A SEMI-MARKOV MODEL OF MOBILITY IN INDUSTRIAL SOCIETIES

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ABSTRACT

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By

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One of the characteristics of advanced industrial societies is the existence of high rates of social mobility. Social mobility studies have usually concentrated on the consequences of mobility and have attempted to give a formal representation of the mobility process. However, the antecedents of mobility are rarely explored, and there has been little or no attempts to incorporate the effects of these antecedents into formal representations of the mobility process.

This research has three aims: (1) to see how aspects of the status-role of the individual, especially economic aspects, effect the propensity of the individual to be mobile, (2) to attempt to represent these aspects of the status-role of the individual in a stochastic model of mobility, and (3) to see if this approach is feasible by applying the model to data collected from a longitudinal study in an industrial society.

It is first shown that most models of mobility are not cognizant of the dynamics of the social structure where mobility occurs. In addition, the models usually inadequately

represent aspects of the status-role of the individual that may affect mobility. The status-role of the individual effects the life-chances of the individual. In advanced industrial societies, one of the life-chances of the individual is the tendency to be mobile.

A stochastic model, the semi-Markov model, is described. The model represents mobility in terms of two processes: movement among a set of graded occupational states, and the time spent in a given occupational state before a move to a different occupational state occurs. The movement among a set of graded occupational states is common to most stochastic models of mobility. We are interested in the second process, the time spent in a state before a move occurs. This is termed the waiting time. The waiting time is represented by a probability distribution function that usually has a Gamma form. We argue aspects of the status-role of the individual affect the parameters of this distribution, which, in turn, would affect the propensity to be mobile.

Three aspects of the status-role of the individual are investigated: sex, whether or not the individual is self-employed, and whether or not the industry in which the occupation is located has been growing in terms of the number of full time workers. The model was applied to a closed system of 511 individuals in Great Britain from 1963 to 1970. Specifically, we looked at individuals who changed occupations and asked how long the individual was in the 1963 occupation before the individual moved to a different occupation. This information provided the information needed to estimate the parameters of the semi-Markov model, especially the waiting time distribution.

Previous models of mobility that have incorporated the idea of a waiting time distribution have assumed the veracity of the axiom of cumulative inertia. The axiom states the longer an individual stays in a state, the harder it is to move out of that state. Our data do not support the axiom for the entire sample, or for any specific type of move, or for any conditions of the status-role of the individual. It was observed, with one exception, the average time until a move occurs is longer for upward than downward moves. In addition, the time until a move occurs is longer for moves between non-adjacent states than for moves between adjacent states. Finally, there is no relationship between the frequency of a move and the average time until that type of move occurs.

Waiting time patterns were also examined for the status-role variables. The sex of the individual did not seem to affect the waiting time distribution. The self-employment status of the individual affected the waiting time distribution. Compared to self-employed individuals, non-self-employed individuals seemed to wait shorter periods of time for upward moves and longer periods of time for downward moves. Finally, the industry in which the occupation is located affected the waiting time distribution. Compared to individuals in non-growing industries, individuals in growing industries waited shorter periods of time for upward moves and longer periods of time for downward moves.

The ease of our analyses suggests it is feasible to incorporate other aspects of the status-role of the individual into a mobility model. We indicate this should be followed by the development of a research program to develop a formal theory of mobility.

A SEMI-MARKOV MODEL OF MOBILITY IN INDUSTRIAL SOCIETIES

By

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INTRODUCTION

Independently of their political basis, modern societies may be characterized by movement toward capital intensive and non-agricultural employment, or industrialization; movement toward greater concentrations of population, or urbanization; and movement toward formalized social relationships, or bureaucratization. This research concerns one part of the process, the movement among ordered occupational grades that is characteristic of industrialization.

We define social mobility as the movement of individuals or family lines in a social structure over a period of time. The social structure is defined as the web of institutions and organizations that contribute to the fulfillment of the on-going needs of collectives of individuals. Implicit in the analysis of social mobility in modern industrial societies is the dominance of the economic institution. This dominance is due to the concentration of activities in this institution. Consequently, mobility is analyzed in economic terms, such as the occupational grade of the individual or family line at various time points.

The first chapter of the dissertation will discuss a specific type of social mobility in industrial society, intragenerational mobility. By intragenerational mobility we mean the movement of individuals among ordered occupational categories or occupational grades. Initially, the chapter discusses the nature of mobility in industrial societies, the importance of studying mobility, and types of mobility. Then the next portion presents the research problem. The first chapter concludes with a discussion of ways to analyze mobility utilizing mathematical models. The graded occupations will be represented as the 'states' of our model. In terms of the model, mobility is then represented as movement among this set of states over a period of time. Hence the analysis will focus on career patterns. Subsequent chapters of the dissertation discuss models of mobility concentrating on a specific class of models, stochastic or probabilistic models, and a specific type of stochastic model, the semi-Markov model. The semi-Markov model is applied to a set of data representing mobility in an industrial society, Great Britain.

We assume that both the population and the social system are closed. This is, for the period being investigated, we assume that no individuals enter into or exit from the population. Further, we assume that no new occupational grades are created nor are any old occupational grades eliminated. By dealing with a closed system over a short period of time we can minimize the confounding effect of the rapidity of change in an industrial society which may result in 'fictitious mobility' due to the increased size of occupational groups, especially manufacturing, technical, and service groups.

