the time, then we can use the travel/ activity pattern for future year transportation demand forecast.

Here, a cross comparison of 1985 and 1994 patterns' time-space images is provided for each life cycle group; personal characteristics associated with each pattern are summarized.

5.6.1 Assessing Stability Analysis via Cluster

In this section, the process of matching activity patterns of 1994 data with 1985 data was using a cluster algorithm is presented in two steps: matching representative activity patterns (RAPs) in the 1994 data with those of 1985 data, and to assign observed activity patterns of 1994 data to the RAPs of 1985 data. The first step is focused on an aggregate measurement of stability of representative activity patterns across two data sets, and the second step is focused on an analysis of pattern members and their membership distribution.

In the first step, the RAPs of 1994 data in each life cycle group are matched with those of 1985 data one by one starting with the pair that are the most similar in distributions of activities and distances from home at different times in comparison to the other pattern alternatives. In Tables 5.13 - 5.18, the Euclidean distance matrices for cross-matching the 1994 representative activity patterns with those of 1985 data are computed and shown. The value in each cell represents the relative distance to the targeted representative activity pattern of 1985 data, and the number is the aggregation of the Euclidean distance in the144 time increments used in this study (5AM-12AM; 10 minutes per increment).

The methodology for Euclidean distance computation is identical to the method of measuring the similarity of activity type and distance from home as described in Chapter 4 in this dissertation. The measure of fit between two activity patterns is defined by the sum of Euclidean distance for each time increment, and two characteristics (type of activity and distance from home) are used to computed the Euclidean distance. The Euclidean distance is formulated as follows:

$$\text{Total Euclidean Distance} = \sum_{i=1}^{N}\left[\sqrt{(g_{1i}-g_{2i})^2+(f_{1i}-f_{2i})^2}\right]$$

where:

$i = 1, N$; time increment

g_{1i}, g_{2i} = activity type for pattern 1 and 2

f_{1i}, f_{2i} = distance from home for pattern 1 and 2

The unit of Euclidean distance is arbitrary but provide the sense of relative scale, and the effects of type of activity and distance from home are equally weighted in this research. The best matched RAP pair is judged based on the magnitude of the total Euclidean distance, and the least is the best. The best matched RAPs pair indicates that both patterns have similar activity types and distance distributions compared to the alternative patterns. Euclidean distance value interprets how closely the patterns look alike, and a second best matched pattern may have very similar distributions of activity and distance also. This Euclidean distance provides a relative measure of closeness of two activity patterns, but this comparison is based on the relative comparison among all the alternative activity patterns. For example, pattern 1C of 1994 data is more close to pattern 1C than 1B of 1985 data, and pattern 1A of 1994 data is more close to pattern 1B than pattern 1A and 1C of 1985 data.

Table 5.13 Classification of 1994 RAPs into 1985 RAPs for Single Person Households

Euclidean Distance		From 1994				
	Pattern (members)	1A (126)	1B (27)	1C (179)	1D (167)	1E (56)
To 1985	1A (26)	387	155*	356	433	369
	1B (222)	77*	427	74	66*	101*
	1C (126)	415	297	58*	387	421

*: the best matched RAPs

Table 5.14A Classification of 1994 RAPs into 1985 RAPs for Single Parent Households

Euclidean Distance		From 1994		
	Pattern (members)	2A (10)	2B (22)	2C (34)
To 1985	2A (19)	288	105*	419
	2B (21)	421	259	98
	2C (27)	378	293	76*
	2D (27)	191*	147	341

*: the best matched RAPs

Table 5.14B Classification of 1994 Children's RAPs into 1985 RAPs for Single Parent Households

Euclidean Distance		From 1994			
	Pattern (members)	2KA (38)	2KB (36)	2KC (8)	2KD (84)
To 1985	2KA (22)	187	141*	259	311
	2KB (37)	74	296	216	111
	2KC (48)	57*	314	144*	89*

*: the best matched RAPs

Table 5.15 Classification of 1994 RAPs into 1985 RAPs for Couples without Children Households

Euclidean Distance		From 1994			
	Pattern (members)	3A (300)	3B (63)	3C (247)	3D (84)
To 1985	3A (49)	318	85*	117	379
	3B (33)	196	374	355	121*
	3C (35)	177	383	258	108*
	3D (278)	98*	405	334	187
	3E (297)	366	146	72*	344

*: the best matched RAPs

Table 5.16A Classification of 1994 RAPs into 1985 RAPs for Single Working Parent Households

Euclidean Distance		From 1994		
	Pattern (members)	4A (78)	4B (30)	4C (70)
To 1985	4A (15)	299	452	164
	4B (91)	315	428	84*
	4C (26)	88*	139	371
	4D (44)	403	355	114
	4E (34)	101	89*	387

*: the best matched RAPs

Table 5.16B Classification of 1994 Children's RAPs into 1985 RAPs for Single Working Parent Households

Euclidean Distance		From 1994			
	Pattern (members)	4KA (21)	4KB (41)	4KC (63)	4KD (26)
To 1985	4KA (113)	121*	325	77*	137
	4KB (29)	197	114*	102	294
	4KC (11)	338	186	287	105*

*: the best matched RAPs

Table 5.17A Classification of 1994 RAPs into 1985 RAPs for Both Working Parents Households

Euclidean Distance		From 1994		
	Pattern (members)	5A (60)	5B (102)	5C (190)
To 1985	5A (100)	367	317	103*
	5B (56)	189	199	178
	4C (60)	139*	154*	214
	4D (96)	201	209	190

*: the best matched RAPs

Table 5.17B Classification of Children's 1994 RAPs into 1985 RAPs for Both Working Parents Households

Euclidean Distance		From 1994	
	Pattern (members)	5KA (121)	5KB (160)
To 1985	5KA (105)	385	65
	5KB (25)	221	104
	5KC (27)	164*	211
	5KD (114)	217	43*

*: the best matched RAPs

Table 5.18 Classification of 1994 RAPs into 1985 RAPs for Life Cycle Group of Others

Euclidean Distance		From 1994			
	Pattern (members)	6A (126)	6B (87)	6C (115)	6D (14)
To 1985	6A (35)	341	185	206	104
	6B (114)	304	93*	153*	88*
	6C (132)	101*	104	199	164
	6D (25)	277	204	217	158
	6E (36)	158	233	254	142

*: the best matched RAPs

After determining the Euclidean distances between the patterns from 1985 and 1994 within each life cycle group, the second step of this matching process is to assign the observed activity patterns of the 1994 data are assigned to each representative activity pattern of the 1985 data based on the similarity of activity types and distances from home at different time (many to one matching). The representative activity patterns (RAPs) of the 1985 data are fixed to be the target centroids of each distinct activity pattern group, and the observed activity patterns of 1994 data are then assigned to the closest pattern group according to the similarity measurement described in session 4.2. In Tables 5.19 - 5.24, the assignment of observed activity patterns of 1994 data are shown, and the percentages in each cell can be considered as the percentage of members of the activity pattern group of the 1994 data being related to the representative activity pattern (RAP) in 1985.

Because of the difficulty of combining the household socioeconomic characteristics with those physical measurement of travelers' time-space distribution, the results from the assignment process do not reflect the similarity of household characteristics in terms of socioeconomic variables, but the daily traveling schedule. In order to amend this deficiency, a subjective visual examination of activity patterns and cross-tabulation of embedded household characteristics of each representative pattern will be used in the next section.

Table 5.19 Classification of 1994 Observed Patterns into 1985 RAPs for Single Person Households

Observations (%)		From 1994					Original 1985 Data Observations
Pattern		1A	1B	1C	1D	1E	
To 1985	1A	0 (0%)	27 (100%)	0 (0%)	0 (0%)	0 (0%)	26
	1B	126 (100%)	0 (0%)	53 (30%)	167 (100%)	56 (100%)	222
	1C	0 (0%)	0 (0%)	126 (70%)	0 (0%)	0 (0%)	126
Total (for 1994 Data)		126	27	179	167	56	

Table 5.20A Classification of 1994 Observed Adult Patterns into 1985 RAPs for Single Parent Households

Observations (%)		From 1994			Original 1985 Data Observations
Pattern		2A	2B	2C	
To 1985	2A	0 (0%)	22 (100%)	0 (0%)	19
	2B	0 (0%)	0 (0%)	15 (44%)	21
	2C	0 (0%)	0 (0%)	19 (56%)	27
	2D	10 (100%)	0 (0%)	0 (0%)	27
Total (for 1994 Data)		10	22	34	

Table 5.20B Classification of 1994 Observed Children Patterns into 1985 RAPs for Single Parent Household

Observations (%)		From 1994				Original 1985 Data Observations
Pattern		2KA	2KB	2KC	2KD	
To 1985	2KA	0 (0%)	27 (75%)	1 (12%)	1 (7%)	22
	2KB	11 (29%)	5 (14%)	3 (38%)	4 (27%)	37
	2KC	27 (71%)	4 (11%)	4 (50%)	11 (73%)	48
Total (for 1994 Data)		38	36	8	15	

Table 5.21 Classification of 1994 Observed Patterns into 1985 RAPs for Couples without Children

Observations (%)		From 1994				Original 1985 Data Observations
Pattern		3A	3B	3C	3D	
To 1985	3A	2 (0%)	55 (87%)	26 (11%)	0 (0%)	49
	3B	27 (9%)	0 (0%)	0 (0%)	38 (45%)	33
	3C	33 (11%)	0 (0%)	0 (0%)	46 (55%)	35
	3D	237 (79%)	0 (0%)	0 (0%)	0 (0%)	278
	3E	1 (0%)	8 (13%)	221 (89%)	0 (0%)	297
Total (for 1994 Data)		300	63	247	84	

Table 5.22A Classification of 1994 Observed Patterns into 1985 RAPs for One Working Parent Households

Observations (%)		From 1994			Original 1985 Data Observations
Pattern		4A	4B	4C	
To 1985	4A	0 (0%)	0 (0%)	6 (9%)	15
	4B	0 (0%)	0 (0%)	43 (61%)	91
	4C	35 (45%)	9 (30%)	0 (0%)	26
	4D	0 (0%)	0 (0%)	21 (30%)	44
	4E	43 (55%)	21 (70%)	0 (0%)	34
Total (for 1994 Data)		78	30	70	

Table 5.22B Classification of 1994 Observed Children Patterns into 1985 RAPs for One Working Parent Families

Observations (%)		From 1994				Original 1985 Data Observations
Pattern		4KA	4KB	4KC	4KD	
To 1985	4KA	20 (95%)	0 (0%)	55 (87%)	12 (46%)	113
	4KB	1 (5%)	35 (85%)	8 (13%)	0 (0%)	29
	4KC	0 (0%)	6 (15%)	0 (0%)	14 (54%)	11
Total (for 1994 Data)		21	41	63	26	

Table 5.23A Classification of 1994 Observed Adult Patterns into 1985 RAPs for Both Working Parents Households

Observations (%)		From 1994			Original 1985 Data Observations
Pattern		5A	5B	5C	
To 1985	5A	0 (0%)	0 (0%)	157 (83%)	100
	5B	11 (18%)	17 (17%)	18 (9%)	56
	5C	41 (69%)	78 (76%)	4 (2%)	60
	5D	8 (13%)	7 (7%)	11 (6%)	96
Total (for 1994 Data)		60	102	190	

Table 5.23B Classification of 1994 Observed Children Patterns into 1985 RAPs for Both Working Parents Households

Observations (%)		From 1994		Original 1985 Data Observations
Pattern		5KA	5KB	
To 1985	5KA	0 (0%)	67 (42%)	105
	5KB	8 (7%)	11 (7%)	25
	5KC	105 (87%)	1 (0%)	27
	5KD	8 (7%)	81 (51%)	114
Total (for 1994 Data)		121	160	

Table 5.24 Classification of 1994 Observed Adult Patterns into 1985 RAPs for Life Cycle of the Others

Observations (%)		From 1994				Original 1985 Data Observations
Pattern		6A	6B	6C	6D	
To 1985	6A	0 (0%)	0 (0%)	10 (9%)	2 (14%)	35
	6B	0 (0%)	59 (68%)	89 (78%)	12 (86%)	114
	6C	108 (86%)	28 (32%)	16 (14%)	0 (0%)	132
	6D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	25
	6E	18 (14%)	0 (0%)	0 (0%)	0 (0%)	36
Total (for 1994 Data)		126	87	115	14	

From Table 5.13 and Table 5.19 for single person households, most observed activity patterns of 1994 data are well-matched with a 1985 representative activity pattern except for pattern 1C. For pattern 1C of 1994 data, 70 percent of the participants are assigned to pattern 1C of 1985 data, where the other 30 percent are assigned to pattern 1B. Although representative activity pattern 1C of the 1994 data is not uniquely related to pattern 1C of the 1985 data, the majority of the observed patterns within 1C of the 1994 data are closest to representative activity pattern 1C of 1984 data. Based on the extent that observed activity patterns in 1994 are related to the representative activity patterns in 1985 data, an assessment of the temporal stability of activity patterns is supported in the single person household life cycle group.

From Table 5.14A and Table 5.20A for single parent family adult members, pattern 2C of 1994 data was split into two subgroups (patterns 2B and 2C of 1985) that are characterized by relatively high percentages of working activities during the daytime hours with an average distance of five miles from home. In fact, patterns 2B and 2C of the 1985 data look extremely similar but with different amounts of evening maintenance activity. From the corresponding activity distribution (see appendix), we conclude that pattern 2C is a combination of patterns 2B and 2C of 1985 data, which have increasing afternoon maintenance activities while the percentage of work activity slight decreases. Otherwise, patterns 2A and 2B of 1994 data are fully assigned to patterns 2D and 2A, respectively. Pattern 2A of 1985 data has an extremely low percentage of work activity in comparison to the others of the 1985 data, and pattern 2D of 1985 data has about 30 percent of work activity that extends to late evening. The majority of observed activity patterns of 1994 data for single parent family have generally inherited the time-space framework of patterns from the 1985 data, providing support for temporal stability for this life cycle group.

For the children in single parent families, the general tendency of school/work activities from 8 AM- 4 PM has been found in every pattern of both 1985 and 1994 data with different lengths of after school recreation. From Table 5.14B and Table 5.20B, although none of the patterns in the 1994 data has a complete match with the 1985 data, the tendency of transferring from one of the patterns in 1994 data to another specific pattern of 1985 data is observed in the tables.

For couples without children, pattern 3A of 1994 data has shown significant relation to pattern 3D of 1985 data, which is characterized with part time workers and a higher ratio of discretionary activity. Most of observed patterns 3B and 3C of 1994 data have been assigned to patterns 3A and 3E of 1985 data, respectively. Both have intensive work activity starting from 7 AM to 6 PM, but with different average distances from home. Otherwise, pattern 3D of 1994 data has been split into halves for patterns 3B and 3C of 1985 data, that have more maintenance and discretionary activities through the daytime hours conducted at a relatively small distance from home. Although some discrepancy is found in pattern transference, the majority of patterns of 1994 data still can be matched with similar representative activity patterns of 1985 data.

From Table 5.16A and Table 5.22A, pattern 4A of the 1994 data for one working parent families was split into patterns 4C and 4E of the 1985 data, each having a relatively high ratio of discretionary activity through the day. Pattern 4C of 1985 data indicates a longer distance from home for the morning activities, while pattern 4E of 1985 data shows the opposite with a high peak for late evening discretionary activity. Most of the observed activity patterns of 4B in the 1994 data correspond to pattern 4E of 1985 data, and most of those in group 4C in 1994 are separated into patterns 4B and 4D, both of which are characterized by regular working schedules and evening discretionary activity. As with couples without children, there is no one-to-one relationship between the 1985 and 1994 patterns. As shown in Tables 5.16A and 5.22 A, the five patterns of the 1985 data have emerged as three distinct patterns in the 1994 data. The majority of patterns 4B and 4C of the 1994 data are related to patterns 4E and 4B, and 55 percent of the observed activity patterns in 4A of the 1994 data are associated with pattern 4E of the 1985 data. Two patterns from the 1985 data seem to disappear, but, in fact, they have emerged into the other three patterns, which has created greater pattern distinctness. Further investigation on the socioeconomic and demographic characteristics of these participants will be done in the next section.

The assignment of activity patterns for children in one working-parent families is presented in Table 5.16 B and Table 5.22B. The tendency of patterns of the 1994 data being directly linked to an activity pattern in the 1985 data is found for the children activity patterns in single parent families. Most of the children's patterns in this life cycle group have a general activity framework which covers a regular school hour schedule and various intensities of discretionary activities afterwards. Pattern 4KD of 1995 data is separated into patterns 4KA and 4KC which have extensive afternoon or after school discretionary activities. Based on these similarity comparisons, the children's activity patterns from the 1985 and 1994 data are then said to be stable temporally.

In comparison to one working parent families, the two working parents families seem more identical in the aspect of working hours for every distinct representative activity pattern. The majority of patterns 5A and 5B of the 1994 data are matched with pattern 5C of the 1985 data, each indicating relatively high similarities that are validated by examining the distributions of the distance centroids and activity types at different times. The two working parent family adult activity patterns seems to not fluctuate as much as those in the one working parent group, and the similarity in the general time-space distributions.

Identical characteristics of regular school/work activity and extended discretionary activity are also found in the comparison of children's activity patterns of the two working parents families. The majority of pattern 5KA of the 1994 data is directed to pattern 5KC of the 1985 data, which has a relatively high ratio of discretionary activity in comparison to school activity. On the other hand, pattern 5KB of 1994 data is more similar to pattern 5KD of the 1985 data in that each tends to have a general framework for school activity. There is not a big difference in the children's activity time-space image and activity type distributions in this group for the 1994 data. The reason for the merging of four representative patterns of 1985 data into 2 distinct patterns in 1994 is the level of homogeneity that exists in the four patterns of 1985 data despite of larger number of groups determined by the clustering technique. The temporal stability, however, is still evident in the children's activity patterns for this life cycle group.

The last life cycle group for pattern analysis is made up of those not assigned to any of the above groups. Although there are significant discrepancies in household member composition, a high variation of pattern stability is not found. The data is shown in Table 5.18 and Table 5.24, but the household and person characteristics need further investigation. However, other than pattern 6B of 1994 data, which is separated into patterns 6B and 6C of 1984 data with a 68%/ 32% split; the rest of the patterns of 1994 data satisfy a one-by-one transference to patterns of 1985 data. Therefore, temporal stability appear to exist in this group, as well.

5.6.2 Visual Examination of 1985 and 1994 Patterns

The final step for pattern stability analysis involves a visual examination of the time-space images of the 1985 and 1994 activity patterns and of the personal characteristics associated with each distinct representative activity pattern. This step is focused on a holistic view of the activity pattern framework, especially focusing for time lag and other effects on activity patterns that computer matching may not detect.

Due to the incompatible level of details in household and personal information of the 1985 and the 1994 data, only a small portion of variables are recorded in both data sets. The income variable is one of the few variables in both data sets, but a significant portion of residents refused to respond to this question. This results in the deletion of the income variable from the socioeconomic characteristics comparison list for 1985 and 1994 data. Therefore, only a percentage of households are used to compare the number of full time workers, the gender distribution, and the means of age and car ownership. A matching fraction is defined as the percentage of observed activity patterns of 1994 data been assigned to one of the representative activity patterns in the 1985 data. A characteristic vector of these attributes is defined in Table 5.25. Children's socioeconomic attributes are not included in this comparison. The insufficient number of descriptive attributes to identify the unique characteristics of each activity patterns in both 1985 and 1994 data limits the overall ability to support the assessment of pattern temporal stability relating to the traveler's socioeconomic characteristics. However, the following analysis uses these socioeconomic characteristics to further match patterns from 1985 and 1994 in support of temporal stability.

Table 5.25 Socioeconomic Characteristics for Pattern Comparison

Sequence	Name	Definition
1	Ftwork	Percentage of Full Time Workers
2	Male	Percentage of Male Members
3	Age	Average Age
4	Vehicle	Average Vehicle Ownership

Life Cycle Group 1: Single Person Households

For the single person household category, pattern 1A of 1985 is related to pattern 1C of 1994, both of which are characterized for typical 8 to 5 workers with an average 5 miles distance from home for mid day work activity (see Fig. 5.1 to Fig. 5.4).

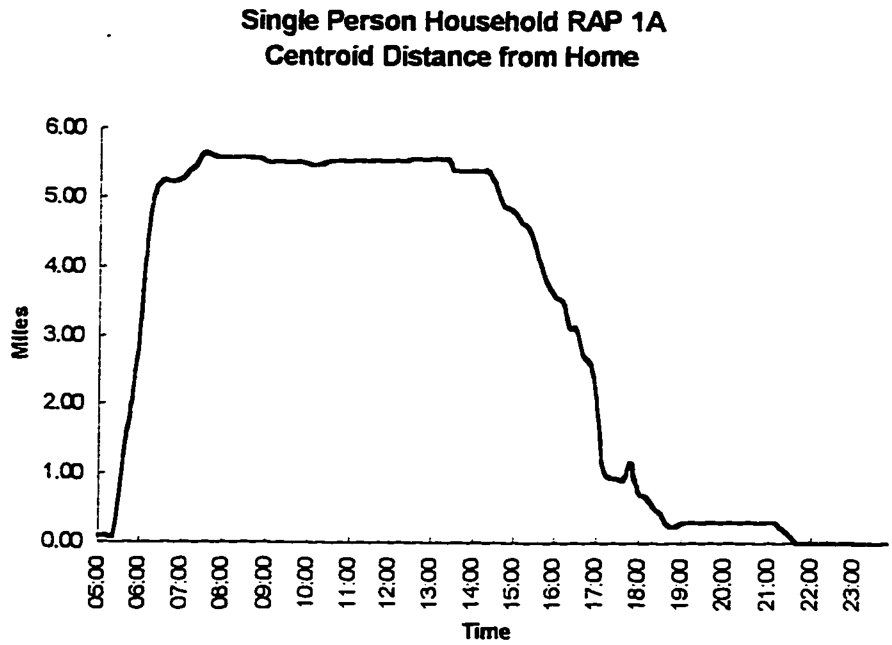


Fig 5.3 Distance Centroid of RAP 1A, 1985

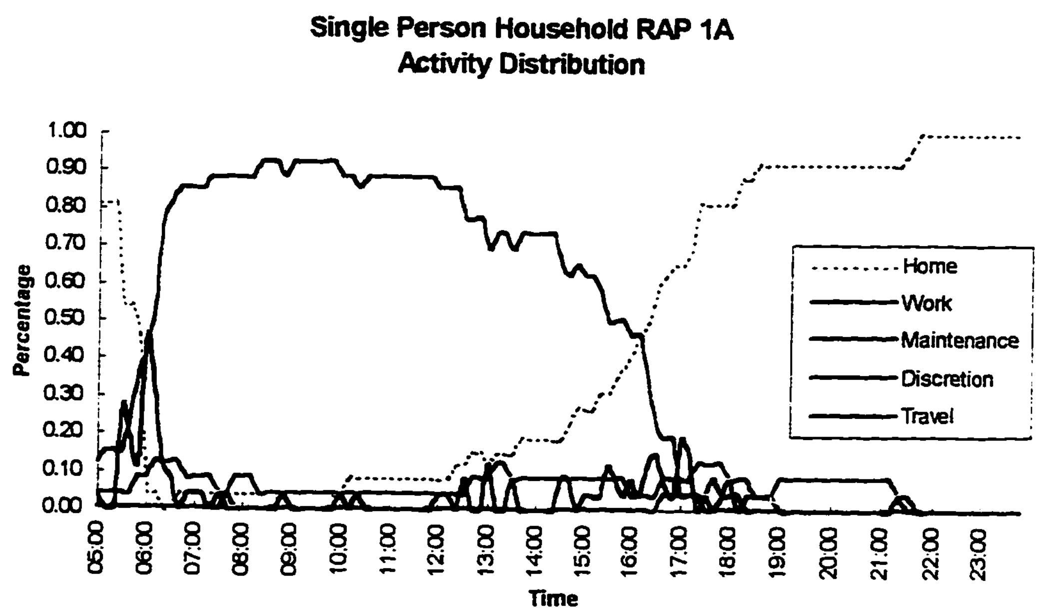


Fig 5.4 Activity Distribution of RAP 1A, 1985

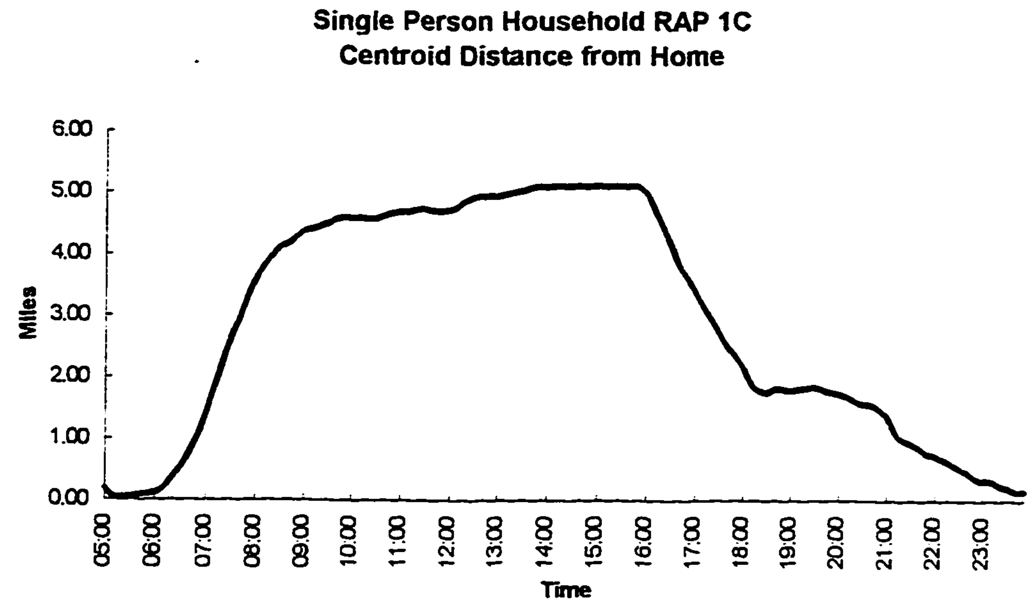


Fig. 5.5 Distance Centroid of RAP 1C, 1994

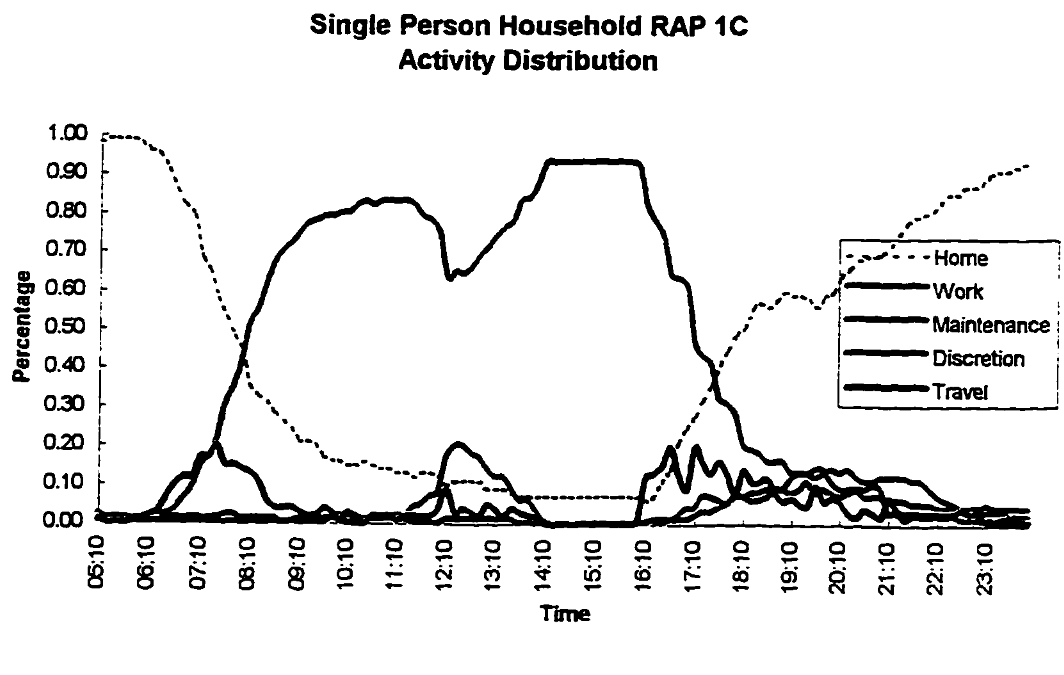


Fig 5.6 Activity Distribution of RAP 1C, 1994

The remainder of the plots of pattern distance and activity distribution are provided in the appendix. For intensive midday discretionary activity, pattern 1B of 1985 can be related to either pattern 1A or 1D of 1994 data, both of which are also characterized with relatively high ratios of discretionary or maintenance activities. The majority of members in group 1D of 1994 tend to stay at home for work and have little evening discretionary activity, which doesn't find any corresponding pattern in the 1985 data. However, based on the assignment of relating observed activity patterns of 1994 data to those RAPs of 1985 data in the earlier section, group 1D of 1994 is fully related to RAP 1B of 1985 data.

The cross-tabulation of member's characteristics for the single person household life cycle group is shown in Table 5.26 (and the definition of characteristics was explained in Table 5.25). The matching factor depicted in a bracket in the table is defined as the percentage of members in each RAPs of the 1994 data related to each RAPs of the 1985 data.

Table 5.26 Cross-Tabulation of Socio-economic Characteristics and Matching factor for Single Person Households

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars		1994 Pattern				
1985 Pattern	FT Emp Male Age Vehicle	**1A** 79.2% 48.6% 43.5 1.08	**1B** 45.5% 47.9% 54.4 1.12	**1C** 88.2% 53.8% 49.1 1.26	**1D** 99.2% 52.4% 50.2 1.23	**1E** 14.3% 44.0% 61.2 0.98
	1A 10.2% 57.1% 48.1 1.82	N. A.	(100%) 45.5% 47.9% 54.4 1.12	N. A.	N. A.	N. A.
	1B 42.2% 47.7% 56.7 0.99	(100) 79.2% 48.6% 43.5 1.08	N. A.	(30%) 0% 50% 52.5 1.50	(100%) 99.2% 52.4% 50.2 1.23	(100%) 14.3% 44.0% 61.2 0.98
	1C 95.2% 58.7% 48.7 1.15	N. A.	N. A.	(70%) 100% 58.5% 49.0 1.19	N. A.	N. A.

As depicted in Table 5.26, most of younger age members of pattern 1C of the 1994 data are more likely to be related to pattern 1C of the 1984 data. The rest of activity patterns of the 1994 data do not have a significant correlation with the patterns of the 1985 data in terms of the characteristic vector.

Life Cycle Group 2: **Single Parent Households**

In the single parent household group, adult pattern 2B of the 1985 data is very similar to pattern 2C at the same year except for the relative high ratio of after work discretionary activity, which corresponds to pattern 2C in the 1994 data. A mixed type of work, maintenance and discretionary activity across the day, pattern 2B of the 1994 data is similar to pattern 2D of the 1985 data on the aspect of distance from home for the work activity (which has an average of 2.5 miles). Otherwise, pattern 2A of the 1994 data represents possibly night shift workers or other evening late behavior and does not find a corresponding pattern in the 1985 data.

Next, children's travel/activity patterns in single parent households are analyzed. Pattern 2KA in the 1994 data of typical school kids for 8 to 3 schooling is similar to pattern 2KB of the 1985 data. With a similar distribution of hours in school, minor traveling and maintenance activities are conducted during the lunch hours, which is characterized by pattern 2KD of the 1994 data. A relatively high ratio of discretionary activity across the day is also found in both patterns 2KC of the 1994 and 2KA of 1985 data that involve intensive traveling and high variations in activity type.

The cross-tabulation of selected socio-economic characteristics vector and the matching factor for adults in single parent households is provided in Table 5.27. Patterns of the 1994 data tend to match with a similar pattern in 1985, with average age and vehicle ownership also comparable.

Table 5.27 Cross-Tabulation of Socio-economic Characteristics and Matching factor for Adults in Single Parent Households

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars	1994 Pattern		
FT Emp Male Age Vehicle	**2A** 27.3% 42.3% 48.5 1.08	**2B** 18.4 50.2% 44.7 0.99	**2C** 92.3% 52.8% 50.2 1.17
1985 Pattern **2A** 11.2% 47.1% 43.1 1.08	N. A.	(100%) 18.4 50.2% 44.7 0.99	N. A.
2B 92.8% 51.3% 46.7 1.25	N. A.	N. A.	(44%) 89.2% 50.1% 52.5 1.20
2C 93.5% 52.5% 43.5 1.13	N. A.	N. A.	(56%) 93.4% 53.9% 49.3 1.15
2D 32.5% 47.7% 45.4 1.09	(100%) 27.3% 42.3% 48.5 1.08	N. A.	N. A.

<u>Life Cycle Group 3</u> : Couples without Children

The life cycle group of couples without children has shown a high degree of activities devoted to discretionary purposes in addition to work. A typical worker group such as pattern 3E of the 1985 corresponds to patterns 3B and 3C of the 1994 data, except pattern 3C has a higher ratio of trip chaining behavior for evening discretionary activity. The majority of members in group 3C of the 1994 data more likely a full time employee, and group 3B tends to include fewer time employees and more female members.

Table 5.28 Cross-Tabulation of Socio-economic Characteristics and Matching Factor for Couples without Children

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars		1994 Pattern			
	FT Emp Male Age Vehicle	**3A** 29.7% 49.3% 58.5 1.88	**3B** 71.5% 42.9% 55.4 1.93	**3C** 92.3% 51.8% 50.7 2.02	**3D** 34.5% 52.4% 63.6 2.07
1985 Pattern	**3A** 10.2% 57.1% 48.1 1.82	(9%) 12.0% 60.8% 48.6 1.50	(87%) 78.0% 37.1% 50.2 1.92	(11%) 69.1% 57.1% 49.8 1.77	N. A.
	3B 21.2% 47.7% 56.7 1.89	(11%) 100% 42.4% 48.6 1.98	N. A.	N. A.	(45%) 65.1% 65.0% 58.7 1.95
	3C 73.5% 54.5% 60.5 1.33	(11%) 100% 52.1% 58.6 1.18	N. A.	N. A.	(55%) 11.0% 45.1% 68.6 1.24
	3D 97.8% 54.7% 45.4 2.03	(79%) 100% 42.4% 48.6 1.98	N. A.	N. A.	N. A.
	3E 28.3% 49.8% 56.9 1.73	N. A.	(13%) 30.0% 44.0% 52.7 1.88	(89%) 95.0% 51.0% 54.9 2.09	N. A.

<u>Life Cycle Group 4</u> : One Working Parent Households

Pattern 4B in the 1985 data is characterized as the adult members in one working parent families and is similar to pattern 4D for the same year for typical 8 to 5 work hours, except that pattern 4B has less evening discretionary activity. The time-space activity/distance distribution is identical to pattern 4C of 1994 data, which is also characterized by typical work hours. Though pattern 4A of the 1985 data doesn't have significant amount of full time employees, the distribution of the time-space image is very similar to the one of pattern 4B of that year. From Table 5.29, pattern 4C of the 1994 data is related to pattern 4B of the 1985 data, which both have comparable ratios of full time employees and a similar gender distribution. Members of pattern 4C in the 1994 data tend to have higher vehicle ownership, and pattern 4B of the 1985 data has the highest vehicle ownership in comparison to the other four patterns.

Table 5.29 Cross-Tabulation of Socio-economic Characteristics and Matching Factor for Adults in One Working Parent Households

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars		1994 Pattern		
1985 Pattern	FT Emp Male Age Vehicle	**4A** 17.5% 48.3% 57.5 1.75	**4B** 25.1% 47.9% 61.4 1.66	**4C** 93.6% 55.8% 50.4 2.18
	4A 10.2% 57.1% 48.1 1.82	N. A.	N. A.	(9%) 20% 48.2% 49.7 1.92
	4B 98.2% 55.7% 49.7 1.92	N. A.	N. A.	(61%) 100% 55.1% 51.2 2.21
	4C 23.5% 48.5% 58.5 1.53	(45%) 24.5% 44.0% 59.2 1.58	(30%) 33.0% 46.5% 60.8 1.63	N. A.
	4D 77.8% 51.7% 49.4 1.91	N. A.	N. A.	(30%) 98.0% 44.5% 50.1 1.96
	4E 17.3% 48.8% 54.9 1.78	(55%) 12.5% 52.5% 56.2 1.82	(70%) 22.0% 48.0% 61.3 1.68	N. A.

Identical to the travel/activity pattern 4KA of the 1985 data for children in one working parent families is the pattern 4KC in the 1994 data. Fluctuations in midday activities for both work and discretionary activities was identified in both pattern 4KB of the 1994 and pattern 4KC of the 1985 data. Pattern 4KC characterizes by a larger distance from home than pattern 4KB. Although the average distances from home at different times for pattern 4KA of the 1985 data is similar to pattern 4KA of the 1994 data, the distributions of activity types of the two patterns are not identical. Space pattern 4KA of the 1985 data shows high ratio of work/school activity performed in the afternoon, while a high ratio of discretionary activities is shown for pattern 4KA of the 1994 data.

Life Cycle Group 5 : Both Working Parents Households

For the life cycle group of two working parents families, pattern 5C of 1985 is very similar to pattern 5A of the 1994 data but with a high variation in activity type and also a late return to home. A typical work group, pattern 5C of the 1994 data and 5A of the 1985 data is also found in this life cycle. In Table 5.30, both patterns of 5C in the 1994 data and 5A in the 1985 data are shown with similar car ownership and relatively high ratio of full time employees. Otherwise, patterns 5A and 5B of the 1994 data are related to pattern 5C in the 1985 data, which are characterized with lower percentages of full time employees and older age distributions.

Children's travel/activity patterns in the both working couples household category, patterns 5KA , 5KB and 5KD of the 1985 data have shown great similarity in typical schooling hours except the difference in evening non-home discretionary activity.

A similar travel/activity in the 1994 data has been found in pattern 5KB, which is characterized for an average distance from home of 2.5 miles. Low percentages of non-home activities have been found in patterns 5KC of 1985 data and 5KA of 1994 data, each of which has a relatively high proportion of non-home discretionary activity.

Life Cycle Group 6 : Other Households

The final life cycle group is a mix of household combinations, which have been identified as for college roommates, older people living together, non-relative correlated housemates and relatives living together. Typical worker patterns have been found in pattern 6A of 1994 and patterns 6C and 6E of the 1985 data, but none of them has exhibits similar average distance from home. Pattern 6B of 1985 data is similar to pattern 6B of 1994 data except for the big activity switch at noon. Otherwise, no other patterns in both years are identical to each other.

In Table 5.31, pattern 6A of the 1994 data is related to patterns 6C and 6E of the 1985 data, which are correlated with high percentages of full time employees and similar value of average age. However, this correlation does not obviously support the relationship between pattern 6C of the 1994 data and pattern 6B of the 1985 data, which have similar car ownership and average age distribution.

Table 5.30 Cross-Tabulation of Socio-economic Characteristics and Matching Factor for Adults in Two Working Parents Households

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars		1994 Pattern		
	FT Emp Male Age Vehicle	5A 20.1% 51.3% 56.5 1.88	5B 26.7% 48.9% 55.4 1.93	5C 92.3% 51.8% 50.4 2.18
1985 Pattern	5A 92.5% 56.1% 48.1 2.12	N. A.	N. A.	(83%) 100% 52.2% 49.3 2.21
	5B 37.2% 48.7% 53.7 2.08	(18%) 0.0% 48.0% 56.4 1.85	(17%) 35.0% 54.0% 54.7 1.87	(9%) 20.0% 80.0% 51.2 2.05
	5C 43.5% 49.2% 59.4 1.93	(69%) 18.0% 52.0% 56.4 1.88	(76%) 26.0% 27.2% 54.9 1.95	(2%) 100% 47.5% 53.8 1.95
	5D 55.2% 52.5% 60.5 2.06	(13%) 65.0% 52.0% 57.3 1.92	(7%) 18.0% 54.0% 59.2 2.01	(6%) 100% 65.8% 58.5 2.23

Table 5.31 Cross-Tabulation of Socio-economic Characteristics and Matching Factor for Life Cycle of Other Households

Match (%) FT Emp (%) Male (%) Mean Age Mean Cars		1994 Pattern			
	FT Emp Male Age Vehicle	6A 92.7% 49.3% 58.5 1.98	6B 71.5% 42.9% 55.4 1.93	6C 92.3% 51.8% 56.7 2.02	6D 34.5% 52.4% 63.6 2.07
1985 Pattern	6A 25.5% 47.1% 50.3 1.92	N. A.	N. A.	(9%) 50.0% 49.0% 51.5 2.00	(14%) 0.0% 0.0% 65.0% 2.50
	6B 18.2% 45.7% 55.7 1.99	N. A.	(68%) 61.0% 45.3% 55.6 1.92	(78%) 98.0% 53.0% 56.7 2.02	(86%) 40.0% 60.0% 63.4 2.01
	6C 92.8% 54.5% 60.5 2.12	(86%) 94.0% 51.9 58.8 2.05	(32%) 94.0% 39.8% 55.2 1.95	(14%) 88.0% 48.0% 56.4 2.03	N. A.
	6D 28.7% 49.7% 45.4 1.98	N. A.	N. A.	N. A.	N. A.
	6E 97.2% 53.8% 56.9 2.11	(14%) 90% 57.3% 58.3 2.15	N. A.	N. A.	N. A.

5.7 Summary

From the identification process of similar travel/activity patterns, the life cycle factor has been utilized market segmentating, and certain homogenous attributes were identified. A satisfactory level of temporal stability in activity patterns was identified in formal classification, and this result is supported by visual examination of activity patterns in most cases which includes the majority of households used in this research. Membership clustering procedure is not fully able to control the distinctness in activity patterns, but a relative homogeneity prevails.

Based on the findings in this section, the majority of activity patterns in 1985 are matched with corresponding patterns in 1994, suggesting a consistency in overall revealed travel behavior. Temporal stability is important because it shows the subsequent models are appropriate for use in forecasting future behavior. The induced demand from activity to travel can then be estimated by analyzing household representative activity patterns. In the next chapter, an operational model which use a category model for the choice of these activity patterns in different life cycle groups will be presented.

Chapter 6

Operational Model

6.1 Introduction

This proposed activity production model is a disaggregate travel demand modeling approach to replace the first step in the conventional trip forecasting process. This model intends to estimate travel needs from the aggregation of individual household trips as a pattern defined across time and space. By the travel/activity patterns of household member, the temporal and spatial distribution of the activities that induce trips can be used to indicate the times and locations when and where trips originate and end. To demonstrate the applicability of the proposed methodology, the approach of category analysis is adopted and can be reducible to the conventional production model. Although discriminant and logit models have been developed and tested during the research process, the results are less robust than the category analysis approach. The general operational framework and data to derive the activity-based production model are presented in this chapter.

6.2 Operational Framework

Based on the similarity of time-space distributions of travel/activity images, distinct patterns have been obtained for different life cycle groups. Although homogeneous travel/activity behavior is found in each life cycle group, differences are apparent in terms of when and where travel occurs and to what type of activity. For instance, a pair of married couples without kids living in a high income neighborhood may have an identical number of trips and activities for a day; but the pattern of how they execute the trips and the duration of each activity may be quite different. Although a life cycle category is characterized by certain homogeneity among group members, while maintaining variation in the actual scheduling of activities. The pattern forms the structure on which daily activity behavior rests. The execution of the activity program produces a specific pattern which maintain the general function while producing a schedule with specific constraints with respect to the environments of the traveler.

To develop an activity-based production model, the general operational framework shown in Figure 6.1 is followed. This figure is to illustrate the process and required estimation techniques for different steps that include life cycle classification, identification of socio-economic characteristics, choice of patterns, and simulation of specific choice for activity generation. In this operational framework, the choice of activity patterns can be achieved in several ways, such as, category, discriminant or logit analysis. Based on the evaluation of each model's relative performance, the category approach will be introduced in the following section given its relative simplicity and similarity to conventional models.

The category production operational framework is based on the advance classification of household travel/activity patterns. In this process, samples are assigned to different homogenous groups based on demographical background factors such as the size of the household and the family roles they played (variables also used in conventional models). This process links each individual to a typical activity pattern set associated with their life cycle group.

Once the socio-economic attributes have been identified via assignment to a life cycle group, a pattern choice model is employed to determine the split for each distinct travel/activity patterns belonging to that life cycle group. Employment status and household car ownership variables are used to categorize the trips/activities rate for individuals in different life cycle groups. The choice of a certain pattern is in proportion to the probability or distribution percentage of that patterns versus other distinct patterns present in each group. Also, the output of this pattern choice model is interpreted as the probability of a person with specific socioeconomic characteristics choosing a specific pattern.

The pattern itself represents a general structure of the time-space distribution which is common to the other members of that pattern group. The distributions of trip distance and activity duration are similar for persons in a specific activity pattern, but the specific location of their households would determine actual spatial choice required to specific feasible activity locations within a default deviation range.

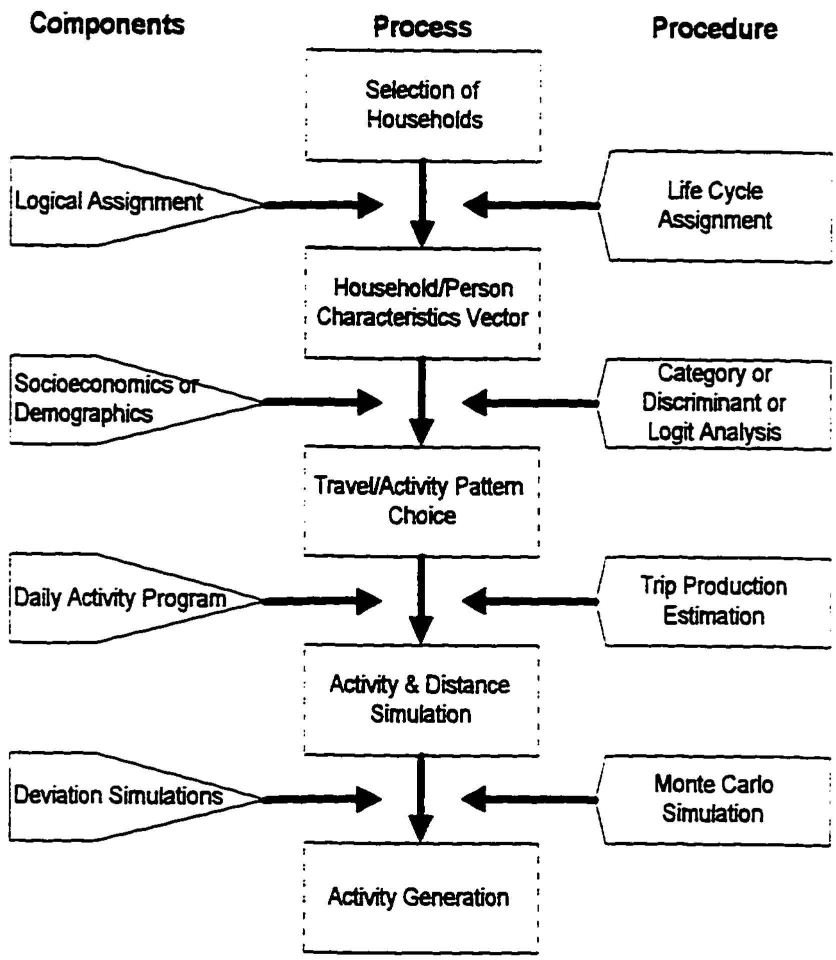


Fig 6.1 Framework of an Operational Activity Generation Model

To verify the feasibility of initial selected travel/activity patterns, Monte Carlo simulation can be used to simulate the variations of activity type, duration and trip distance. A variety of characteristics for a specified life cycle group and a selected representative activity pattern, such as mileage traveled and number of trips, are easily computed. The extension of the proposed activity production model with travel character has embedded in the activity patterns to distribution and mode choice components is straight-forward..

6.3 Description of Data for Activity-Based Model

A total of 3,241 persons in 1652 households have been selected for this research. This section has two purposes: first, to provide a graphical explanation of how the activity patterns correlate with trip rates, and second, to provide the statistical model which explains how household demographics and socioeconomics correlate with activity pattern.

Due to the size of samples, one lifecycle group will be selected as an example study. Among the six life cycle groups, the stage of couples without children is the transition point when an individual starts to organize a family and to have children that add constraints to the daily activity program. Also, the patterns in this group seem very stable from the 1985 data to the 1994 data with respect to the distribution of activities and distance from home. Therefore, patterns of couples without children in 1994 data will be used as example to illustrate the calibration process. The calibrated models for all other life cycle groups, using the 1994 data, are attached in the appendix for reference.