Our major interest is to ascertain whether or not the sociological factors of the sex of the working individual, the employment status (whether or not the individual is self-employed), and the industrial location of the occupational grade affect the life-chances of the individual and level of job satisfaction of the individual. As these two factors may contribute to the propensity to be mobile, they are assumed to influence the career trajectory or occupational mobility of the individual. Therefore, our basic unit of analysis is the working individual and our basic process is movement among occupational categories as modified by background factors.

Social structures may be compared on the basis of their permeability. One extreme, immobility, would be a caste structure in which movement is not allowed between segments of the social structure; the other extreme, perfect mobility, (Prais, 1955), in which movement between segments of the social structure is completely unrestricted. Another basis of comparison is exchange between segments of the social structure, for we can ask to what extent segments of the social structure exchange equally sized cohorts (Berger and Snell, 1963).

In an equal exchange type of society, the same absolute number of the units of analysis move between states. The unit of analysis is usually family lines or individuals depending on whether or not one is talking about intergenerational or intragenerational mobility respectively. The absolute number of units of analysis is a function of the proportion of the population in a state and the size of the population in all states. Hence two states may be in equal exchange with each other, but have different proportions of the total population. This is because equal exchange refers to the exchange of units of analysis, not the similarities of the odds of movement between two states.

Because we are dealing with mobility in urban, industrialized societies, we will concentrate on the non-caste type of social structure. The segments of the social structure that interest us are surrogates for social class. Due to problems of measurement, social mobility studies in urban, industrialized societies usually employ occupation as the surrogate. Social mobility studies in urban, industrialized societies usually employ occupation as the measure of social class and life chances, because income is highly variable. Industrialization has resulted in the increased importance of occupation as a factor in differentiating individuals from each other and in the movement from differentiation based on membership in a caste that usually resulted from birth, to differentiation based on membership in an economic class that usually results from holding a specific occupation.

The political ideologies occurring with increased industrialization, urbanization, and bureaucratization have been also associated with changes in the economic structure. These changes have produced an emphasis upon the ideal nature of exchange between social groups. Societies are viewed as moving from a caste type to an equal exchange type. However, due to changes in the economic structure, especially the growth of service, government, and technical sectors, coupled with a liberalization of the availability of education, the effect upon mobility is unclear. We must entertain the possibility of fictitious mobility (Hauser, et al., 1975). That is, we must ask: "Is mobility due to changes in the social structure by a growth of some segments and decline of others, for example the growth of civil service and decline of agriculture in the economic structure, or is it due to changes inside a fixed social structure?" "Are movements away from a caste and towards equal exchange due to actual patterns of mobility or growth of a segment of the social structure?"

The rapidity of change in urban, industrialized societies would make any long run prediction about mobility ludicrous. Hence we will focus on a relatively short period of time, seven years, for the same cohort of individuals. In other words, we are selecting a problem that is not concerned with changes of the social structure itself, but tries rather to explain the reasons for changes within the social structure. Our main concern will be to incorporate structural factors to initially explicate, and then possibly explain the reason for various degrees of occupational mobility.

Our main argument is that most changes in mobility patterns and in the distribution of individuals among occupational groups can be explained by structural factors, for example the sex of the individual worker, whether or not the worker is self-employed, and the industrial location of the occupation.

Central to this argument is the idea that mobility is considered to be a life-chance of the individual in advanced industrial societies (Miller, 1971). Life-chance is used in the Weberian sense to refer to the odds an individual will fulfill his or her full potential as a member of a society, as determined by economic factors. The achievement orientation of individuals in an advanced industrial society has resulted in the expectation the individual, in the world of work, will be mobile, usually in the upward direction. If mobility is a life-chance, it should be a function of the components of the economic systems of advanced industrial societies, especially the component which directly affects the individual, the labor market. The labor market is the part of the economic system that identifies the work role, and, in turn, provides the rewards for the performance of the work role. We assume individuals try to maximize these rewards, which, in turn, result in the individual trying to maximize his or her life-chances and life-style.

Hence we postulate mobility is a function of aspects of the world of work. Mobility may be a function of how fixed characteristics of the individual are evaluated in the world of work. An example of this is sex. Mobility may be a function of the investment of the individual in the occupational role and how this modifies the individual's world of work. An example of this is whether or not the individual is self-employed. Finally, mobility may be a function of the size of the labor market. An example of this is whether or not the specific industry in which the individual is employed is expanding or contracting. Note these examples are not exhaustive and do not consider possible interactions.

We do not intend to see mobility as a cause of social behavior, such as mental illness rates or voting behavior. We intend to see the feasibility of viewing mobility as a consequent of the economic structure of a society. This is an extension of a long tradition in sociological theory that began with work on circulation of elites.

CHAPTER I

PURPOSES AND SCOPE OF RESEARCH

This chapter of the dissertation discusses the reasons why mobility is studied. We then proceed to review substantive findings about intragenerational mobility in industrial societies and argue a need exists to codify these findings to facilitate the determination of the causes of mobility. Finally, we compare ways to analyze mobility.

1.1 Why Study Mobility

Sociologists study social mobility for a variety of reasons. The first reason is mobility analysis indicates the nature of the structural basis of a society. Mobility is an indicator of the degree of achievement orientation in a society due to the continuous operation of economic factors. For example, Blau and Duncan (1967) have indicated the existence of separate and non-equal systems of mobility for Blacks and Whites in the United States and the positive effects of education and small family size in overcoming structural barriers.