There are one 158 individuals out of the 852 persons (426 households) reported to produce no out-of-home trips during the survey time period. These have been classified as a new activity pattern group which is characterized as staying at home all day long and making no trips. From previous pattern classification procedure, there are five distinct travel/activity patterns found in the 1994 data for life cycle group of couples without children. The five candidate travel/activity patterns are briefly described here :

1. Pattern 3A: A mix of different activities (discretionary activity in the evening ;Fig. 6.2 & Fig. 6.3).
2. Pattern 3B: A late start to work and a extension to work late, most likely part-time workers with an average 5 miles commute from home (Fig. 6.4 & Fig. 6.5).
3. Pattern 3C : Typical 8 to 5 work schedule with an average 6 miles commute from home, maintenance activity is mixed at the noon hours (Fig. 6.6 & Fig. 6.7).
4. Pattern 3D: Predominantly to stay at home with a relatively high ratio of maintenance activity in comparison with any other activity through the day (Fig. 6.8 & Fig. 6.9).
5. Pattern 3E: No non-home activities.

In Table 6.1and 6.2, information about persons and households in each distinct activity pattern is provided. Pattern 3A has the most retired people and older age populations, which represents a pattern that most of people will stay at home and do work-related activity. Similarly, pattern 3D has relatively high ratio of retired person and older age population, but members in this category tends to have more trips that relate to maintenance and discretionary activities. Otherwise, people in Pattern 3D tend to live in single family houses (which in the conventional modeling approach will expect to have higher trip rates).

In contrast to the patterns 3A and 3D, the patterns 3B and 3C have high ratios of work activities and maintenance activities at the noon hours. Relatively low percentages of unemployed and retired populations with higher ratios of car ownership is the characteristic to describe these two patterns. In pattern 3B, a slight higher ratios of female and part-time workers lead to the fluctuations of activities distribution and distance from home at the morning hours in comparison to pattern 3B. People in pattern 3B tend to be centered at about age 50 and live in a single family of houses, whereas, people in pattern 3C tend to be full time workers, have higher cars ownership, and more live in apartments or mobile homes. Otherwise, pattern 3B and pattern 3C are similar in regard to starting morning commuting trips and the tendency to have evening discretionary activities.

To be comparable to the conventional approach for trip generation, a cross classification type of trip generation will be constructed in the next section using conventional variables such as employment status and vehicle ownership. In each cell, an average trip rate is given with different probabilities of each activity pattern associated with these characteristics. The employment status variable is defined as employed or not employed, and the vehicle ownership is divided into 0, 1 and 2+ car categories. The trip rate is defined at the person-level and is computed with the reported number of trips made during the survey period. The pattern itself not only contains the information about the number of trips, but also the general location and the times when those trips will be generated. Therefore, this approach is comparable to the conventional method for trip generation yet it provides complete information on trip scheduling and trip linkages that conventional modeling approach can not.

Table 6.1 Distributions of Age, Employment and Gender for Couples without Children Households of the 1994 Data

	Pattern 3A	Pattern 3B	Pattern 3C	Pattern 3D	Pattern 3E
Persons	300	63	247	84	158
Age					
< 30	4.0%	3.0%	0.8%	0	12.1%
30 to 45	16.0%	35.4%	38.5%	22.0%	18.9%
45 to 60	32%	47.3%	45.0%	34.0%	21.6%
> 60+	48%	14.3%	7.7%	44.0%	47.4%
Employment					
Full Time	29.7%	71.5%	92.3%	34.6%	47.3%
Part Time	11.4%	26.9%	6.1%	11.9%	28.9%
Unemployed	6.3%	0	0%	6.0%	8.3%
Retired	45%	0	1.6%	38.1%	4.5%
Homemaker	10%	1.6%	0%	9.5%	11.0%
Gender					
Male	49.3%	42.9%	51.8%	52.4%	48.7%
Female	50.7%	57.1%	48.2%	47.6%	51.3%

Table 6.2 Distributions of Home Type and Vehicle Ownership for Couples without Children Households of the 1994 Data

	Pattern 3A	**Pattern 3B**	**Pattern 3C**	**Pattern 3D**	**Pattern 3E**
Persons	300	63	247	84	158
Home Type					
Single Family	85.7%	84.1%	81.8%	94.1%	86.8%
Apartment	8.3%	15.9%	13.0%	3.6%	9.5%
Mobile Home	6%	0%	5.2%	2.3%	3.7%
Vehicles					
0	2.7%	1.6%	1.2%	1.2%	2.2%
1	21.3%	20.6%	15.4%	27.4%	23.6%
2	61.3%	55.6%	61.1%	60.7%	59.8%
3+	14.7%	22.2%	22.3%	10.7%	14.4%

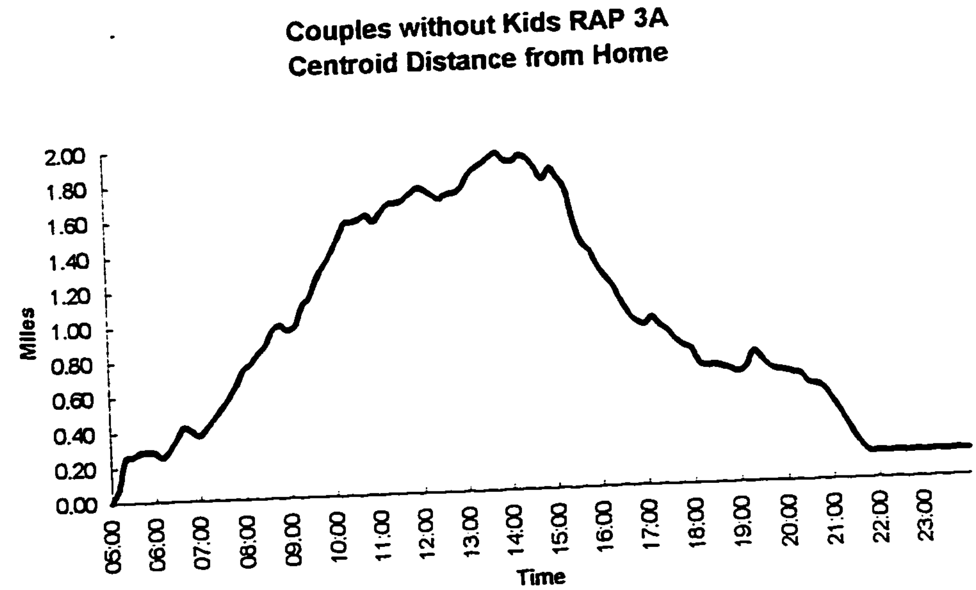


Fig. 6.2 Pattern 3A Distance Distribution with 1994 Data

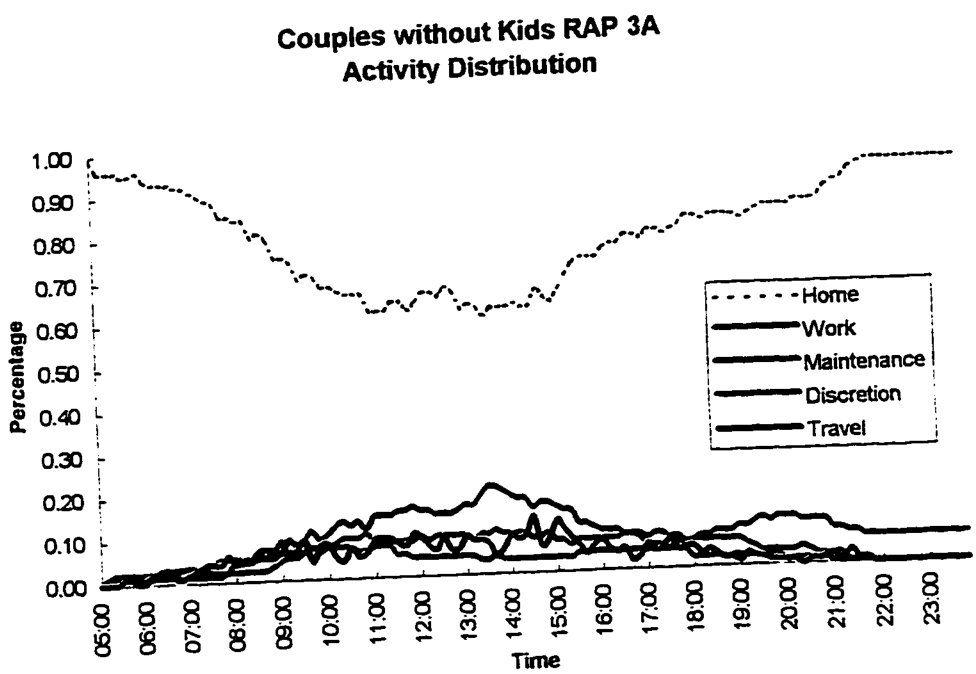


Fig 6.3 Pattern 3A Activity Distribution with 1994 Data

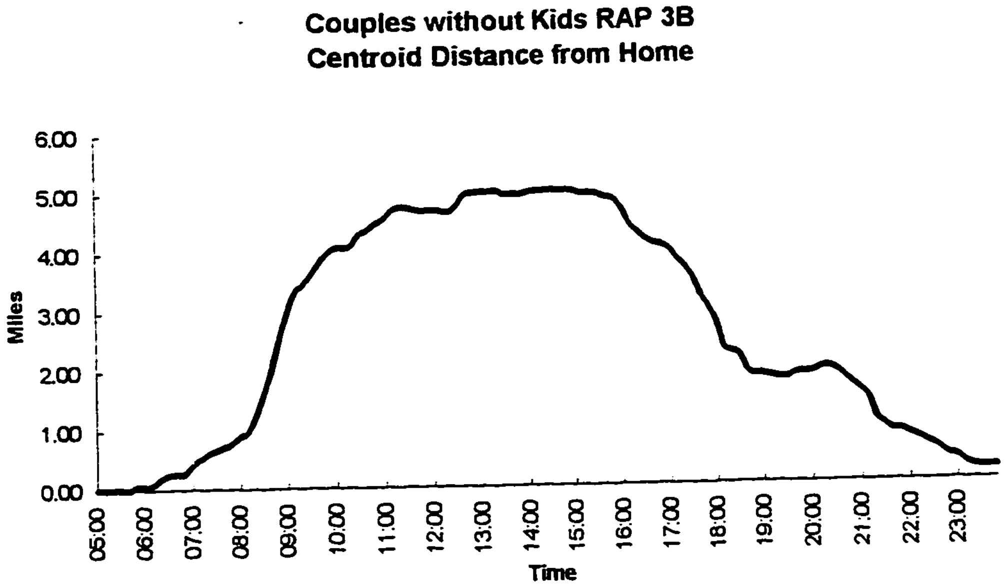


Fig 6.4 Pattern 3B Distance Distribution with 1994 Data

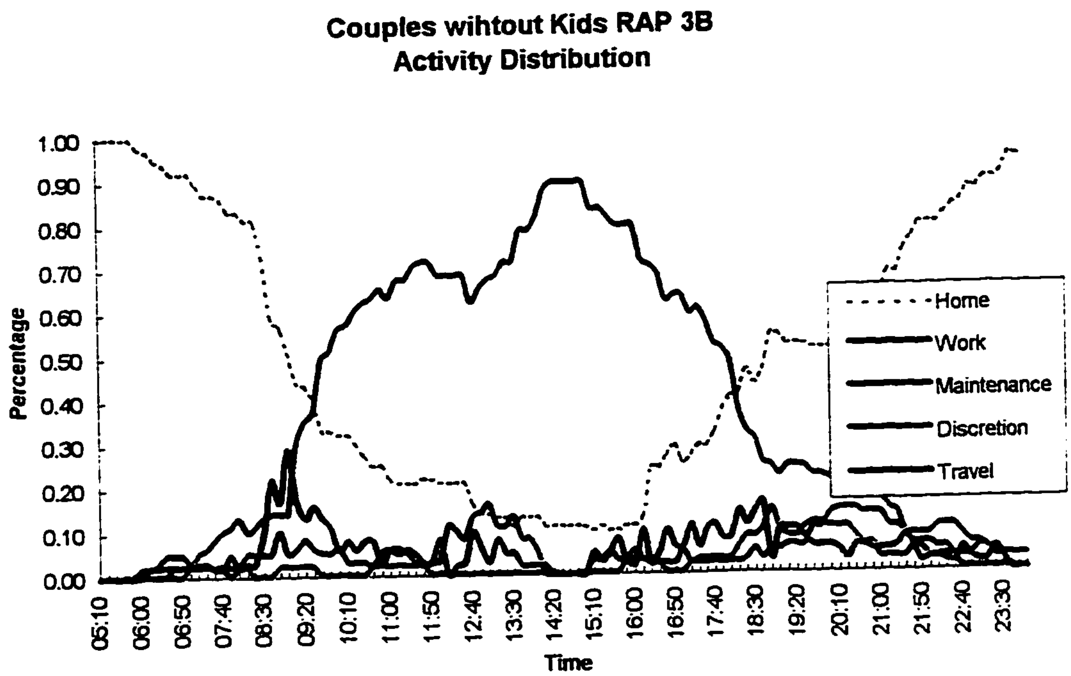


Fig 6.5 Pattern 3B Activity Distribution with 1994 Data

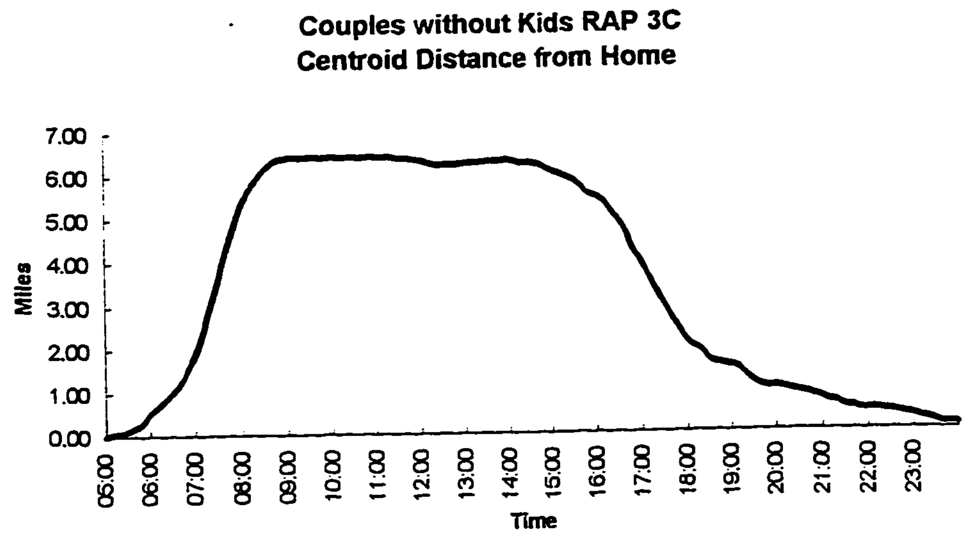


Fig 6.6 Pattern 3C Distance Distribution with 1994 Data

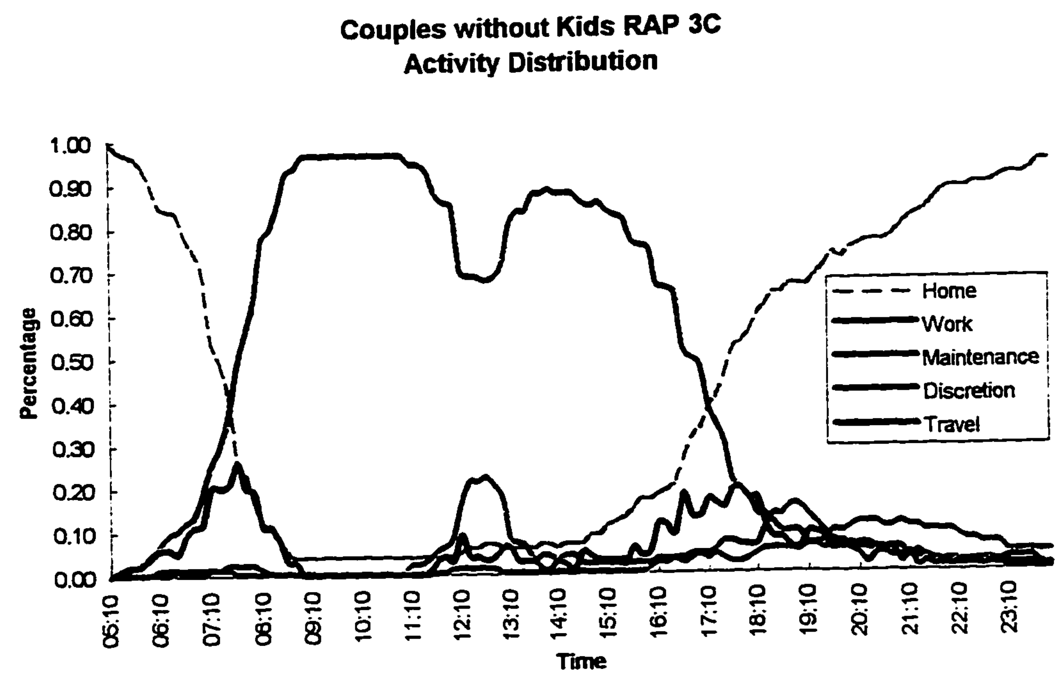


Fig 6.7 Pattern 3C Activity Distribution with 1994 Data

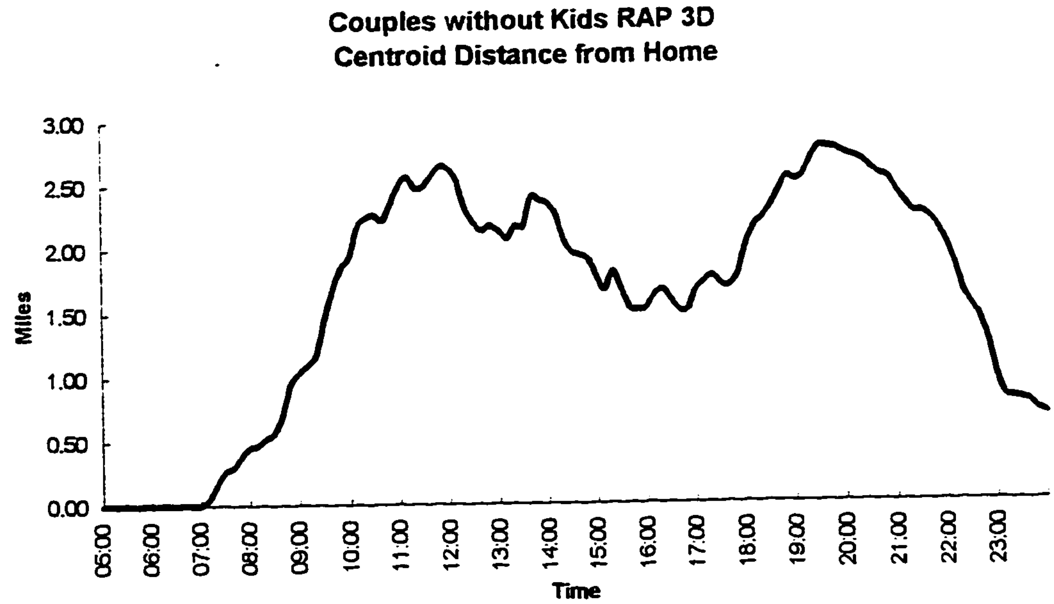


Fig 6.8 Pattern 3D Distance Distribution with 1994 Data

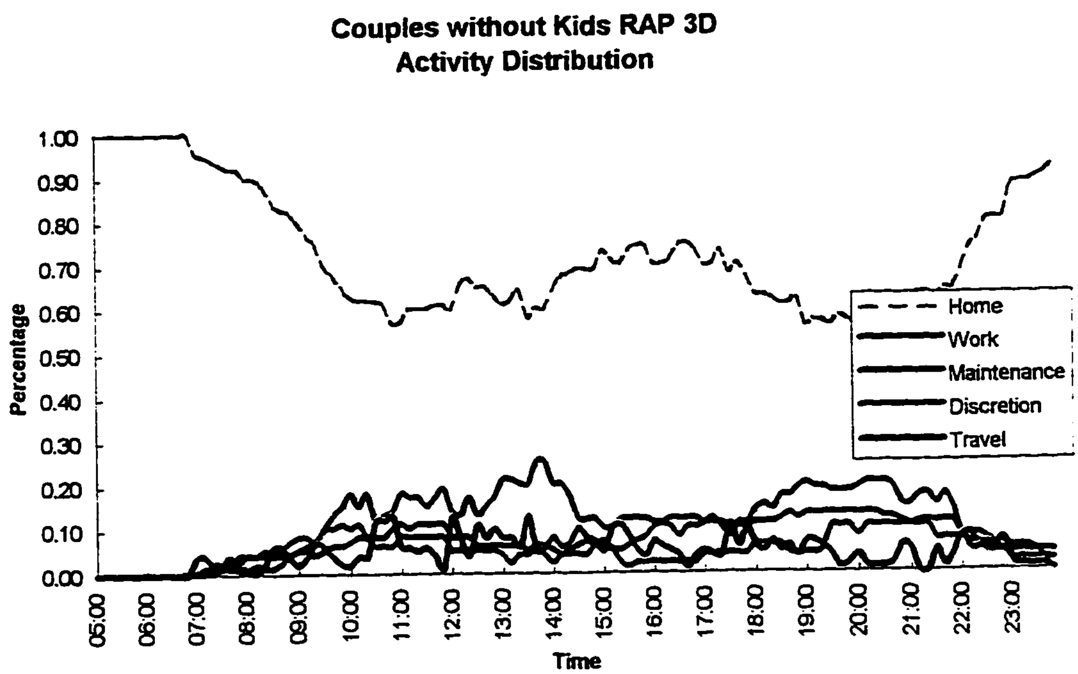


Fig 6.9 Pattern 3D Activity Distribution with 1994 Data

6.4 Activity-Based Trip Rate Table

Supernak (1983) first introduced the person category analysis method for trip production. Similar techniques at a level of household or person have been used in many metropolitan areas for transportation planning purposes. This research will employ conventional household and person socio-economic variables to categorize person trips/activities rates. The activity-based trip rate is expected to be as stable as the conventional approach but inclusively containing temporal and spatial information regarding trip execution.

The defined lifecycle groups comprised of household in the 1994 Portland Household Survey introduced earlier are used in the process to derive the trips/activities rate table. There are several reasons to derive such a trips/activities rate table, and they are stated as follows:

1. Conventional trip rate table for trip production is believed to be reliable, and the values of a trip rate table have remained stable across years at the same research area.
2. A trip rate table provides an efficient method to estimate trip production, and it only requires very few variables for operation.
3. Trip represents the demand induced from an activity, thus the model can be re-interpreted as a conventional model as well.

Based on the selected six lifecycle groups members, the trips/activities rate tables are obtained and shown in Tables 6.3 - 6.8. The trips/activities rate is categorized by the type of employment at the person-level and car ownership at the household-level. Household members are also divided into adults and children by lifecycle groups. An aggregate trips/activities rate is also computed for each corresponding pair in the table.

Table 6.3 Activity-Based Production Model for Single Person Households (1994 Portland Survey Data)

Cars / Employment	Adult		
	0	1	2+
Employed	(N= 79) Pattern 1A: 11.4% Pattern 1B: 0 % Pattern 1C: 30.4% Pattern 1D: 17.7% Pattern 1E: 7.6% No Travel: 32.9% Trips/Person: 2.53	(N=278) Pattern 1A: 18.0% Pattern 1B: 5.8% Pattern 1C: 47.9% Pattern 1D: 14.7% Pattern 1E: 8.6% No Travel: 5.0% Trips/Person: 3.71	(N=51) Pattern 1A: 7.8% Pattern 1B: 4.0 % Pattern 1C: 37.1% Pattern 1D: 17.6% Pattern 1E: 17.6 % No Travel: 15.9% Trips/Person: 3.21
Not Employed	(N=67) Pattern 1A: 25.5% Pattern 1B: 3.2 % Pattern 1C: 0 % Pattern 1D: 39.9% Pattern 1E: 6.4% No Travel: 25.0% Trips/Person: 2.94	(N=151) Pattern 1A: 25.2% Pattern 1B: 2.0 % Pattern 1C: 1.3% Pattern 1D: 45.1% Pattern 1E: 7.3% No Travel: 19.1% Trips/Person: 2.91	(N=41) Pattern 1A: 21.9% Pattern 1B: 2.4% Pattern 1C: 2.4% Pattern 1D: 24.4% Pattern 1E: 4.9% No Travel: 44.0% Trips/Person: 2.23

In Table 6.3, trips/activities rate for single person households has been broken down by household car ownership and individual person's employment status. It has shown that employed persons tend to be more likely to have pattern 1C, whereas not employed persons tends to be in pattern 1D.

Table 6.4 is developed for single parent households in which the parent is categorized as employed or not employed and children are divided into in-school and not-in-school groups. On average, the parent in such a household tends to produce more trips when he or she is employed, and children not in school produce less trips (due primary to age). Single parent without a vehicle and no job produces more trips than one with at least a car.

The trips/activities rate table for couples without children is presented in Table 6.5. The trip rate rises as the number of vehicles increase, but not-employed adults with single vehicles are more active in traveling in comparison to the other categories. Overally, not-employed adults with no car tend to stay at home, which has been observed in the 0 car ownership households in this life cycle group.

Table 6.4 Activity-Based Production Model for Single Parent Households (1994 Portland Survey Data)

Employment \ Cars	Adult 0	Adult 1	Adult 2+
Employed	(N= 5) Pattern 2A: 0.0% Pattern 2B: 20.0% Pattern 2C: 20.0% No Travel: 60.0% Trips/Person: 1.75	(N=34) Pattern 2A: 20.6% Pattern 2B: 20.6% Pattern 2C: 55.9% No Travel: 2.9% Trips/Person: 4.13	(N=32) Pattern 2A: 5.0% Pattern 2B: 20.0% Pattern 2C: 70.0% No Travel: 5.0% Trips/Person: 4.04
Not Employed	(N=9) Pattern 2A: 0.0% Pattern 2B: 47.7 % Pattern 2C: 42.3 % No Travel: 9.0% Trips/Person: 3.97	(N=10) Pattern 2A: 20.0% Pattern 2B: 60.0 % Pattern 2C: 0.0% No Travel: 20.0% Trips/Person: 3.79	(N=3) Pattern 2A: 0.0% Pattern 2B: 66.7% Pattern 2C: 0.0% No Travel: 33.3% Trips/Person: 3.21
Children			
In School	(N= 16) Pattern 2KA:18.8% Pattern 2KB:37.5% Pattern 2KC: 6.3% Pattern 2KD: 0.0% No Travel: 37.5% Trips/Person: 1.94	(N= 19) Pattern 2KA:21.1% Pattern 2KB:21.1% Pattern 2KC: 5.3% Pattern 2KD:36.8% No Travel: 15.8% Trips/Person: 3.52	(N= 36) Pattern 2KA:50.0% Pattern 2KB:16.7% Pattern 2KC: 0.0% Pattern 2KD:22.2% No Travel: 11.1% Trips/Person: 3.60
Not in School	(N= 16) Pattern 2KA:12.5% Pattern 2KB:37.5% Pattern 2KC:25.0% Pattern 2KD:0.0% No Travel: 25.0% Trips/Person: 2.41	(N= 17) Pattern 2KA: 5.9% Pattern 2KB:59.8% Pattern 2KC:11.8% Pattern 2KD: 0.0% No Travel: 23.5% Trips/Person: 2.32	(N= 7) Pattern 2KA: 0.0% Pattern 2KB:57.1% Pattern 2KC: 0.0% Pattern 2KD: 0.0% No Travel: 42.9% Trips/Person: 1.64

Table 6.5 Activity-Based Production Model for Couples without Children Households (1994 Portland Survey Data)

Employment \ Cars	Adult		
	0	1	2+
Employed	(N= 28) Pattern 3A: 14.3% Pattern 3B: 3.6 % Pattern 3C: 10.7% Pattern 3D: 3.6% No Travel: 67.9% Trips/Person: 1.04	(N=100) Pattern 3A: 18.0% Pattern 3B: 12.8% Pattern 3C: 38.0% Pattern 3D: 6.0% No Travel: 25.0% Trips/Person: 2.53	(N=412) Pattern 3A: 21.6% Pattern 3B: 11.7 % Pattern 3C: 48.9% Pattern 3D: 7.7% No Travel: 10.1% Trips/Person: 2.94
Not Employed	(N=17) Pattern 3A: 0.0% Pattern 3B: 0.0 % Pattern 3C: 0.0 % Pattern 3D: 23.5% No Travel: 76.5% Trips/Person: 0.89	(N=94) Pattern 3A: 48.9% Pattern 3B: 0.0 % Pattern 3C: 0.0% Pattern 3D: 15.4% No Travel: 35.7% Trips/Person: 2.91	(N=201) Pattern 3A: 69.1% Pattern 3B: 0.0% Pattern 3C: 1.9% Pattern 3D: 14.0% No Travel: 15.0% Trips/Person: 2.23

Table 6.6 represents the activity-based trip production table for single working parent households in the 1994 Portland Survey data. In this life cycle group, greater car ownership results in more traveling regardless of status of employment for the parents. The children's trip production is not affected by household vehicle ownership but can be distinguished by in-school and not-in-school groups.

Table 6.6 Activity-Based Production Model for One Working Parent Households (1994 Portland Survey Data)

Employment \ Cars	Adult		
	0	1	2+
Employed	(N= 2) Pattern 4A: 0.0% Pattern 4B: 0.0% Pattern 4C: 50.0% No Travel: 50.0% Trips/Person: 1.59	(N= 27) Pattern 4A: 22.3% Pattern 4B: 14.8% Pattern 4C: 40.9% No Travel: 22.0% Trips/Person: 2.82	(N= 32) Pattern 4A: 48.7% Pattern 4B: 11.8% Pattern 4C: 30.3% No Travel: 9.2% Trips/Person: 3.53
Not Employed	(N=2) Pattern 4A: 0.0% Pattern 4B: 50.0 % Pattern 4C: 0.0 % No Travel: 50.0% Trips/Person: 1.86	(N= 24) Pattern 4A: 45.8% Pattern 4B: 8.3 % Pattern 4C: 20.8 % No Travel: 25.1% Trips/Person: 2.98	(N=65) Pattern 4A: 36.9% Pattern 4B: 7.7% Pattern 4C: 41.5% No Travel: 13.1% Trips/Person: 3.22
Children			
In School	(N= 13) Pattern 4KA: 0.0% Pattern 4KB:38.5% Pattern 4KC:30.8% Pattern 4KD:15.4% No Travel: 15.4% Trips/Person: 3.04	(N= 37) Pattern 4KA: 0.0% Pattern 4KB:43.2% Pattern 4KC:21.6% Pattern 4KD:32.4% No Travel: 2.7% Trips/Person: 3.56	(N= 38) Pattern 4KA: 0.0% Pattern 4KB:34.2% Pattern 4KC:36.8% Pattern 4KD:21.1% No Travel: 7.9% Trips/Person: 3.23
Not in School	(N= 21) Pattern 4KA:19.0% Pattern 4KB: 4.8% Pattern 4KC: 9.5% Pattern 4KD: 0.0% No Travel: 66.7% Trips/Person: 1.12	(N= 46) Pattern 4KA:23.9% Pattern 4KB: 8.7% Pattern 4KC:47.8% Pattern 4KD: 2.2% No Travel: 17.4% Trips/Person: 2.65	(N= 30) Pattern 4KA:20.0% Pattern 4KB: 6.7% Pattern 4KC:43.3% Pattern 4KD:10.0% No Travel: 20.0% Trips/Person: 2.57

Similarly to Table 6.6, Table 6.7 represents the production model for two working parents households and has the same tendency to show increased trip frequency as household vehicle ownership increases. Children have less variation in travel, perhaps explained as that they are in school or day care when bother parents need to work. The trip rates for children in this lifecycle group are average regardless of household vehicle ownership.

In Table 6.8, the trips/activities rate table is computed for any type of households not in the previous categories. In general, employed persons produce more trips than not-employed persons in this group, and trip frequency increases as household vehicle ownership does. Although it has been noticed in the previous five tables that not-employed adults with no vehicles tend to make more trips in comparison to the average, such adults here do not perform more trips than a employed person.

Table 6.7 Activity-Based Production Model for Both Working Parents Households (1994 Portland Survey Data)

Employment \ Cars	Adult 0	Adult 1	Adult 2+
Employed	N. A.	(N= 35) Pattern 5A: 5.8% Pattern 5B: 28.7% Pattern 5C: 54.6% No Travel: 10.9% Trips/Person: 3.99	(N=349) Pattern 5A: 15.0% Pattern 5B: 26.7% Pattern 5C: 50.3% No Travel: 8.0% Trips/Person: 4.15
Not Employed	N. A.	N. A.	N. A.
Children			
In School	(N= 17) Pattern 5KA:23.5% Pattern 5KB:41.1% No Travel: 35.3 Trips/Person: 2.02	(N= 91) Pattern 5KA:51.6% Pattern 5KB:39.6% No Travel: 8.8% Trips/Person: 2.96	(N= 68) Pattern 5KA:54.4% Pattern 5KB:29.4% No Travel: 16.2% Trips/Person: 2.76
Not in School	(N= 23) Pattern 5KA:34.8% Pattern 5KB:47.8% No Travel:17.4% Trips/Person: 2.61	(N= 52) Pattern 5KA:13.5% Pattern 5KB:75.0% No Travel:11.5% Trips/Person: 2.66	(N= 74) Pattern 5KA:24.3% Pattern 5KB:63.5% No Travel:12.1% Trips/Person: 2.70

Table 6.8 Activity-Based Production Model for Life Cycle of Other Households (1994 Portland Survey Data)

Employment \ Cars	Adult 0	Adult 1	Adult 2+
Employed	(N= 8) Pattern 6A: 10.7% Pattern 6B: 53.6 % Pattern 6C: 0.0% Pattern 6D: 10.7% No Travel: 25.0% Trips/Person: 2.68	(N= 64) Pattern 6A: 34.6% Pattern 6B: 6.3% Pattern 6C: 17.2% Pattern 6D: 18.9% No Travel: 23.0% Trips/Person: 2.55	(N= 227) Pattern 6A: 40.1% Pattern 6B: 14.6 % Pattern 6C: 20.7% Pattern 6D: 8.3% No Travel: 16.3% Trips/Person: 2.99
Not Employed	(N= 4) Pattern 6A: 0.0% Pattern 6B: 0.0 % Pattern 6C: 25.0 % Pattern 6D: 25.0% No Travel: 50.0% Trips/Person: 1.84	(N= 55) Pattern 6A: 0.0% Pattern 6B: 21.4 % Pattern 6C: 37.0% Pattern 6D: 23.4% No Travel: 18.2% Trips/Person: 2.81	(N= 104) Pattern 6A: 1.9% Pattern 6B: 22.1% Pattern 6C: 24.1% Pattern 6D: 26.0% No Travel: 25.9% Trips/Person: 2.67

6.5 Linking the Productions with Attractions

A complete generation model in the conventional approach includes two components: production and attraction models. A trip production model represents the likelihood of a person traveling, and an attraction model represents the distributions of trip ends shaped by resource locations and network accessibility. Aggregate assumptions concerning accessibility are required for conventional trip distribution models, which generally employ gravity-type models to match the number of trips between origins and destinations with a simple exponential equation.

The advantage of the proposed activity-based generation model is its ability to analyze travel/activity patterns and to simulate attractions at locations within feasible traveling distances. The equilibrium between the trip production and the trip attraction will exist based on the number of available opportunities and accessibility, in general. As discussed in earlier sections, a person will be assigned to one of the typical travel/activity patterns available in a specific life cycle group, according to the proportions estimated by the category model. Each set of travel/activity patterns contains the frequencies of how different types of activities will be performed daily, and that implicitly indicates the trip end information by type of activity and the associated traveling distance.

Instead of balancing the trips and utilizing a conventional trip distribution model, this activity-based approach simulates the actual travel pattern (given the RAP structure), the household location and the distributions of travel characteristics. This activity-based trip generation model not only forecasts productions according to time of the day, but also provides distance constraints on where the trip can be distributed. It eliminates unrealistic trip distributions and also prevents activities being assigned to unavailable time windows.

While it is unlikely that an entire pattern is generated then executed without potentially significant individual variations in spatial, temporal, activity, and transportation dimensions, it is believed that such a base unit of travel behavior provides an underlying structure and also represents a significant improvement over the convention specification of household trip rates by purpose and selected demographic classification variables. Where the conventional model would generate non-linked trip ends than re-link origins and destinations via an aggregate spatial interaction model, the proposed approach generates full activity patterns containing representative linkages. It is hypothesized that the general characteristics of these linkages (activity type, distance and travel time, start time and duration, etc.) are representative of what similar individuals residing in similar sub-areas would also display. The specific sequencing, scheduling, and location dimensions of the pattern are simulated based on distribution of these characteristics for each identified RAP.

The procedure to match the trip origin and destination is a stochastic process. The implementation of this operational activity-based trip generation model is described as follows:

1. Select a sub-area from the region under analysis.
2. Select a household location based on population density within the sub-area. Assign household and individual demographics based on census and survey data.
3. Select a target RAP based on the distribution of potential RAPs in the parent data set.
4. Based on sample distributions of the selected dimensions, select target parameters for the activity pattern to be generated. For this example, each dimension can be defined by a mean and standard deviation (and minimum and maximum constraints).
5. Using a GIS, allocations within the annulus defined by the mean and

standard deviation trip distance are bounded. Using the GIS overlay of land use, population and employment density, and other appropriate trip attractors, the probability of a trip destination within the annulus is established (discrete sectors were utilized in the manual application). A random draw establishes the activity location. If the activity is not the first trip on a chain, than a second distance measure, distance from home, is used to construct a second annulus. The interaction of these areas defines the search space. If no solution is found, various simulation correction loops restart the process. This insures that the chain's ultimate return home trip reflects that observed in the target RAP.

6. If the simulation extends the chain, the process depicted for activity 2 is repeated. Otherwise, a return home trip is simulated followed by a determination of whether a complete activity pattern has been simulated or if further activities (new chains) are needed. Noted that although the RAP contained two separate single activity trip chains, the simulation uses the underlying activity distributions and produced a chained second activity.
7. Other constraints may be imposed such as minimum and maximum participation times. If a simulated activity would violate a set constraint, then that activity would not be performed, and the simulation would proceed.

For example, a person with a set of personal socioeconomic and demographic characteristics in the category of couples without children, has the probabilities of 0.14, 0.04, 0.11, 0.04, or 0.68 to choose from patterns 3A - 3E, respectively. If pattern 3C is chosen to simulate, then the representative activity pattern (RAP) will be used as the template to construct the daily travel/activity pattern. Then, the distance distribution of this specific RAP will be used to simulate activity distance from home, and the overall average distance will be equal to group centroid distance. The variation of activities being performed is then simulated by the distribution of activity types according to time and duration.

Chapter 7

Conclusions and Future Research

7.1 Conclusions

Activity analysis depicts travel behavior as a derived consequence of the production and consumption decisions of households in a time-space fashion. Until the launch of the Travel Model Improvement Program (TMIP), the transportation demand modeling system has only focused on estimation of individual trip making rather than using the inter-personal and time-space characteristics that define regional travel patterns. Although much research has been conducted in the investigation of trip-making decisions, few researchers have developed an operation activity-based model. By analyzing the representative patterns in different life cycle groups, the evolution of travel behavior through different life stages facilitated, and the effect of household interactions can be simulated with the selected RAPs using the proposed category model approach.

In the past, the analysis of distinct activity patterns has been recognized as related to the study of travel frequency and purpose, and household socioeconomic and demographic factors. The incorporation of such a concept into an operational model that employs Monte Carlo simulation techniques to model activities and trips is an advancement in travel demand research.

This dissertation provides insights on the temporal stability of travel/activity patterns by analyzing the 1985 and 1994 Portland, Oregon Household Travel Survey, and advances the activity-based research a significant step forth. In the research process, distinct travel/activity patterns are obtained for household life cycle groups, and the number of activities as well as the number of trips are computed. The variations of time-space images over life cycle groups are observed.

Individuals are linked to different types of travel/activity patterns with a category model which is composed of conventional socio-economic and demographic variables. The benefit of employing the category model is its relative efficiency in application and simplicity in implementation.. In that process, variables such as gender, age, employment status, and household role, are used to identify the patterns that implicitly reveals the travel demand of different life cycle groups.

The results of this research provide a detailed investigation of household travel/activity patterns and the chance to construct a transportation demand model with a comprehensive theoretical foundation derived from the activity-based approach. The implementation of this research will stimulate further advancements in activity-based research.

7.2 Future Research

More is needed to be done in order to design a complete process for an activity-based transportation demand model. Some essential aspects which must bee accounted for to make this research more valuable, is a micro-simulation, model to complete the remaining steps of this process.

The proposed technique to find feasible activity locations is based on Monte Carlo simulation, which is an exhaustive simulation process to specify patterns for all persons. Though a constraint of distance from home has been imposed in the research, more constraints should be implemented to reduce the computation iterations and to be applicable for real world transportation practitioners. To provide more environmental information of the real world, geographical information systems (GIS) have been widely used to duplicate the distribution of environment resources and transportation infrastructure and should be used in future research. A well-specified electronic map of transportation network and resource locations should provide more accurate destination choice information, and it will also provide more precise information to reduce the computation load in the Monte Carlo simulation process.

Finally, urban congestion effects should be addressed in terms of the substitution of in-home and out-of-home activities due to the excessive of travel times. Activity-based research should include the investigation of self adaptation behavior. The incorporation of traffic congestion modeling with activity research will lead to work on dynamic trip origin/destination matrix estimation that accounts for variations of congestion by time of day and location in an urban area. The completeness of these above aspects will allow for the development of the next generation of travel demand models and the applicability of this research.

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Appendix A: Single Person Household RAP 1A

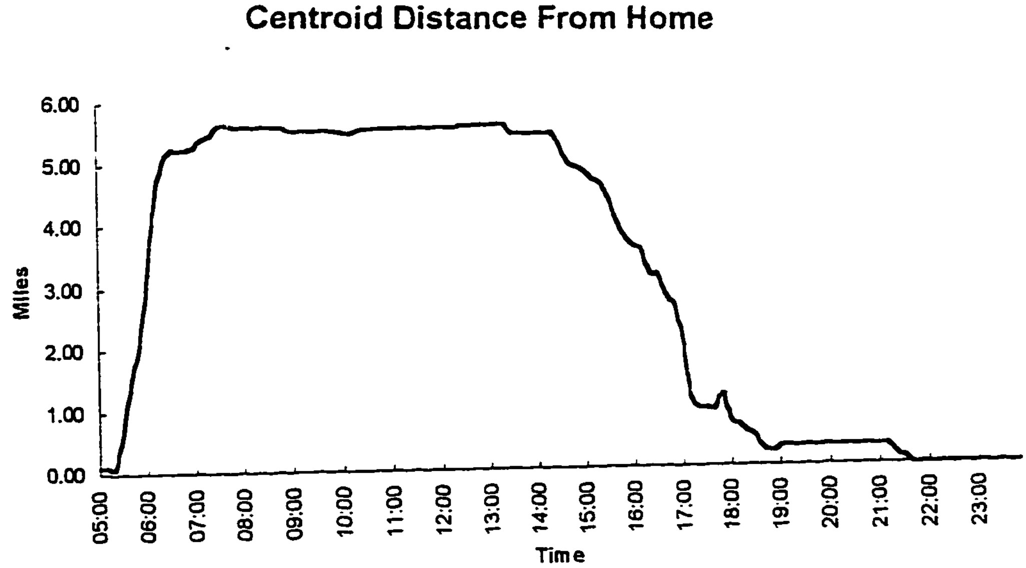


Fig. A.1 Pattern 1A Distance Distribution with 1985 Data

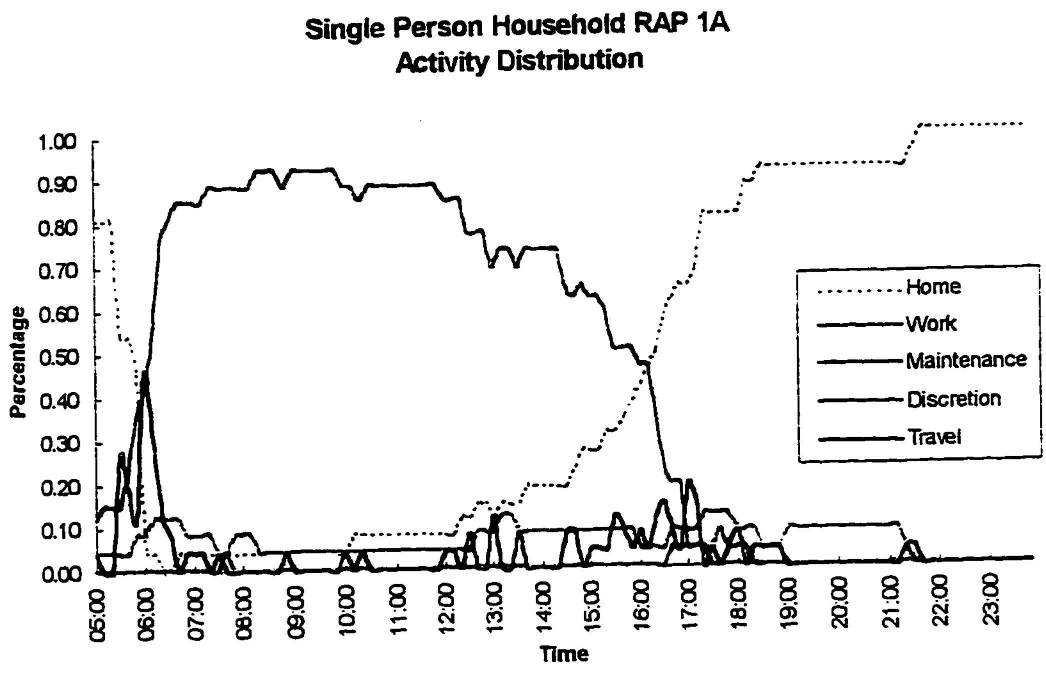


Figure A.2 Pattern 1A Activity Distribution with 1985 Data

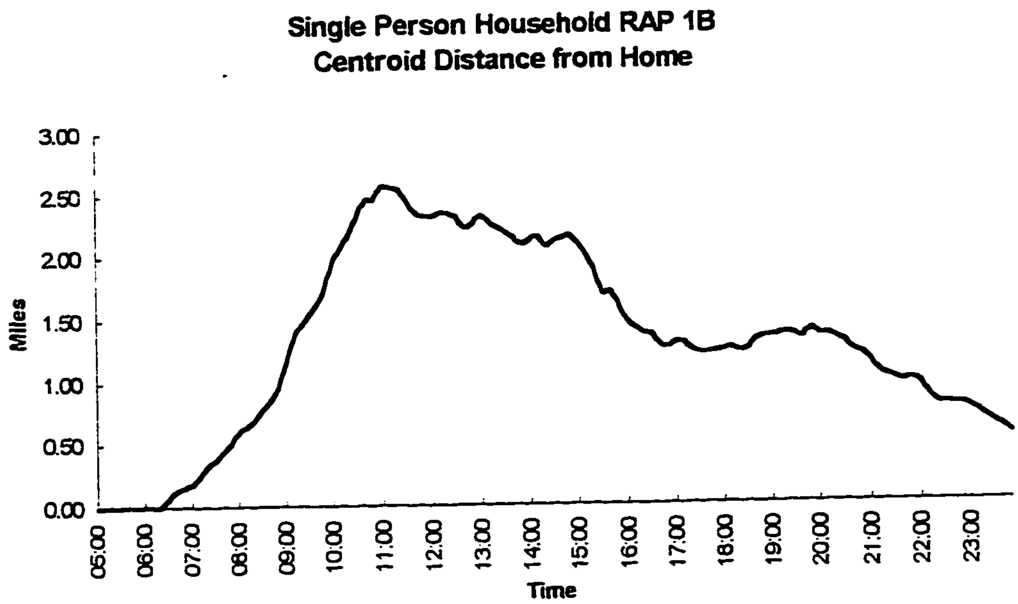


Figure A.3 Pattern 1B Distance Distribution with 1985 Data

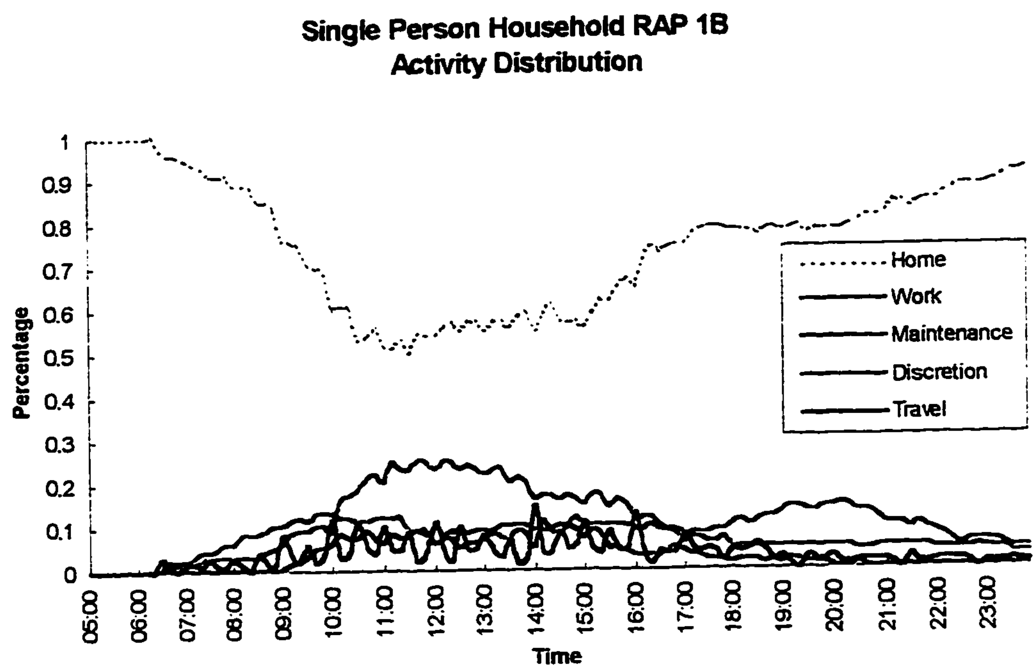


Fig. A.4 Pattern 1B Activity Distribution with 1985 Data

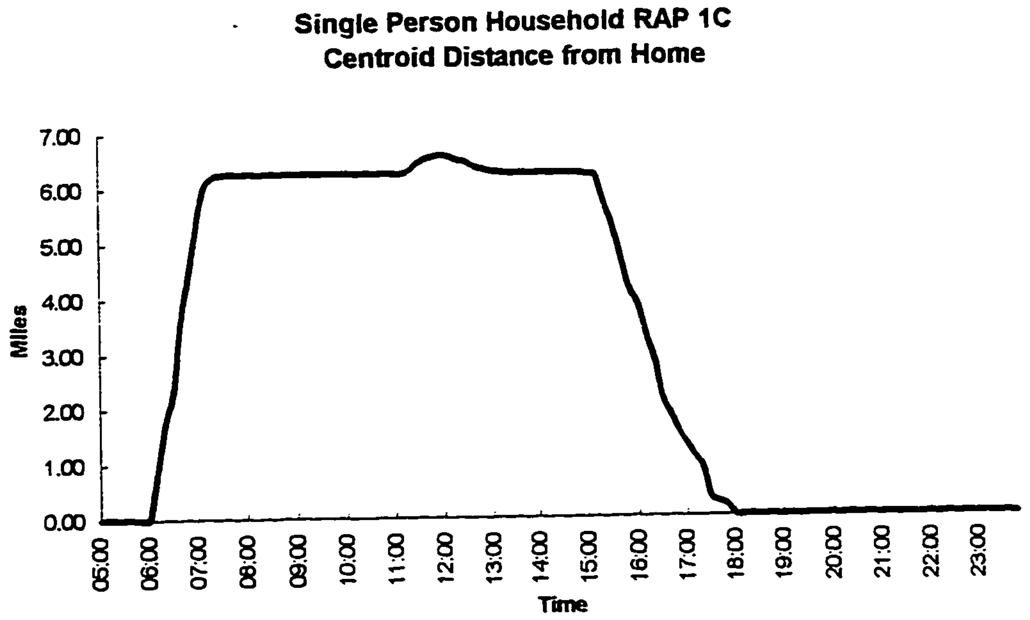


Fig A.5 Pattern 1C Distance Distribution with 1985 Data

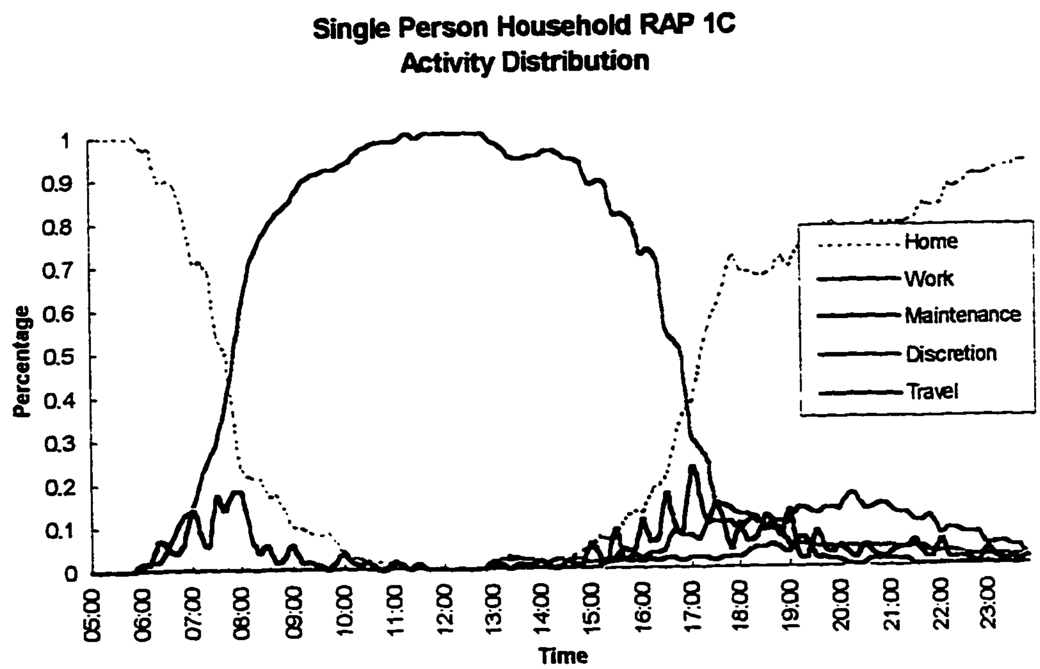


Fig A.6 Pattern 1C Activity Distribution with 1985 Data

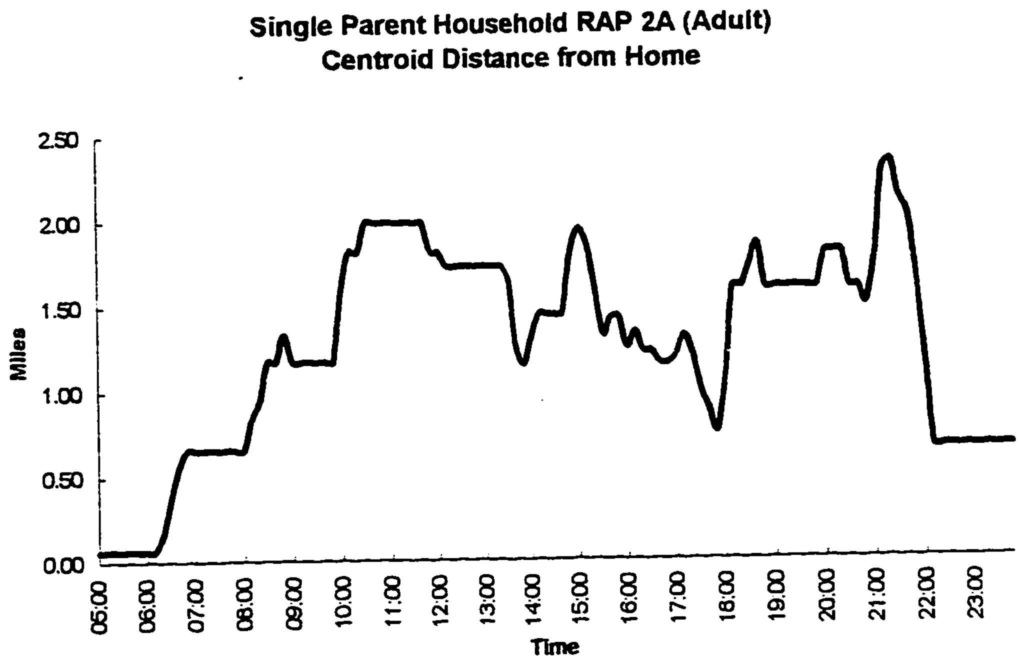


Fig A.7 Pattern 2A Distance Distribution with 1985 Data

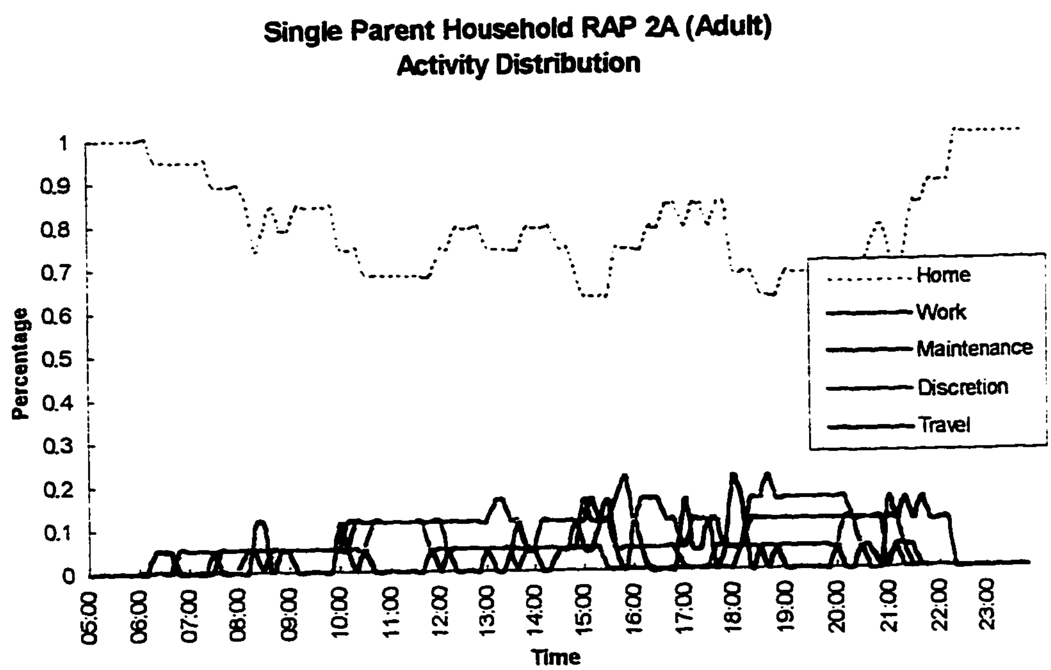


Fig A.8 Pattern 2A Activity Distribution with 1985 Data

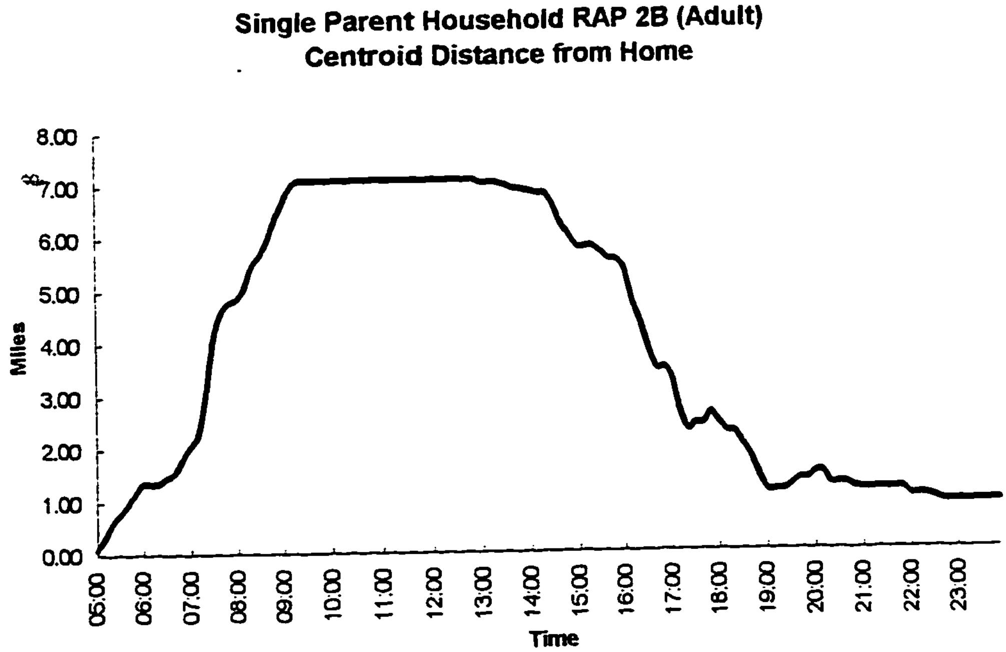


Fig A.9 Pattern 2B Distance Distribution with 1985 Data

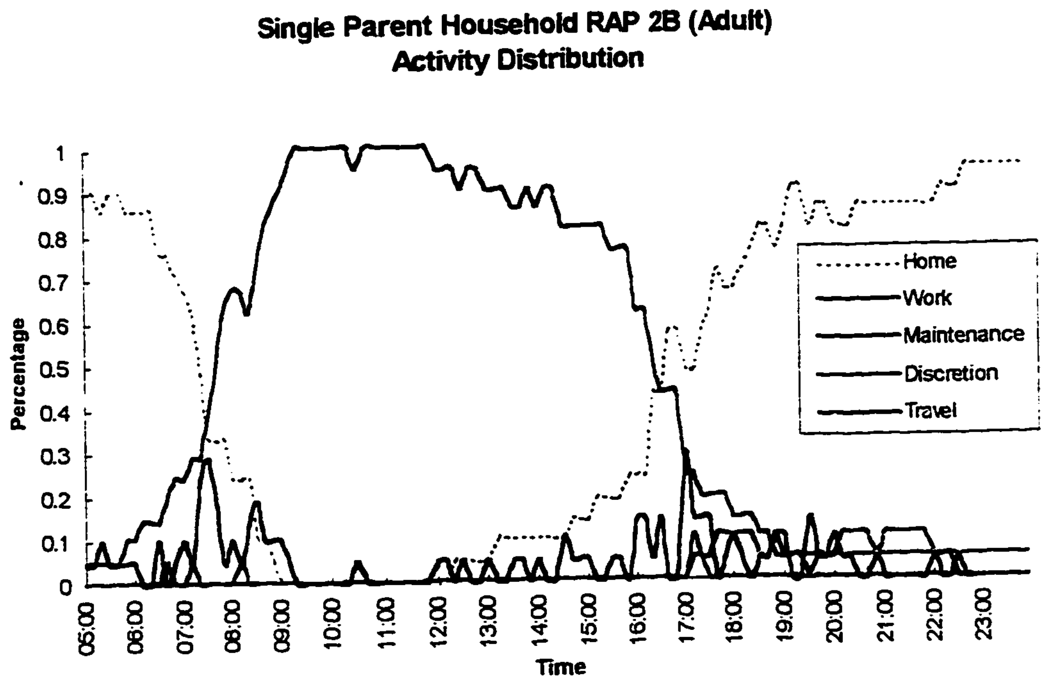


Fig A.10 Pattern 2B Activity Distribution with 1985 Data

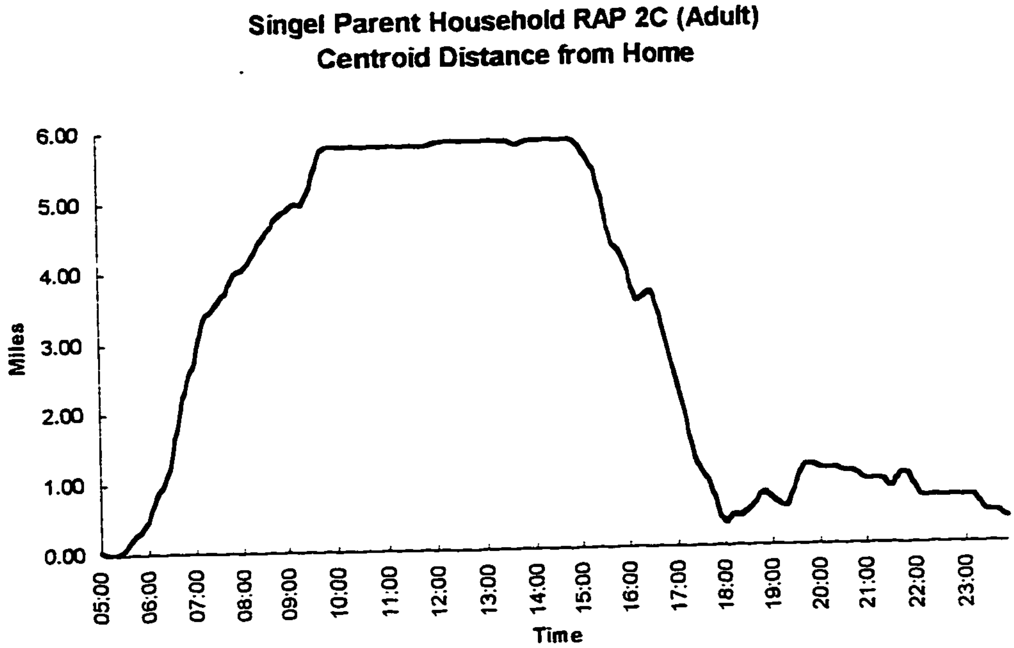


Fig A.11 Pattern 2C Distance Distribution with 1985 Data

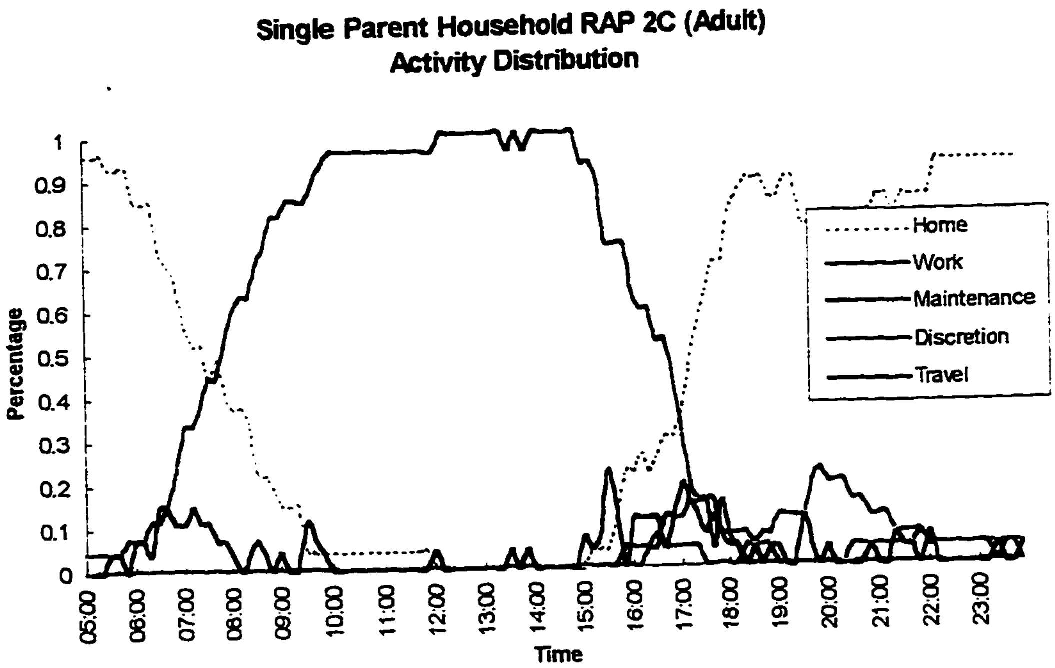


Fig A.12 Pattern 2C Activity Distribution with 1985 Data

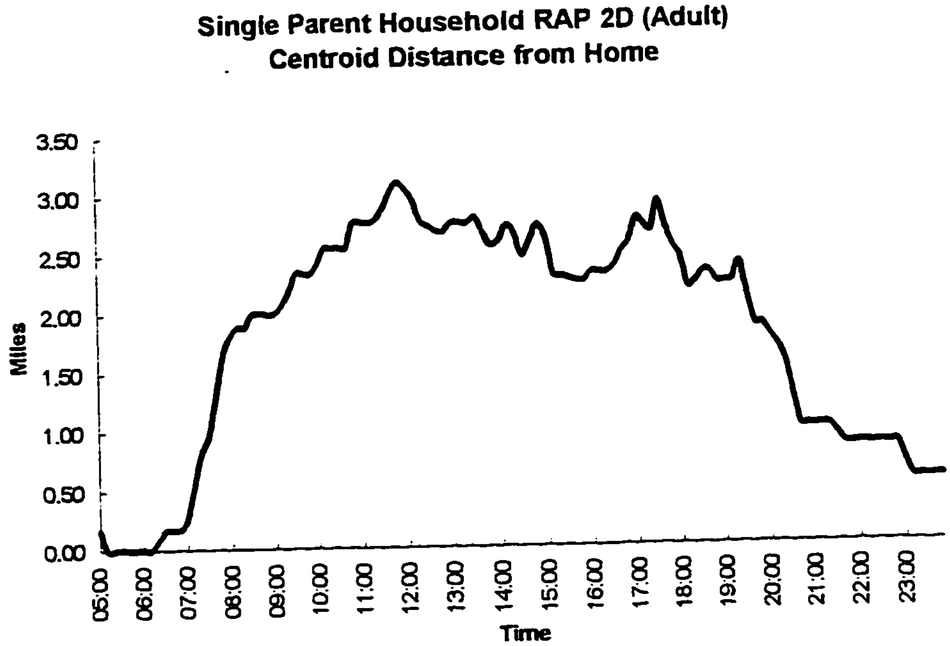


Fig A.13 Pattern 2D Distance Distribution with 1985 Data

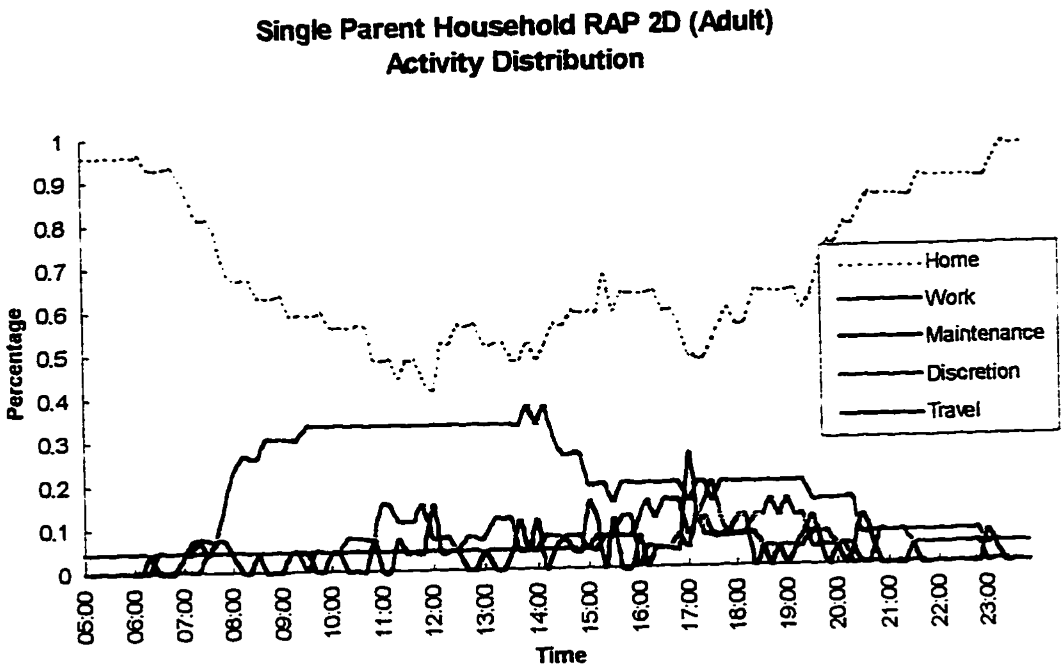


Fig A.14 Pattern 2D Activity Distribution with 1985 Data

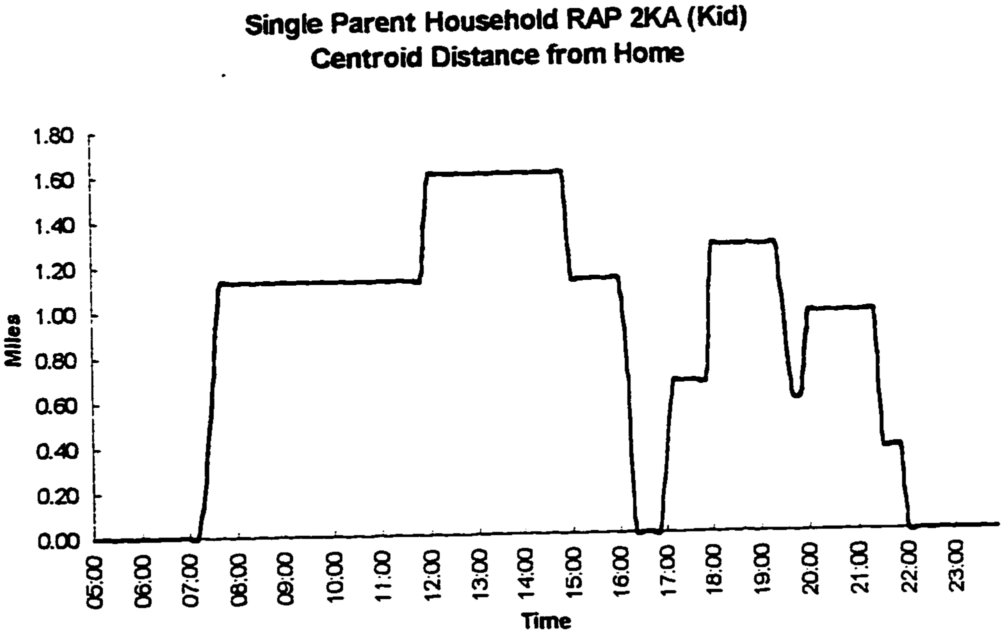


Fig A.15 Pattern 2KA Distance Distribution with 1985 Data

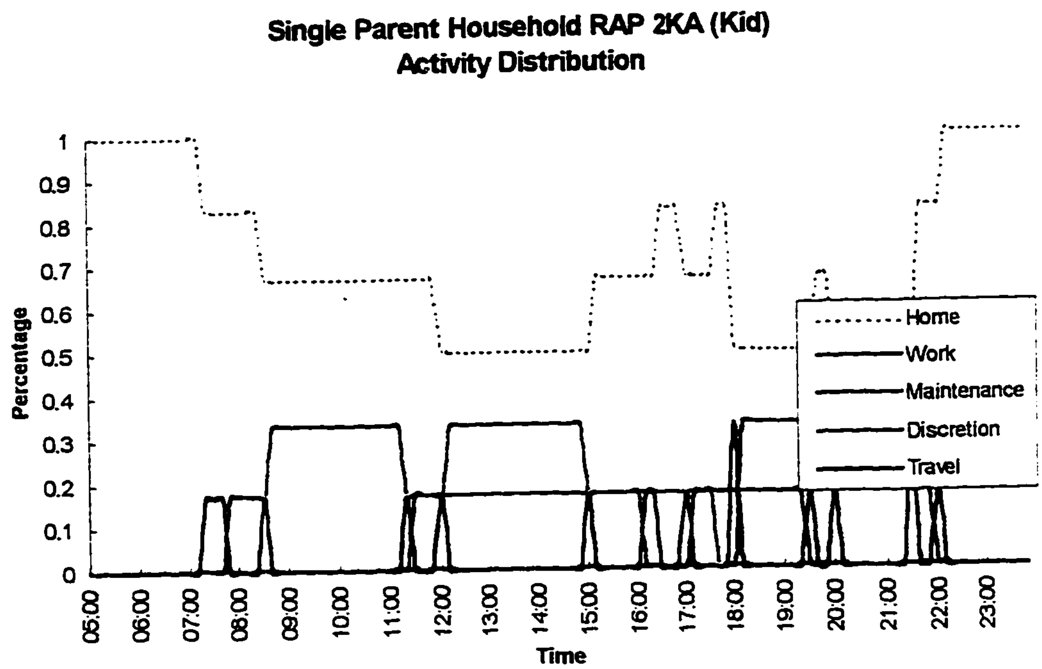


Fig A.16 Pattern 2KA Activity Distribution with 1985 Data

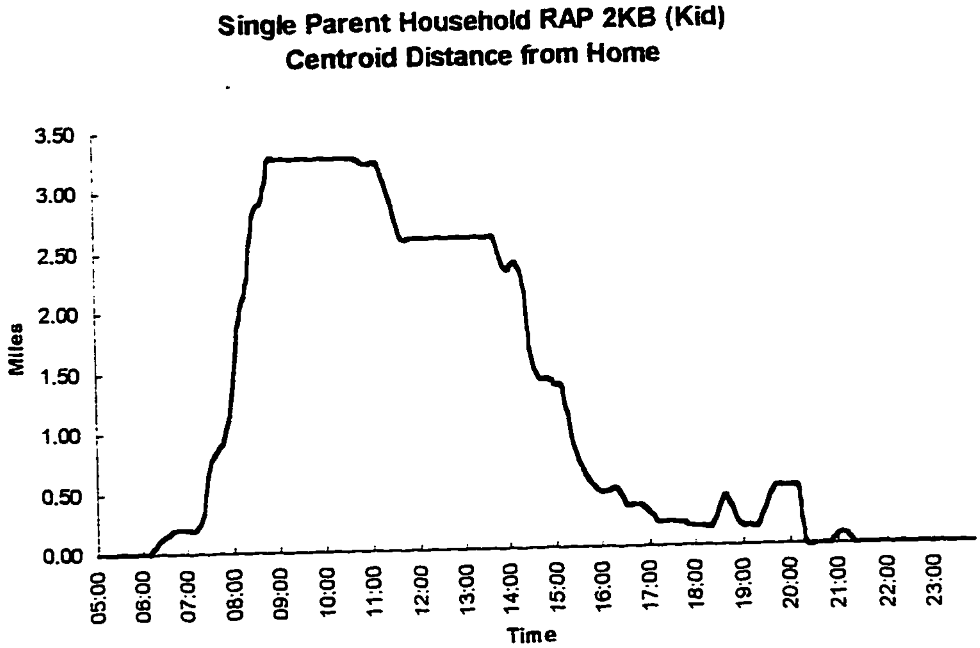


Fig A.17 Pattern 2KB Centroid Distance with 1985

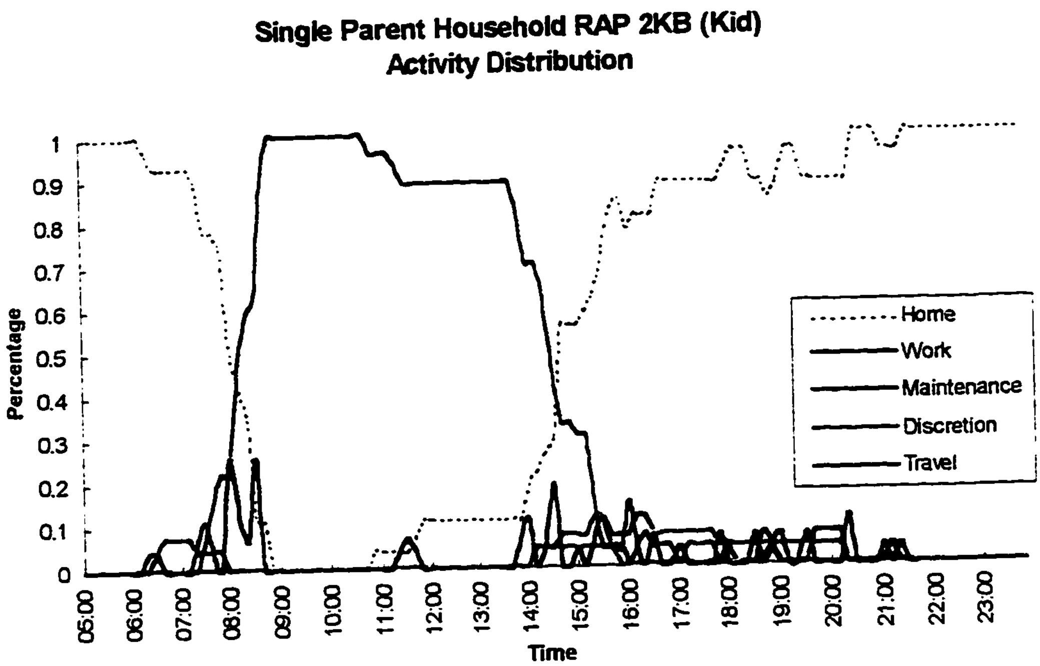


Fig A.18 Pattern 2KB Activity Distribution with 1985 Data

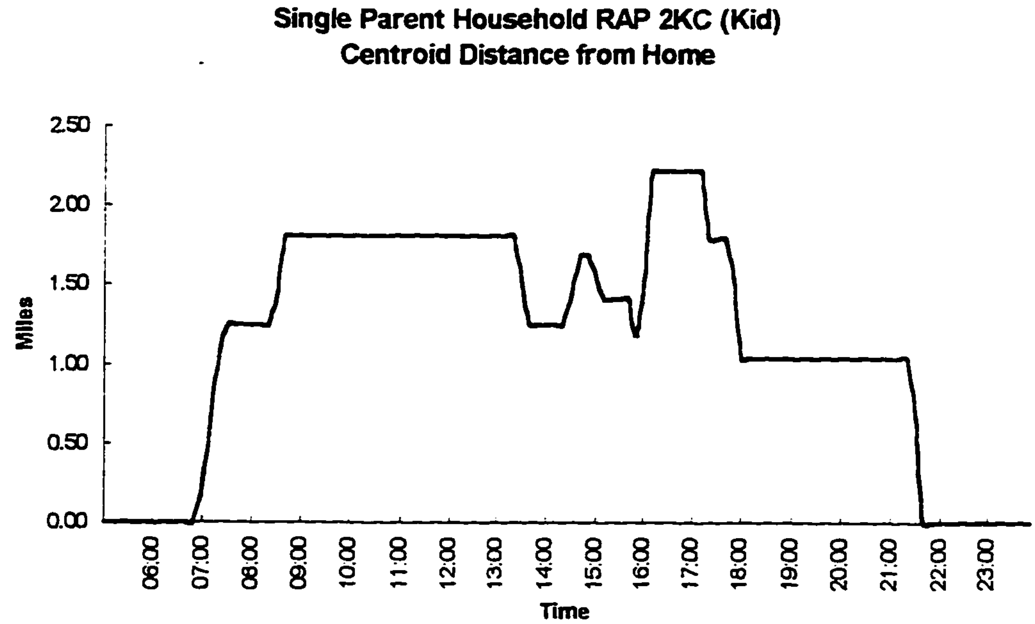


Fig A.19 Pattern 2KC Centroid Distance with 1985 Data

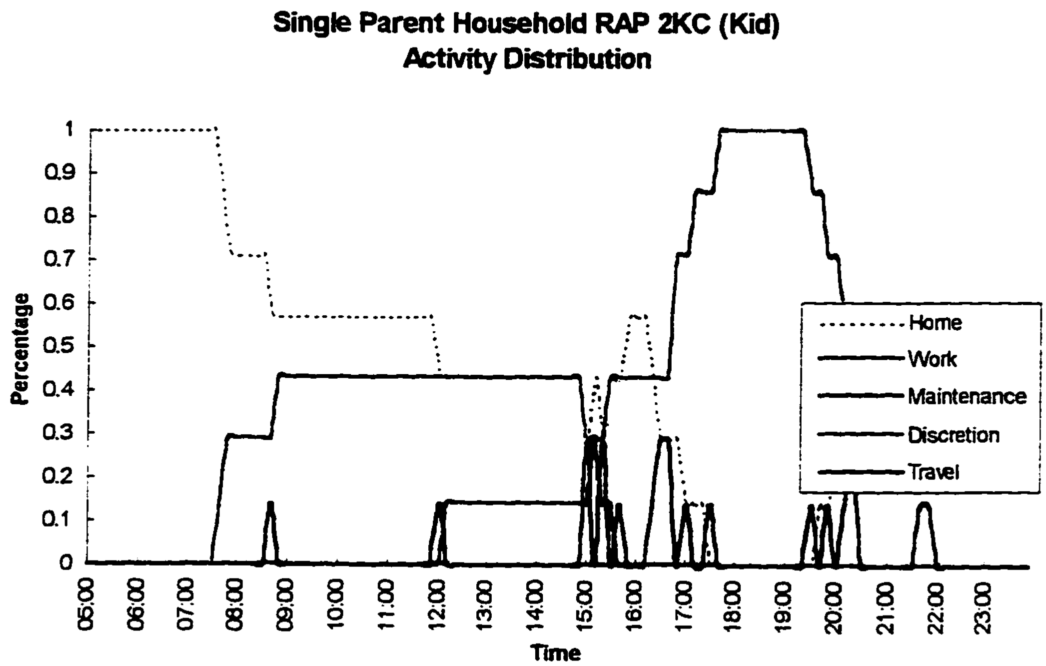


Fig A.20 Pattern 2KC Activity Distribution with 1985 Data

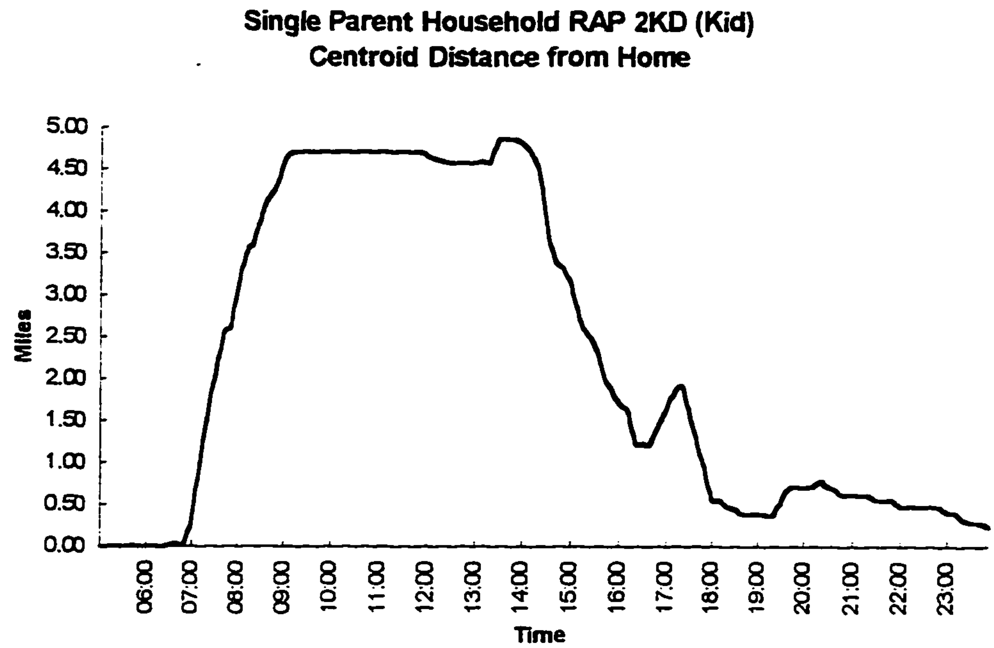


Fig A.21 Pattern 2KD Distance Distribution with 1985 Data

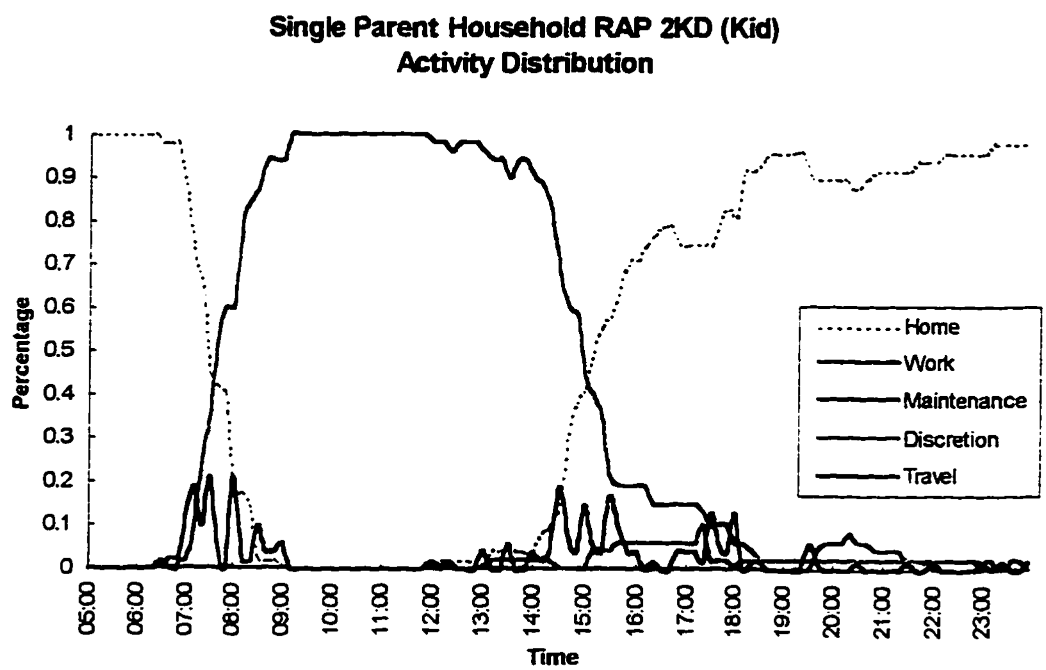


Fig A.22 Pattern 2KD Activity Distribution with 1985 Data

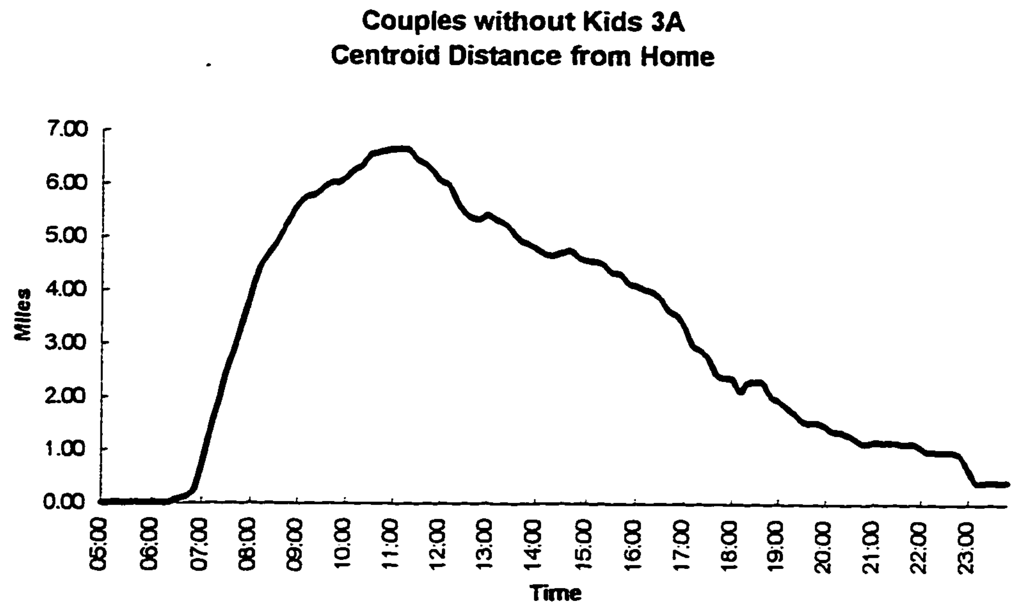


Fig A.23 Pattern 3A Distance Distribution with 1985 Data

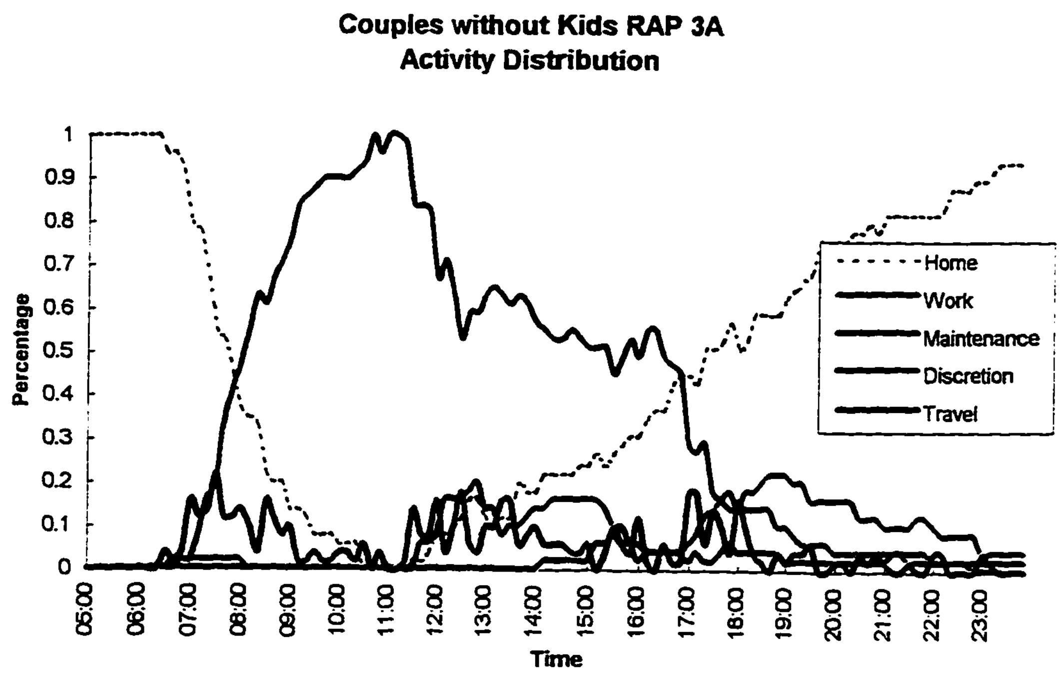


Fig A.24 Pattern 3A Activity Distribution with 1985 Data

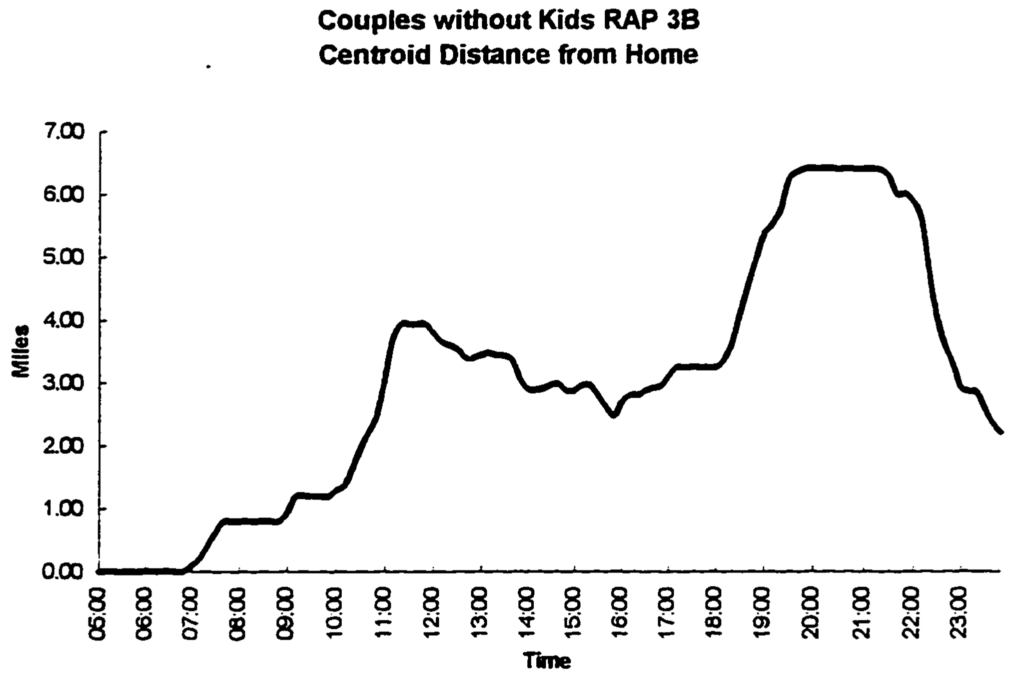
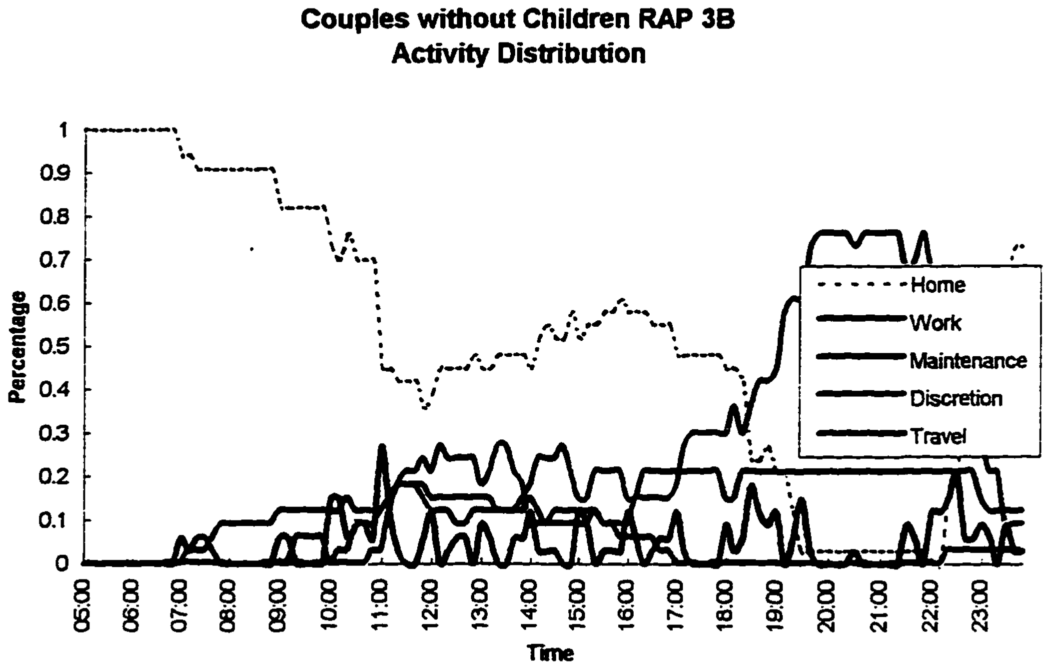