If we interpret mobility in the traditional Weberian class framework, movement among occupational grades or occupations is an indicator of the flexibility of class barriers in an industrial society, and in turn may be used as a valid indicator of the stratification system. Since the stratification system affects the life style and life chances of the individual, we believe an analysis of occupational mobility is fundamental to the analysis of differentiated social collectives. In an industrial society, the occupational role of an individual is the key determinant of that individual's position in the stratification system (Caplow, 1954; Hall, 1975). The result is that an individual's occupation not only is the key symbol of one's social status but, more importantly, it carries with it expectations for behavior both by and toward the holder of the status.

If we can identify the possible determinants of mobility we may study the intensity of specific variables in determining the 'stratification space' of a society (Hope, 1972). The 'stratification space' is the set of axes or dimensions which determines the social distance between social groups. Hence, if the key axes of the 'stratification space' could be identified, then the extent of stratification in a society and the degree to which specific variables determine the extent of stratification in a society could be evaluated. Consequently, mobility analyses should attempt to determine the 'stratification space' of a given society. For example, if the mobility patterns of males were found to be different from those patterns of females, we would conclude that sex is an axis of the 'stratification space.' We have selected for study here the variables of sex, self-employment status, and the industrial location of the occupation as possible axes of the 'stratification space.'

The second reason why sociologists study mobility is that it leads to a world view, for we are forced to think in terms of process rather than structure independent of process. By examining the dynamics of a society over a period of time of substantive interest, we can conceive of the movement of a society as the movement from a caste system towards an equal exchange system. Comparative sociologists, especially those dealing with social change and economic development, often compare societies along these dimensions in terms of the time it takes to reach a certain point on these dimensions.

In addition, a social process orientation appears to be a more realistic orientation. Social institutions and organizations are assumed to be loci of information processing units involving memory, delay, feedback, and decision making affecting a social cohort. The urban, industrialized societies we are dealing with can be envisioned as complex decision making structures governed by bounded growth and restrained by purposeful maintenance of the social structure. Social mobility also allows us to evaluate the results of these decisions, especially to assess the efficacy of planned growth of a segment of the social structure. For example, the forthcoming replication of the Blau and Duncan work of a decade ago will show the results of the programs of the "Great Society" in the 1960's (Featherman, 1974). In economic terms, a mobility approach allows us to display the dynamics of a society's opportunity structure and extent of underemployed talent.

This reason why sociologists study mobility follows from the substantive importance of the processual orientation. Social mobility is a metric to compare different societies or the same society at different periods of time. By being a large scale metric, we can compare societies in terms of the movement from caste and the degree of equal exchange, independent of the different historical and cultural bases of a given society's institutions. For example, capitalist and noncapitalist societies can be compared, or the same society can be compared before and after the implementation of social welfare programs.

One of the major intellectual traditions in sociology is identification of the common characteristics of societies so as to isolate the unique characteristics that differentiate societies. This is a major theme of the Weberian school. Social mobility, by being a social metric and a social indicator, allows us to operationalize this tradition.

Social mobility enables us to appreciate the efficacy of social and economic change in record-keeping societies. Featherman (1974) reports a series of studies that will compare the same nation at two points in time to discover patterns of change. In short, due to its power of replication, social mobility could be a social indicator, or a "statement of direct normative interest which facilitates concise, comprehensive and balanced judgments about the conditions of major aspects of society" (Duncan, 1969;3).

The third and final reason why we study social mobility concerns the potential policy implications of sociological research. Sociologists tend to be increasingly viewed as central and non-ancillary to social planning and decision making. This is evidenced by an interest in social indicators. Social mobility provides a means to see the structural effects of our policies, especially in the economic sector. By providing a metric to compare different societies or to compare the same society at different points in time, social mobility allows us to evaluate the reality of a classless Eastern European society or the flexibility and opportunity in an Atlantic community democracy. Hence the analysis of social mobility for a specific society may reinforce or depreciate the non-monarchical political themes in the Western world since the French revolution, especially Marxist socialism and Keynesian capitalism. Thus, independent of an individual's political orientation, the study of mobility is a means to observe the structural effects of social policies, especially in the labor market.

1.2 Scope Conditions of Research

The types of mobility can be classified along three dimensions (Caplow, 1954). The first of these dimensions is the time period in which mobility occurs. This usually defines the type of unit that is mobile. Time is classified as intergenerational or intragenerational. Hence mobility studies can be dichotomized as the movement of individuals over their occupational career or the movement of family lines along various economic classes determined by the occupation of the head of the family. This is called intragenerational and intergenerational mobility respectively.

The second dimension is the dimension of space, which is usually covered in work on migration. Migration may be caused by changes in economic opportunity in a given geographical region or by differential fertility. Ladinsky (1967) has shown the degree of geographical movement between jobs is related to material investment of an individual in the tools of his occupation. Thus, physicians in private offices who have a large capital investment in equipment have a lower rate of geographical mobility than physicians associated with a medical school. For purposes of analysis, we will not consider migration to be significant since we will deal with movements among occupational categories and the structural variables behind these movements. The data set we will use is a panel study for which the assumption was made that a respondent was located at the same place of residence at all points in time. Migration can be dichotomized as being germane or not germane for purposes of analysis.