Fig A.25 Pattern 3B Distance Distribution with 1985 Data



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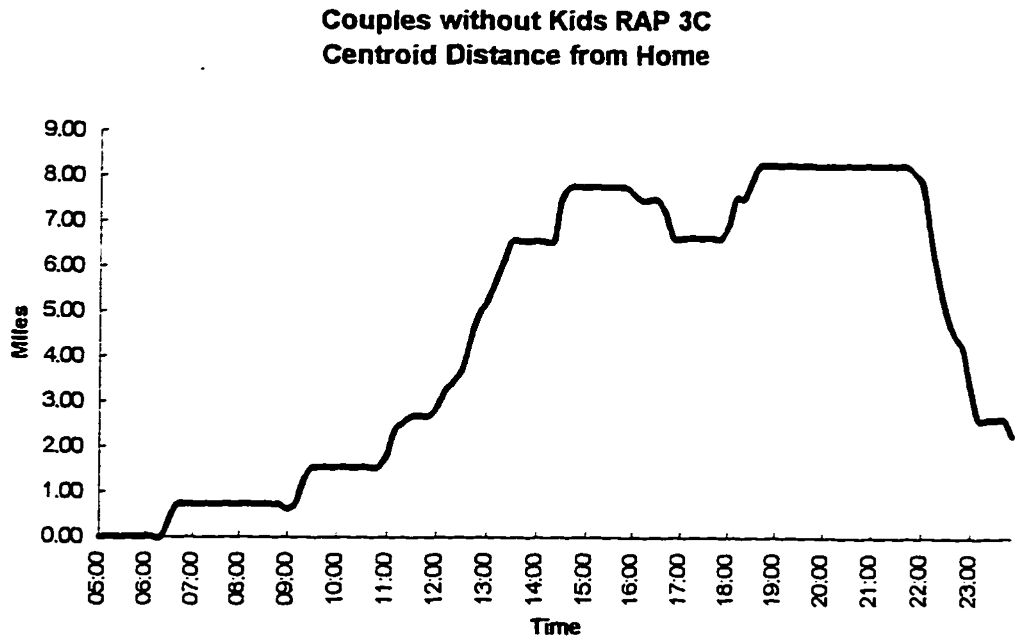


Fig A.27 Pattern 3C Distance Distribution with 1985 Data

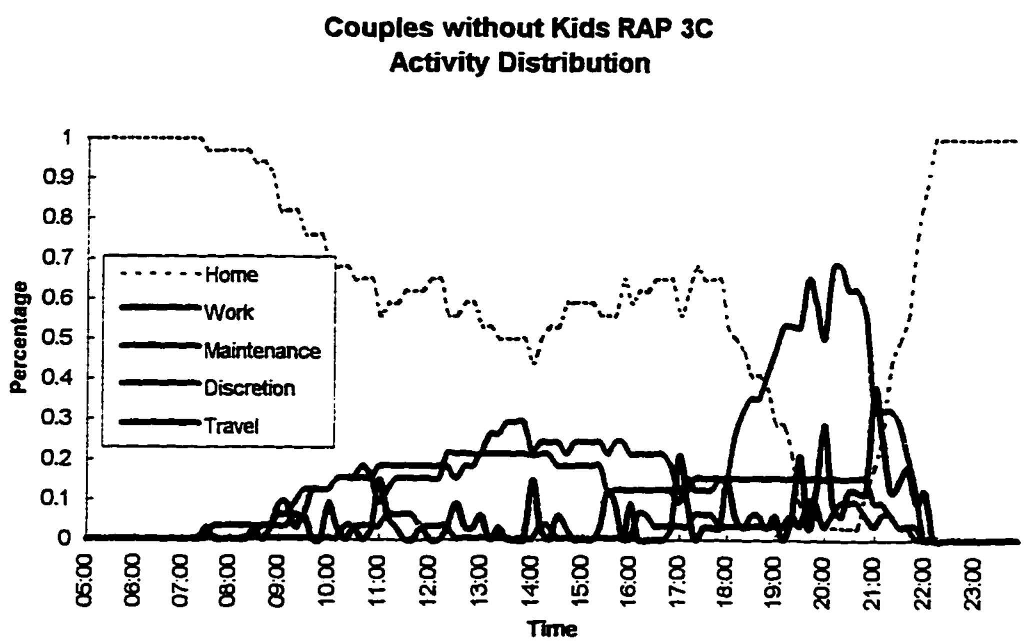


Fig A.28 Pattern 3C Activity Distribution with 1985 Data

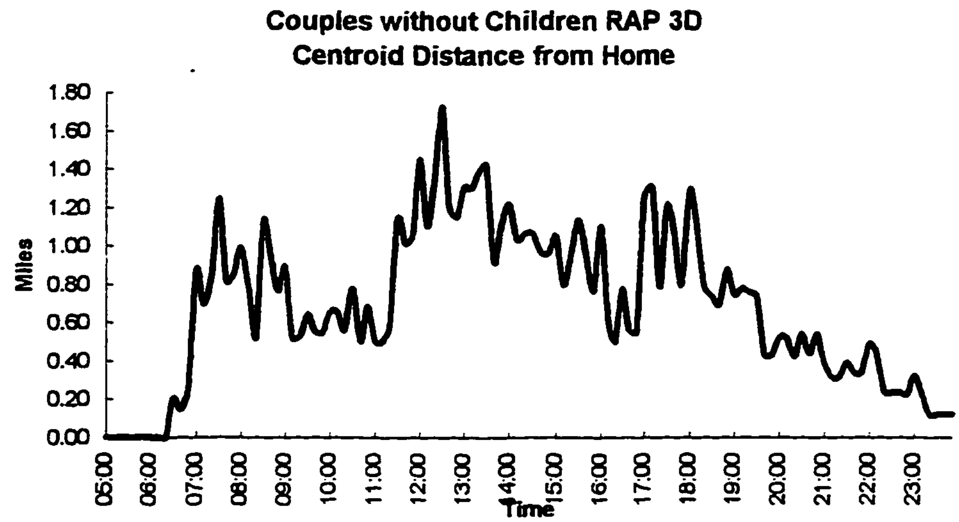
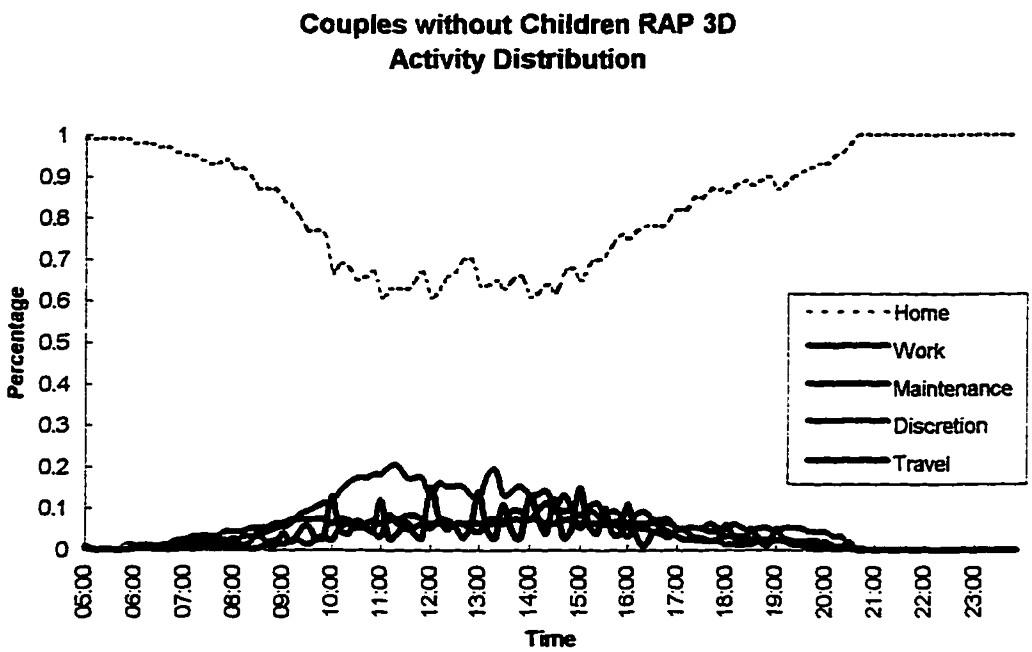


Fig A.29 Pattern 3D Distance Distribution with 1985 Data



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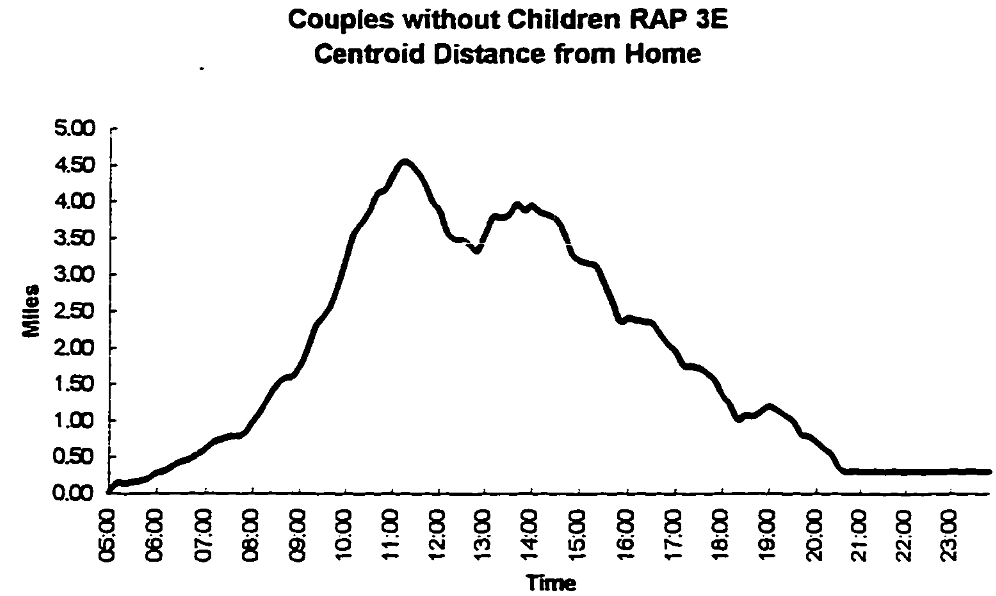
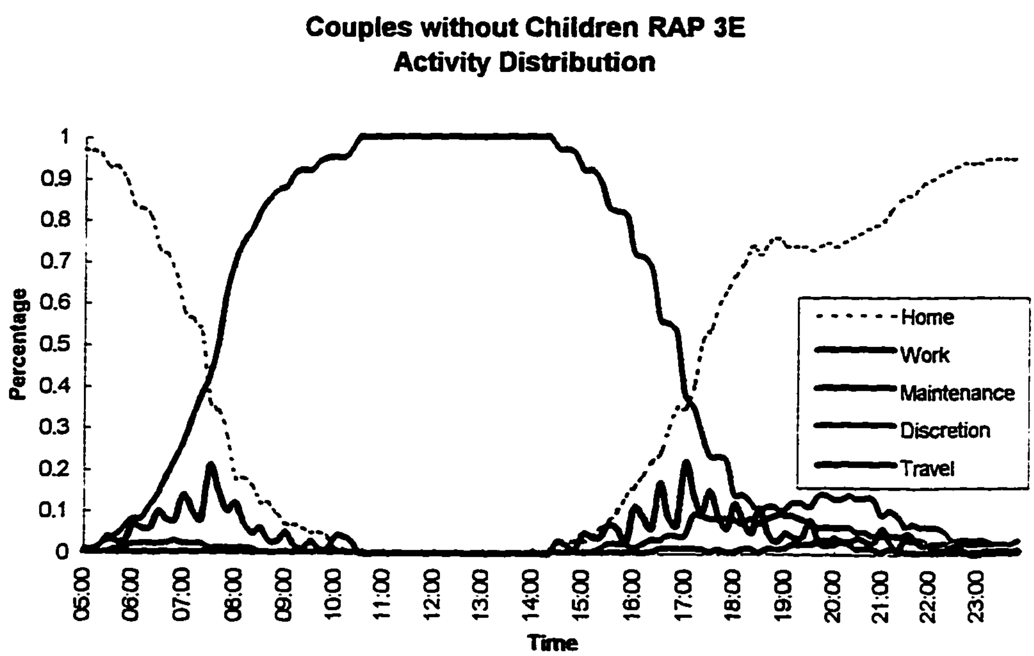


Fig A.31 Pattern 3E Distance Distribution with 1985 Data



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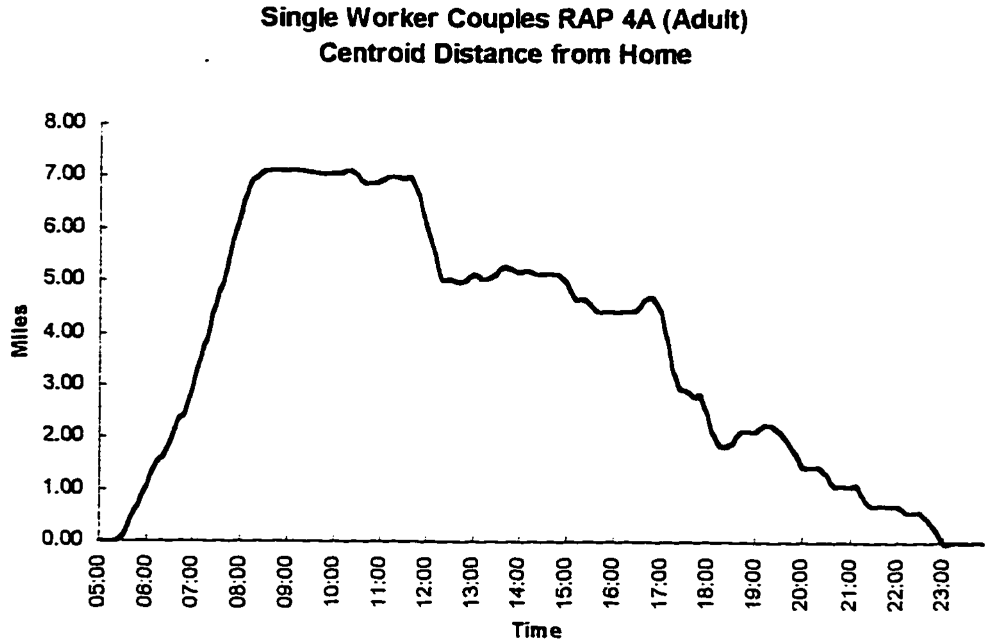
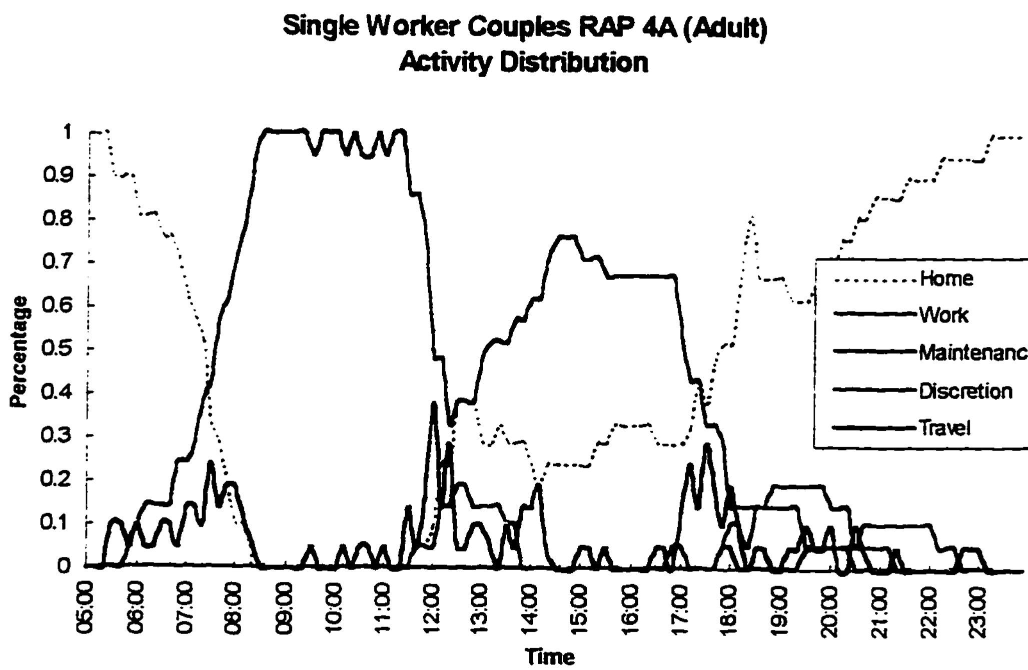


Fig A.33 Pattern 4A Distance Distribution with 1985 Data



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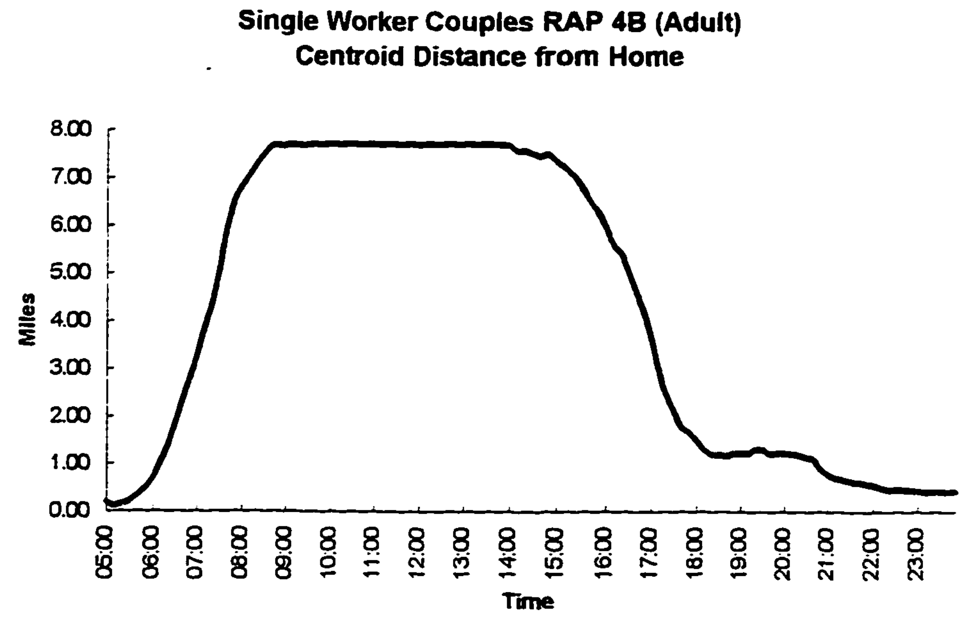

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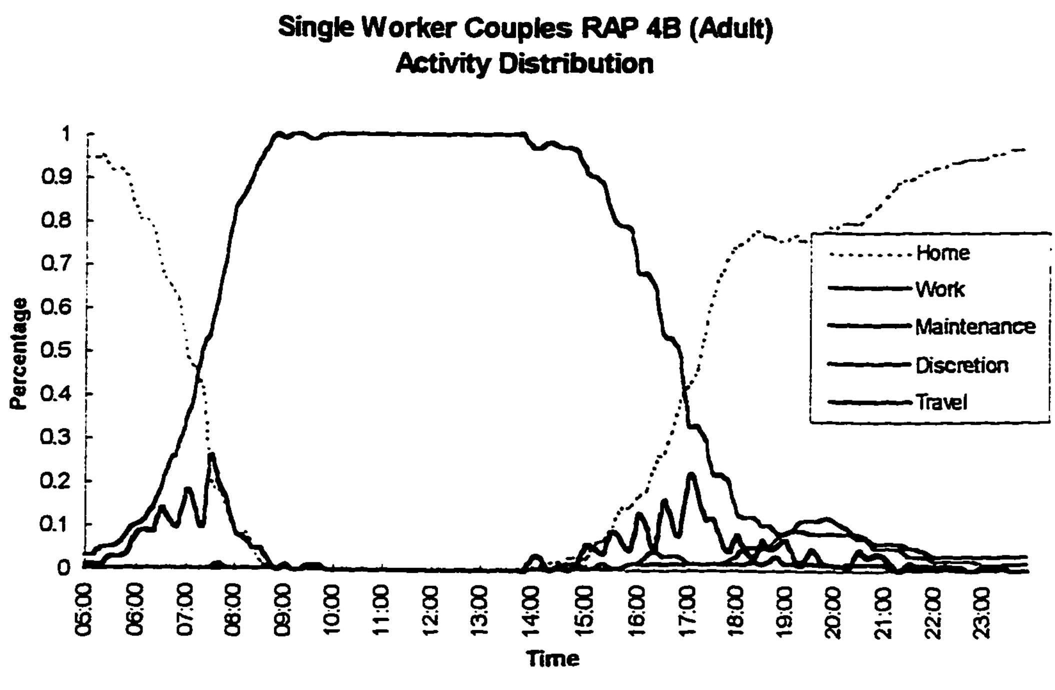

Fig A.36 Pattern 4B Activity Distribution with 1985 Data

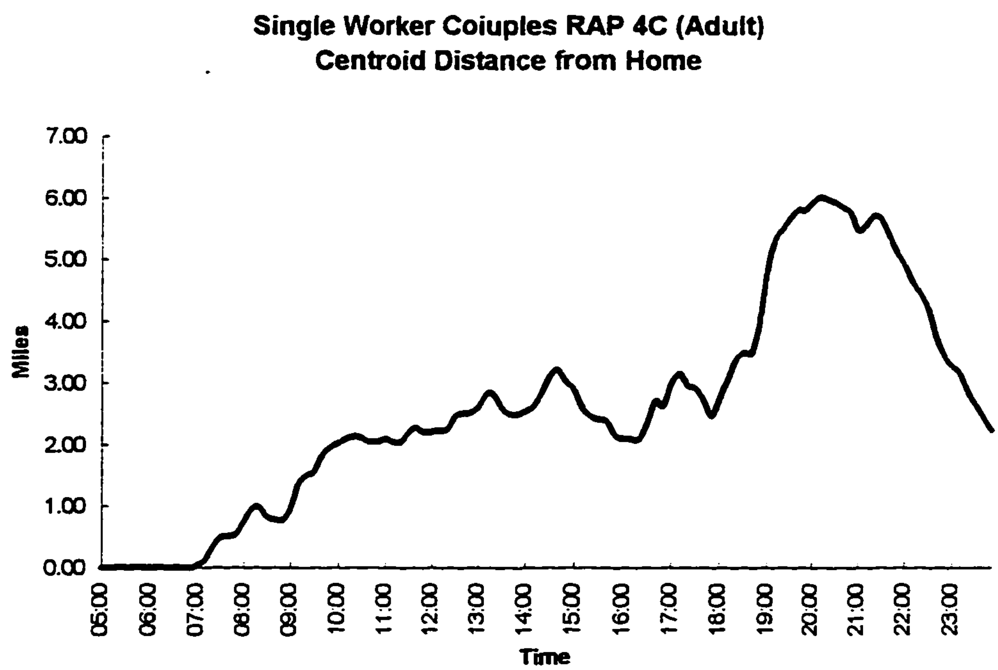

Fig A.37 Pattern 4C Distance Distribution with 1985 Data

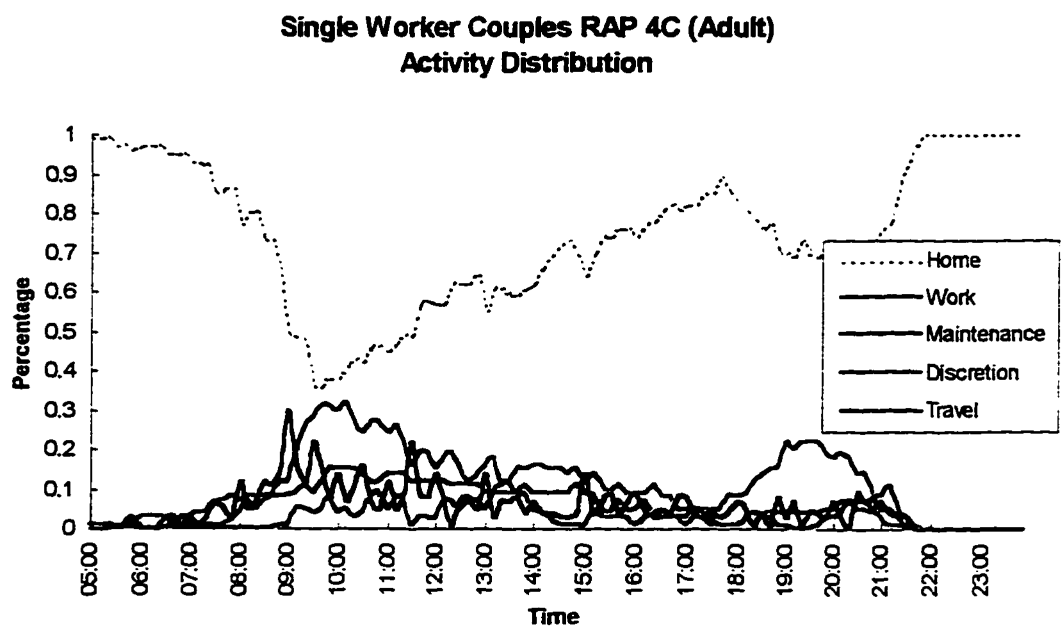

Fig A.38 Pattern 4C Activity Distribution with 1985 Data

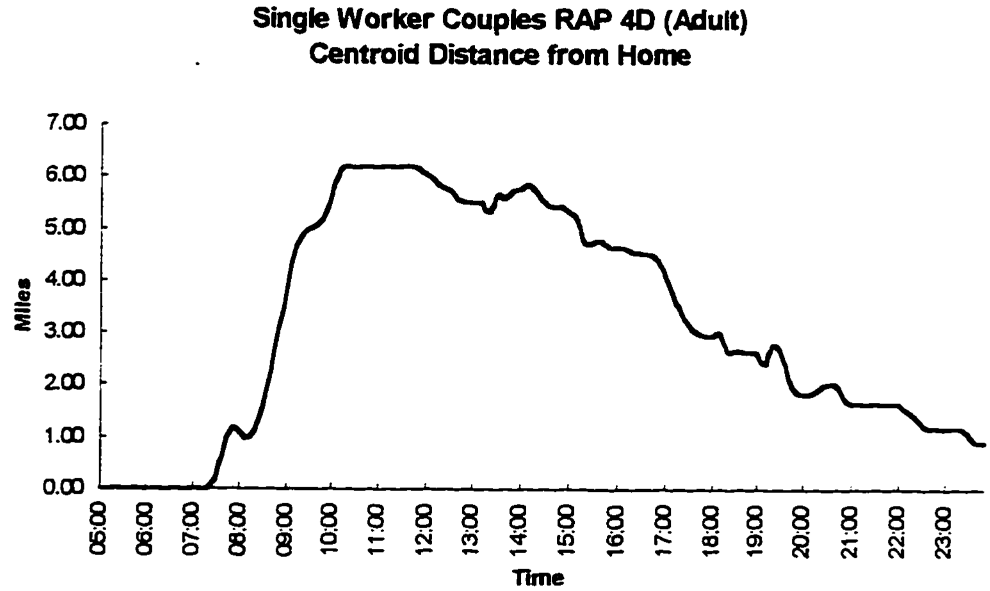

Fig A.39 Pattern 4D Distance Distribution with 1985 Data

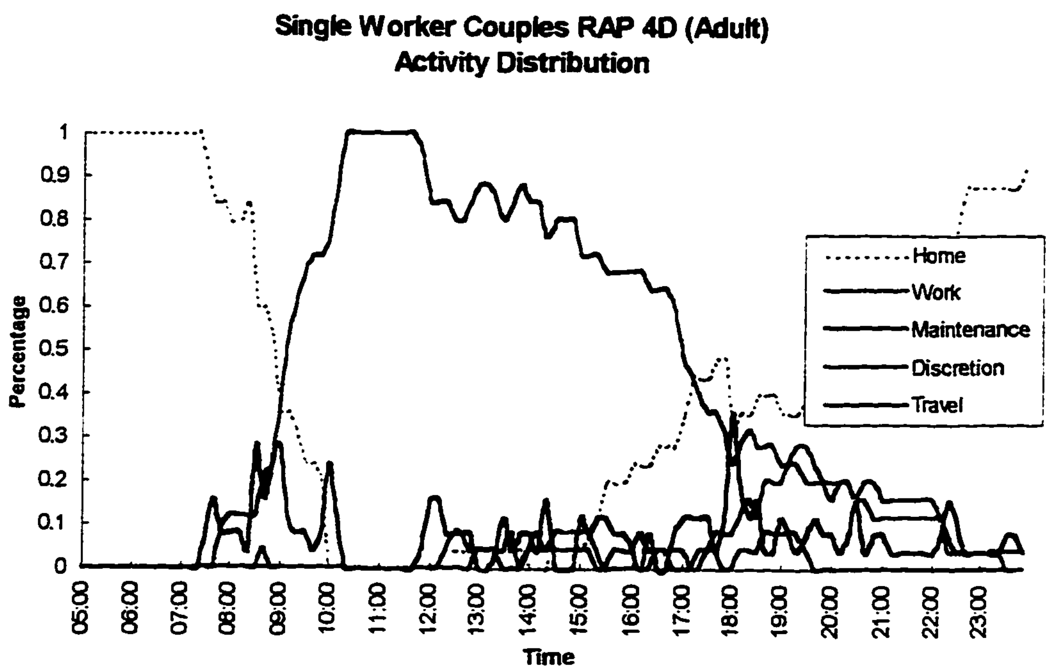

Fig A.40 Pattern 4D Activity Distribution with 1985 Data

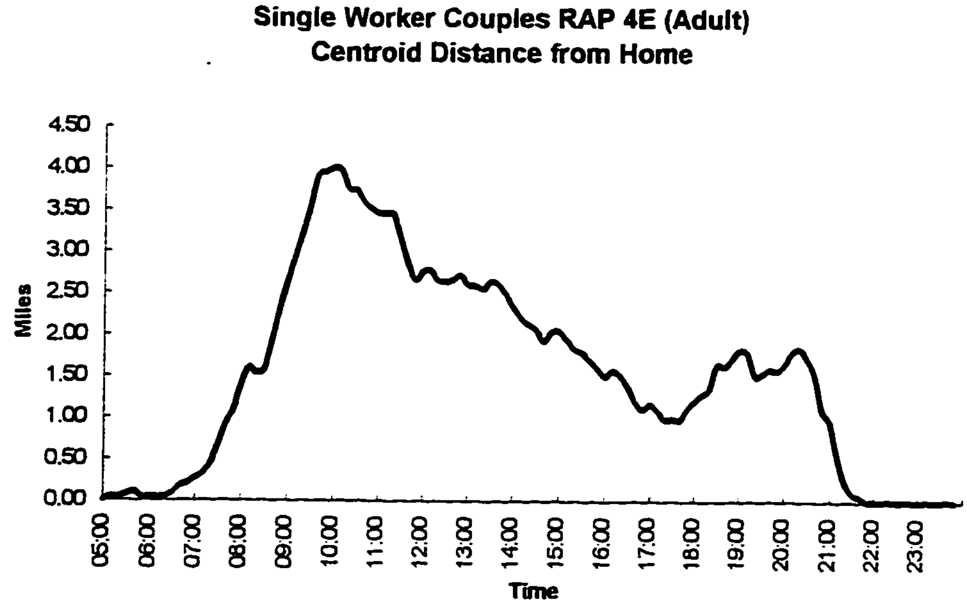

Fig A.41 Pattern 4E Distance Distribution with 1985 Data

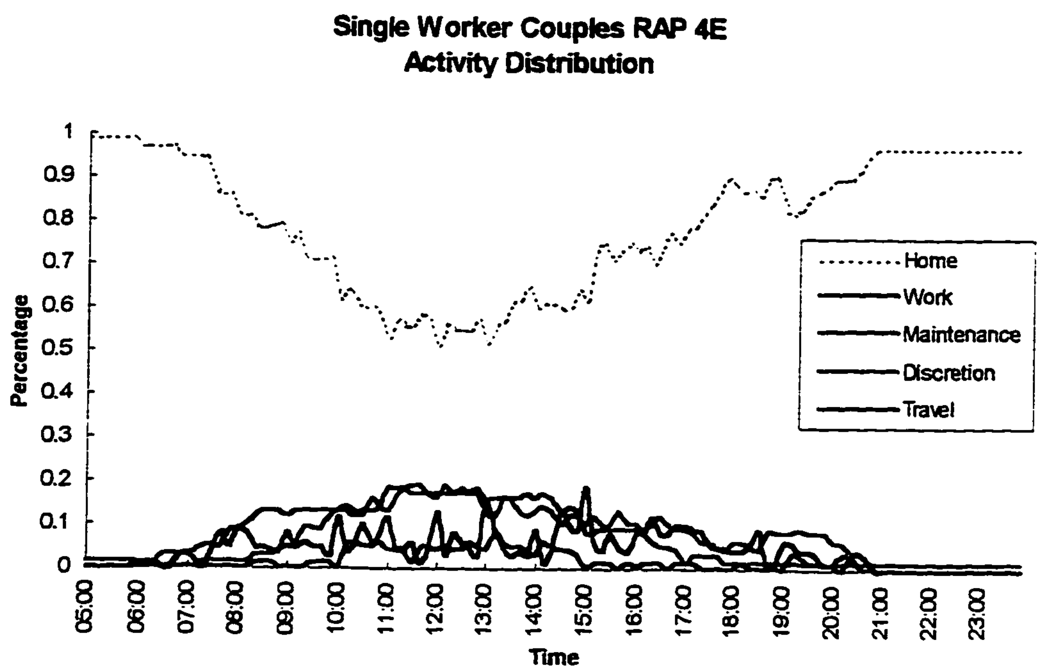

Fig A.42 Pattern 4E Activity Distribution with 1985 Data

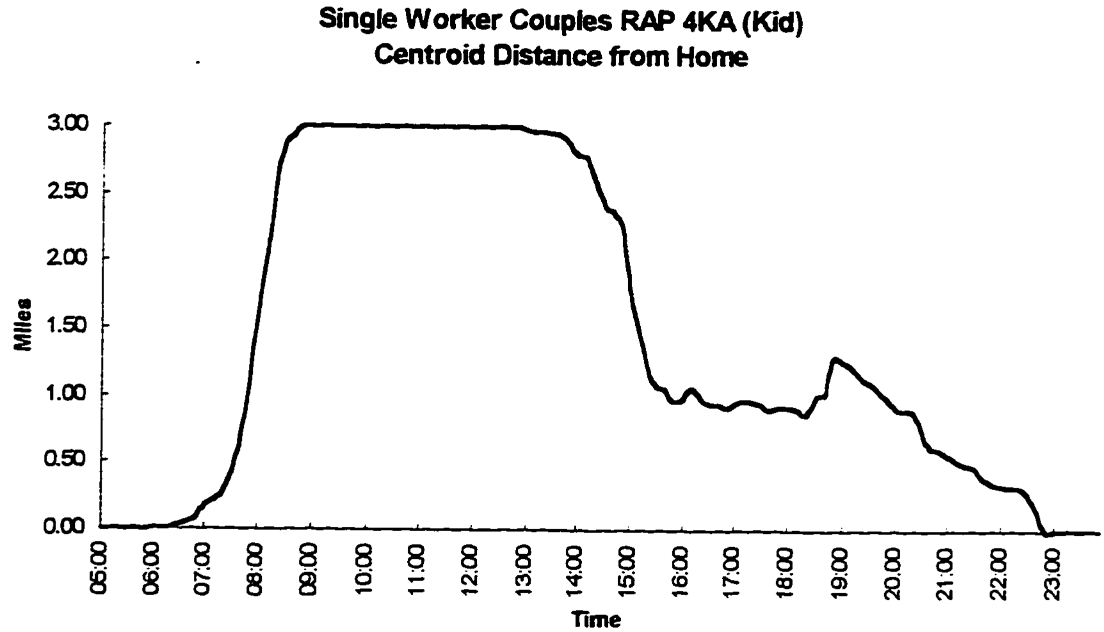

Fig A.43 Pattern 4KA Distance Distribution with 1985 Data

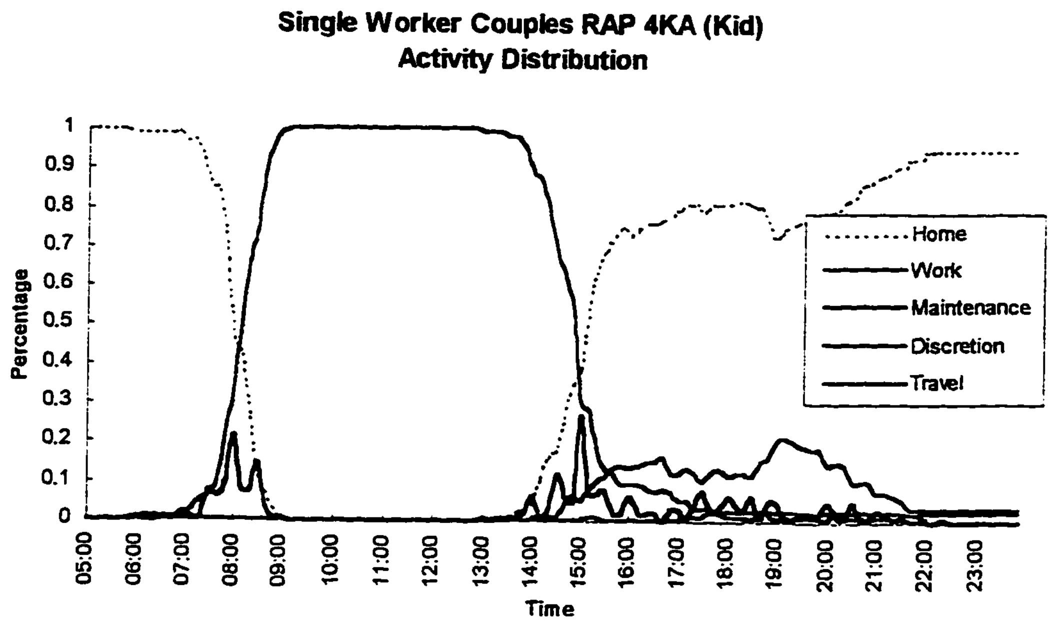

Fig A.44 Pattern 4KA Activity Distribution with 1985 Data

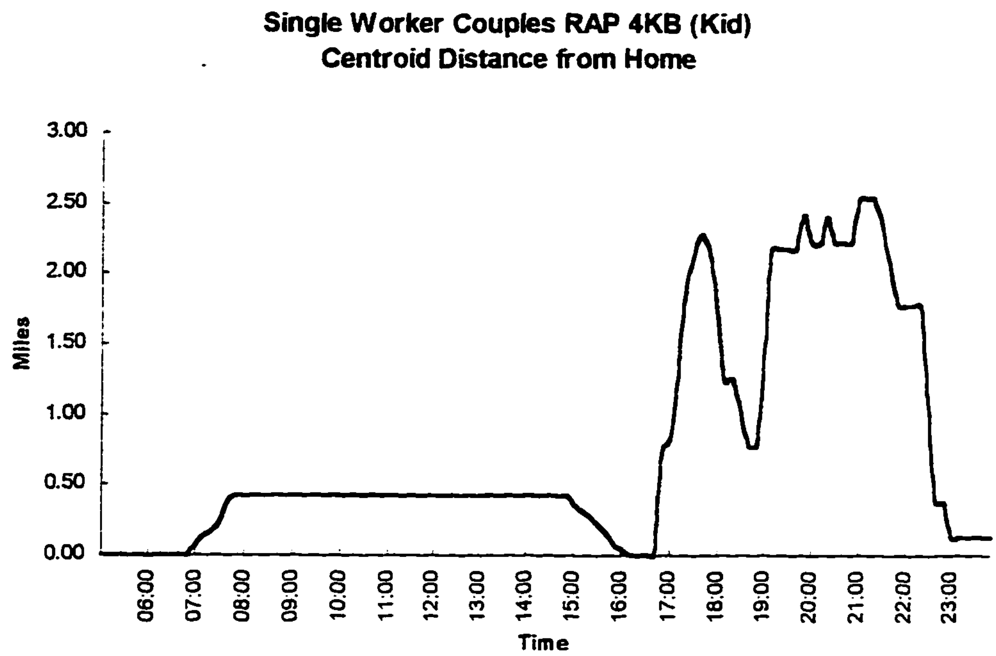

Fig A.45 Pattern 4KB Distance Distribution with 1985 Data

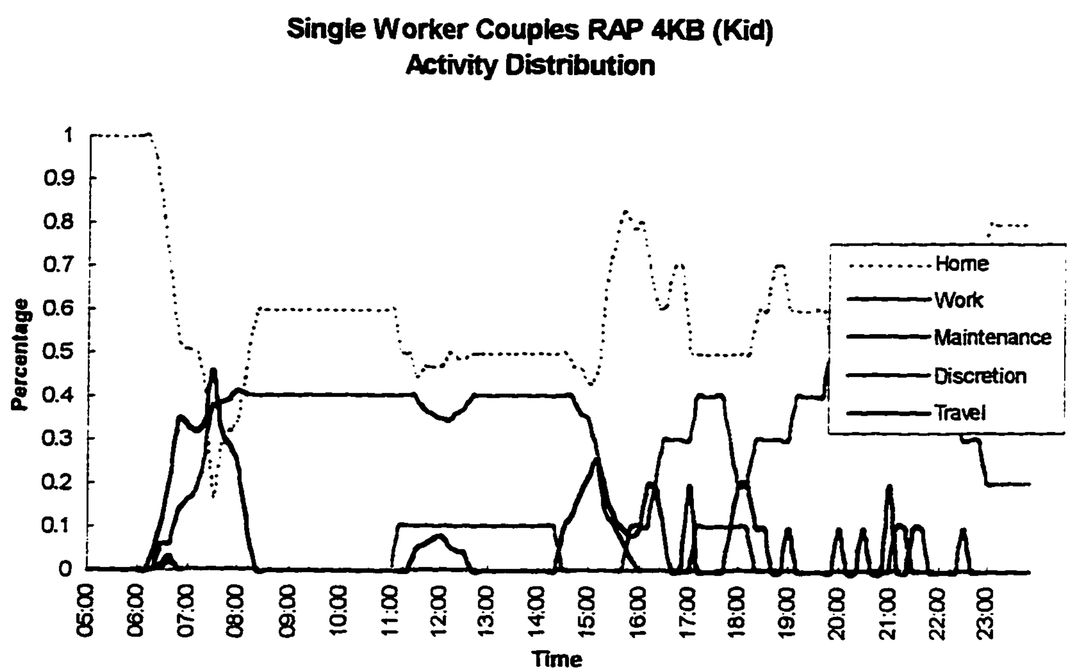

Fig A.46 Pattern 4KB Activity Distribution with 1985 Data

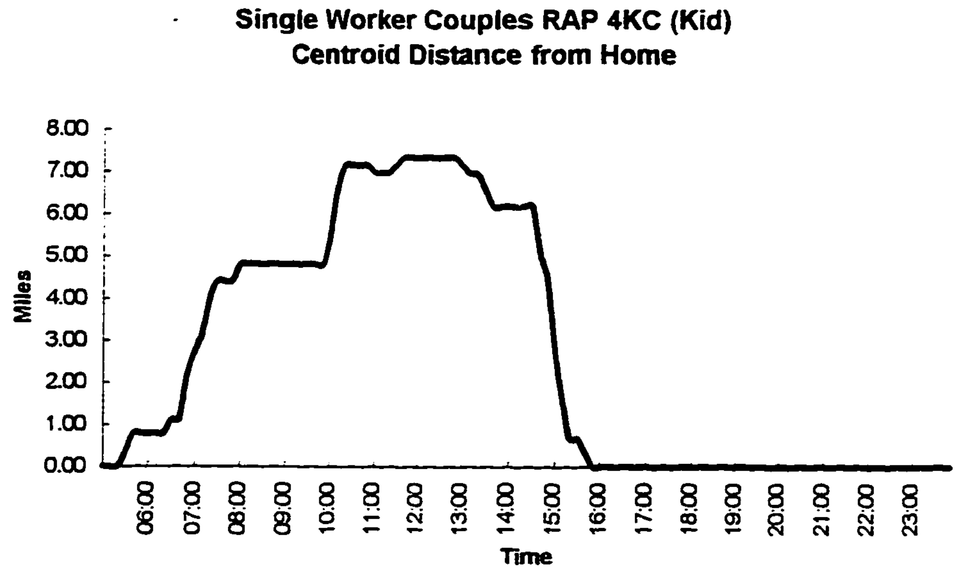

Fig A.47 Pattern 4KC Distance Distribution with 1985 Data

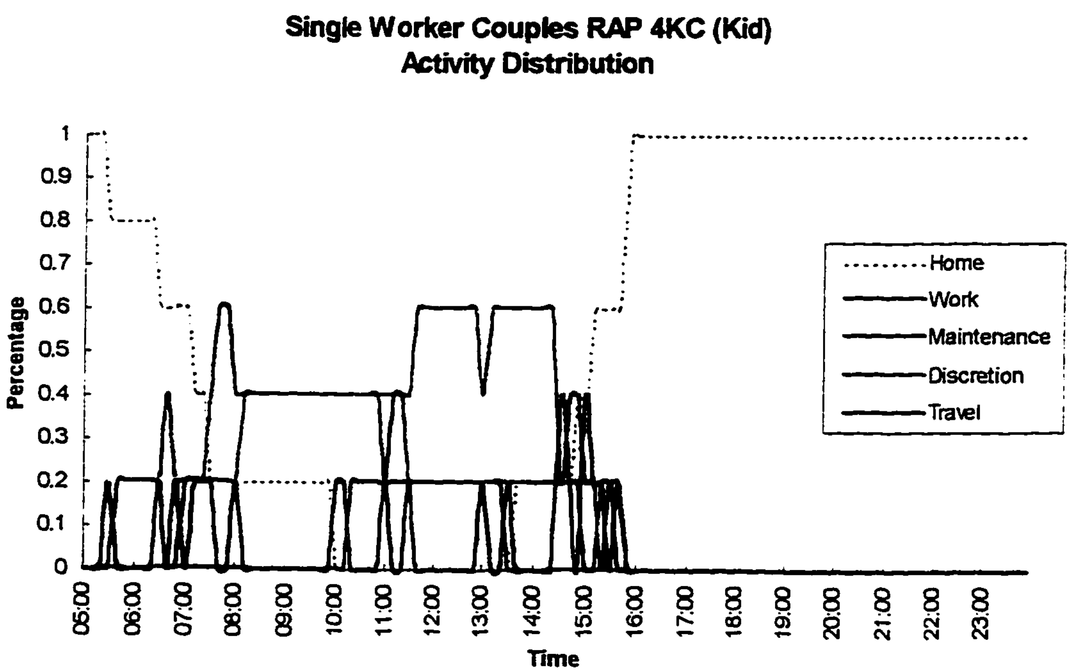

Fig A.48 Pattern 4KC Activity Distribution with 1985 Data

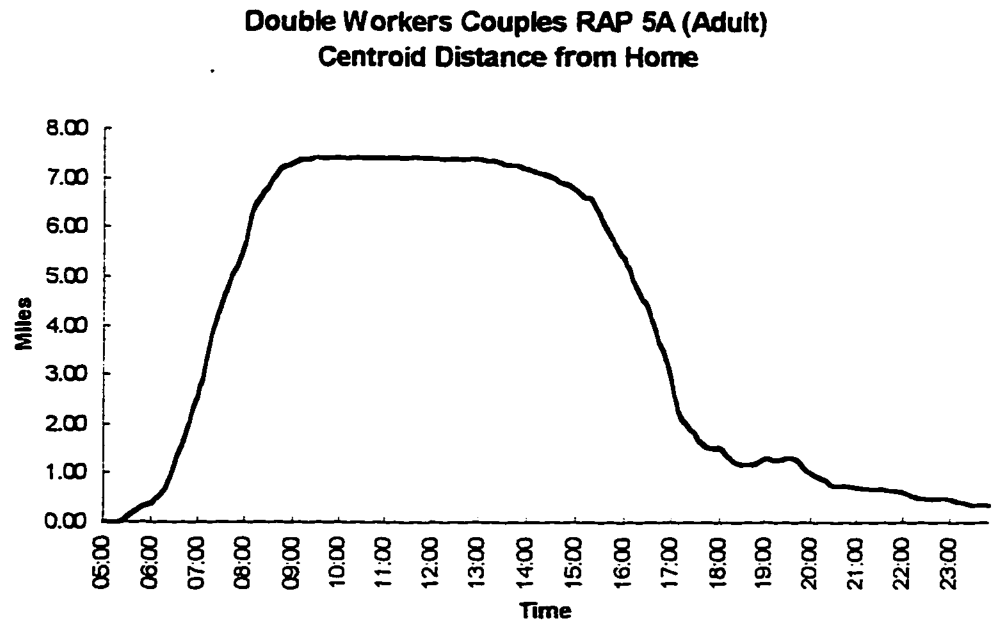

Fig A.49 Pattern 5A Distance Distribution with 1985 Data

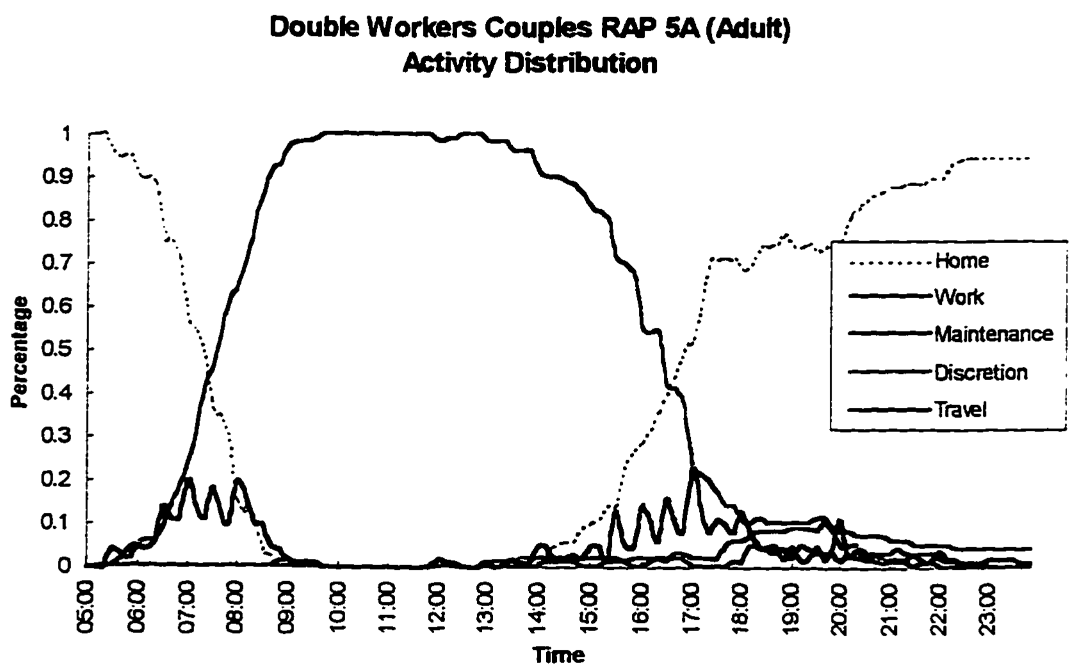

Fig A.50 Pattern 5A Activity Distribution with 1985 Data

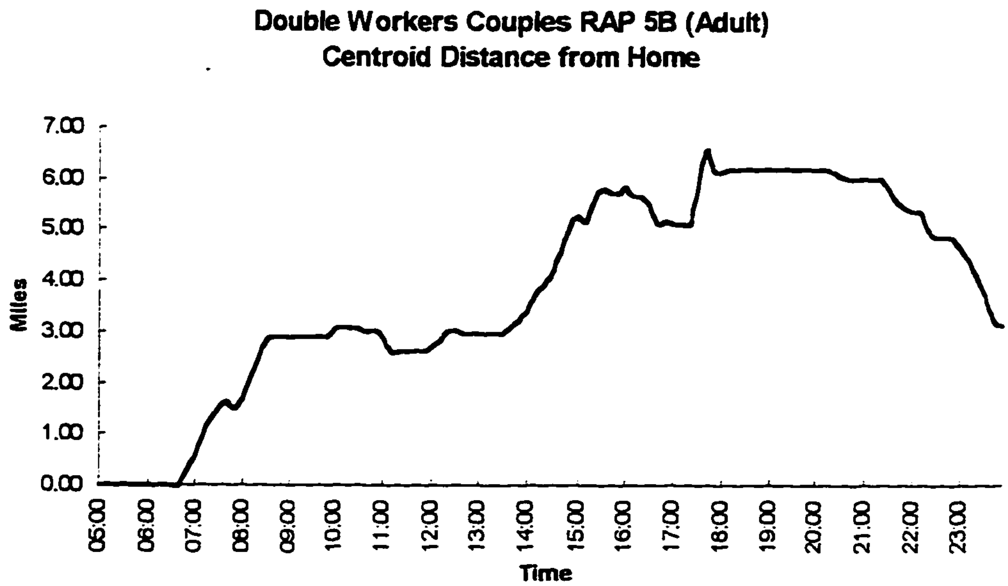

Fig A.51 Pattern 5B Distance Distribution with 1985 Data

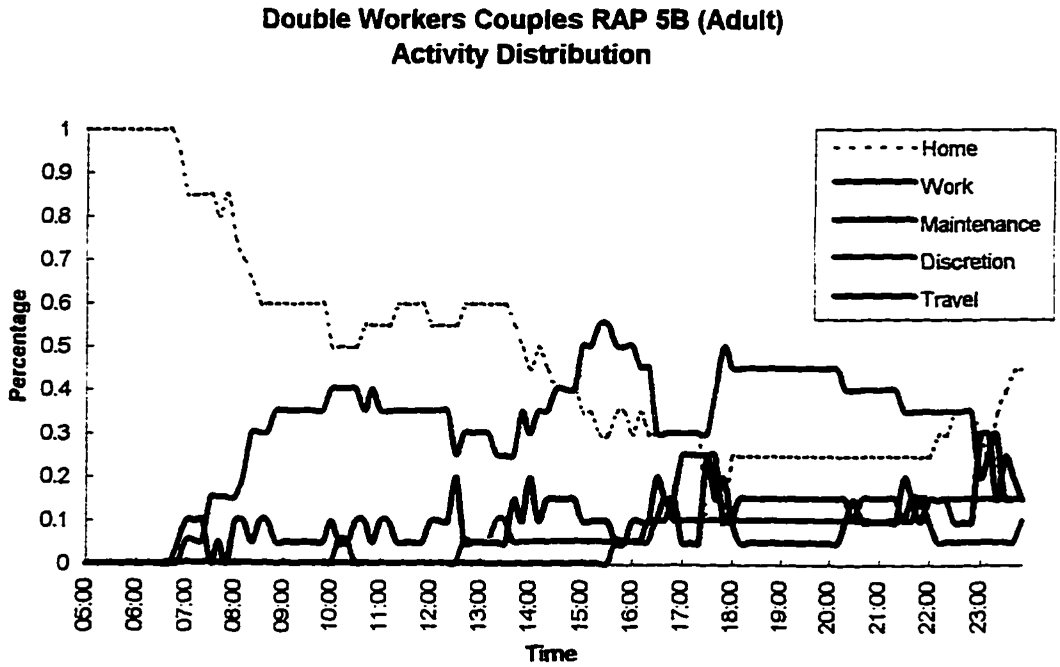

Fig A.52 Pattern 5B Activity Distribution with 1985 Data

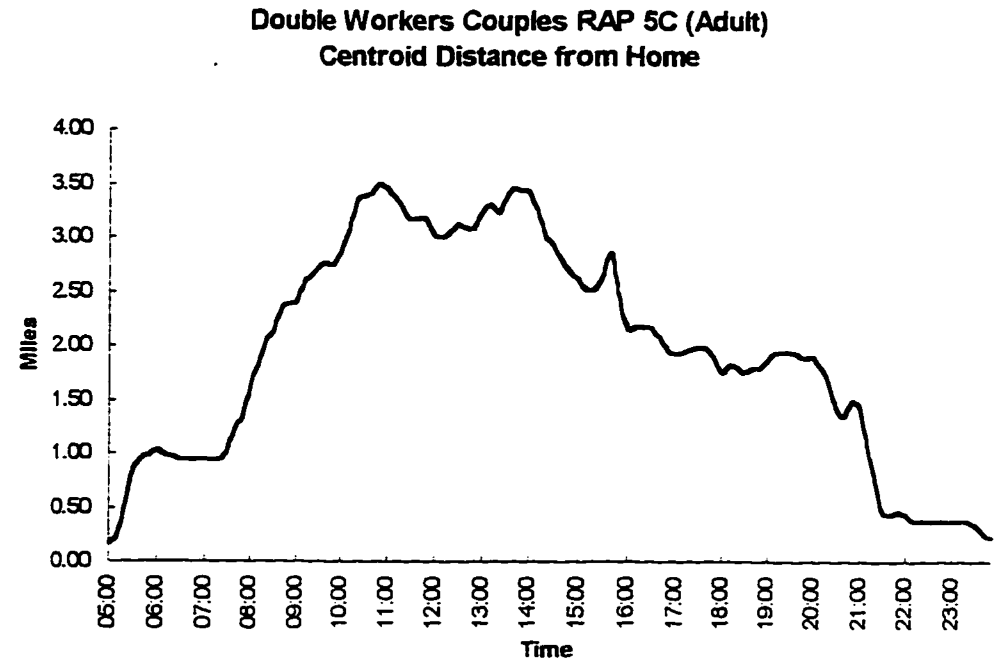

Fig A.53 Pattern 5C Distance Distribution with 1985 Data

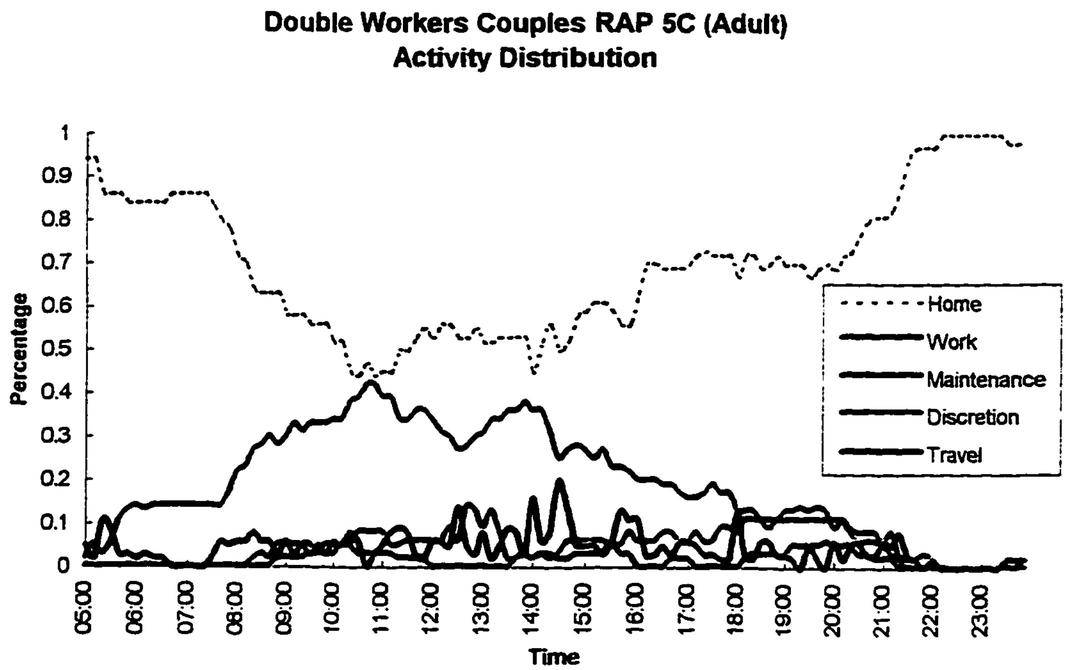

Fig A.54 Pattern 5C Activity Distribution with 1985 Data

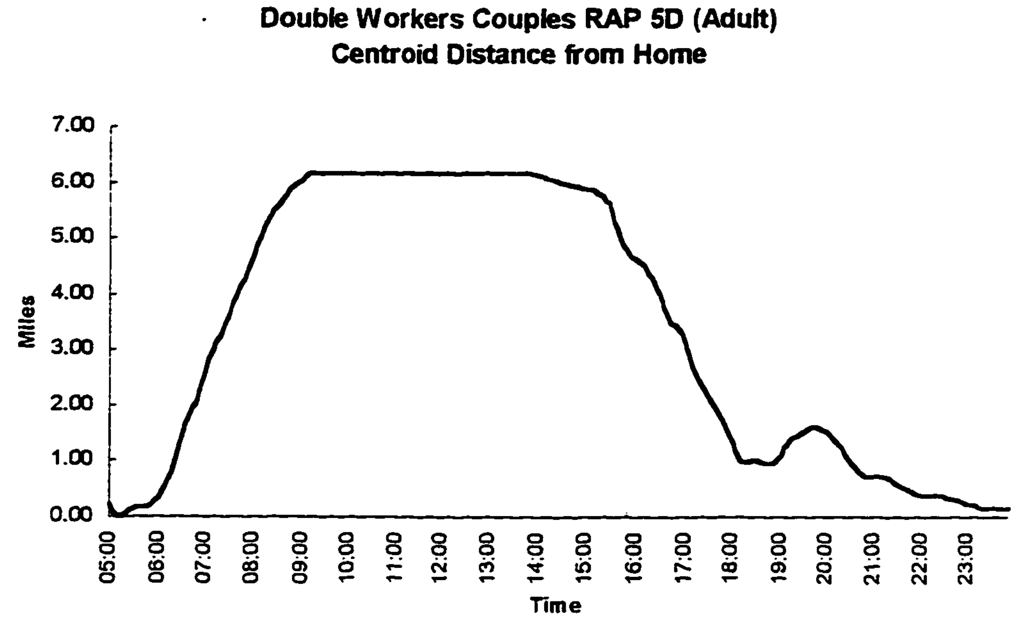

Fig A.55 Pattern 5D Distance Distribution with 1985 Data

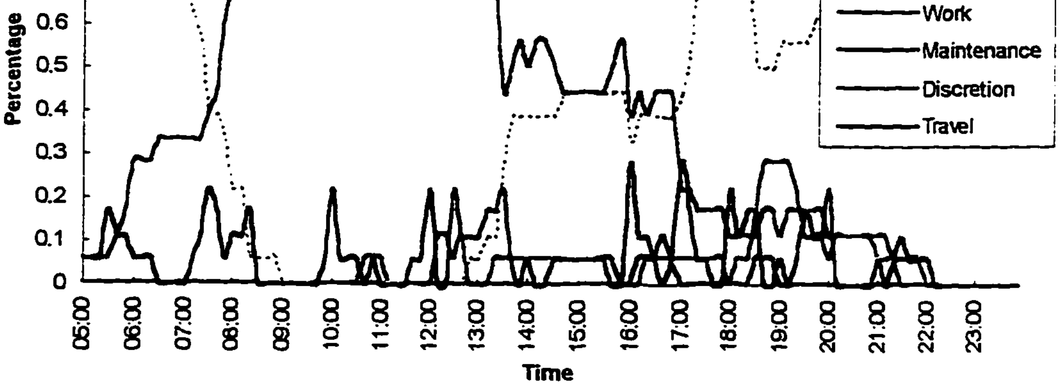

Fig A.56 Pattern 5D Activity Distribution with 1985 Data

Double Workers Coiuples RAP 5KA (Kid)
Centroid Distance from Home

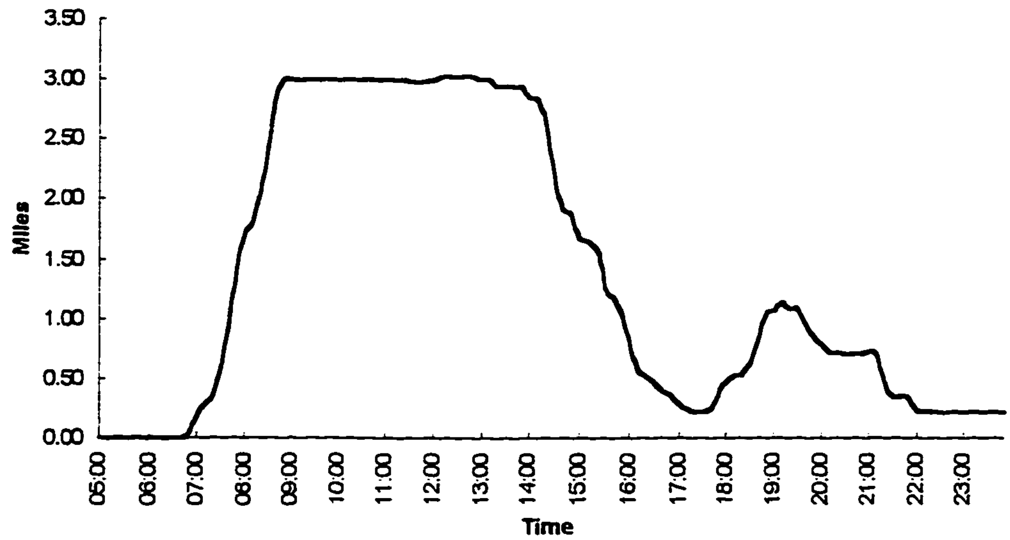

Fig A.57 Pattern 5KA Distance Distribution with 1985 Data

Double Workers Couples RAP 5KA (Kid)
Activity Distribution

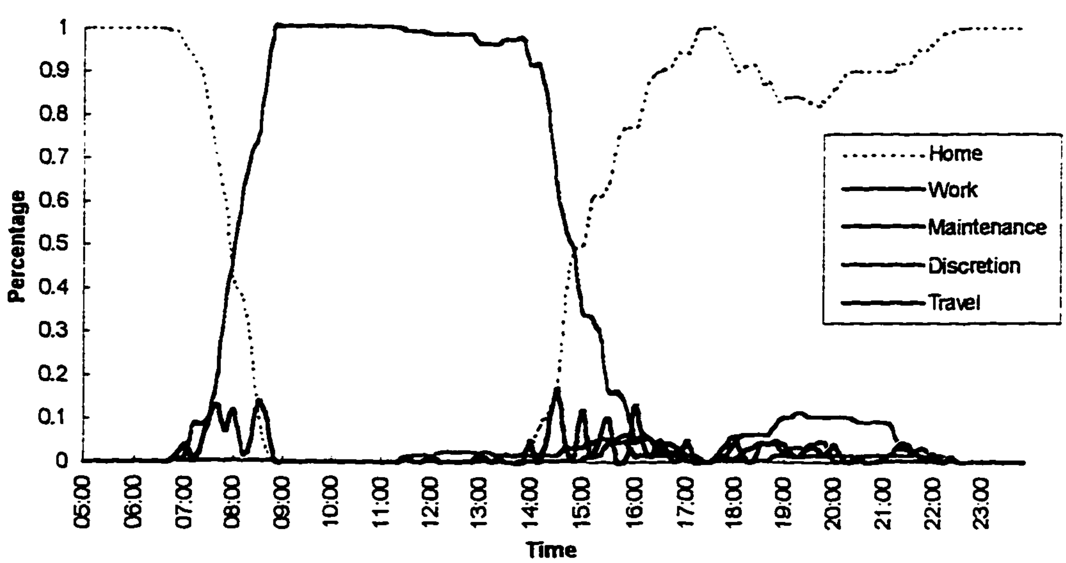

Fig A.58 Pattern 5KA Activity Distribution with 1985 Data

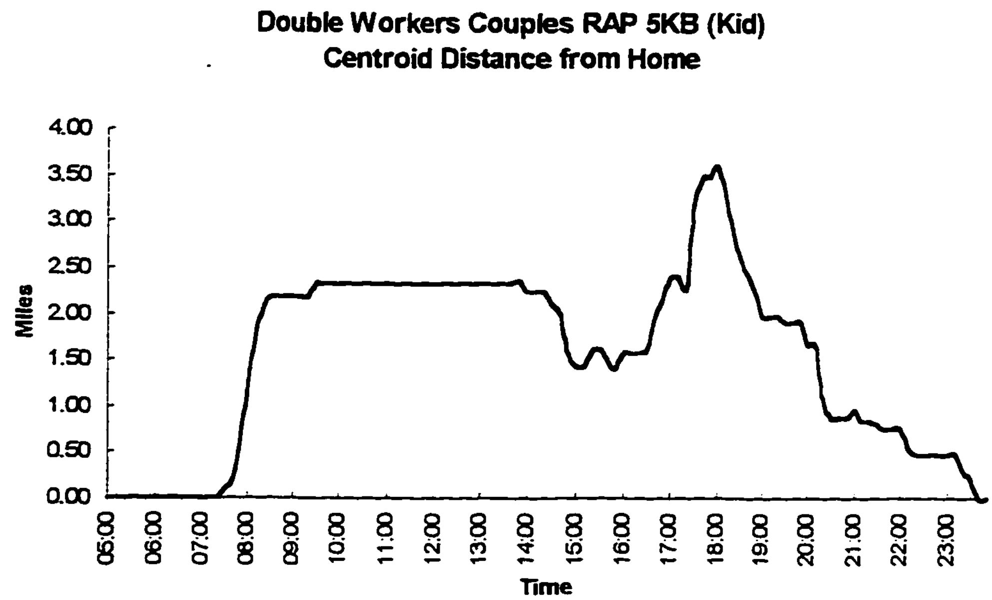

Fig A.59 Pattern 5KB Distance Distribution with 1985 Data

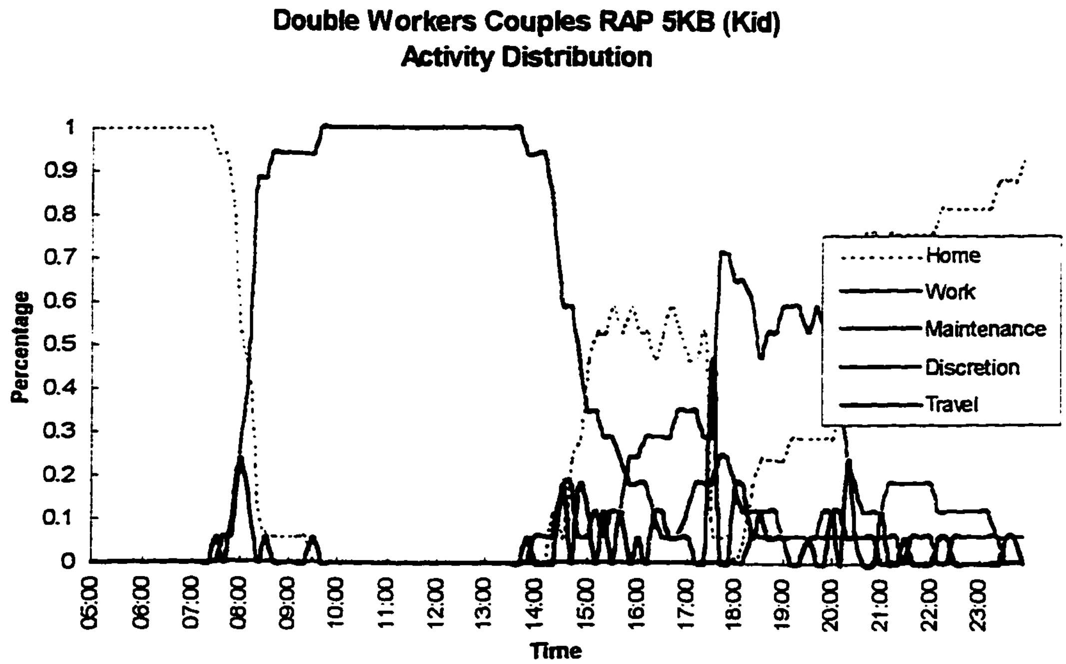

Fig A.60 Pattern 5KB Activity Distribution with 1985 Data

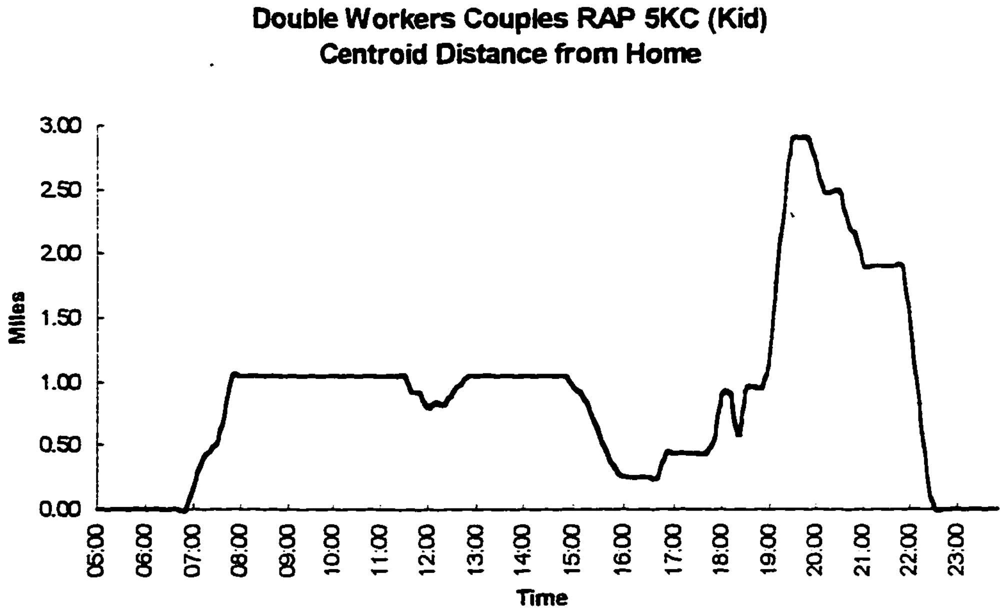

Fig A.61 Pattern 5KC Distance Distribution with 1985 Data

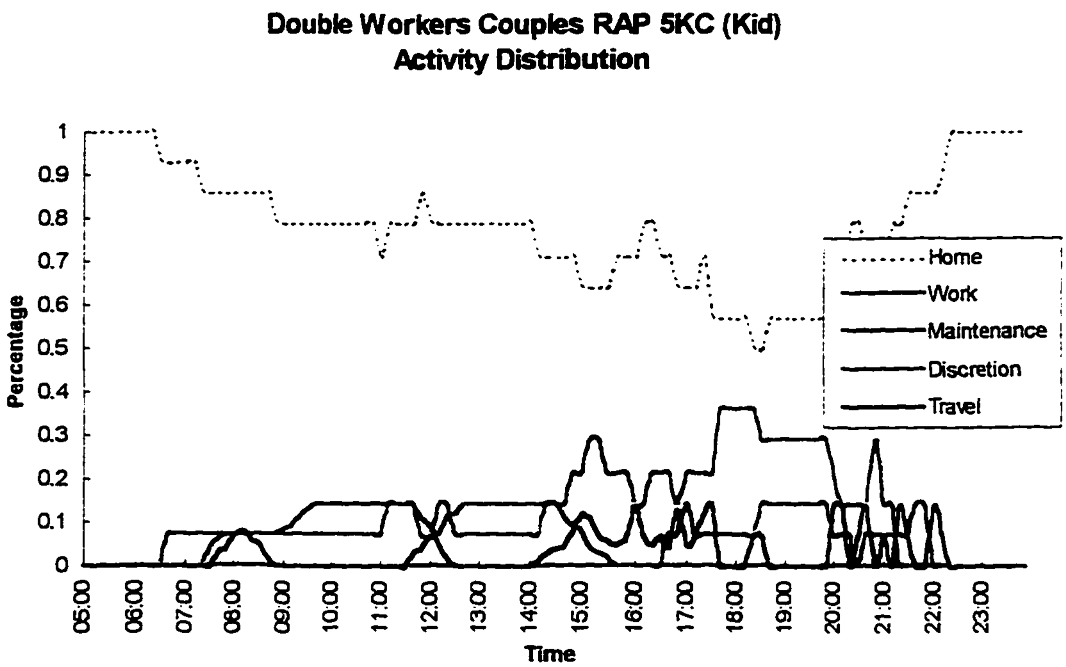

Fig A.62 Pattern 5KC Activity Distribution with 1985 Data

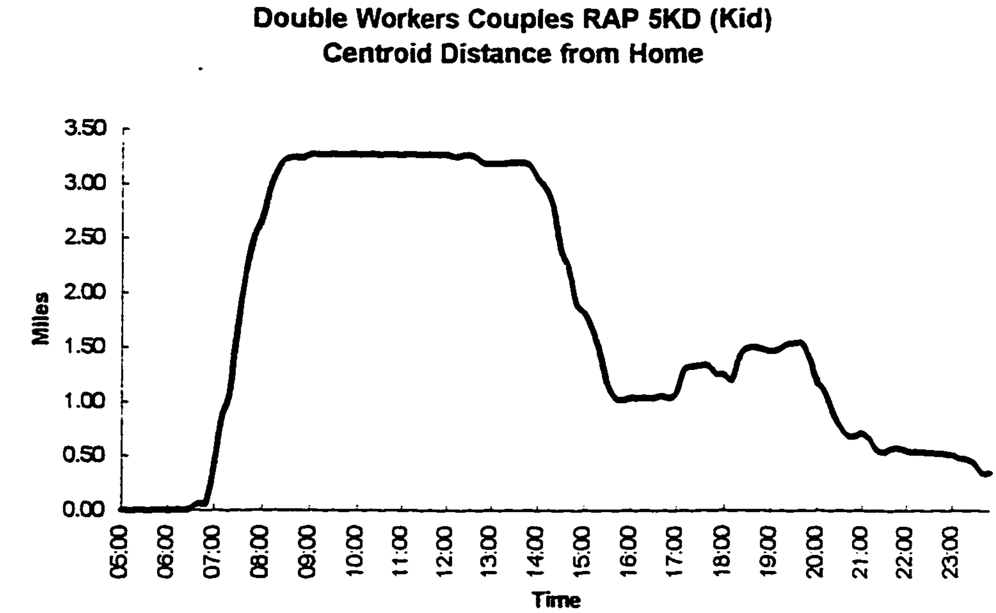

Fig A.63 Pattern 5KD Distance Distribution with 1985 Data

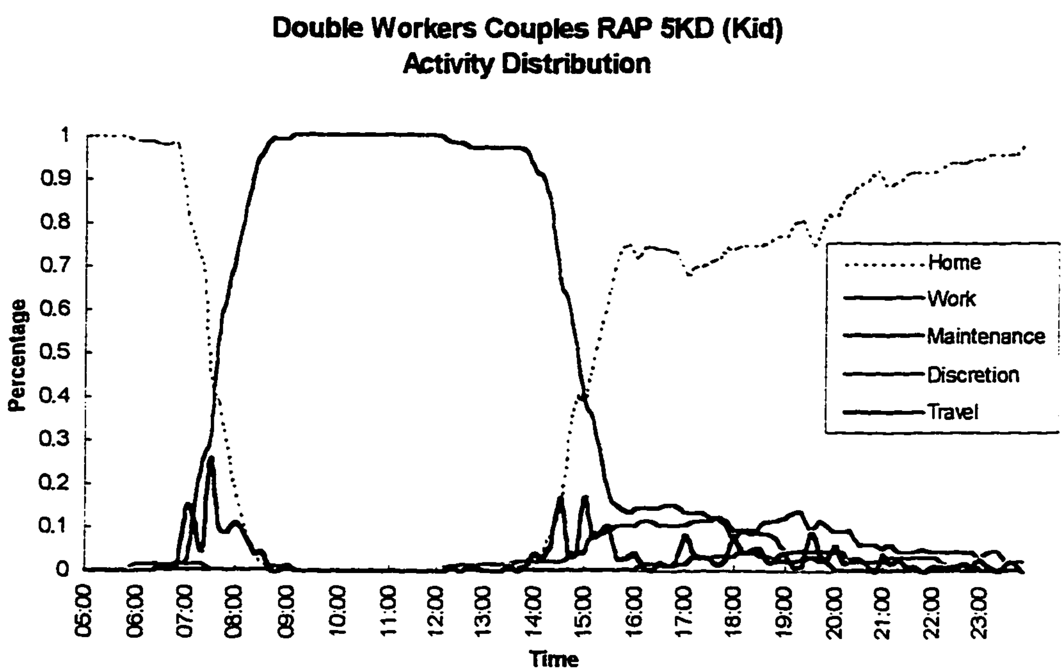

Fig A.64 Pattern 5KD Activity Distribution with 1985 Data

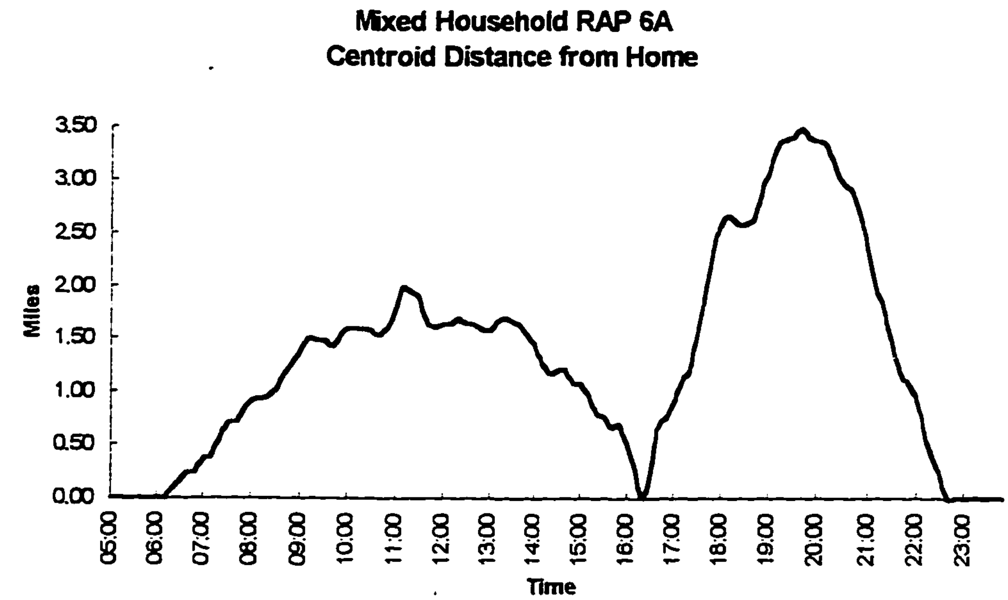

Fig A.65 Pattern 6A Distance Distribution with 1985 Data

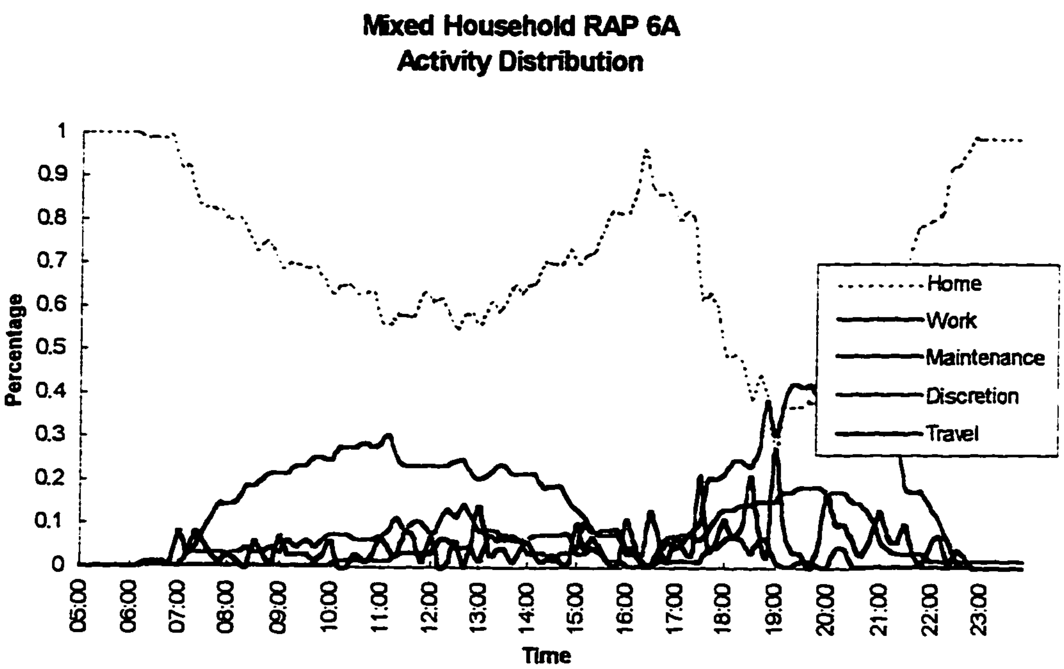

Fig A.66 Pattern 6A Activity Distribution with 1985 Data

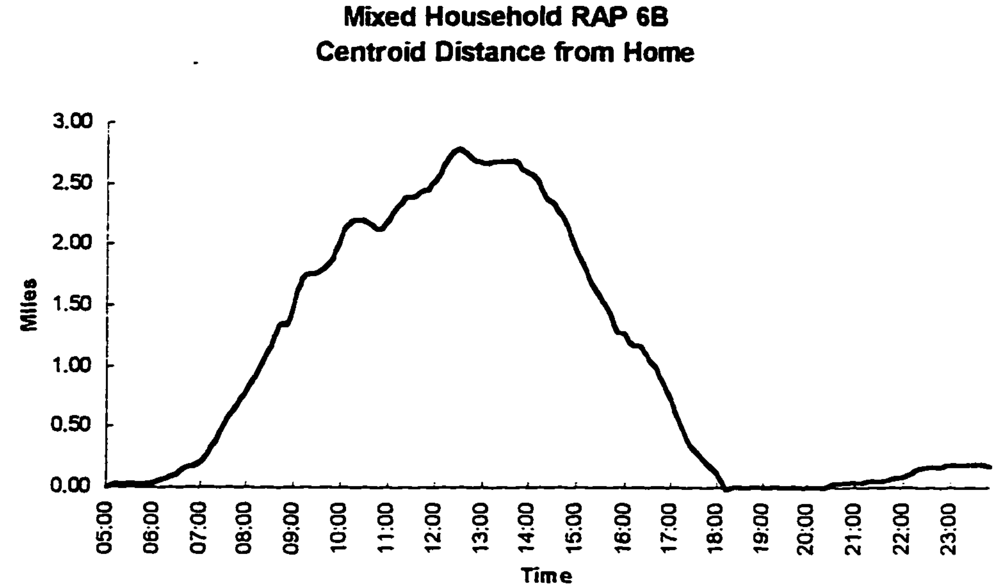

Fig A.67 Pattern 6B Distance Distribution with 1985 Data

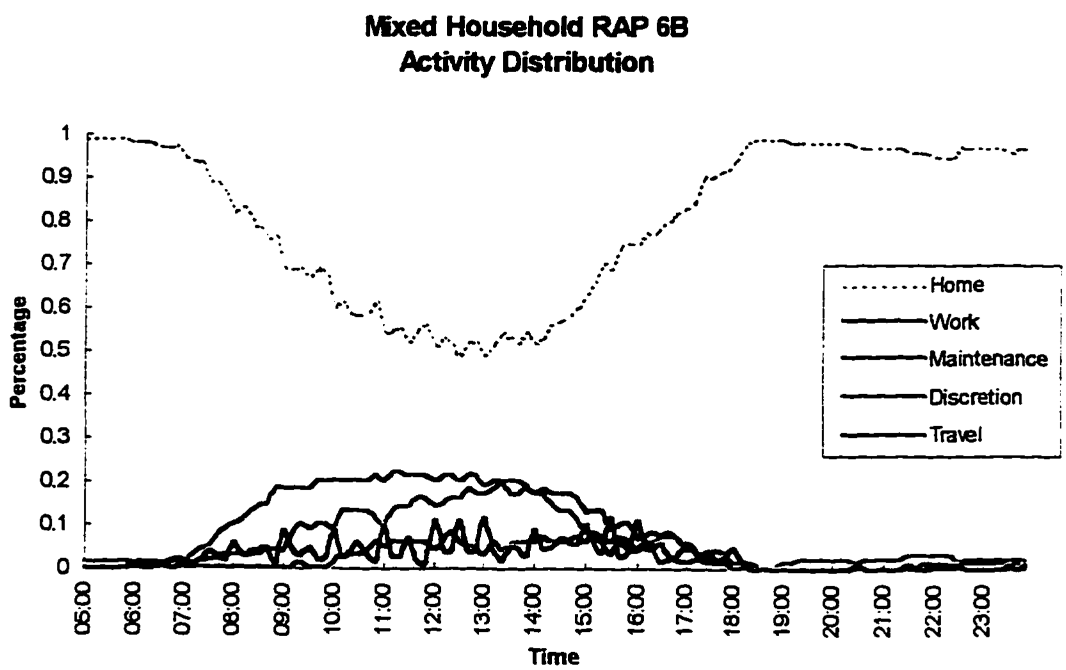

Fig A.68 Pattern 6B Activity Distribution with 1985 Data

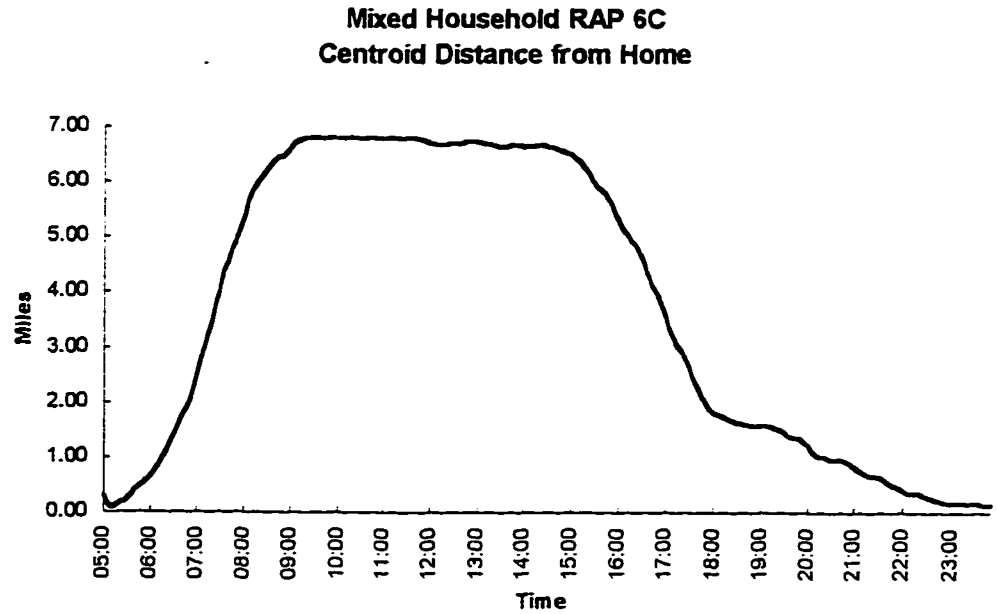

Fig A.69 Pattern 6C Distance Distribution with 1985 Data

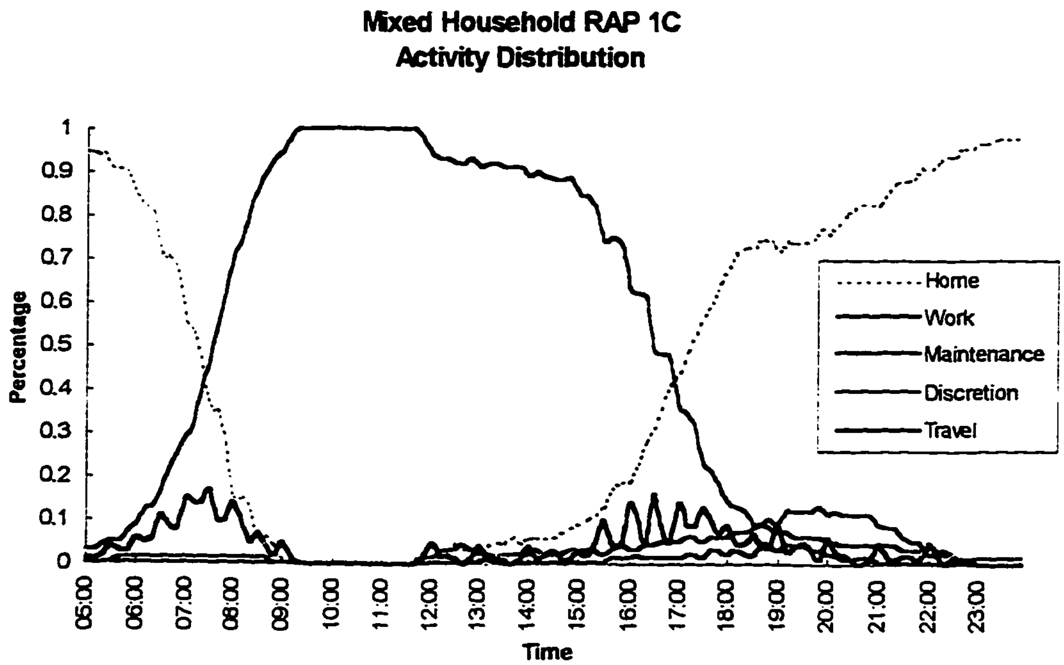

Fig A.70 Pattern 6C Activity Distribution with 1985 Data

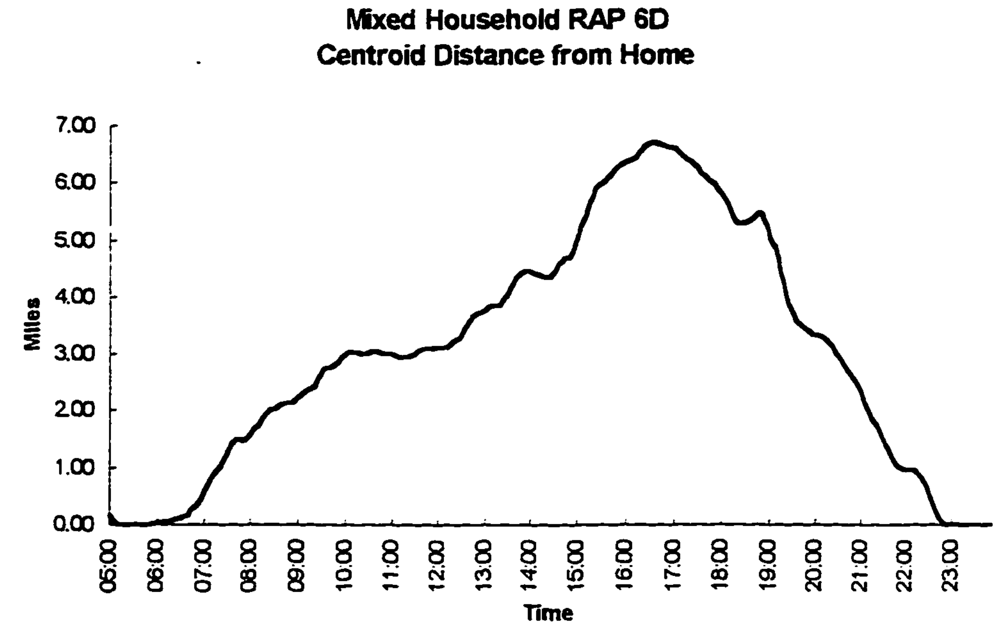

Fig A.71 Pattern 6D Distance Distribution with 1985 Data

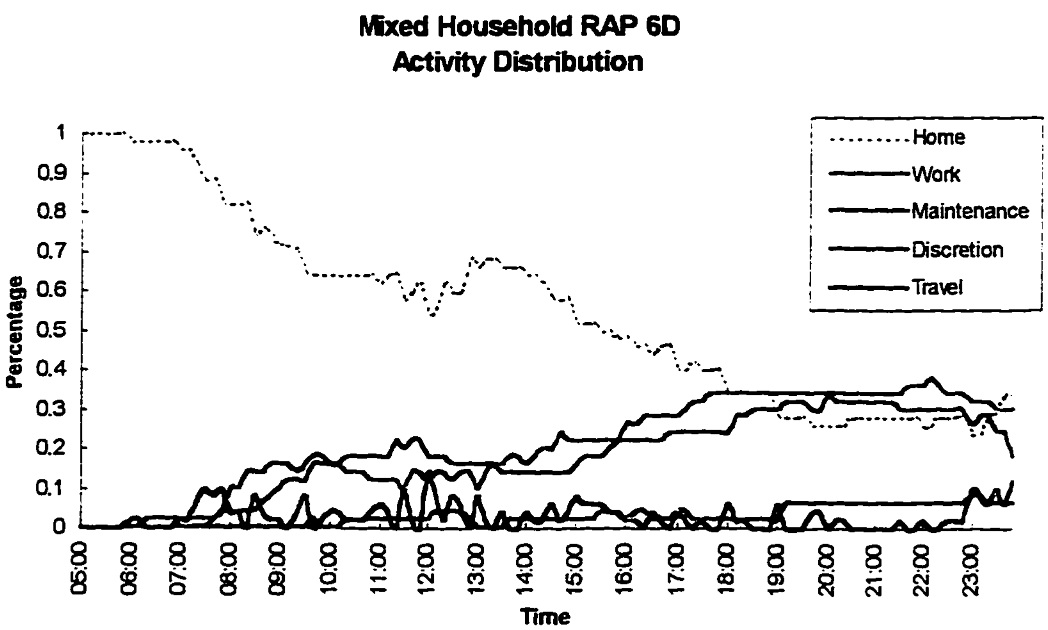

Fig A.72 Pattern 6D Activity Distribution with 1985 Data

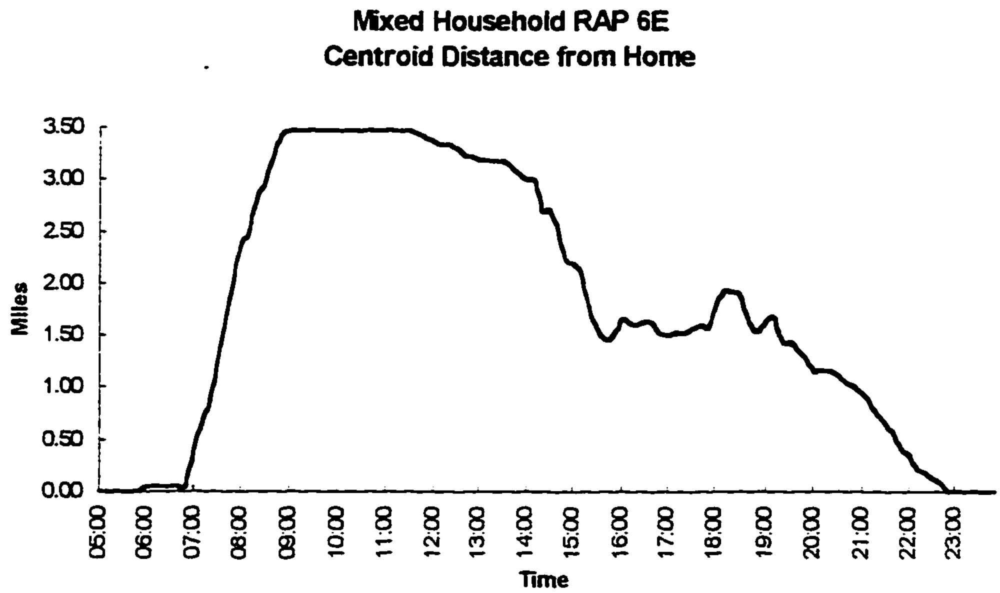

Fig A.73 Pattern 6E Distance Distribution with 1985 Data

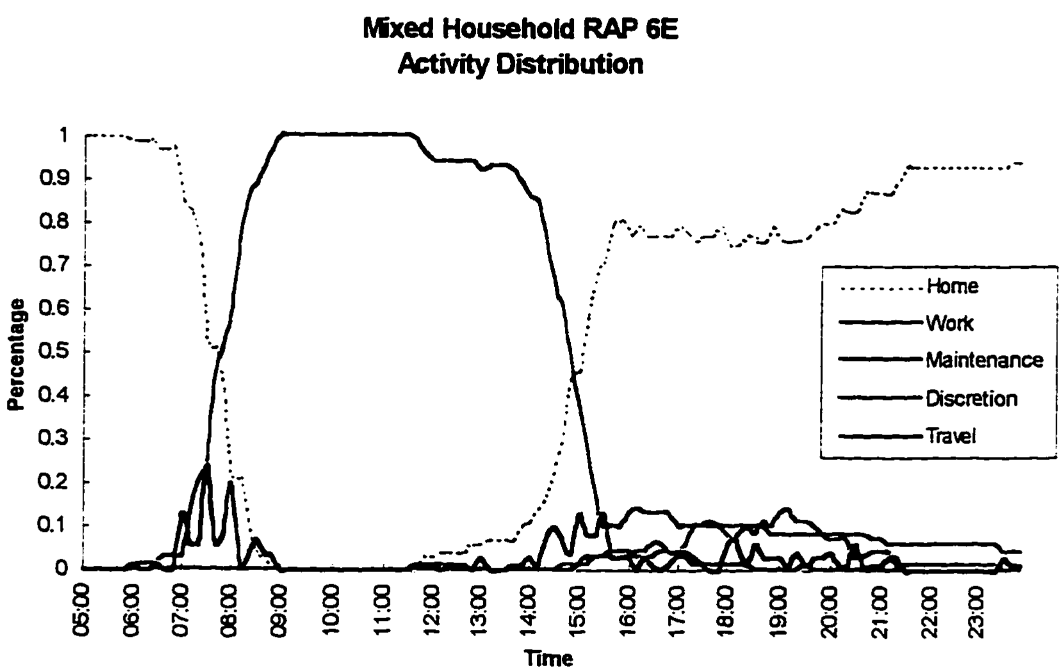

Fig A.74 Pattern 6E Activity Distribution with 1985 Data

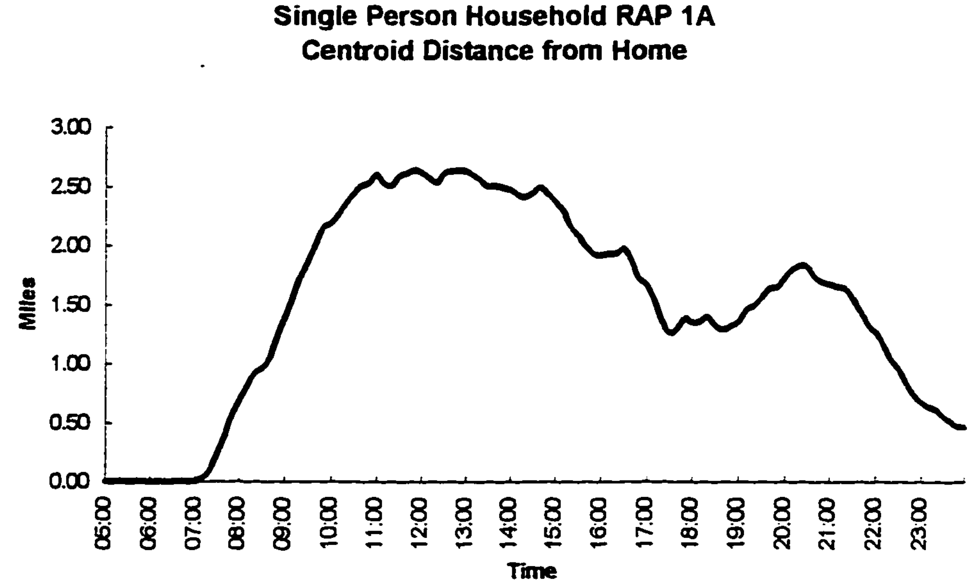

Fig A.75 Pattern 1A Distance Distribution with 1994 Data

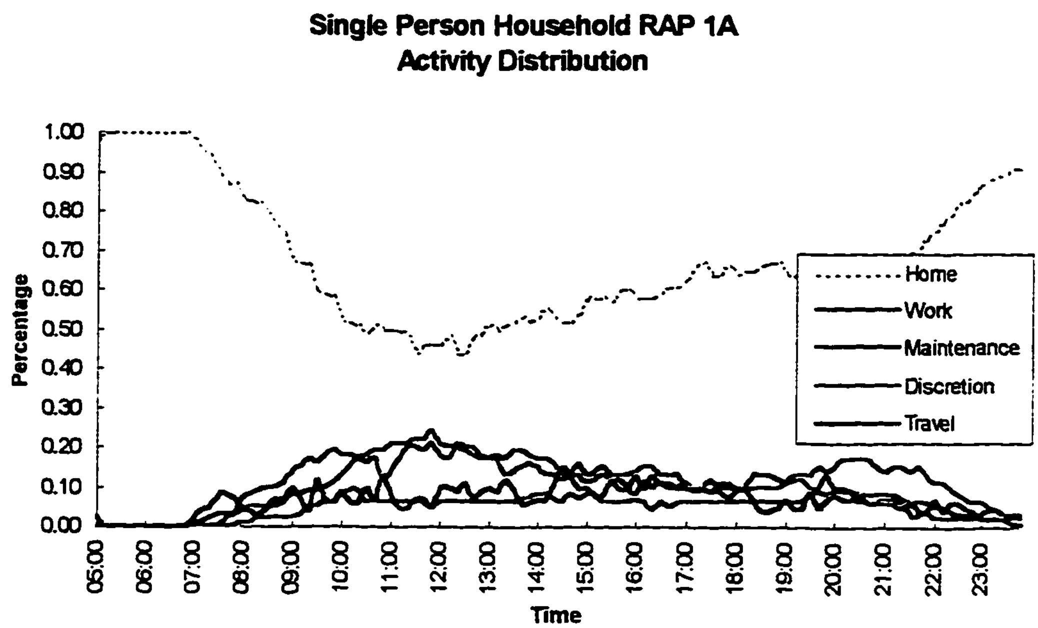

Fig A.76 Pattern 1A Activity Distribution with 1994 Data

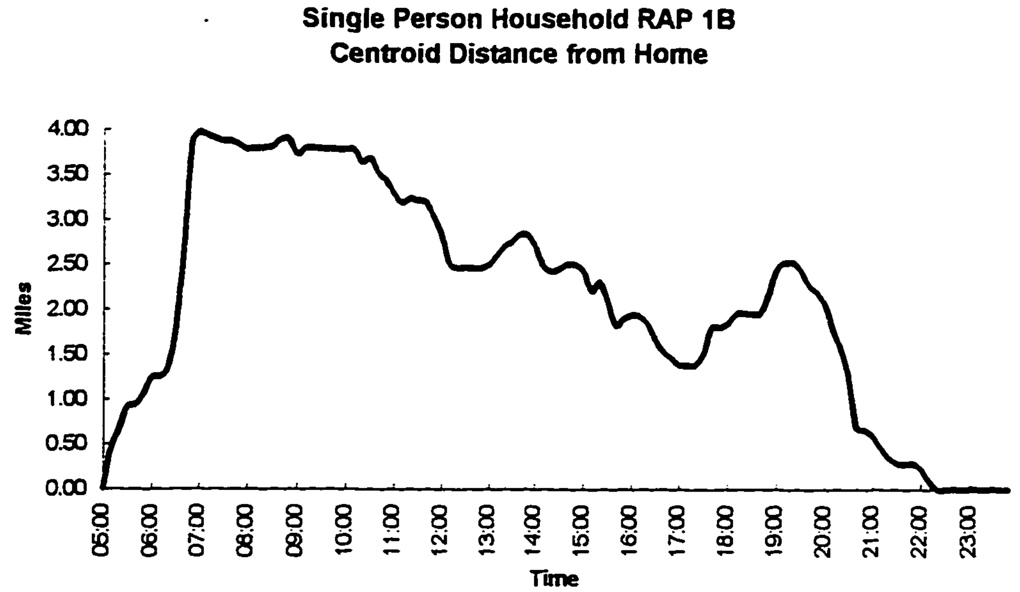