The final dimension of mobility is direction inside the social structure. Are we interested in vertical mobility, movement among ranked segments of the social structure, usually occupations, or are we interested in movement among different organizations but in the same ranked occupation, horizontal mobility? Usually industrialized social structures are partitioned along occupational lines that are ranked. A line worker becoming a foreman in the same factory would be mobile in a vertical sense in an occupational scheme but would not be mobile in an industrial category scheme. But this does not prohibit us from examining all line workers who become foremen to compare their mobility rates for workers in manufacturing and non-manufacturing organizations to see if any factors inherent in the social structure of these organizations may explain different mobility rates. Hence the final dimension can be dichotomized as horizontal or vertical mobility.

Therefore, our focus of interest shall be on intragenerational vertical mobility in an ordered occupational system that reflects the social structure during a period of time selected such that the number of segments in the order and the nature of the ordering remains constant. We shall ignore migration factors. Also, we shall assume that we are dealing with a closed population system. That is, we assume that all individuals in our analysis are continuously employed and no individual enters or leaves this population.

Despite the substantive limit of our scope conditions, we cannot avoid considering previous mobility studies of the other types of mobility. These studies have made us aware of some of the determinants of mobility. Mobility studies have developed certain types of techniques, especially models. The universal ideas that appear in these studies and the types of analysis used in them allows us to continue in the work of the past, making mobility one of the few areas of cumulative research in the social sciences. Methods of analysis and techniques to study mobility are not necessarily limited to a specific historical time period, the size or nature of the cohort, or the geographical location of the social structure being analyzed.

1.3 Mobility in Industrial Societies

Industrialized societies have most of their economic activity concentrated in the processing of raw materials needed for the maintenance and bounded growth of a collective of individuals. Related to industrialization is differentiation, or the division of labor, and bureaucratization, the rise of complex, formal organizations. The process of industrialization results in a further growth of certain occupational categories, especially those involved in manufacturing. Advanced stages of industrialization deal with the manipulation of information in addition to the manipulation of raw materials, and deal with problems of social cohesion created by differentiation. The advanced industrialized society's differentiation results in a bifructation of highly skilled decision makers and low level white collar workers (Meyer, 1972). Hence in our study we have a problem of selecting a time unit that minimizes the extent of differentiation of an industrialized society. This would minimize the problem of identification of lines of differentiation in a society that might result in 'fictitious mobility.' We assume our period of 1963-1970 in Great Britain minimizes problems of differentiation since it is a short period of fairly constant and stable growth (Whitaker's Almanack, 1965, 1971, 1974).

By fairly constant growth we mean growth occurs at a constant, bounded rate. That is, there are no fluctuations in the growth rate. Sometimes this is called stable growth. A series of examples will explain this seemingly contradiction in terms. In a mathematical sense we mean the derivative of the growth rate is zero; that is, the growth does not change as time changes. An example of this is a car moving at a constant speed. The car is moving, but there is no change in the rate of movement. In demographic terms, stable growth means the difference between the crude birth rate and crude death rate is constant. If this difference is positive, population would grow, just as the car moved, but the growth and movement would be at a constant rate, well defined, and bounded, ceritus paritus.

Complex organizational structures have developed to control and integrate the differentiation in industrialized societies. Research in this area has concentrated on how the work setting may govern the pace of work and degree of worker alienation which in turn determines the propensity to be mobile (Blauner, 1964); how the type of product being produced or the size of the formal organization governs the organizational structure (Woodward, 1965; Blau and Schoenherr, 1971); and how the structure of an organization may result in opportunities for promotions or demotions since positions or vacancies must be filled (White, 1970; Stewman, 1975).

A specific organizational structure has differential rewards commensurate with location in the organization that results in inducements for mobility. These rewards are usually salary and monetary rewards associated with seniority but may also include informal status allocation and peer group relationships. We will assume that the organizational structure will determine these reward levels. We will also assume that the individual wants to maximize these rewards and will be mobile if given an opportunity to be mobile.

Differentiation and bureaucratization set parameters on career mobility and the worker's orientation toward his colleagues, his occupation, and his strategy for advancement (Thompson, Avery, Carlson, 1962). Complete analysis of this problem would result in a very complex analysis involving how structural factors result in various social psychological attitudes of workers toward mobility.

Mobility may be characterized by the time it takes for advancement in a certain type of career. Is there an early or late ceiling? An early ceiling occupation, like a nurse, reaches a rapid upper bound and has a limit to more status in the future. A late ceiling occupation, like an engineer becoming a manager, has an upper bound that takes a long time to reach. Perhaps the occupations that have early ceilings manifest their mobility in horizontal forms more than the occupations with late ceilings. Occupations with little room for advancement may manifest mobility in a horizontal rather than vertical manner (Hall, 1975).

Mobility may also be determined by the orientation of the worker toward his occupation or toward his current place of work. An orientation to the occupation would result in mobility patterns being determined by the need of an organization for individuals with specific types of training and experience. An orientation toward the organization would result in mobility patterns determined by the structural factors inherent in the specific organization, especially the number of advanced positions. Different strategies toward advancement may result in different lengths of duration in a specific occupation because one occupation may be a preparatory stage for subsequent occupations (Hall, 1975).