Fig A.77 Pattern 1B Distance Distribution with 1994 Data

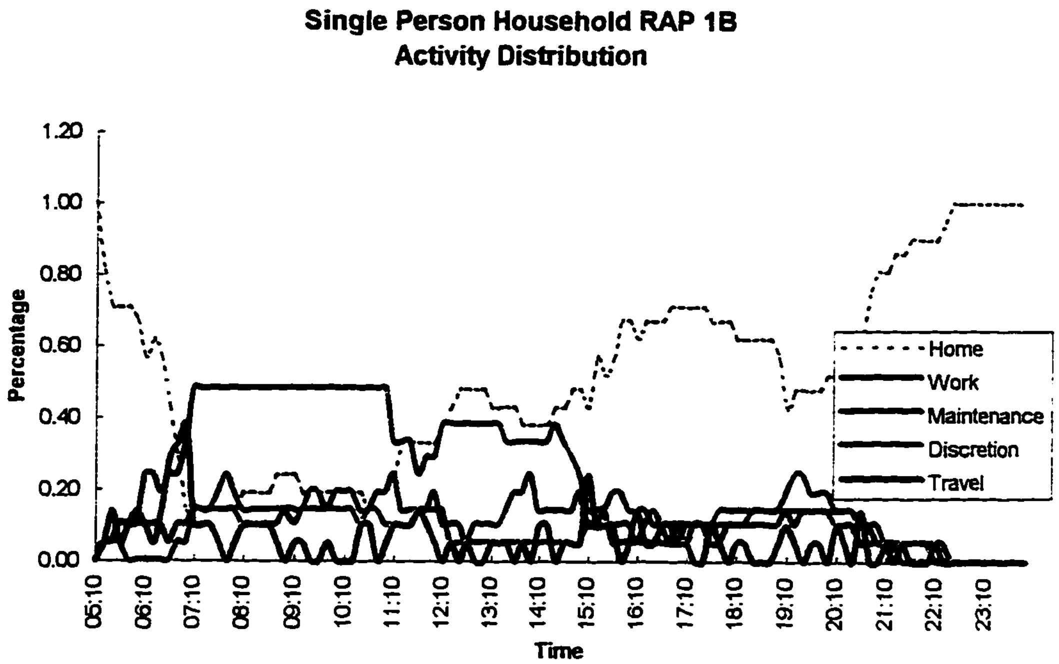

Fig A.78 Pattern 1B Activity Distribution with 1994 Data

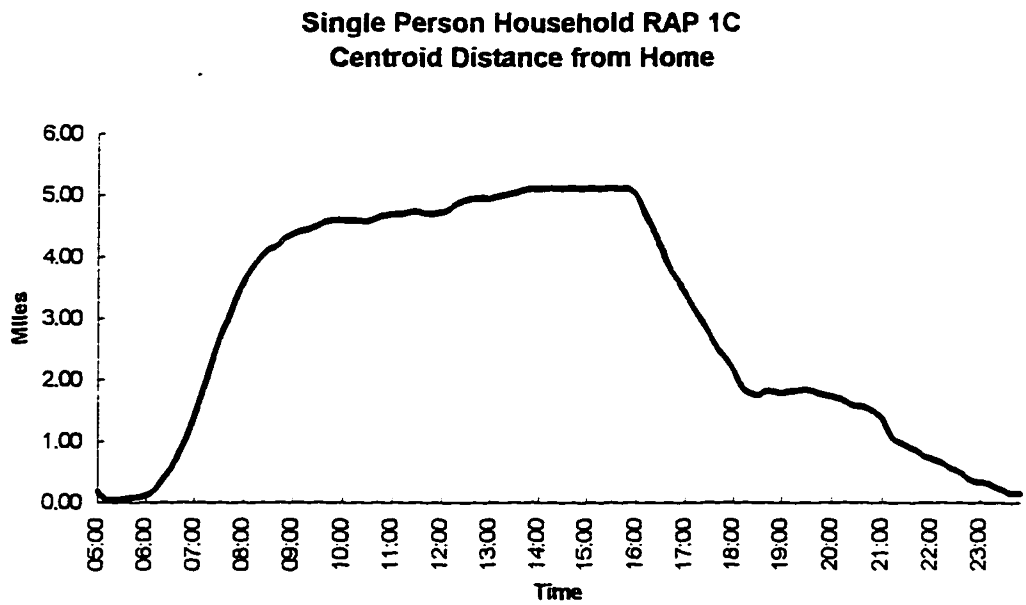

Fig A.79 Pattern 1C Distance Distribution with 1994 Data

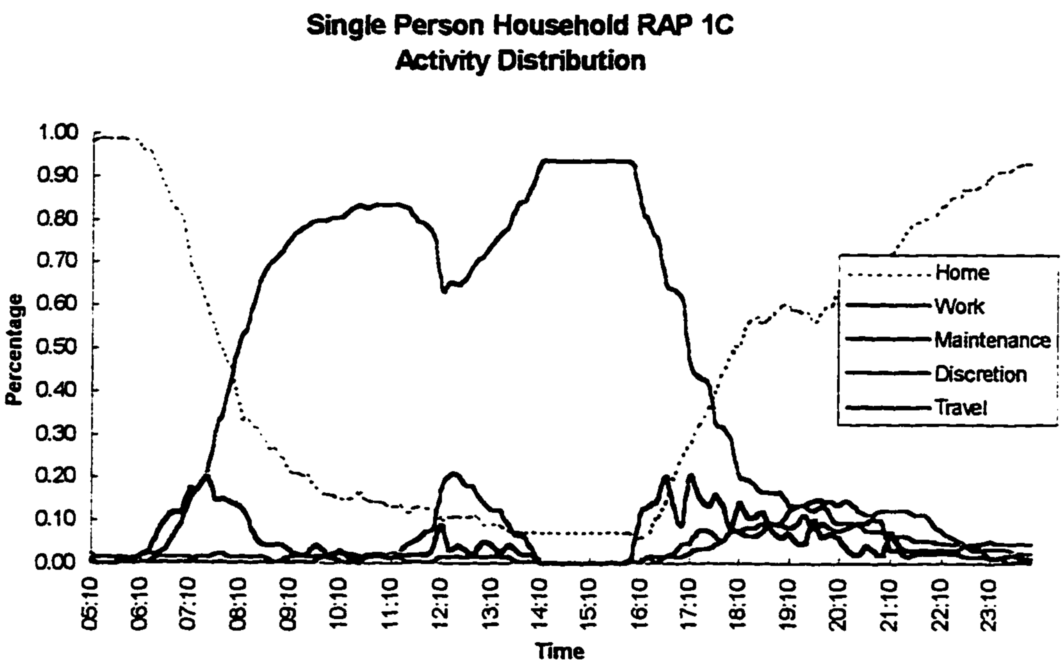

Fig A.80 Pattern 1C Activity Distribution with 1994 Data

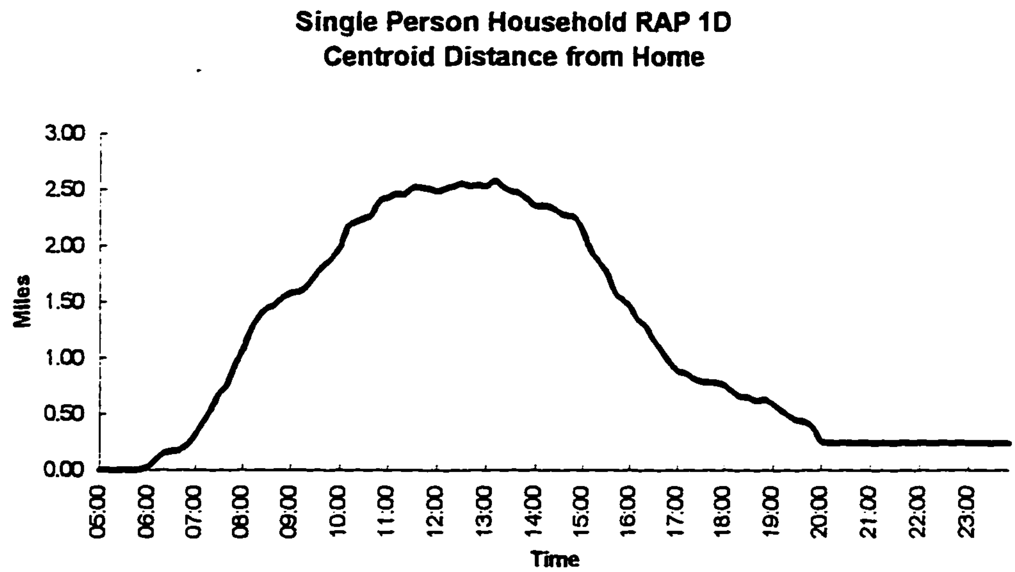

Fig A.81 Pattern 1D Distance Distribution with 1994 Data

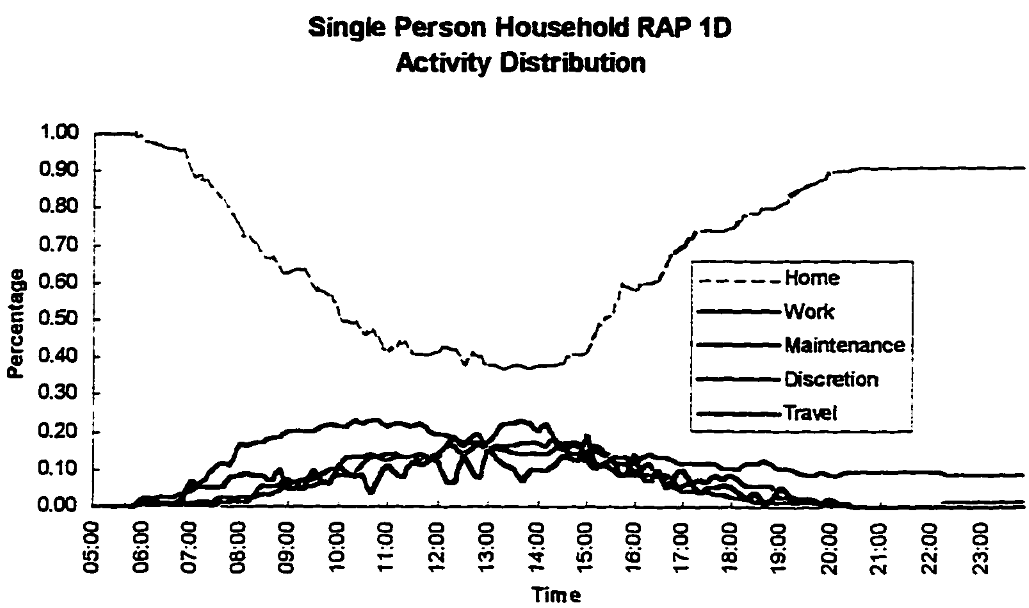

Fig A.82 Pattern 1D Activity Distribution with 1994 Data

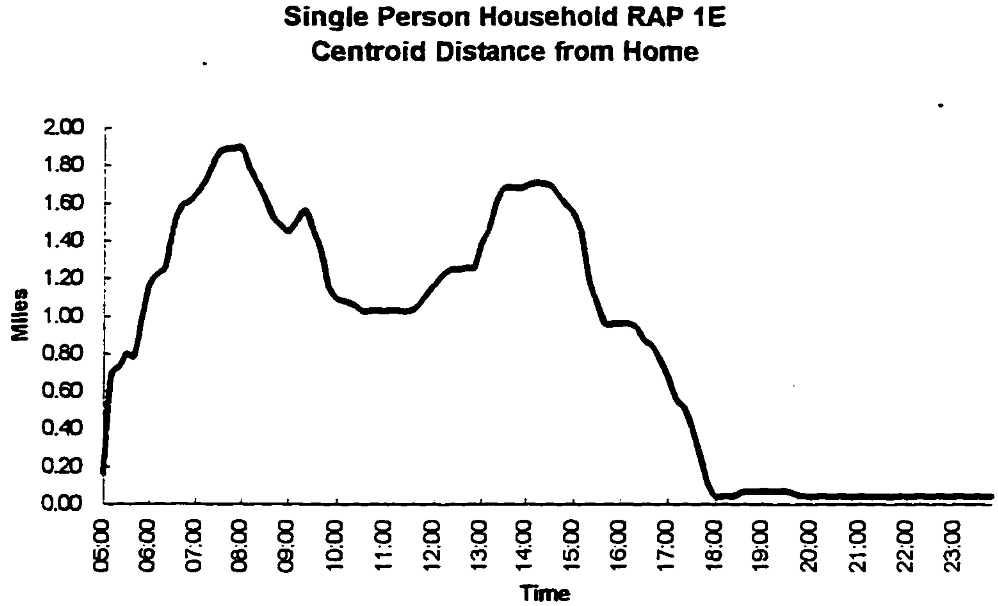

Fig A.83 Pattern 1E Distance Distribution with 1994 Data

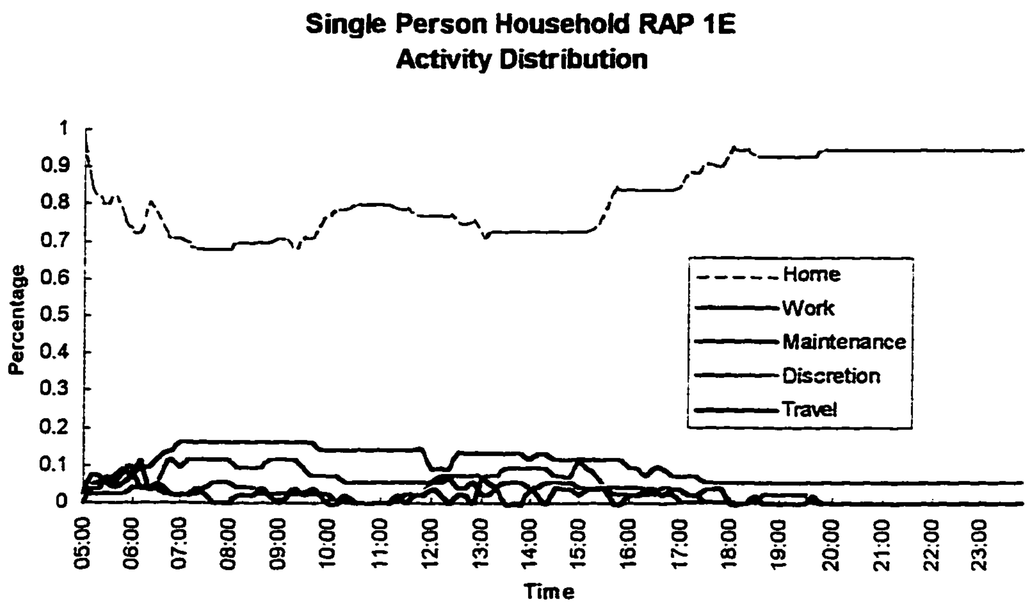

Fig A.84 Pattern 1E Activity Distribution with 1994 Data

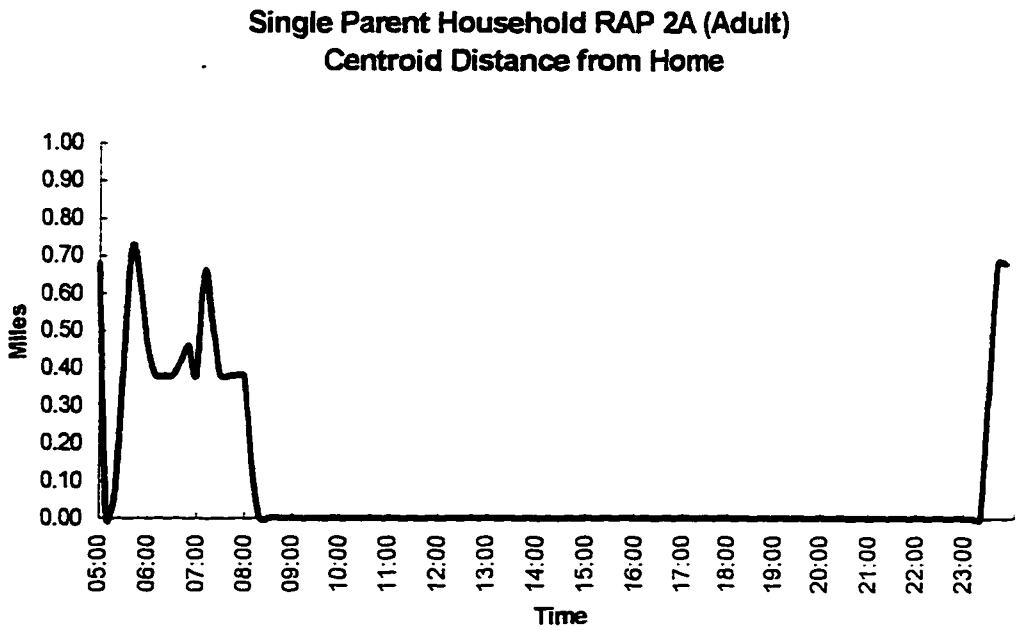

Fig A.85 Pattern 2A Distance Distribution with 1994 Data

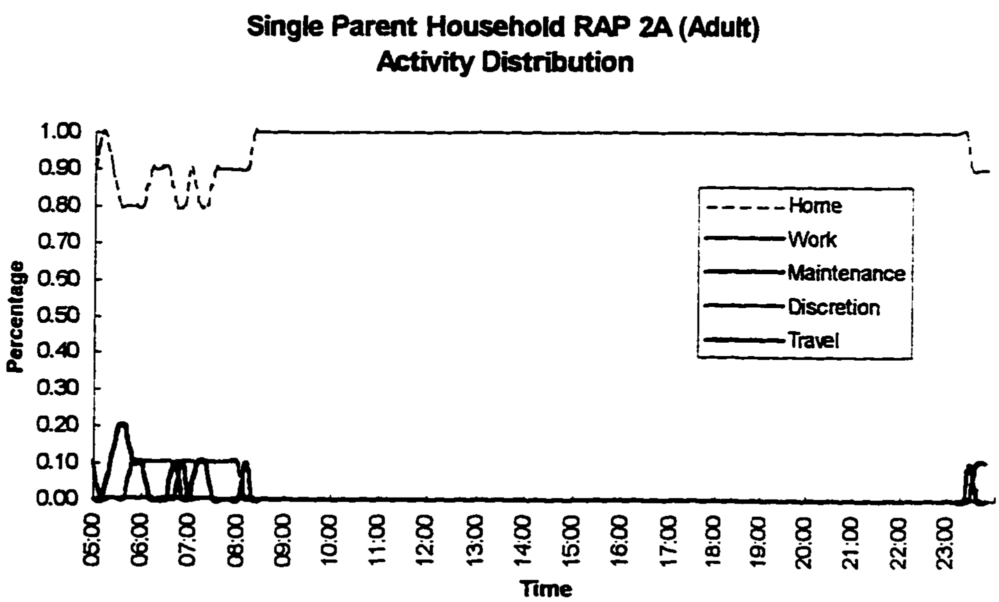

Fig A.86 Pattern 2A Activity Distribution with 1994 Data

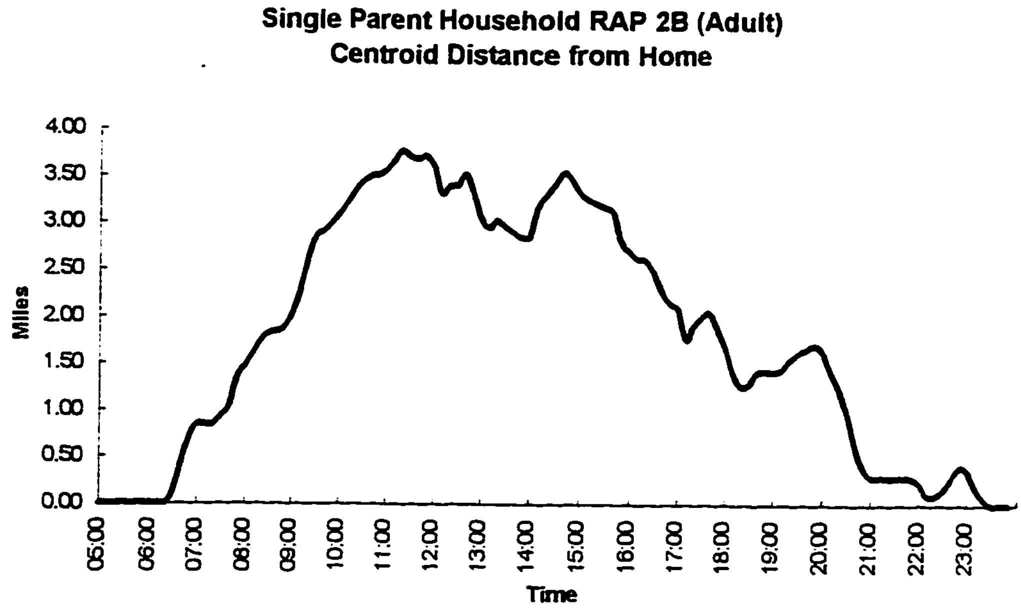

Fig A.87 Pattern 2B Distance Distribution with 1994 Data

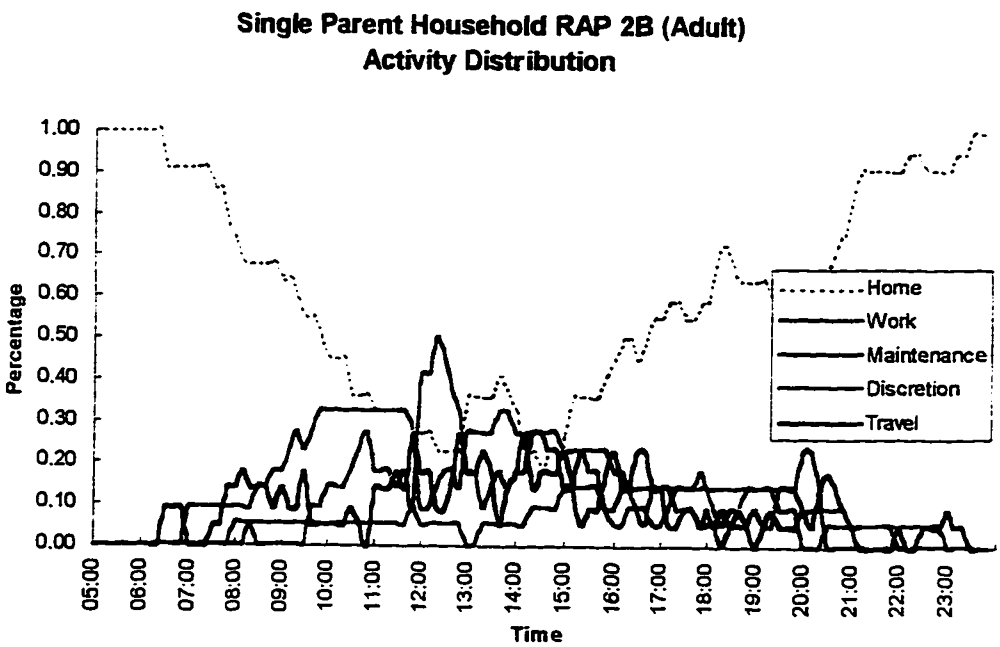

Fig A.88 Pattern 2B Activity Distribution with 1994 Data

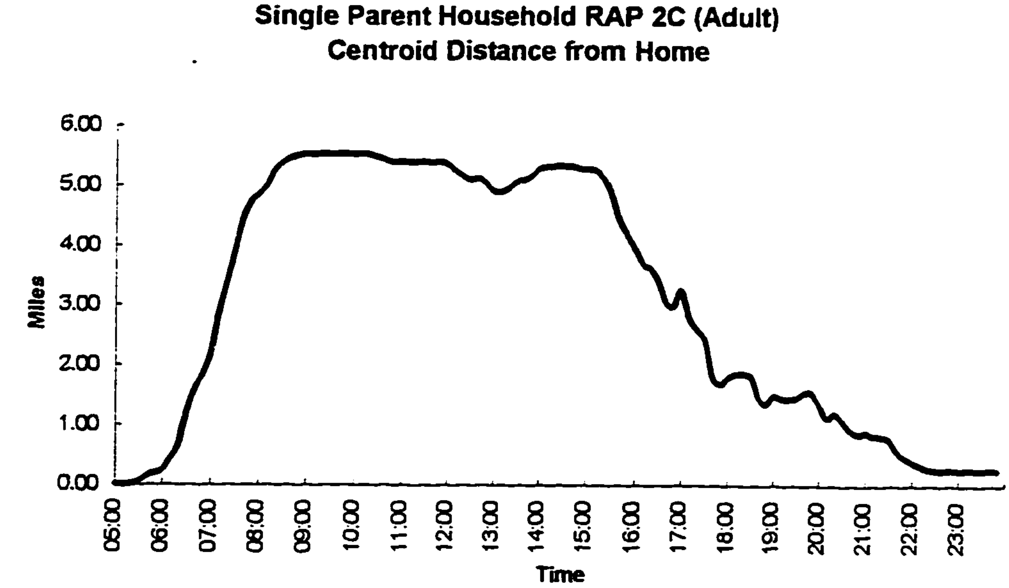

Fig A.87 Pattern 2C Distance Distribution with 1994 Data

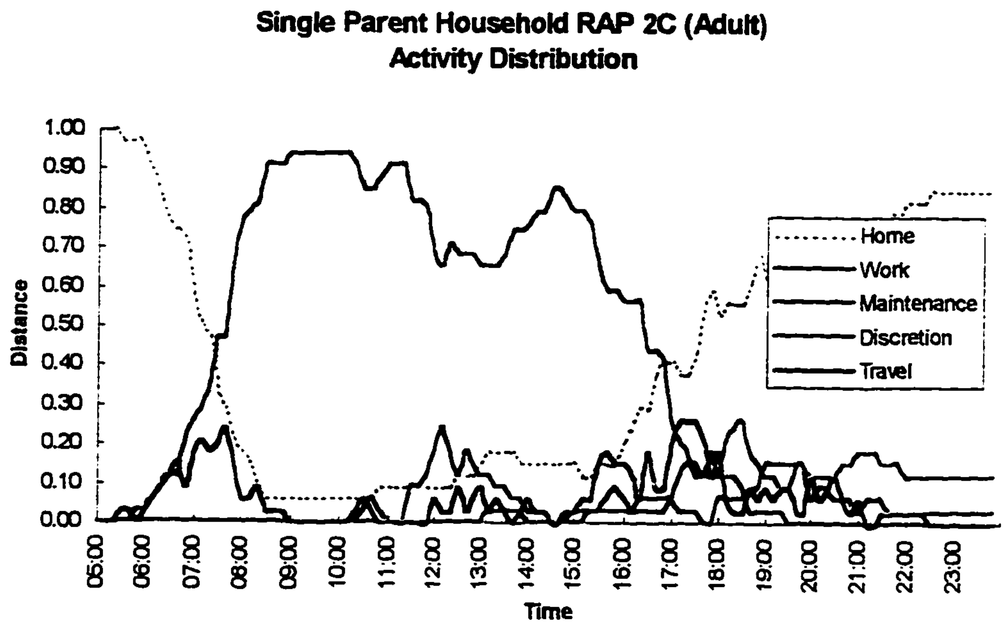

Fig A.90 Pattern 2C Activity Distribution with 1994 Data

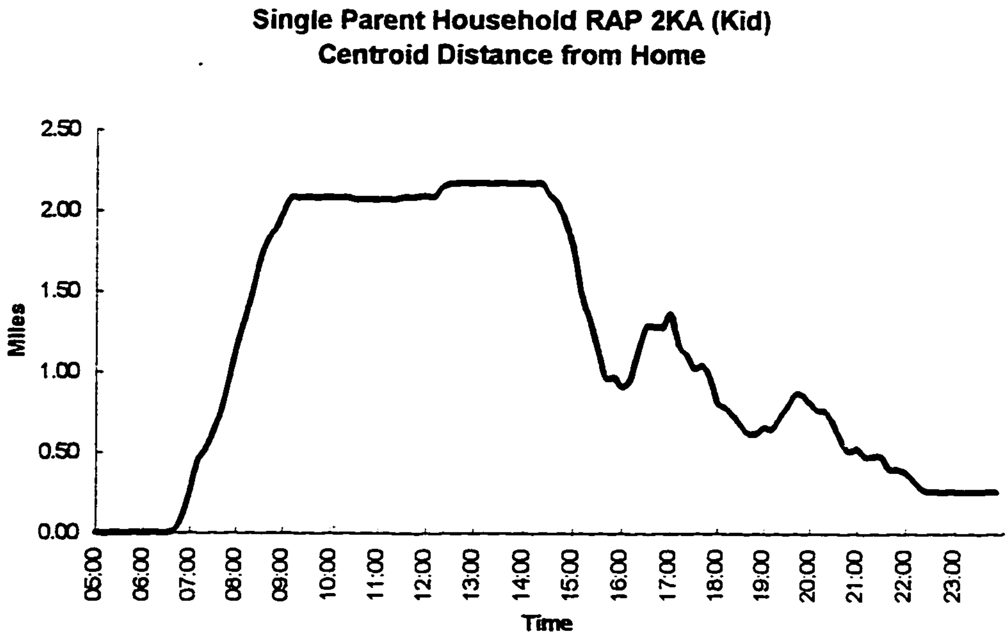

Fig A.91 Pattern 2KA Distance Distribution with 1994 Data

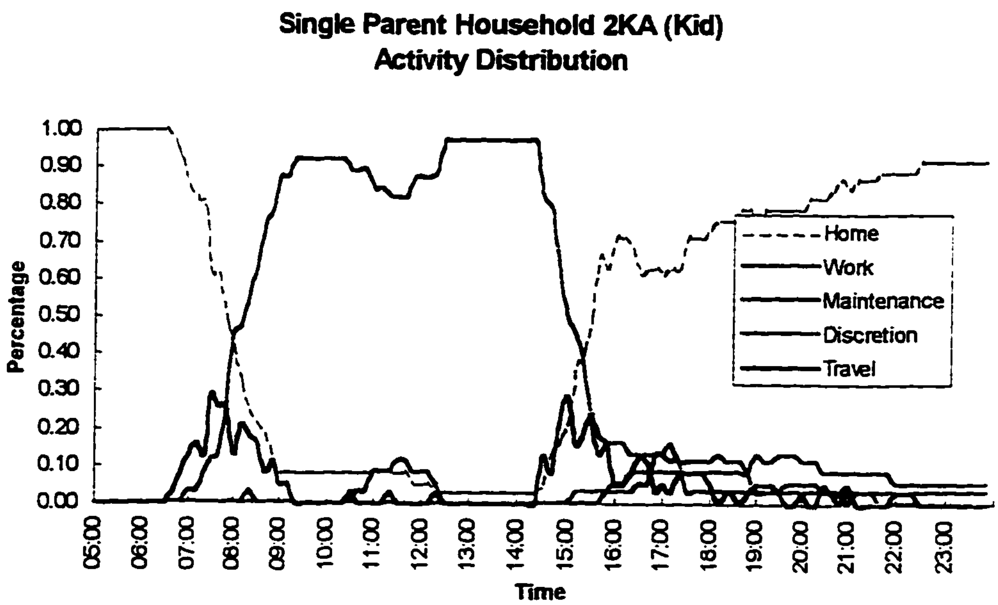

Fig A.92 Pattern 2KA Activity Distribution with 1994 Data

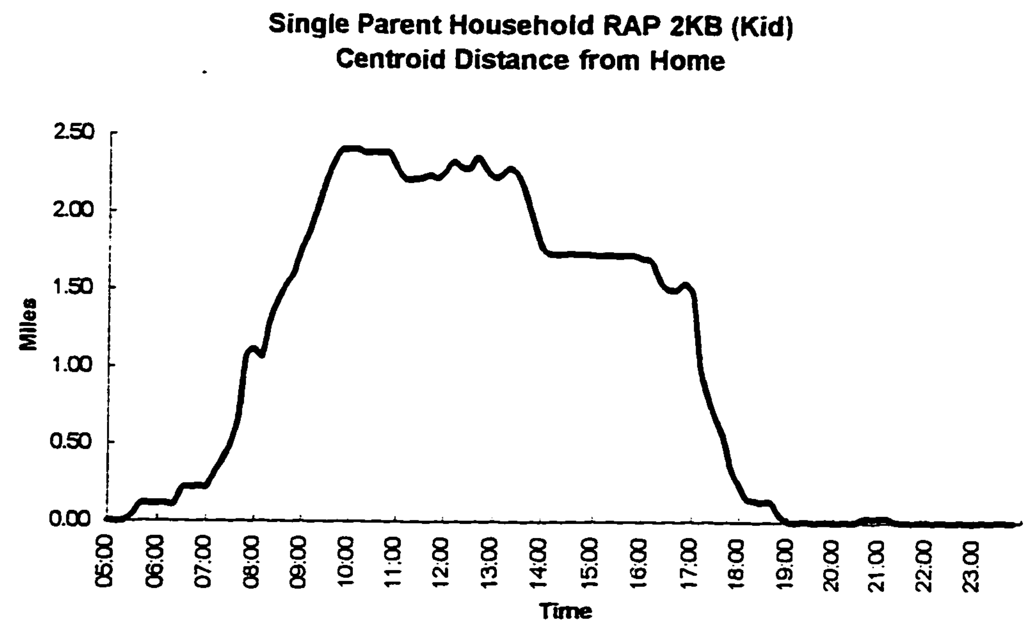

Fig A.93 Pattern 2KB Distance Distribution with 1994 Data

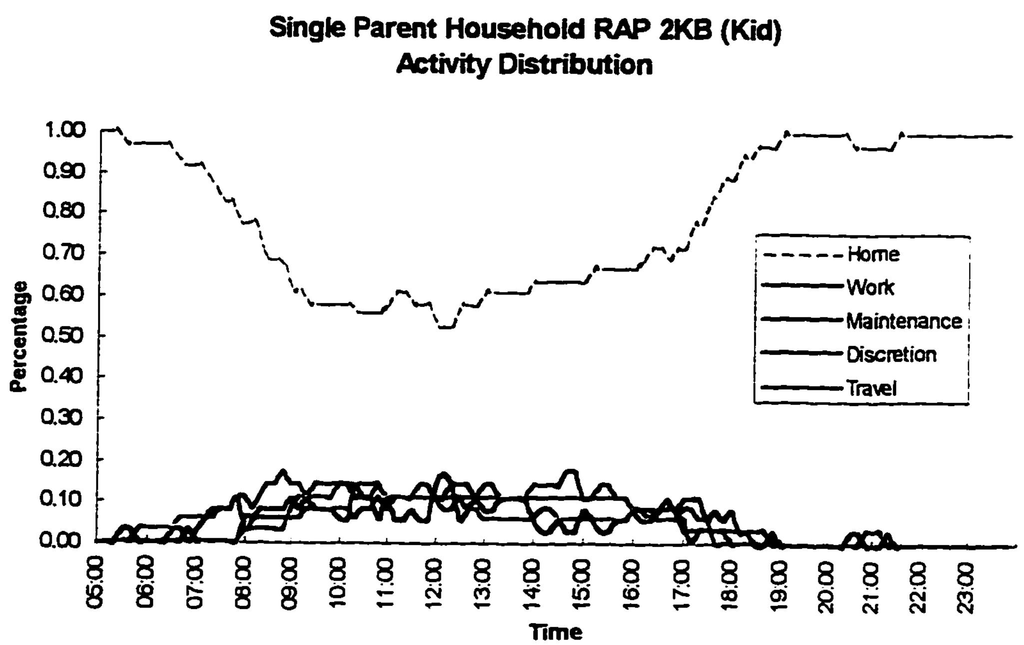

Fig A.94 Pattern 2KB Activity Distribution with 1994 Data

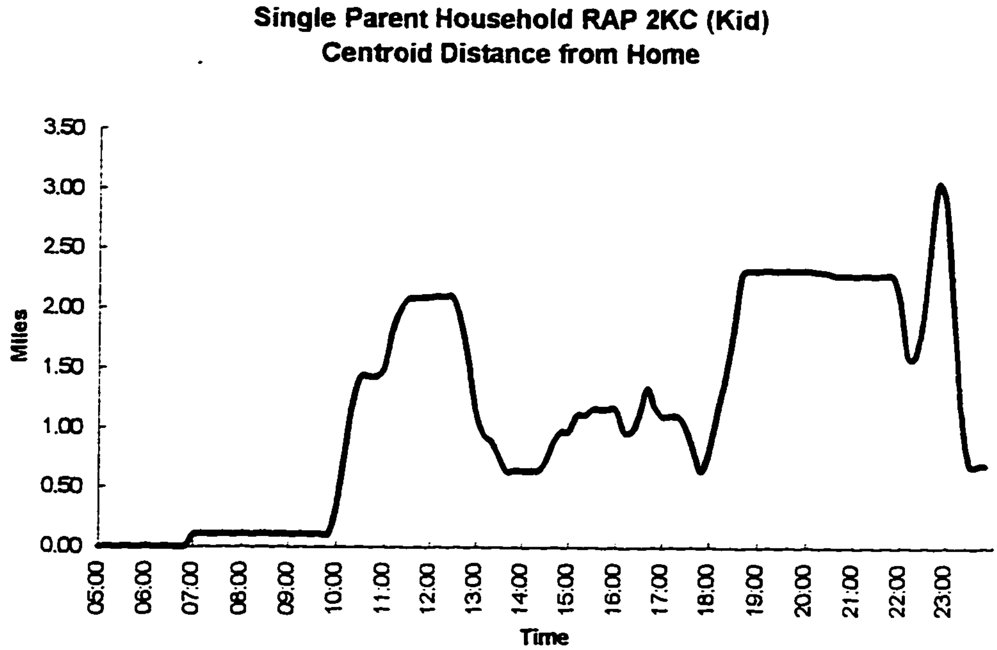

Fig A.95 Pattern 2KC Distance Distribution with 1994 Data

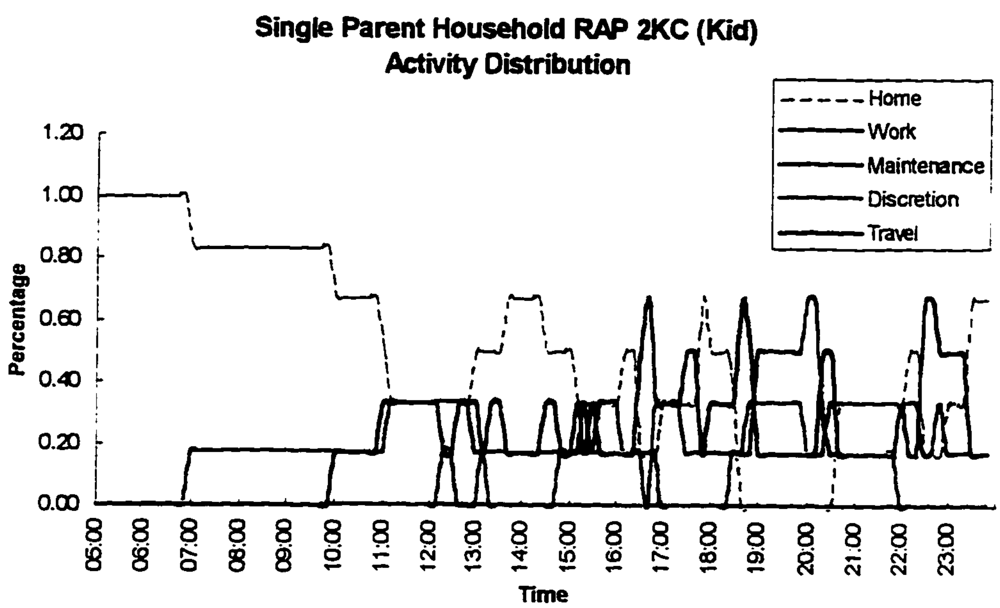

Fig A.96 Pattern 2KC Activity Distribution with 1994 Data

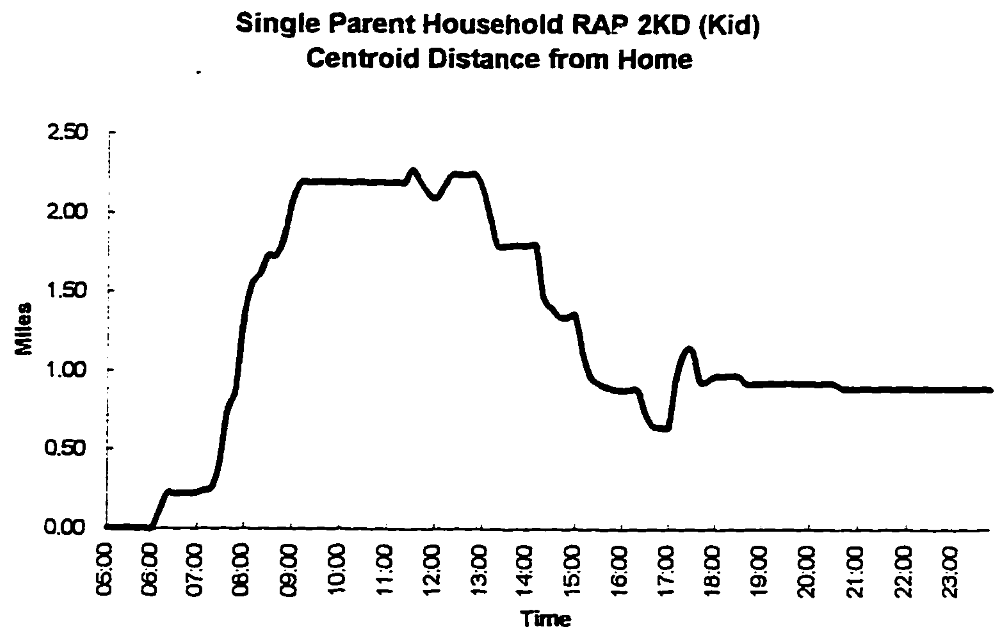

Fig A.97 Pattern 2KD Distance Distribution with 1994 Data

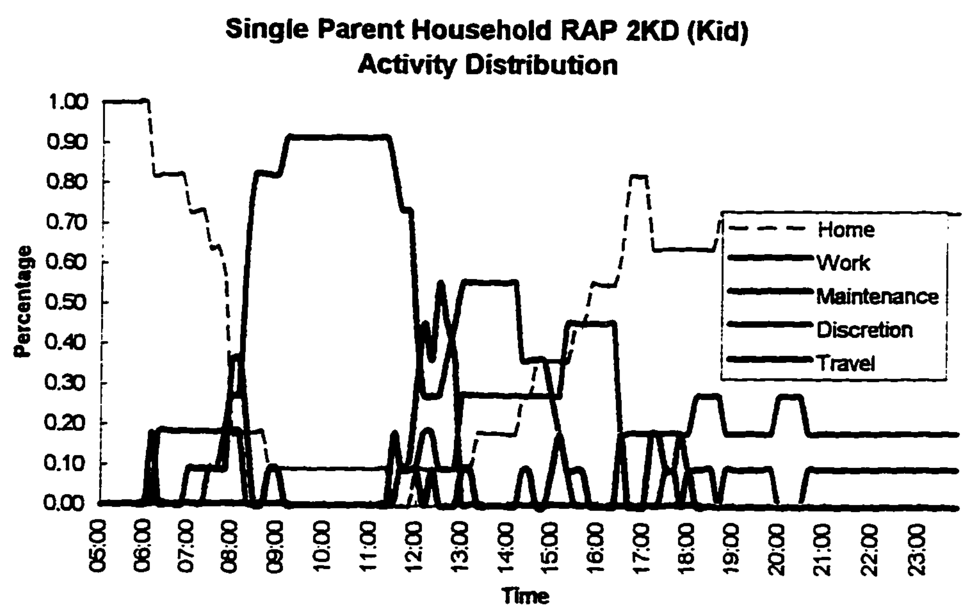

Fig A.98 Pattern 2KD Activity Distribution with 1994 Data

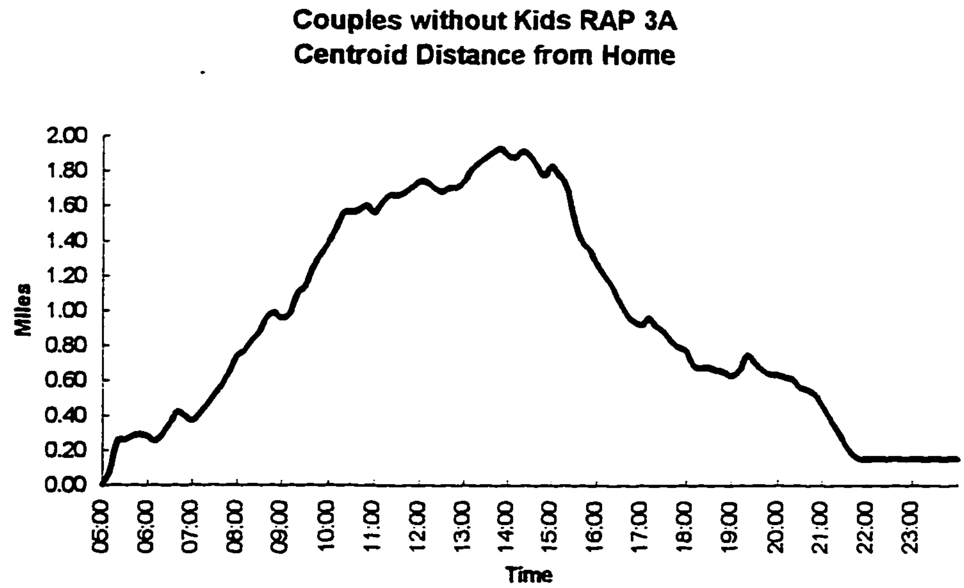

Fig A.99 Pattern 3A Distance Distribution with 1994 Data

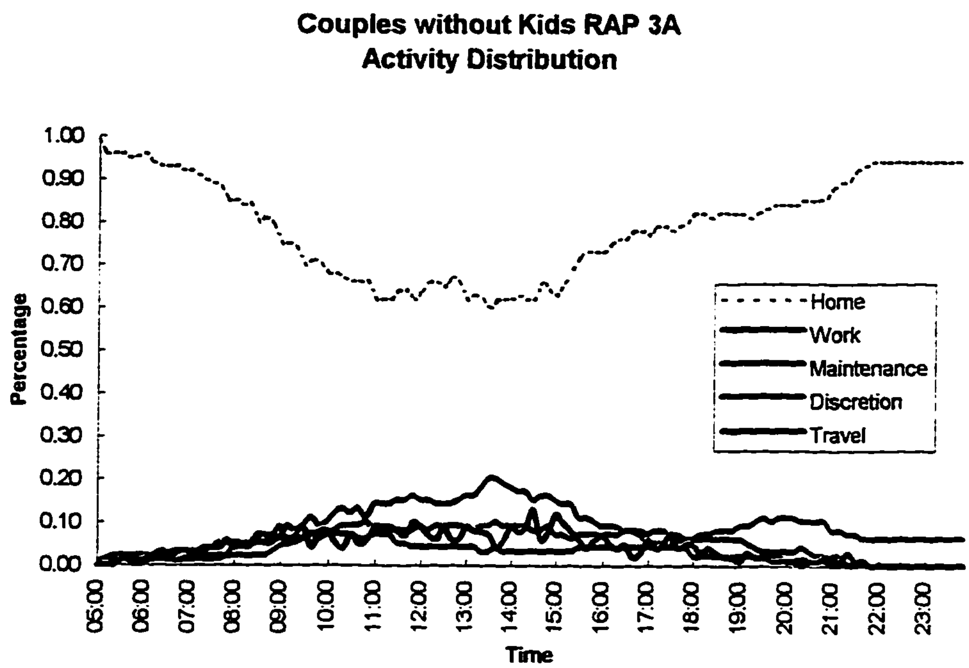

Fig A.100 Pattern 3A Activity Distribution with 1994 Data

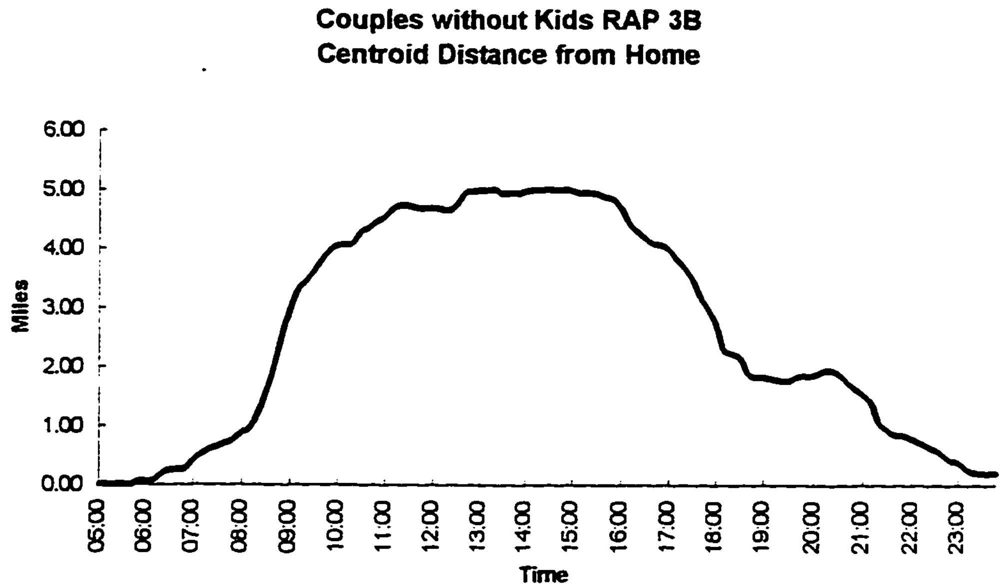

Fig A.101 Pattern 3B Distance Distribution with 1994 Data

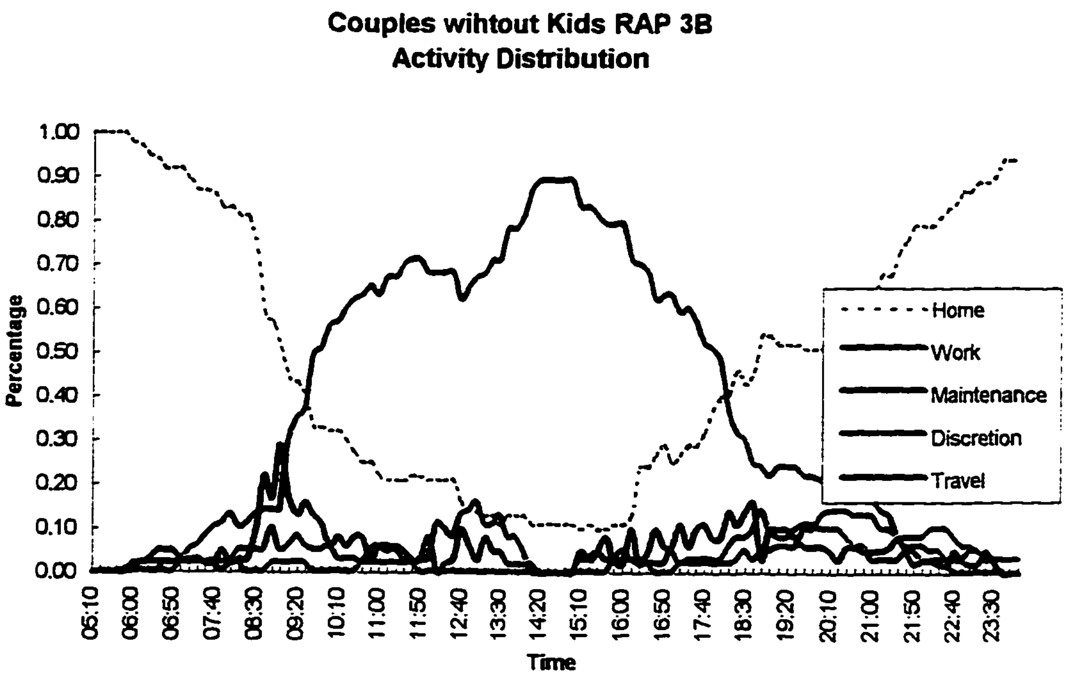

Fig A.102 Pattern 3B Activity Distribution with 1994 Data

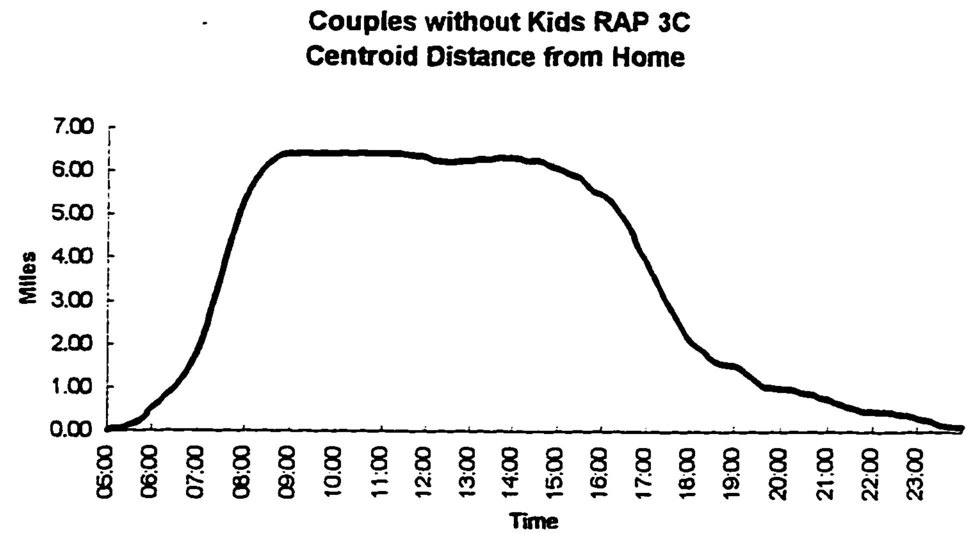

Fig A.103 Pattern 3C Distance Distribution with 1994 Data

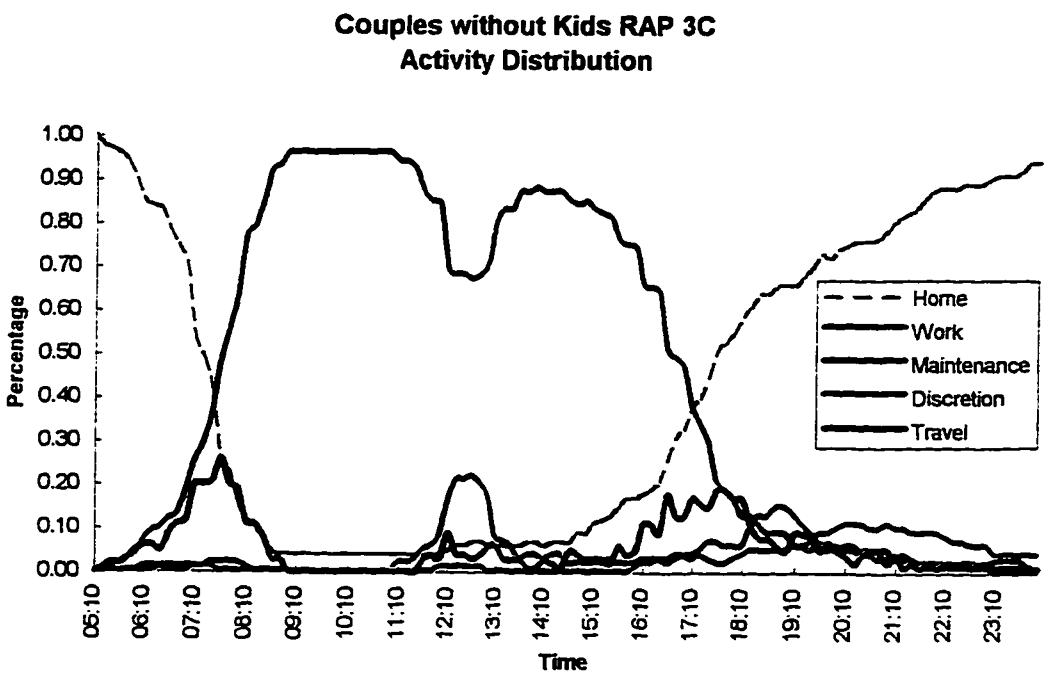

Fig A.104 Pattern 3C Distance Distribution with 1994 Data

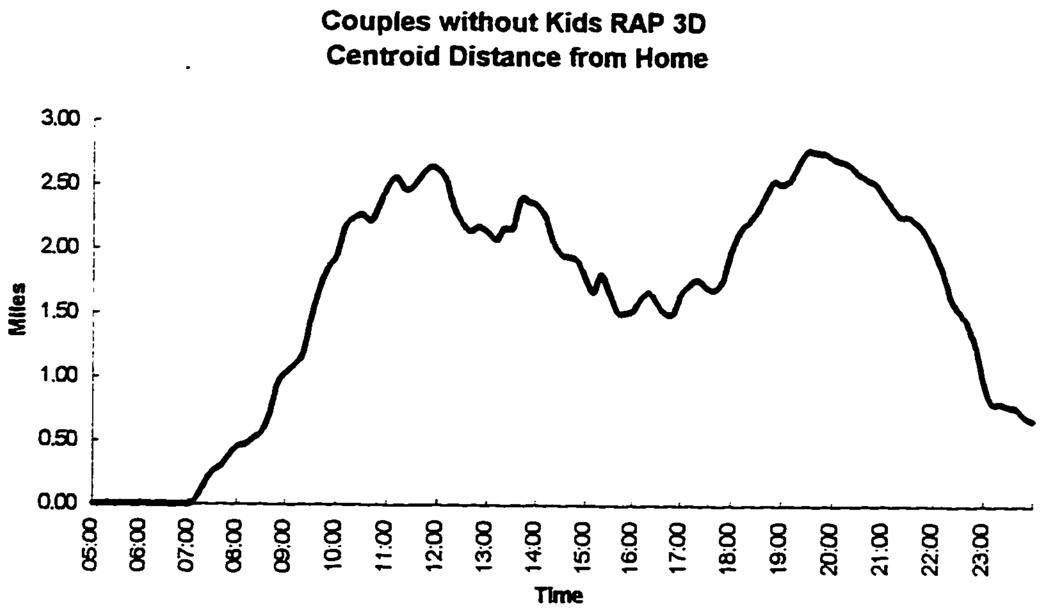

Fig A.105 Pattern 3D Distance Distribution with 1994 Data

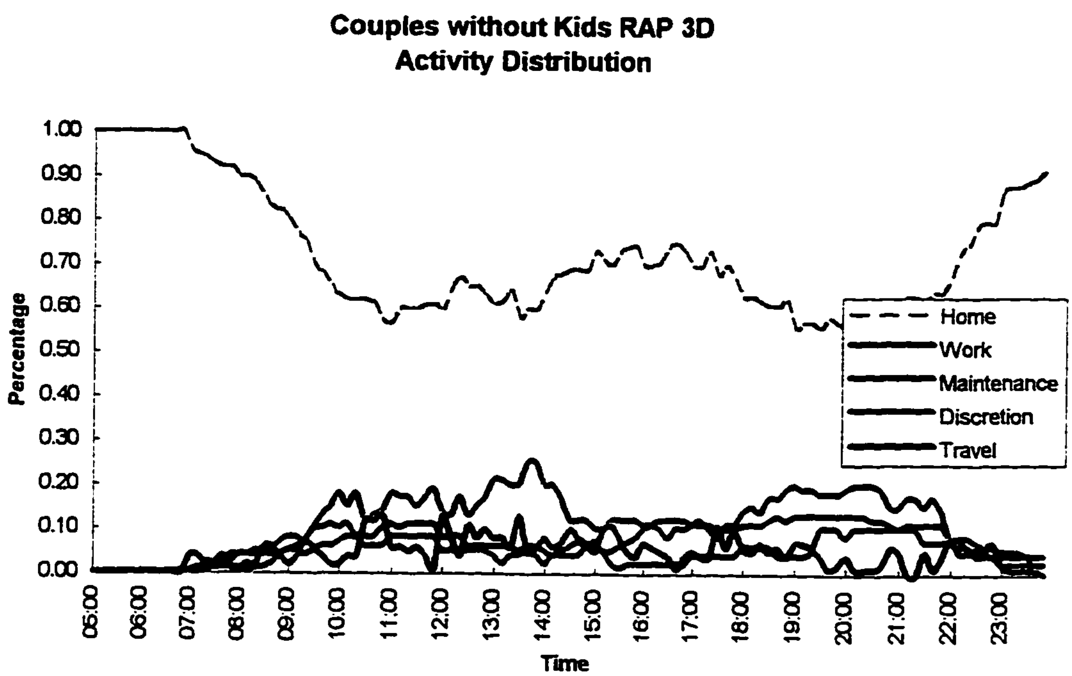

Fig A.106 Pattern 3D Activity Distribution with 1994 Data

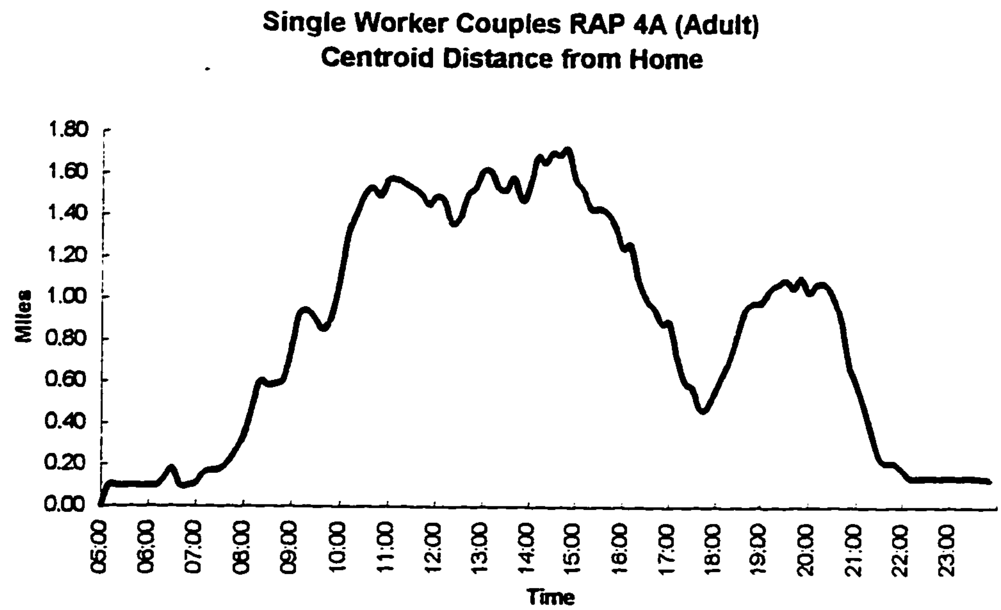

Fig A.107 Pattern 4A Distance Distribution with 1994 Data

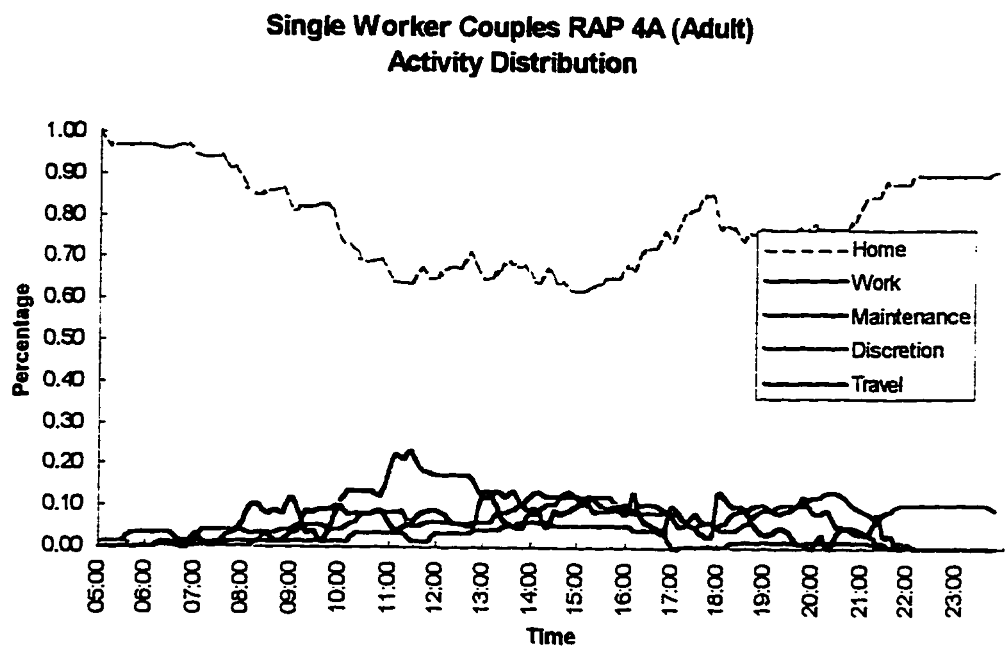

Fig A.108 Pattern 4A Activity Distribution with 1994 Data

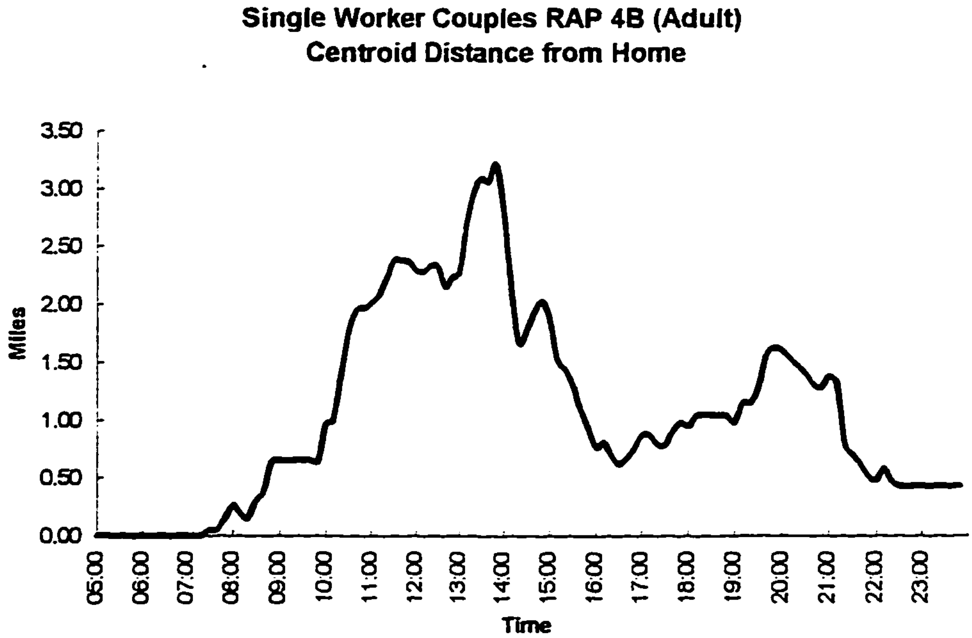

Fig A.109 Pattern 4B Distance Distribution with 1994 Data

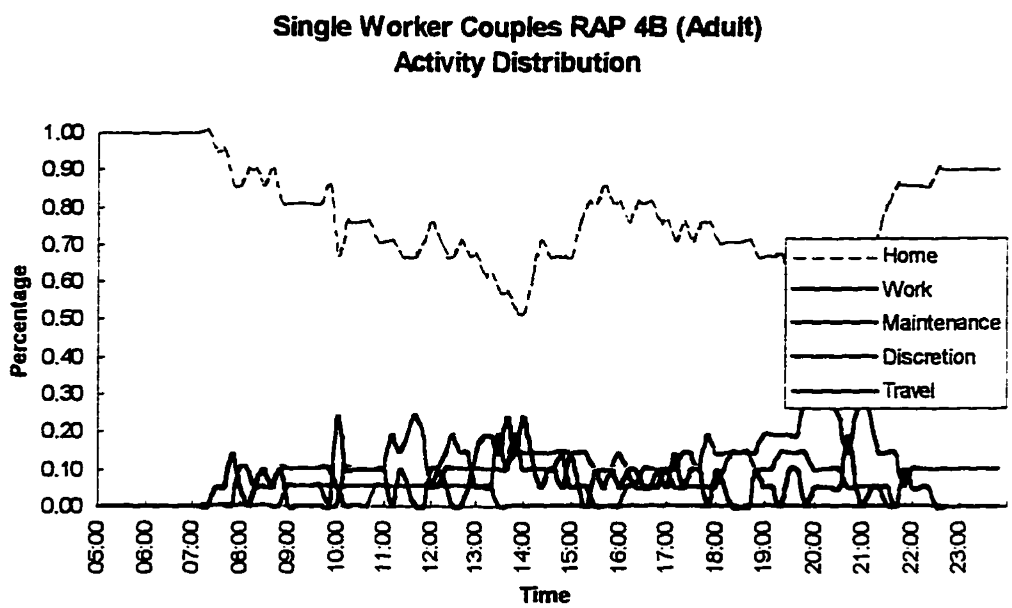

Fig A.110 Pattern 4B Activity Distribution with 1994 Data

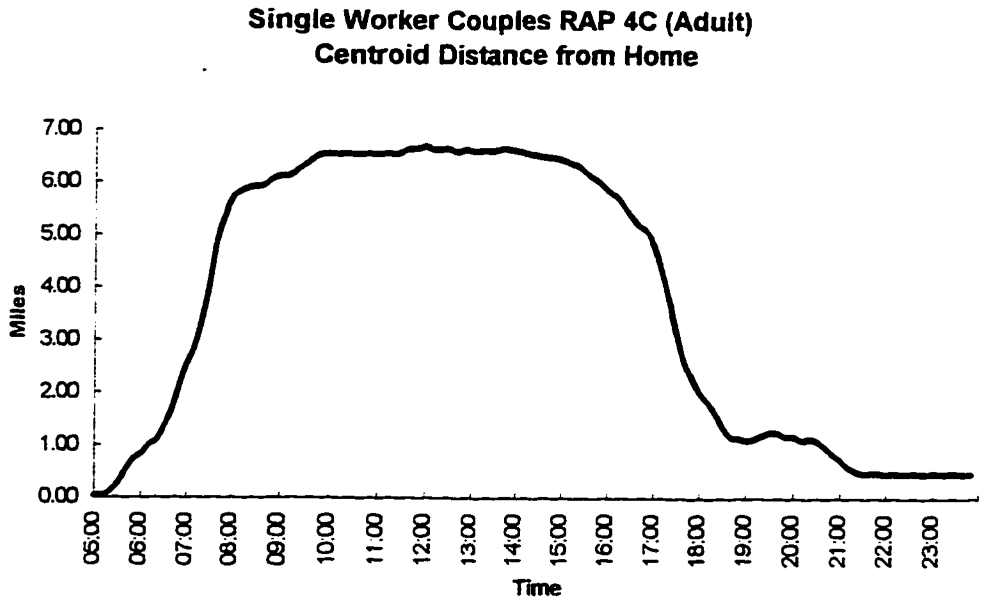

Fig A.111 Pattern 4C Distance Distribution with 1994 Data

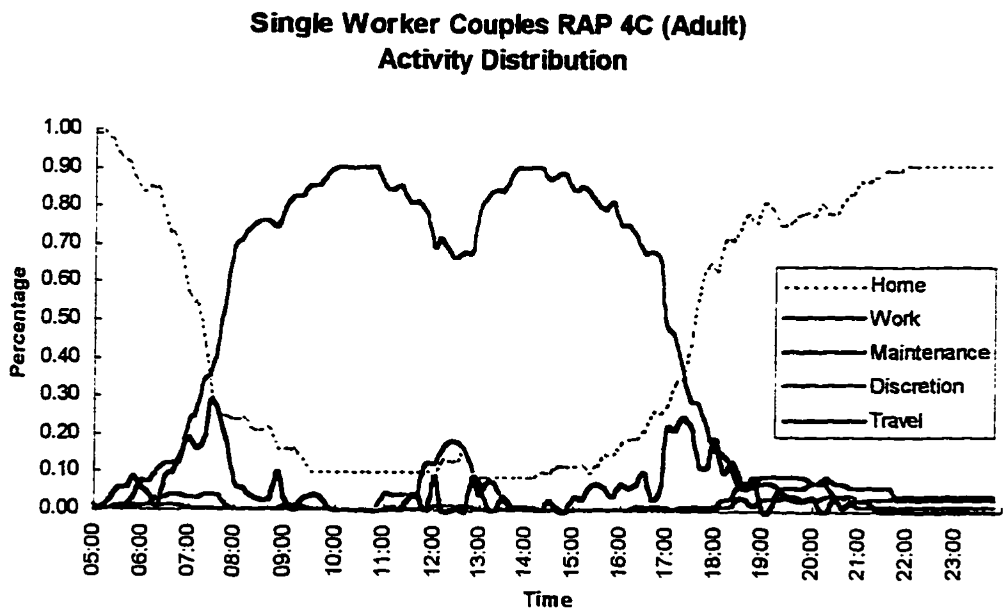

Fig A.112 Pattern 4C Activity Distribution with 1994 Data

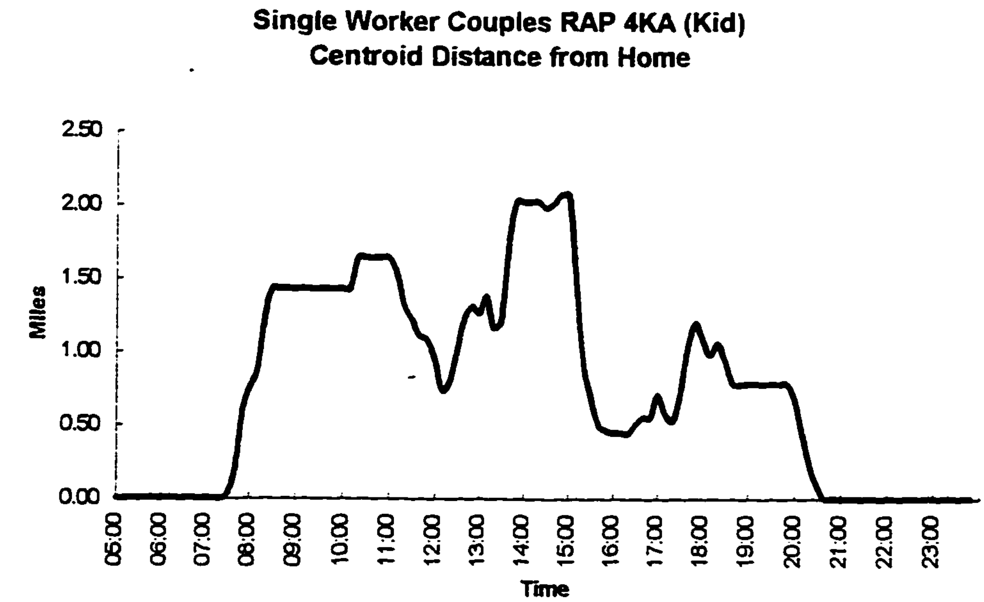

Fig A.113 Pattern 4KA Distance Distribution with 1994 Data

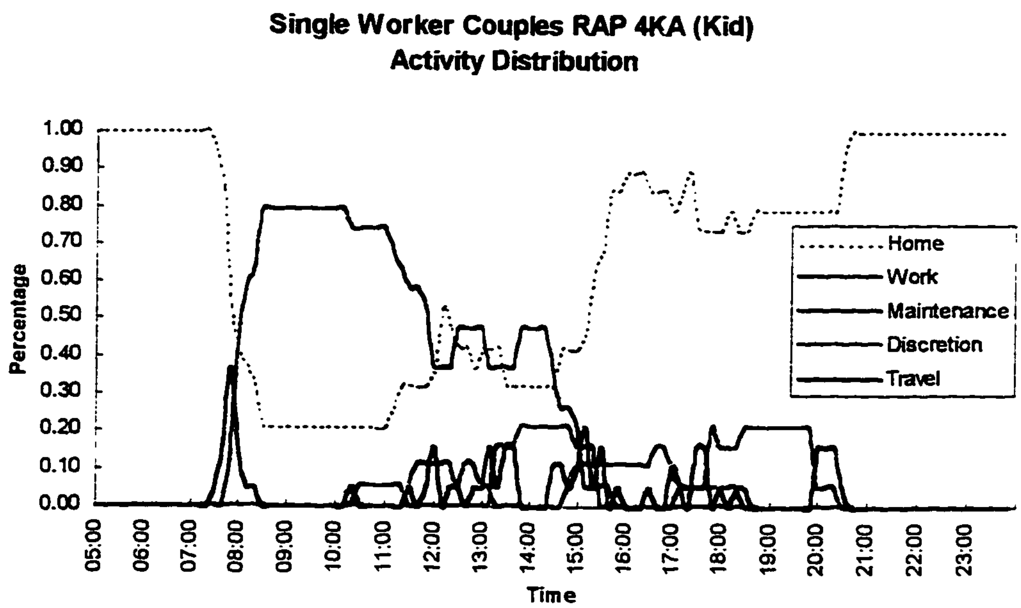

Fig A.114 Pattern 4KA Activity Distribution with 1994 Data

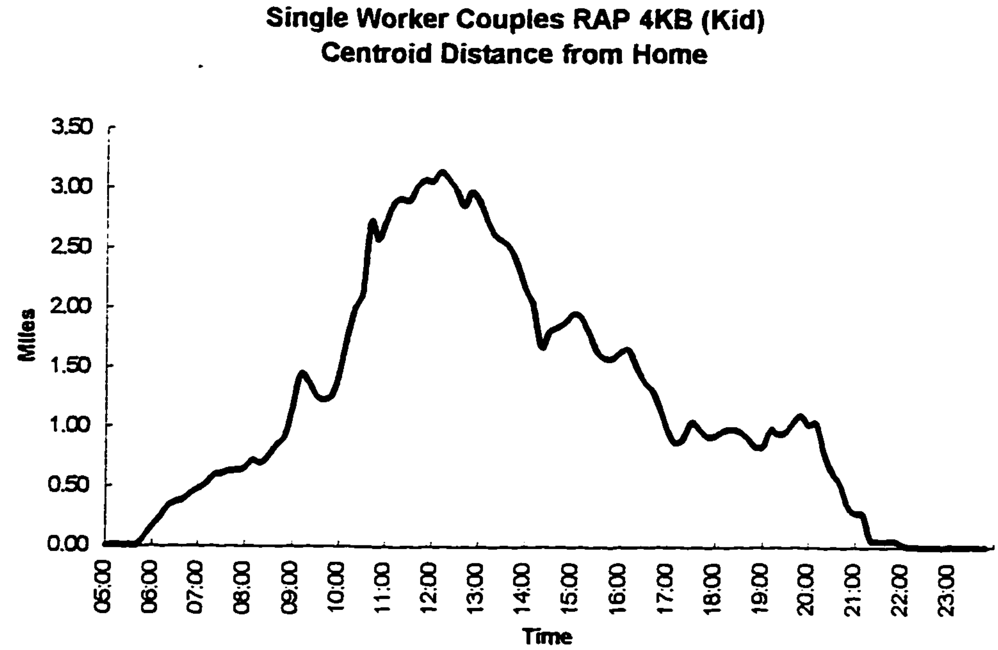

Fig A.115 Pattern 4KB Distance Distribution with 1994 Data

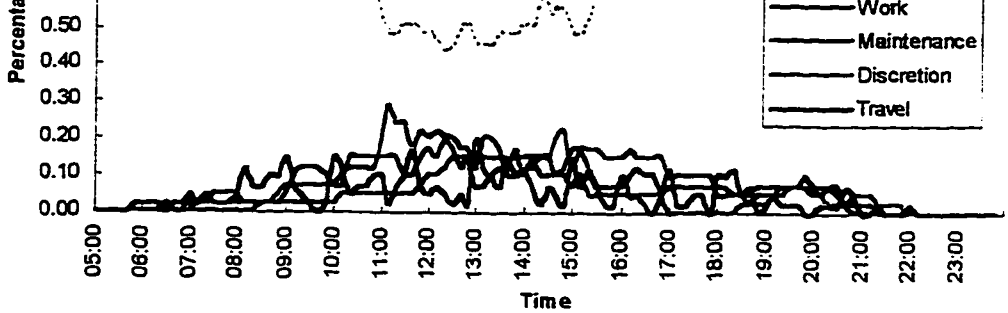

Fig A.116 Pattern 4KB Activity Distribution with 1994 Data

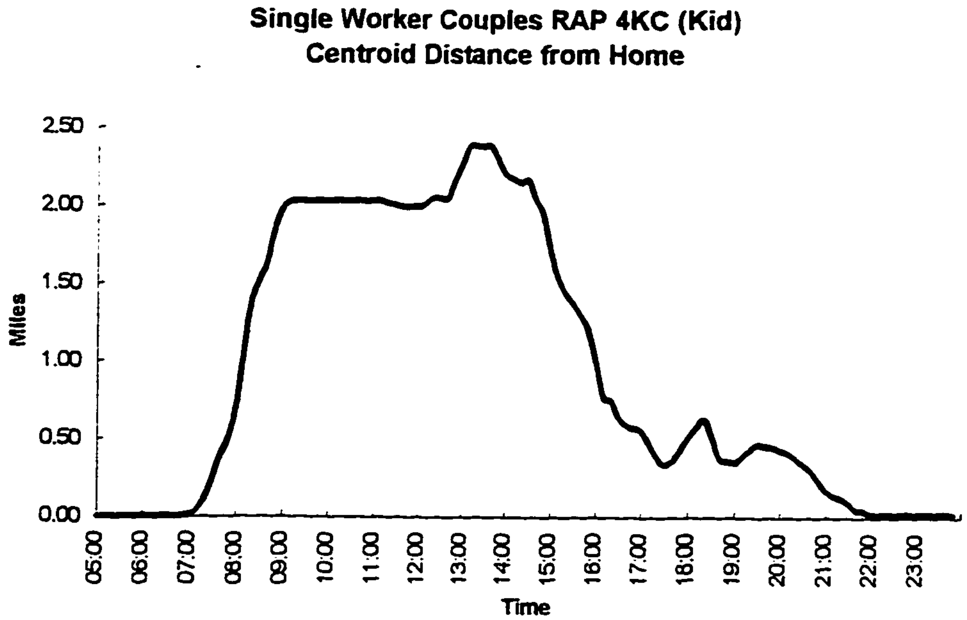

Fig A.117 Pattern 4KC Distance Distribution with 1994 Data

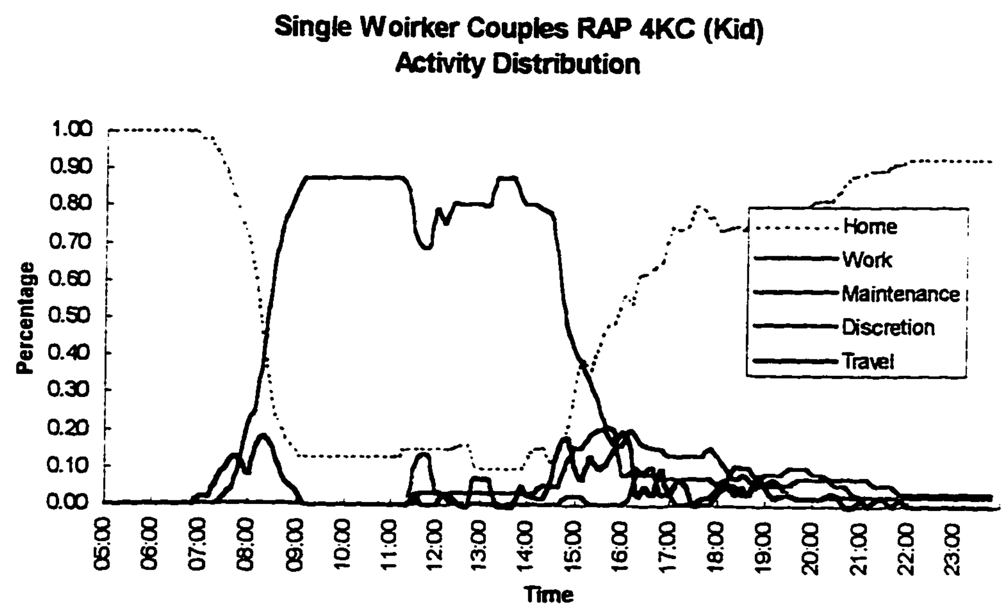

Fig A.118 Pattern 4KC Activity Distribution with 1994 Data

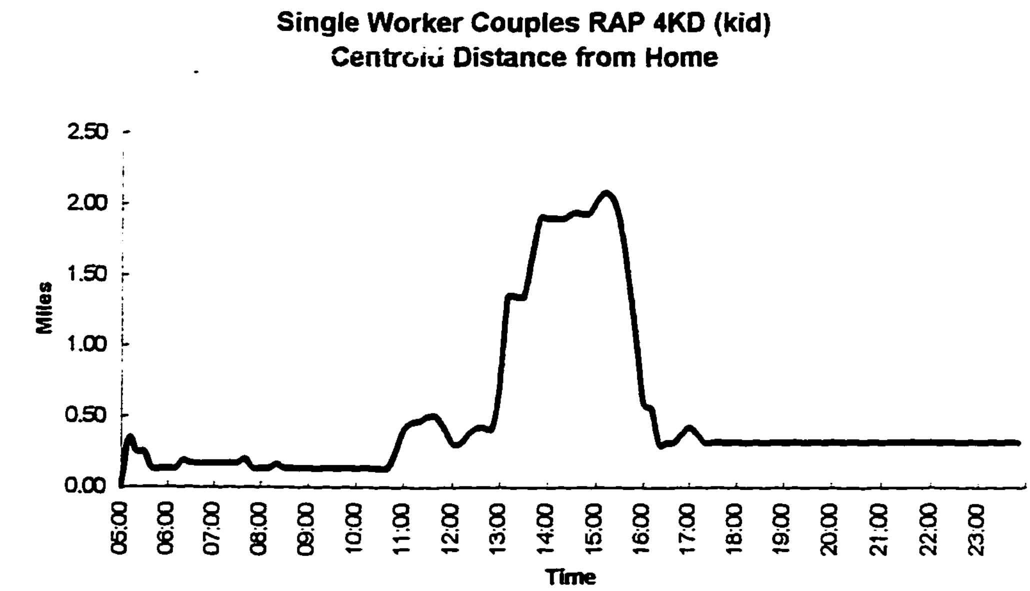

Fig A.119 Pattern 4KD Distance Distribution with 1994 Data