Consequently, a complete analysis of mobility should be able to distinguish mobility in the same formal organization from other formal organizations and immobility in a formal organization from a horizontal movement to the same occupation in a different organization. In addition, a complete data analysis would involve questioning the impact of industrial setting of the occupation and the specific organizational structure where the occupation is located. The impact of these aspects of the world of work incur different levels of rewards that result in various inducements for mobility.

Unfortunately, the data problems involved in such an undertaking are beyond the limited resources of this thesis. Hopefully, the results of our research will be preparatory to a study of these problems at a future time. However, as mentioned above, we will examine the impact of the industrial setting of the occupation on mobility patterns.

Analysis of data about mobility reveals no definite increase in size of prestigious occupational groups when the growth of non-agricultural occupations is included. Shifts in the distributions among occupations have remained virtually non-existent in recent years (Hauser and Featherman, 1973; Hauser, et al., 1975). Recent reanalysis of mobility data reveals no great change in the patterns of intergenerational mobility in the United States independent of changes in the occupational distribution, i.e., the growth of specific occupational categories (Hauser, et al., 1975). In short, the dependence of a son's occupation on a father's occupation has been stable for the past fifty years.

We would expect changes in the occupational distribution to be characteristic of an advanced industrial and post-industrial society. However, due to the short time period of our proposed research, seven years, we do not consider this to be problematic. Studies of mobility should address themselves to how government policies of state capitalism or state socialism affect mobility patterns. Stewman's (1975) analysis of the Michigan State Police and Tuma's (1972) analysis of Mexican-Americans have hinted at the effect of such policies on the stability of an occupational system. Our research attempts to formally represent determinates of mobility that may be generalized to incorporate the effect of such exogenous factors on mobility in industrial and post-industrial societies.

The data set we propose to analyze reveals a constant distribution among occupational categories (see Table 1).

Work using intergenerational mobility data, which compares occupational distributions at the same time point for different aged individuals, would not allow us to deduce the nature of intragenerational mobility since different life-experiences have happened to each group being at different stages of their working careers.

TABLE 1

DISTRIBUTION OF THE SAMPLE AMONG OCCUPATIONAL GRADES IN TERMS OF PROPORTIONS

	Year			
Occupational Grade	1963	1964	1966	1970
Professional-managers	.143	.147	.164	.204
White collar	.278	.264	.280	.270
Blue collar	.579	.589	.556	.526

NOTES: Computed from edited data tape, as described in Chapter 3.

Sample size equals 511.

Occupational shifts in industrial society are generally from manual to non-manual, from being self-employed to being a salaried worker, and from low to high status occupations within a gross occupational category. This leads to the main questions: What are the reasons for such mobility, and what patterns occur when social groups are compared? For example, how do mobility patterns of males and females or self-employed and salaried workers in the same occupation differ? One of the critical questions in such an analysis is how the length of time at a job, job tenure, affects mobility and how social factors affect job tenure.

We have information on parts of this process. For example, we know that professionals are unwilling to change their occupations since such a change would result in a loss of educational investment (Hall, 1975). We also know that lower boundaries exist to mobility between white and blue collar occupations and between blue collar and agricultural occupations (Blau and Duncan, 1967). Finally, we know that self-employed workers exhibit less geographical mobility than salaried workers since the self-employed workers, independent of occupation, must invest in capital goods and develop a clientele (Ladinsky, 1967). Tuma (1972) has studied the mobility of Mexican-Americans in terms of their occupation, industrial setting of the occupation if the individual is an operative, age of the individual when working life commenced, level of education of the individual, geographic area of origin of the individual, and duration of an individual in an occupation. Tuma argued that mobility is composed of two subprocesses: the process of leaving a job and the process of being attracted to an alternative job. (A job is defined as an occupation in a social location, where a social location is usually the industrial or geographic location of the occupation.) Tuma concluded that the length of duration in a job is a determinant both of the rate of job termination and of the attraction to alternative jobs. With respect to leaving a job, Tuma found education to be negatively related to job duration. The level of education of the individual is the key factor affecting duration in a job. The age when the individual commenced work and geographical origin of the individual are of little or no importance. Time measured as duration in a job is a better indicator of mobility than time measured as the age of the individual. With respect to being attracted to alternative jobs, Tuma found rates of attraction are dependent on the actual age of individuals, are not necessarily related to previous occupation, and, surprisingly, are independent of the level of education of the individual.

Recently, Tuma (1975) has re-examined the same set of data and showed the rate of leaving a job declines with duration in the job. This rate also depends on the initial level of job rewards, the level of individual resources, especially education, and the socially defined value of these resources. Duration in a job was found to increase as median occupational earnings increased. Duration in a job was found to decrease as the individual's educational level increased. The skill level of the current job relative to the previous occupations of the individual and the age of entry into the labor force had no effect on the rate of mobility. However, the number of previous jobs held by the individual affected the mobility rate, albeit in a curvilinear pattern. In general, Tuma found the rate of mobility declined at decelerating rates as duration in the job increased.

Finally, Hall (1975) has noted that individuals with specialized training are unlikely to move to occupations where the training is irrelevant. In addition, he feels there is less occupational inheritance for females than males, and individuals with advancement possibilities reinforce these possibilities by anticipatory socialization.

No attempts to construct a theory which discusses mobility in terms of ascribed and achieved characteristics of individuals in dynamic economic structures exists. We propose to lay the basis for the development of such a theory.

1.4 Ways to Study Mobility

Using empirical data, there are three ways to study mobility. The first way is to compare the same society at two points in time or compares different societies at the same or at multiple points in time. Commonly, the proportion of the work force engaged in gross occupational categories, usually agriculture and non-agriculture, is contrasted. The second way is to compare societies in a more complicated way by using a statistic or index that summarizes the movement between segments of the social structure. The third way is to construct mathematical models. In all three cases, we can test the adequacy and validity of our work only if we have the appropriate empirical data.

The crudest way to represent mobility at the national level is to report the proportion of a nation engaged in crude occupational categories at two points in time and to compare the proportions to other nations. The data is usually some permutation of the number of individuals or family lines in a given occupational category. Since the data is from demographic sources, there is nonuniform categorization, different sampling procedures, and an inability to deal with structural changes. For example, it would be hard to compare the increase in the number of white collar workers in France and Poland in the last twenty years due to different definitions of white collar workers used in the collection of data in France and Poland.

Such data reveals little or no mobility into more prestigious occupational groups when the growth of non-agricultural positions is considered. Perhaps this is because this type of analysis is inappropriate for nations undergoing rapid economic growth and structural change. Comparative data is a crude index since it gives us summary data about the social structure indicating only a change in the distribution of workers in various occupational categories.

Unlike basing comparative data on the distribution of individuals in the social structure, indices are usually concerned with patterns of movement among partitions of the social structure. An index of social mobility is a permutation of the movement between social categories rather than among the distribution of a population of individuals or family lines across social categories. This can be clarified if we use an n by n matrix, where n is the number of social categories of interest. The rows of the matrix represent the segments of the social structure at one time point and the columns of the matrix represent the segments of the social structure at another time point. The entries of the matrix represent the movement from one segment of the social structure, represented by the row, to another, represented by the column, during a time interval that is the difference of the two time points. The rows and columns are arranged in such a manner that reading down for the rows and across for the columns the nominal and ordinal nature of the social categories is preserved. This type of matrix is called a transition or mobility matrix.

Observations are made about the location of individuals or family lines in the social structure at two or more time points. In our set of data we shall use information about the occupations of individuals at time points that are 1 year, 3 years, and 7 years after our initial observation.

The problem of developing and testing indices has been called a problem of measurement (Boudon, 1973). Manipulations are done on the entries in the matrix, usually comparing the true entry to the expected entry based on the underlying multinominal distribution, somewhat analogous to the use of a chi-square distribution to analyze contingency tables. The expected entries, computed this way, reflect perfect mobility, the opposite of the caste type society. In a vacuous sense, the simple permutations in comparative data are base-line indices. A recent detailed review of indices of mobility concludes there is "no unique best index of mobility" (Boudon, 1973).

Indices seem to beget the major problem of the study of mobility, the explication and explanation of mobility. Even though structural changes may be incorporated into the construction of indices (Boudon, 1973) this incorporation fails to give any insight into how structural factors modify mobility processes. We conjecture that we can gain more insight from mathematical models.

The use of models to study mobility exhibits more work of a cumulative nature than the work on comparative data and indices. As we shall show in the next chapter, the models we develop are built upon the results of twenty years of accumulated research and ideas.

We define a model as the result of the intellectual process of translating from one language to another and manipulating ideas and thoughts in terms of the second language in order to gain insight about the phenomena we are studying. Specifically, we are concerned with the translation from one natural language, English, to a formal language, that of stochastic processes, a type of mathematics which is processually oriented. The formal language is usually more parsimonious and exact than the natural language. Due to these characteristics, the model results in exact communication among the students of a specific phenomena, in this case social mobility. This exactness adds to the cumulation of knowledge resulting in a series of works that explicate and try to explain the phenomena of movement in the social structure classified as social mobility.

In a formal language, as in a natural language, the rules of syntax are not restricted to a specific subject area. Hence, models from other subject areas may have applications in sociology. The models we propose originated in an area of operations research that deals with the failure of electronic or mechanical components in a system called renewal theory or point processes (Cox and Miller, 1965).

This chapter has presented an introduction to the subject of mobility. We have stressed the relationship of mobility to the area of stratification, focusing on the nature of mobility in complex industrial societies. We stressed the need to determine the factors that cause mobility and argued that the interdependencies of the processes of industrialization and bureaucratization give insight into some of the possible determinants of mobility. We then listed unorganized findings about mobility and concluded that a need exists to attempt to codify these findings to facilitate the determination of the causes of mobility. Finally, ways to analyze mobility were compared, focusing on descriptive data, indices, and mathematical models. The next chapter concentrates on the development and use of mathematical models in mobility studies.

CHAPTER II

MODELS OF MOBILITY

This chapter of the dissertation recapitulates the mathematical development of mobility models. The two main types of models, causal and stochastic models, are introduced, stressing the advantages of the latter over the former. Then, the cumulative development of stochastic models is mentioned, stressing how the awareness of the substantive aspects of mobility aided this development. Finally, the argument is made that these considerations lead to the semi-Markov model. In this context, the utilization of a semi-Markov formulation has led us to think in terms of the time spent in an occupation before a move to a different occupation is made, which is called the waiting time. The argument that the waiting is a probability distribution which can represent substantive factors of mobility is made as the conclusion of this chapter.