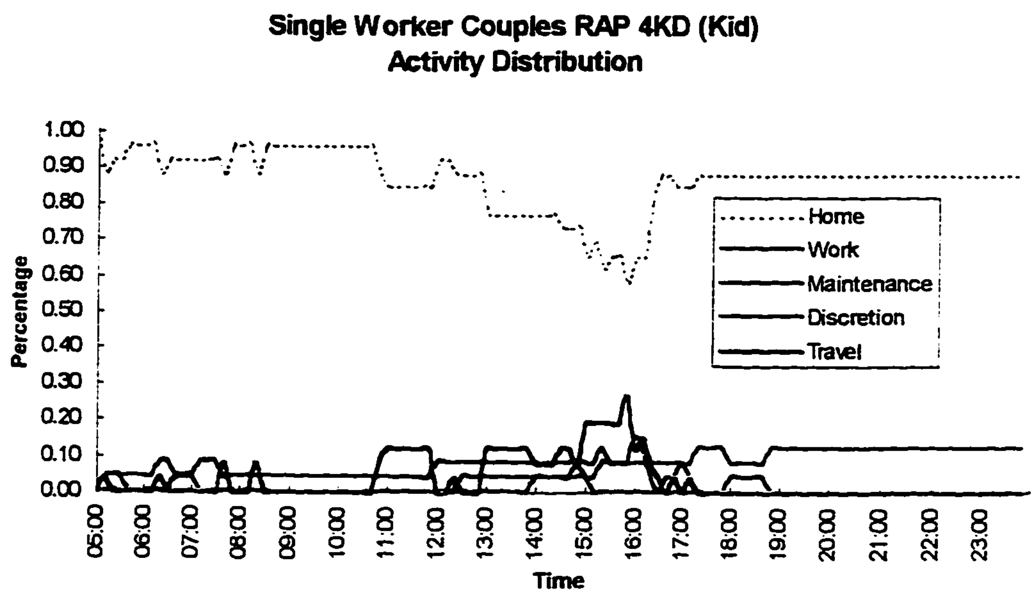

Fig A.120 Pattern 4KD Activity Distribution with 1994 Data

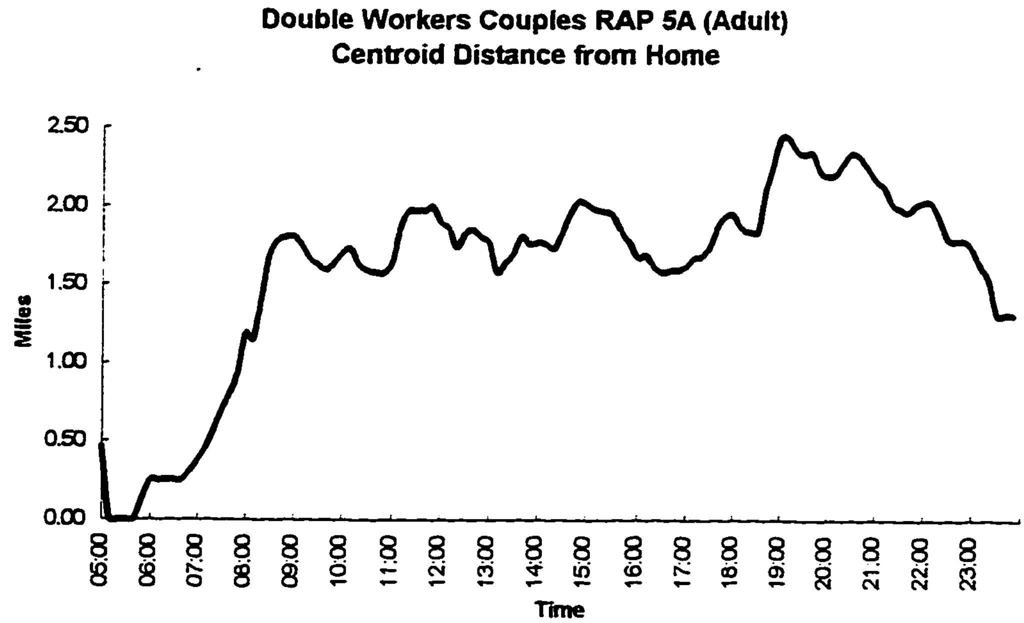

Fig A.121 Pattern 5A Distance Distribution with 1994 Data

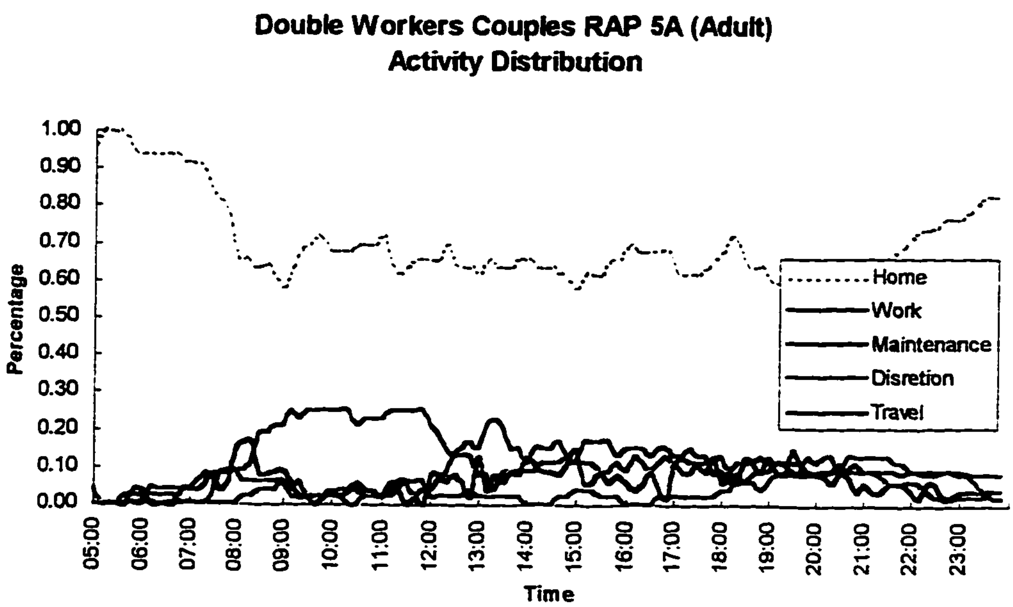

Fig A.122 Pattern 5A Activity Distribution with 1994 Data

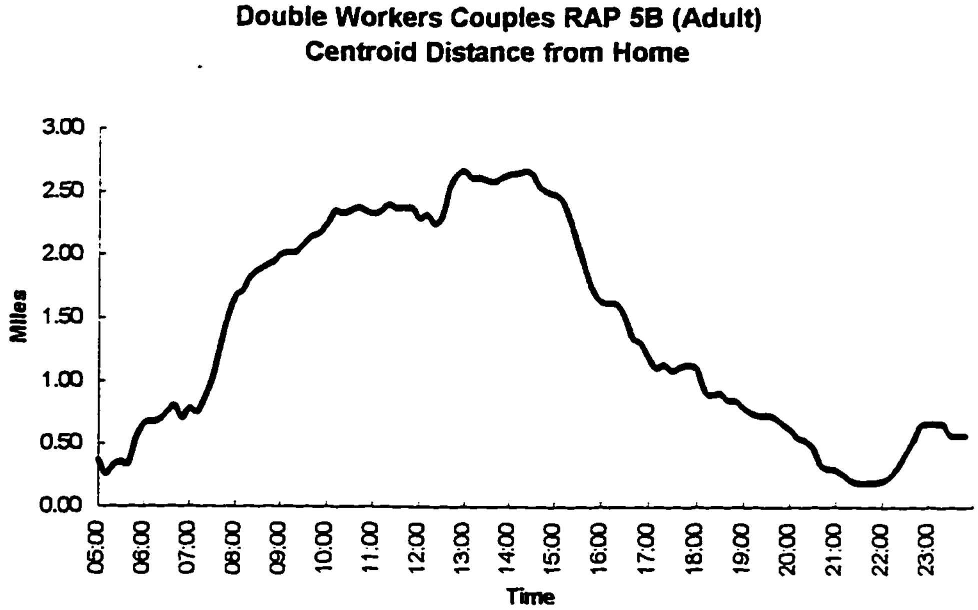

Fig A.123 Pattern 5B Distance Distribution with 1994 Data

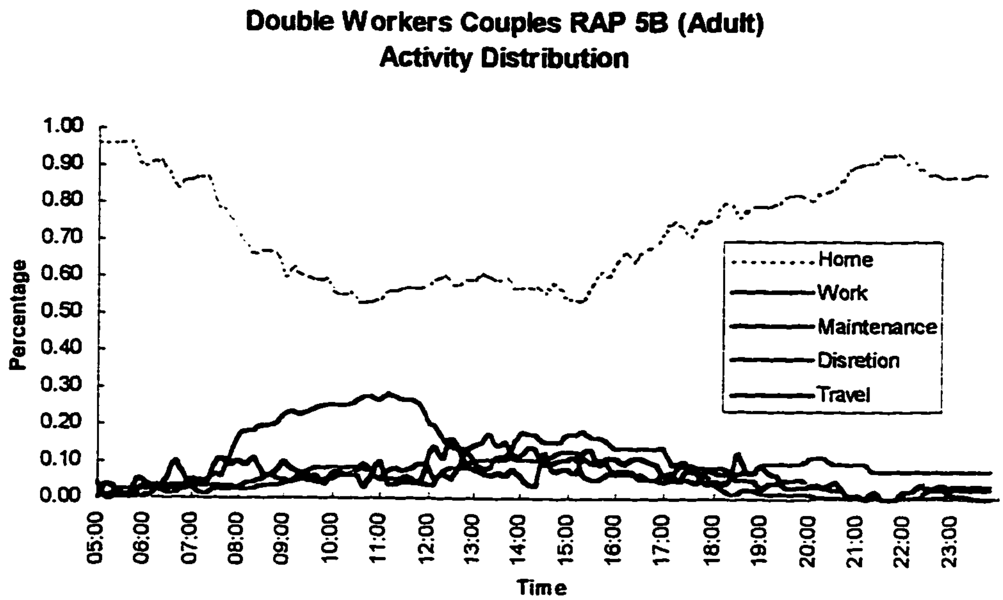

Fig A.124 Pattern 5B Activity Distribution with 1994 Data

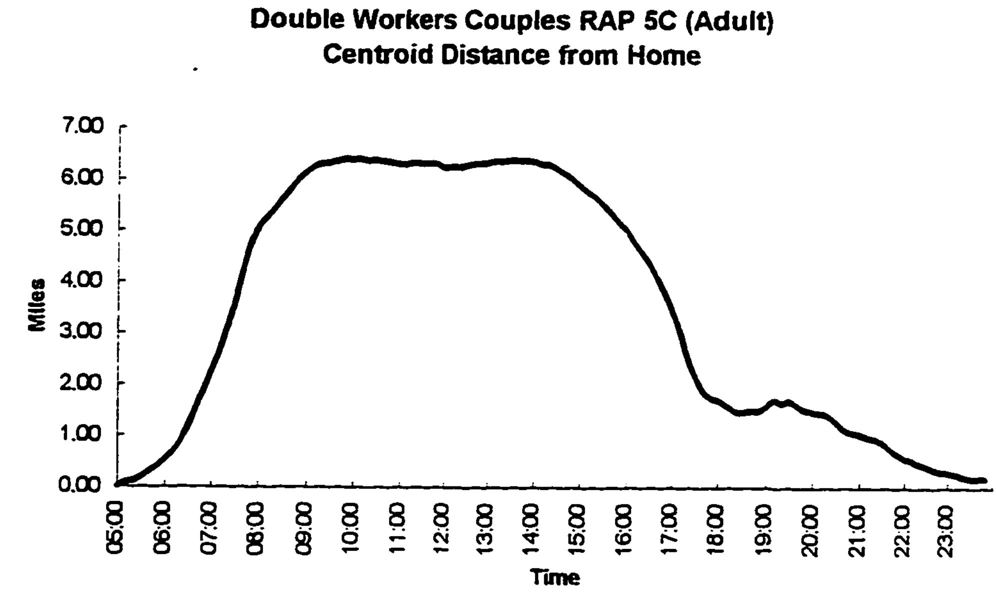

Fig A.125 Pattern 5C Distance Distribution with 1994 Data

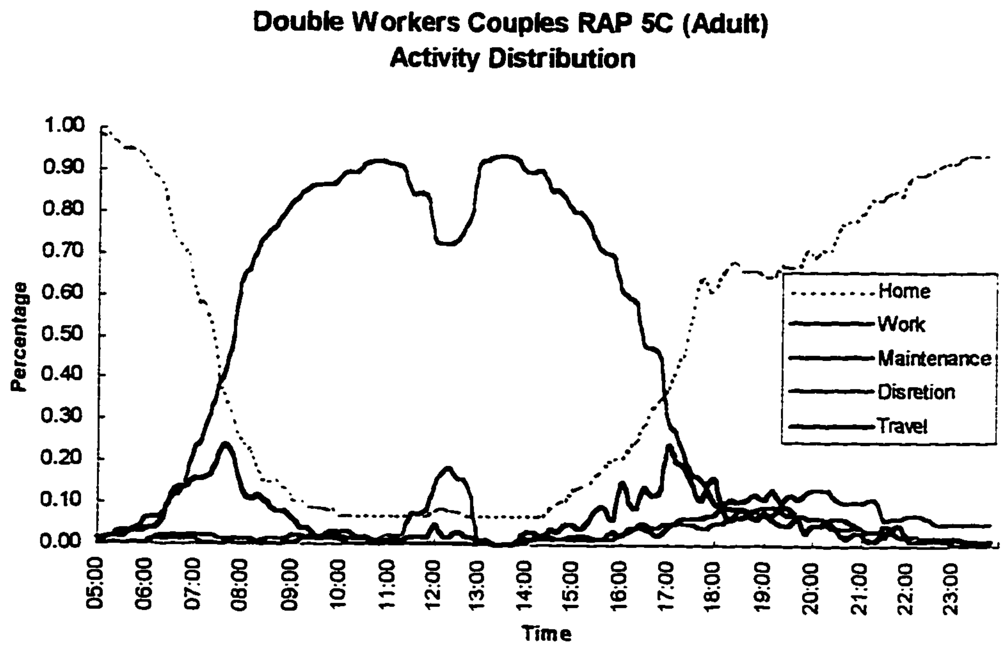

Fig A.126 Pattern 5C Activity Distribution with 1994 Data

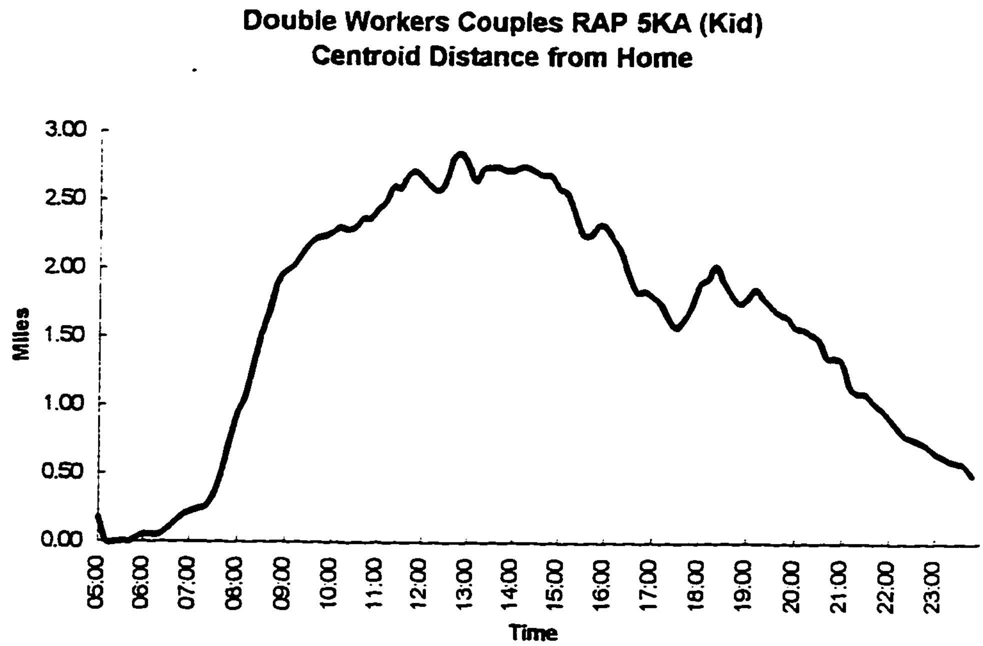

Fig A.127 Pattern 5KA Distance Distribution with 1994 Data

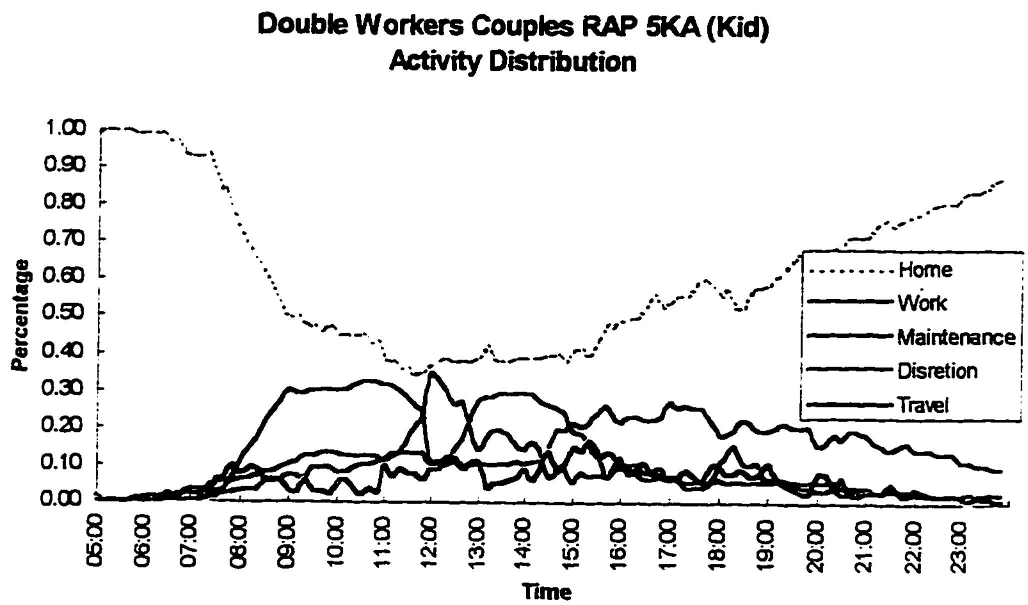

Fig A.128 Pattern 5KA Activity Distribution with 1994 Data

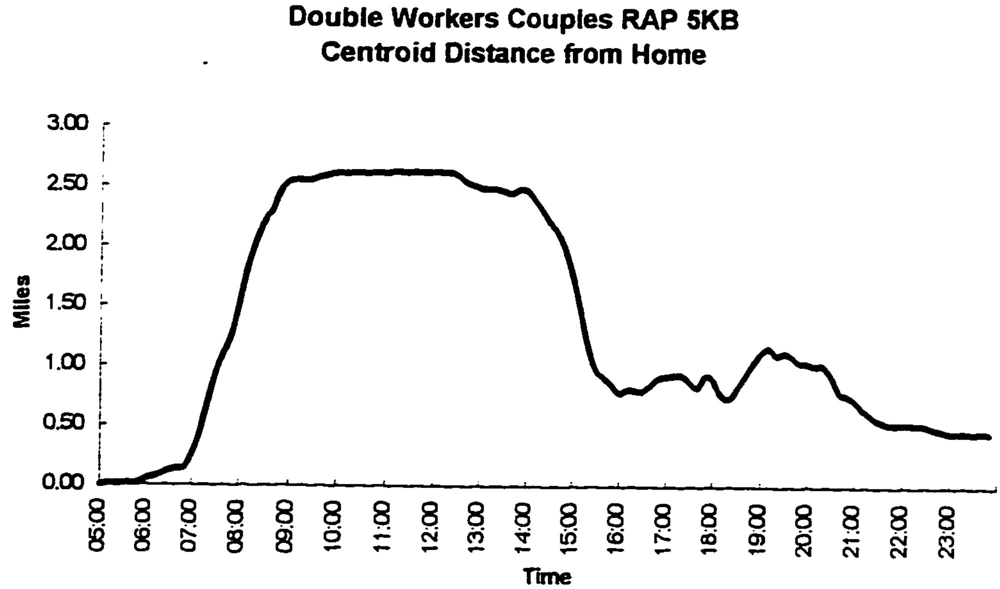

Fig A.129 Pattern 5KB Distance Distribution with 1994 Data

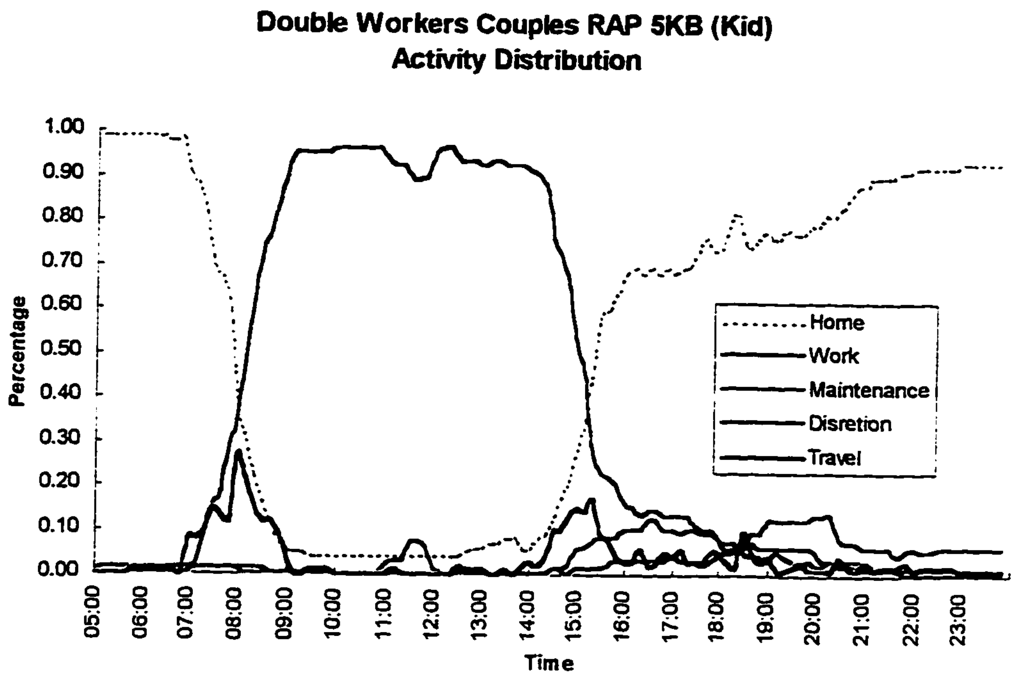

Fig A.130 Pattern 5KB Activity Distribution with 1994 Data

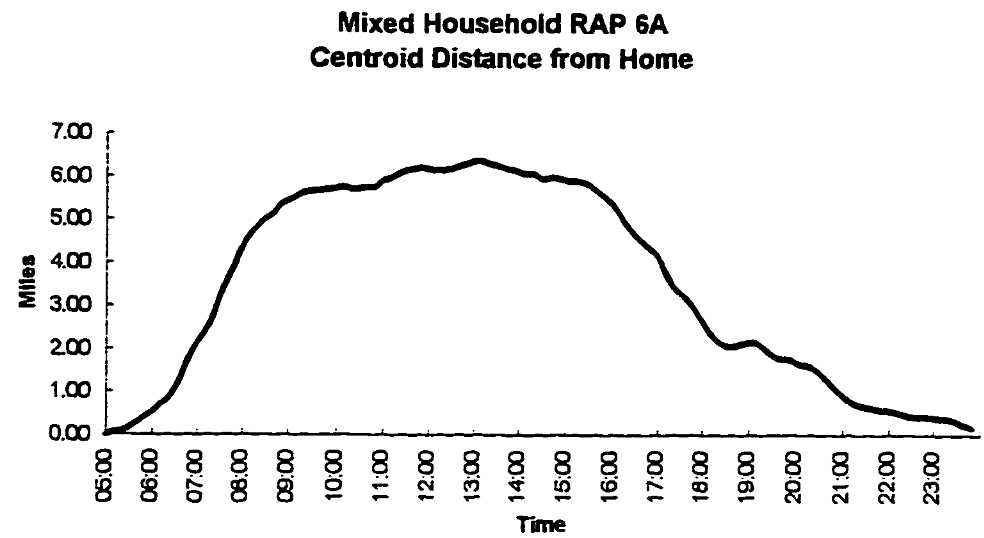

Fig A.131 Pattern 6A Distance Distribution with 1994 Data

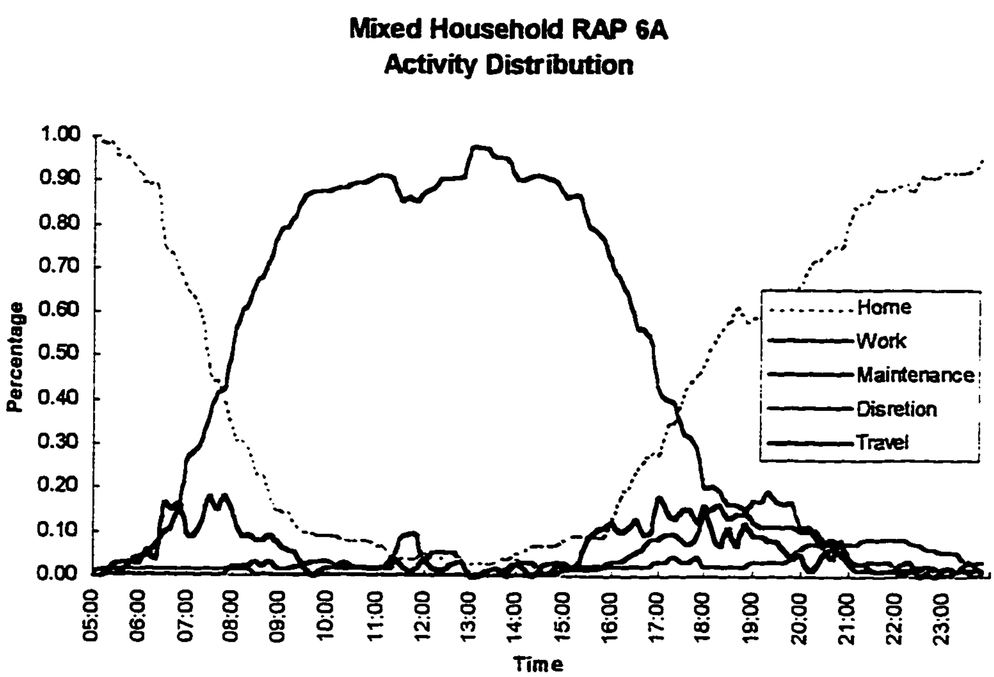

Fig A.132 Pattern 6A Activity Distribution with 1994 Data

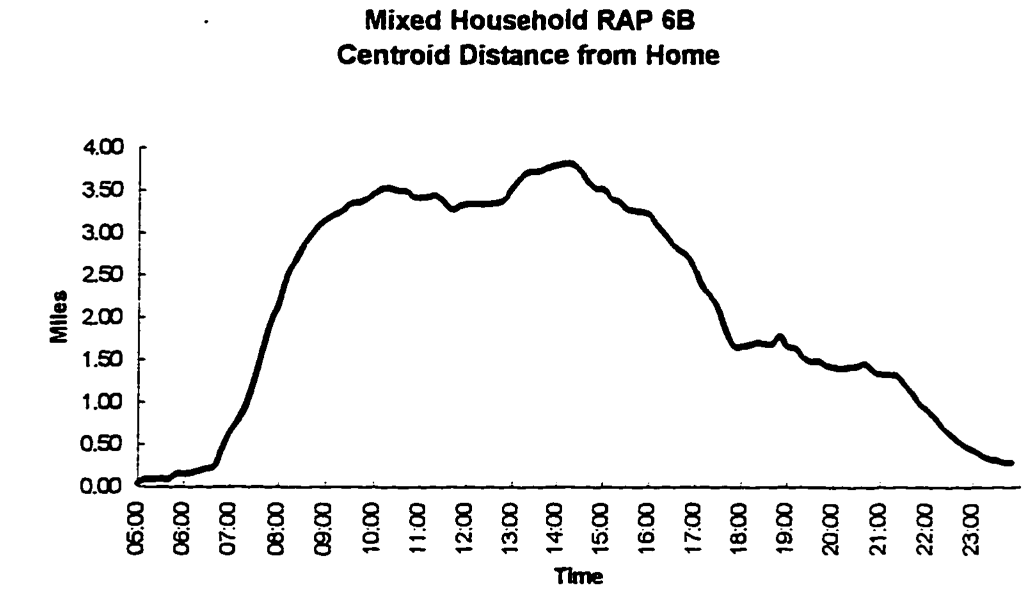

Fig A.133 Pattern 6B Distance Distribution with 1994 Data

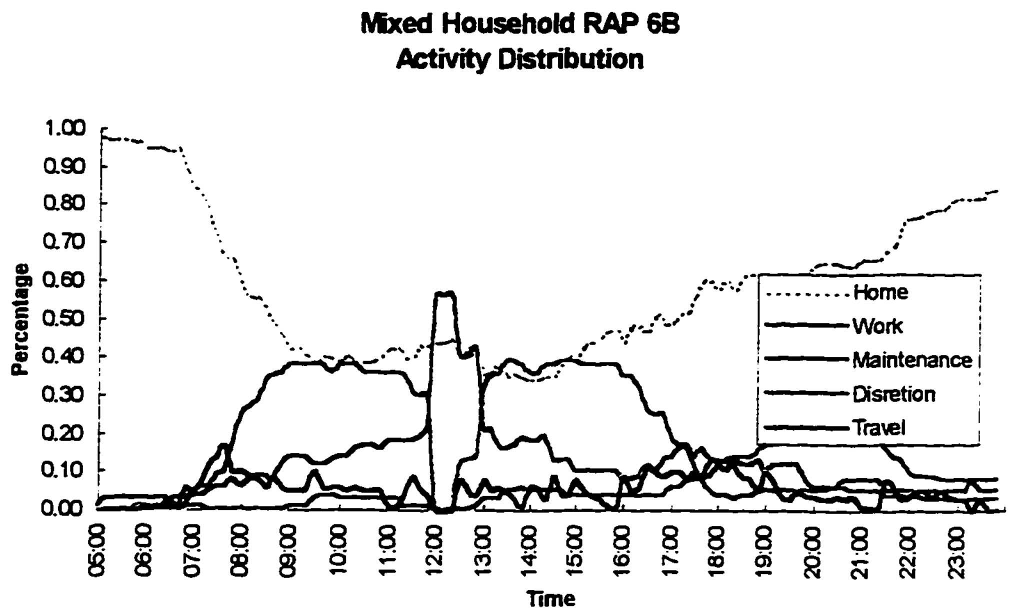

Fig A.134 Pattern 6B Activity Distribution with 1994 Data

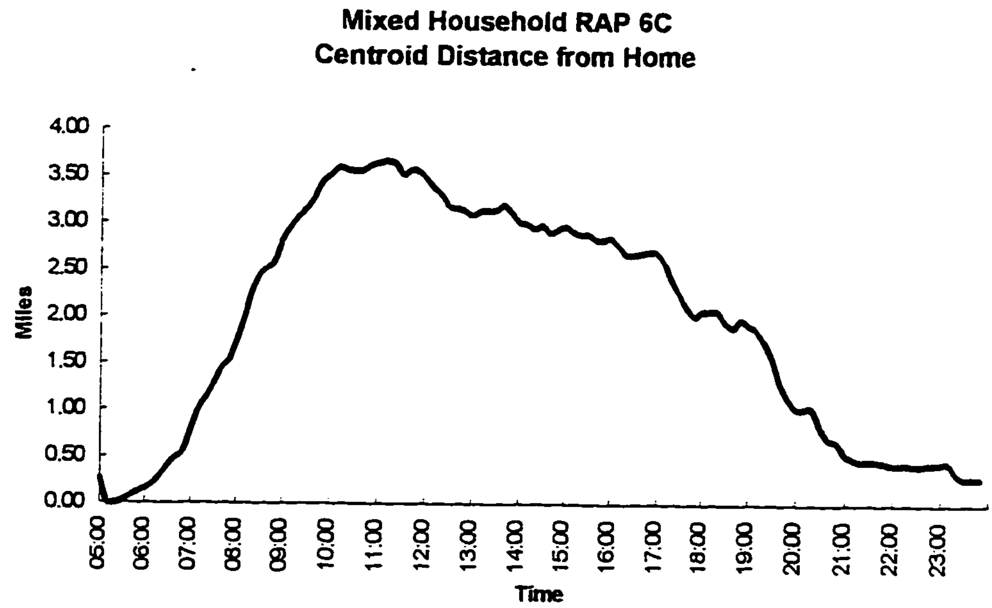

Fig A.135 Pattern 6C Distance Distribution with 1994 Data

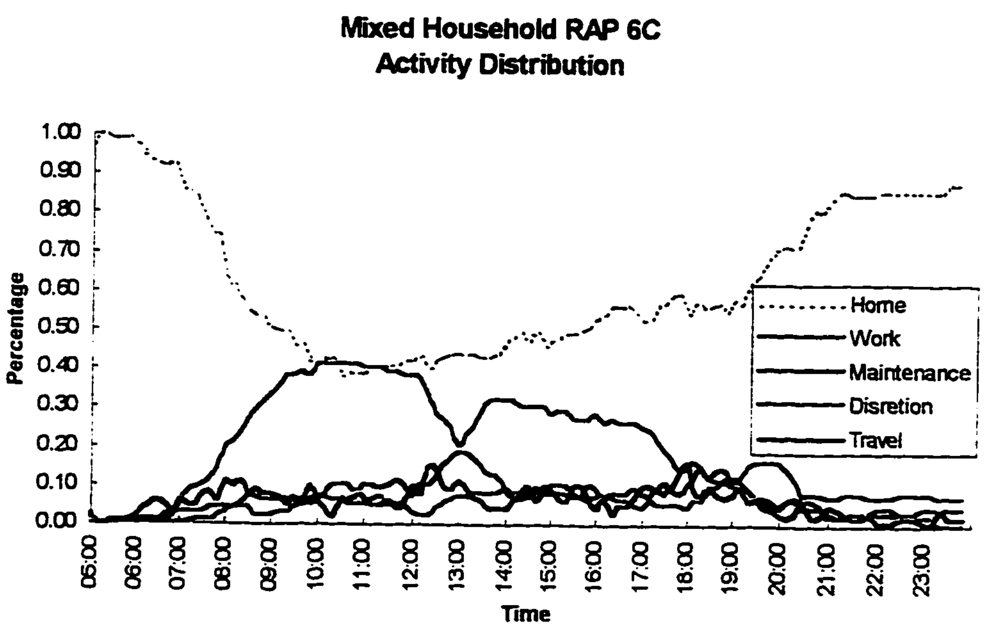

Fig A.136 Pattern 6C Activity Distribution with 1994 Data

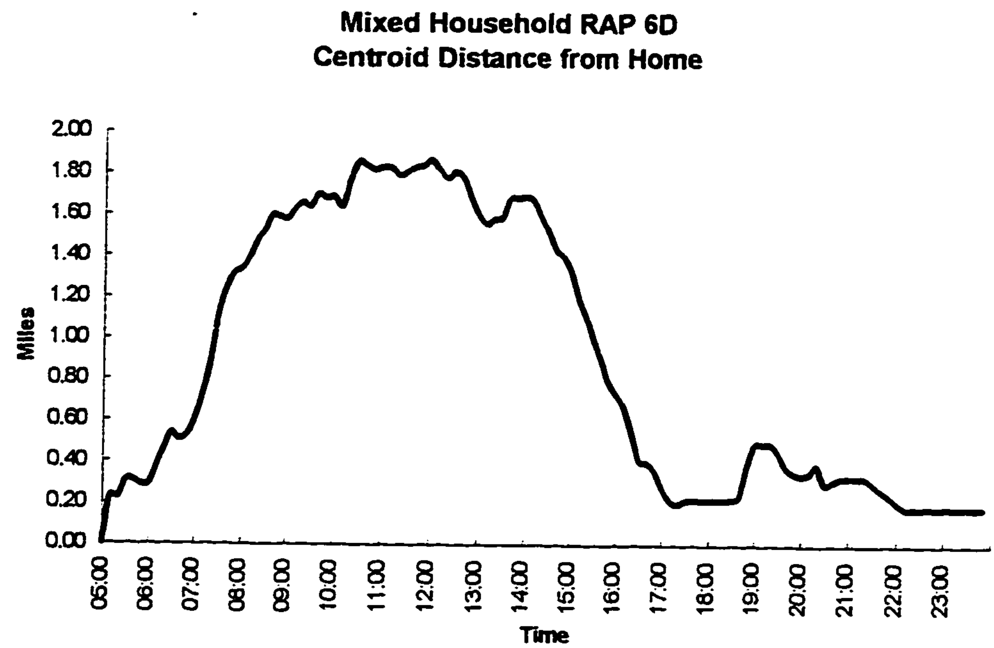

Fig A.137 Pattern 6D Distance Distribution with 1994 Data

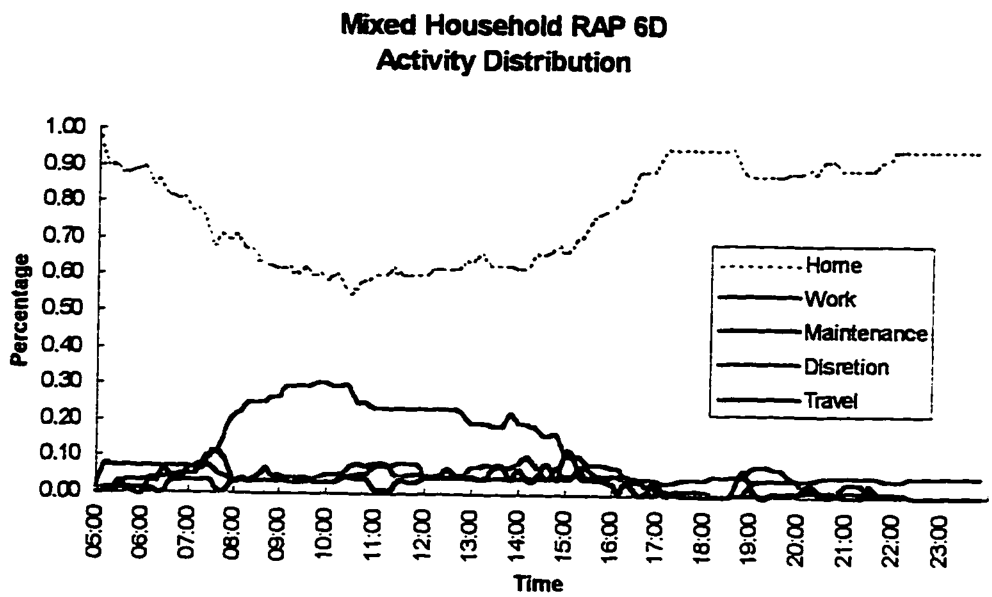

Fig A.138 Pattern 6D Activity Distribution with 1994 Data

Appendix B

Table B.1 Trip Rates for Single Person Households for 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
1A	1.73 (0.66)	0.69 (0.37)	0.88 (0.66)	0.58 (0.41)
1B	0.95 (0.91)	1.05 (0.38)	1.71 (1.02)	0.69 (0.44)
1C	1.72 (0.55)	0.78 (0.66)	1.16 (1.05)	0.70 (0.65)

( ) for standard deviation

Table B.2 Trip Rates for Single Parent Family for 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
2A	1.18 (0.95)	1.50 (0.77)	1.45 (0.86)	1.03 (0.88)
2B	1.81 (0.42)	0.81 (0.82)	0.95 (0.92)	0.90 (0.74)
2C	1.69 (0.47)	0.91 (0.72)	0.98 (0.82)	0.87 (0.74)
2D	1.33 (0.84)	0.93 (0.78)	1.70 (0.96)	0.74 (0.66)
2KA	0.83 (0.74)	0.67 (0.47)	1.00 (0.47)	0.50 (0.29)
2KB	1.65 (0.79)	0.91 (0.80)	0.94(0.95)	0.65 (0.34)
2KC	1.67 (0.91)	0.67 (0.58)	0.81 (0.41)	0.60 (0.45)

( ) for standard deviation

Table B.3 Trip Rates for Couples without Children of 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
3A	2.91 (1.14)	0.99 (0.76))	1.50 (1.07)	0.81 (0.68)
3B	0.92 (0.84)	1.17 (1.15)	1.92 (1.45)	0.65 (0.56)
3C	1.07 (0.79)	1.10 (0.99)	2.07 (1.03)	0.78 (0.62)
3D	0.64 (0.69)	1.14 (0.65)	1.48 (0.75)	0.67 (0.44)
3E	1.64 (0.63)	0.72 (0.46)	1.01 (0.47)	0.72 (0.49)

( ) for standard deviation

Table B.4 Trip Rates for One Working Parent Family for 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
4A	2.59 (0.78)	0.79 (0.18)	1.49 (0.77)	0.93 (0.55)
4B	1.68 (0.17)	0.68 (0.24)	0.83 (0.55)	0.72 (0.65)
4C	0.73 (0.78)	0.79 (0.51)	1.48 (0.58)	1.02 (0.82)
4D	1.21 (0.48)	1.08 (0.78)	1.36 (0.92)	1.17 (0.94)
4E	1.58 (0.95)	1.64 (1.39)	2.95 (1.88)	1.75 (1.21)
4KA	1.50 (0.24)	0.69 (0.11)	1.03 (0.36)	0.64 (0.27)
4KB	0.99 (0.75)	0.83 (0.79)	1.47 (0.78)	0.78 (0.49)
4KC	1.54 (1.01)	0.85 (0.82)	1.55 (0.86)	0.45 (0.31)

( ) for standard deviation

Table B.5 Trip Rates for Two Working Parents Family for 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
5A	1.76 (0.49)	0.97 (0.82)	0.82 (0.79)	0.82 (0.53)
5B	1.77 (0.88)	1.17 (0.84)	0.67 (0.60)	0.77 (0.74)
5C	1.84 (0.87)	1.61 (0.88)	1.24 (0.97)	1.16 (0.66)
5D	2.94 (1.32)	1.17 (0.84	1.22 (0.89)	0.89 (0.39)
5KA	1.57 (0.19)	0.82 (0.32)	0.81 (0.43)	0.62 (0.31)
5KB	1.71 (0.21)	1.47 (0.44)	1.71 (0.57)	0.76 (0.48)
5KC	0.56 (0.51)	0.56 (0.47)	1.19 (0.46)	0.19 (0.16)
5KD	1.19 (0.23)	0.73 (0.30)	1.58 (0.51)	0.65 (0.35)

( ) for standard deviation

Table B.6 Trip Rates for Life Cycle of the Others of 1985 Data