Models provide a formal language to organize and manipulate our observations about social reality. They serve as symbolic analogies which facilitate our thinking and communication about social phenomena.

Despite the existence of several different typologies of the dimensions of models, the causal-stochastic dimension is a dominant theme. The causal or deterministic-stochastic idea has been a dominant theme in works on models in the philosophy of science since the Continental versus English schools represented by Duhem and Campbell, respectively, over seventy years ago. More importantly, this dimension is germane to the refinement of mobility models.

We will use the word modeling for the process of constructing a model. The ideal result of modeling, the exposure of the necessary and sufficient mechanism underlying the observed phenomena, is called theory construction.

The use of models in social mobility allows us to think in terms of longitudinal factors, delays, accumulations of effects, and feedback. By applying mathematical analysis, especially the limiting properties of certain mathematical relationships, we can see how mobility represented as the patterns of movement of a population among occupations will look at any point in time, ceritus paritus. We can also see how these patterns will look if there is no change in the system in a time interval, that is, when the system is in a stable state. Finally, we can see how the stability is affected when disturbed.

Modeling occurs in four steps. The first step, called feasibility analysis in applied science, like engineering, involves gaining insight into the problem and a substantive knowledge of the problem. We have attempted to do this in the first chapter. The second step is the actual translation of the relevant parts of the problem in an isomorphic manner from a natural language to a formal language. This is called the design phase in applied science. The third step involves deductions and solutions in terms of the formal language, the process of analysis in applied science. Finally, these deductions and solutions are empirically tested by means of statistics or computer simulations. That is, we attempt to verify the accuracy of our translation.

Models are not fixed by time, space, or the size of the phenomena being studied as long as the conditions of applicability or scope conditions of the model are fulfilled. Hence our translation and model of mobility should be an adequate translation for mobility in England from 1963 to 1970 (Butler and Stokes, 1969) or other sets of data that meet the conditions of applicability, like the National Longitudinal Survey which covers the United States for 1966 to 1971 (Hauser, et al., 1975).

Models of occupational mobility are usually one of two types, causal-deterministic-static or stochastic-dynamic, a processually oriented model. Recent work in a third type of model, purposeful theory or game theory models (Coleman, 1973) may have some potential for determining the utilities available to a worker which may determine his propensity to be mobile. However, these models, as currently developed, cannot incorporate how changes in the social structure may determine changes in the utilities and hence the propensity to be mobile.

The first of the two models, which we will term the static model, is atheoretical and fails to explain the relationship between covarying factors. The best known example of this model is Blau and Duncan's path analysis (Blau and Duncan, 1967). The model is causal only in the sense that the variables antecedent to the end result are uniquely forwardly ordered in time. The sequence is usually postulated by gaining some substantive knowledge about the problem and tries to give weights to the specific links between variables in the sequence. This is done by multivariate techniques, seeing how the variance in one variable in the sequence may be explained by other variables in the sequence. To say one variable is related to another variable due to the amount of variance in one variable explained by the variance in the other variable is not the same as explaining the relationship between the variables. Quite often intervening factors occur that may amplify a false relationship between the variables, yielding spurious correlation.

The path analysis model of Blau and Duncan should not be termed atheoretical since this qualifier can be equally applied to our proposed stochastic model or any type of model. All models are atheoretical since they are only conceptualizations of reality in ideal terms, void of empirical substance. In this perspective, at most, a model may indicate the form of the theory to the scientist, not the substantive and empirical content of the theory.

The second main type of model used to study mobility, stochastic or dynamic models, which we will call stochastic models, has a processual orientation. We argued in the first chapter of this dissertation that the analysis of social mobility forces us to think in terms of a processual orientation. We now discuss both families of models.

2.1 Causal-static Models

The causal model of mobility can only state the existence of a relationship between variables. At most, the model can only indicate if one variable is a necessary or a sufficient cause of another variable. Usually these relationships are linear algebraic functions of correlation coefficients.

The dominant causal model in mobility is path analysis (Blau and Duncan, 1967; Hope, 1972). The model derives weights for the postulated path linking sequences of variables from correlation coefficients. The sequence is constructed by assuming that some of the variables are temporarily anterior to others. Frequently, consideration is given to the theoretical relationship between the variables. For example, a major link in Blau and Duncan's analysis is father's income and level of education to self's first occupation, thus implying the dominance of achieved over ascribed factors as determinants of mobility. Usually the model indicates the sequence by a line with an arrow showing the temporal order of events. The base of the line is an anterior variable leading to a posterior variable occurring later in time at the tip of the arrowhead. The line may represent residual effects if no variable is specified at the base of the line, a causal relation if there is one arrowhead and a variable specified at the base of the line, or a simple correlation between variables if the line has arrowheads at either end.

The causal model ignores changes in the social structure over time. Ideally, the paths should show the influence of structural variables on the mobility process. The path values are constants in a set of structural equations representing the variables in the mobility system. However, the values in these structural equations are derived from how much of the variance in one of the variables is related to the variance in other variables at a specific point in time. The model does not allow us to ask if the variances, and hence the effects of the variables, represent changes in the effects of social structure on the mobility process over time. Thus path analysis results in confounding the level of analysis. For example, do anterior variables represent initial conditions at one point in time or constant factors that originate in a previous time period? In addition, how comparable are the path weights at different points in time? We claim that the causal model is too inflexible because it cannot represent structural changes during a time interval. Since path weights are not identical to correlation coefficients, a change in a weight does not necessarily mean a change in the degree of association between variables (Hope, 1972). The path model assumes that the social structure and all effects of the social structure on the mobility process is in a state of equilibrium. Therefore changes in the social structure or its effects on the mobility process are unidentifiable.