Trips/Person	Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
6A	1.48 (0.69)	1.63 (0.91)	1.87 (0.87)	1.07 (0.74)
6B	1.15 (0.55)	1.40 (0.77)	0.90 (0.71)	0.68 (0.55)
6C	1.76 (0.39)	0.89 (0.68)	0.86 (0.69)	0.59 (0.47)
6D	1.11 (0.61)	1.11 (0.91)	0.81 (0.67)	0.67 (0.56)
6E	1.60 (0.49)	0.71 (0.57)	0.81 (0.65)	0.67 (0.43)

( ) for standard deviation

Table B.7 Trip Rates for Single Person Households for 1994 Data

Per Person		Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
1A	Act.	2.82 (1.65)	2.16 (1.01)	1.76 (1.13)	0.56 (0.37)
	Trips	1.94 (0.99)	1.09 (0.71)	0.79 (0.66)	0.51 (0.35)
1B	Act.	3.10 (1.23)	1.91 (0.88)	1.86 (0.97)	0.52 (0.39)
	Trips	2.57 (0.92)	1.29 (0.75)	1.14 (0.74)	0.52 (0.39)
1C	Act.	2.41 (0.78)	1.53 (0.82)	1.56 (1.01)	0.32 (0.21)
	Trips	1.77 (0.61)	0.80 (0.58)	0.75 (0.66)	0.38 (0.19)
1D	Act.	2.31 (1.28)	1.99 (1.01)	2.59 (1.11)	0.13 (0.11)
	Trips	1.68 (0.99)	0.86 (0.62)	0.97 (0.72)	0.12 (0.11)
1E	Act.	2.50 (1.65)	1.77 (0.98)	2.46 (1.32)	0.13 (0.12)
	Trips	1.80 (1.01)	0.95 (0.84)	0.71 (0.66)	0.13 (0.13)

( ) for standard deviation

Table B.8 Trip Rates for Single Parent Family for 1994 Data

Per Person		Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
2A	Act.	3.52 (1.99)	1.81 (1.21)	2.10 (1.85)	0.20 (0.21)
	Trips	2.31 (1.78)	0.91 (0.89)	1.10 (0.98)	0.20 (0.21)
2B	Act.	3.73 (2.01)	2.91 (1.02)	1.52 (0.89)	0.28 (0.18
	Trips	2.55 (1.01)	1.41 (0.78)	0.57 (0.40)	0.28 (0.17)
2C	Act.	3.21 (1.33)	1.85 (0.77)	1.38 (0.67)	0.35 (0.22)
	Trips	1.88 (0.68)	0.94 (0.68)	0.82 (0.44)	0.32 (0.19)
2KA	Act.	1.39 (0.44)	3.33 (2.12)	1.67 (1.04)	0.67 (0.44)
	Trips	1.05 (0.38)	1.67 (1.09)	0.54 (0.35)	0.67 (0.46)
2KB	Act.	2.21 (1.46)	1.45 (0.98)	1.71 (1.05)	0.18 (0.15)
	Trips	1.68 (1.01)	0.55 (0.48)	0.47 (0.36)	0.18 (0.15)
2KC	Act.	1.81 (1.56)	1.92 (1.33)	2.25 (1.66)	0.44 (0.32)
	Trips	1.42 (1.35)	0.75 (0.69)	0.81 (0.68)	0.39 (0.35)
2KD	Act.	1.33 (0.66)	3.33 (1.89)	2.17 (1.52)	1.17 (0.85)
	Trips	1.17 (0.59)	1.83 (1.08)	1.17 (0.93)	1.02 (0.78)

( ) for standard deviation

Table B.9 Trip Rates for Couples without Children of 1994 Data

Per Person		Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
3A	Act.	1.59 (0.99)	2.13 (1.01)	2.73 (1.52)	0.13 (0.07)
	Trips	0.92 (0.62)	0.83 (0.45)	1.02 (0.88)	0.13 (0.06)
3B	Act.	2.98 (0.92)	1.95 (1.12)	1.32 (0.88)	0.22 (0.09)
	Trips	2.25 (0.96)	0.86 (0.66)	0.54 (0.41)	0.21 (0.12)
3C	Act.	2.37 (1.02)	1.68 (0.97)	1.42 (0.91)	0.13 (0.08)
	Trips	1.73 (0.78)	0.82 (0.66)	0.69 (0.45)	0.13 (0.08)
3D	Act.	2.94 (1.89)	2.46 (1.05)	1.71 (0.95)	0.36 (0.19)
	Trips	1.86 (1.01)	0.98 (0.78)	0.60 (0.41)	0.33 (0.18)

( ) for standard deviation

Table B.10 Trip Rates for One Working Parent Family for 1994 Data

Per Person		Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
4A	Act.	3.64 (1.89)	2.09 (1.32)	2.65 (1.45)	0.08 (0.07)
	Trips	2.45 (1.45)	0.87 (0.68)	1.01 (0.82)	0.05 (0.07)
4B	Act.	2.48 (1.77)	1.76 (1.55)	1.33 (1.26)	0.43 (0.21)
	Trips	1.76 (1.32)	0.76 (0.66)	0.76 (0.63)	0.43 (0.22)
4C	Act.	2.41 (1.26)	1.71 (1.21)	1.43 (0.98)	0.11 (0.07)
	Trips	1.75 (0.88)	0.81 (0.63)	0.52 (0.41)	0.10 (0.07)
4KA	Act.	2.11 (1.11)	1.53 (0.97)	1.84 (1.19)	0.26 (0.19)
	Trips	1.42 (0.85)	0.47 (0.31)	1.21 (0.83)	0.26 (0.20)
4KB	Act.	1.98 (1.09)	2.22 (1.88)	3.24 (2.13)	0.15 (0.13)
	Trips	1.71 (1.08)	0.88 (0.71)	1.44 (1.05)	0.12 (0.13)
4KC	Act.	1.85 (0.83)	1.52 (0.82)	1.80 (0.93)	0.30 (0.17)
	Trips	1.44 (0.67)	0.43 (0.29)	0.85 (0.58)	0.23 (0.11)
4KD	Act.	1.27 (1.19)	2.12 (1.88)	4.12 (2.95)	0.69 (0.34)
	Trips	1.04 (1.05)	0.54 (0.53)	1.31 (1.25)	0.58 (0.31)

( ) for standard deviation

Table B.11 Trip Rates for Two Working Parents Family for 1994 Data

Per Person		Work/ School	Maintenance	Discretion	Pick-up/ Drop-off
5A	Act.	3.11 (1.66)	1.96 (1.32)	1.30 (0.99)	0.51 (0.43)
	Trips	2.01 (0.96)	1.16 (0.83)	0.75 (0.62)	0.45 (0.37)
5B	Act.	4.15 (3.15)	2.51 (1.66)	1.12 (1.07)	0.25 (0.21)
	Trips	2.97 (1.55)	0.89 (0.82)	0.65 (0.63)	0.25 (0.21)
5C	Act.	3.10 (1.08)	1.80 (0.66)	2.12 (0.89)	0.12 (0.05)
	Trips	2.30 (0.82)	0.89 (0.45)	1.06 (0.47)	0.12 (0.05)
5KA	Act.	1.70 (1.28)	1.82 (0.88)	2.47 (1.35)	0.41 (0.24)
	Trips	1.32 (0.84)	0.67 (0.52)	1.12 (0.82)	0.38 (0.21)
5KB	Act.	2.04 (0.78)	1.30 (0.78)	1.69 (0.88)	0.21 (0.05)
	Trips	1.48 (0.46)	0.49 (0.32)	0.76 (0.62)	0.19 (0.04)

( ) for standard deviation