In addition, we claim that causal models are 'snap-shot' models, one picture of the social structure at one point in time. This implies that the mobility analysis represents a stable system or that all variables operate on each other at the same time instant or at the same rate (Leik and Meeker, 1975). Just as a single snap-shot is not a motion picture, a causal model is not a dynamic analysis. When path models are combined with the time lags of research, the result is an unrepresentative picture of the social structure.

2.2 Stochastic Models: An Overview

Due to the unpredictable nature of human behavior and due to the need to explicate and explain the variability of human behavior over time in social structures, we maintain that social mobility is a dynamic process subject to uncertainty.

Statements about mobility made in English may be translated into a processual oriented mathematical language such that the random nature of human behavior is not lost in translation. The result is called a stochastic process. When applied to mobility, the result is a stochastic model which represents movement among a set of occupations. The movement is governed by probabilistic laws. Thus, movement in the social structure is represented as a set of functions that give the probability of movement between occupational states in a given time period. Since mobility is subject to uncertainty due to the unpredictable nature of humans, we propose to use a stochastic representation of mobility.

Although stochastic models are probability models indexed by time or space as we are concerned with movement between partitions in the social structure at various time points, we will index our model by time. Further, we shall incorporate the social structure in terms of occupations which will be represented as "states" in the model. Hence, the question of asking what determines mobility patterns becomes the question of what determines the probability of moving between states in a specific time interval. The main inadequacy of the stochastic approach to date has been the lack of work determining how these probabilities are modified by sociological factors (Boudon, 1973). We propose to try to overcome this inadequacy by investigating the possibility of representing mobility by a specific type of stochastic model that appears to be able to incorporate sociological factors and that seems to be a logical extension of previous mobility models. In order to do this we need to outline the cumulative development of stochastic models of mobility. The mathematical details of the models mentioned in this section are presented in Appendix A.

The simplest stochastic model of mobility is the Markov chain (Blumen, Kogan, and McCarthy, 1955; Prais, 1955). The model assumes moves between states are dependent only on the state from which the move originates and is independent of the previous sequence of moves. This is called the Markov or one-step dependency assumption, common to all Markov processes. By observation of the movement between states and the distribution of the population among states, the probabilities of movement and distribution at any subsequent time point can be computed. This model has two assumptions in addition to the Markov assumption. First, the model assumes the probability of moving between two states is the same for all individuals. This is the assumption of homogeneity of movers. The second assumption is the probabilities of movement are identical for any two time periods of equal length. This is called the stationarity assumption. The relaxation of these assumptions has produced more advanced models of mobility.

Blumen and his associates concluded that the simple model inadequately predicted the number of non-movers. The predicted proportion of non-movers was smaller than the actual proportion of non-movers. Hence non-movers are underrepresented in the simple model. This led Blumen and his associates to question the assumptions of the simple model, especially the homogeneity assumption. Consequently, they developed the mover-stayer model where the assumption of homogeneity was relaxed: two distinct types of individuals are postulated, those prone toward mobility, movers, and those prone to immobility, stayers. This model resulted in a better prediction of movement. Recent work by McFarland (1970) has extended this idea by assuming each individual is governed by a unique Markov chain between the ideal types of movers and stayers, resulting in a disaggregation of the simple model. This approach seems to lead to a dead end since mobility may appear as a result of a statistical artifact of the disaggregation (Morrison, 1973).

The approaches mentioned so far in this section are termed demographic approaches by Stewman (1975) since mobility is conceptualized as a flow of manpower. An alternative stochastic model of mobility is the vacancy chain. Vacancy chains have been successful in predicting mobility in well defined, highly formalized, autonomous and hierarchical authority systems such as church groups (White, 1970) and state police groups (Stewman, 1975). The vacancy chain conceptualizes mobility in terms of the flow of interrelated job vacancies in a formal organization. Vacancies are created when a new job is created, or an individual in the organization dies, quits, or is fired. Vacancies are filled when the job is abolished or a new recruit fills the job. The advantage of the vacancy chain model is a conceptualization of the internal dynamic interrelationships of an organization. The main disadvantage of the vacancy chain model is its atemporal nature. White (1970), Tuma (1972), and Stewman (1975) contend the model is stationary since vacancies are rapidly filled, but they point out the model varies in degree of heterogeneity with respect to external economic conditions that create the vacancies.

The vacancy chain model can be interpreted as conforming to the Markov assumption if one is interested in the average time until a vacancy is filled or the time a vacancy stays within a set of states. However, Boudon (1973) indicates that the Markov assumption is violated if the vacancy chain model is adopted to analyze the overall transition matrix of individuals over time among a set of states.

In substantive terms, the vacancy chain model may be limited in its scope since multiple formal organization settings of different occupations result in the necessity of consideration of temporal factors in the forms of time delays due to the complex interdependencies of modern economics. For example, vacancies in an organization engaged in automobile production may determine vacancies in an organization engaged in steel production.

The relaxation of the stationarity assumption is aided by utilizing pre-existing mathematical work on continuous time stochastic processes. Mayer (1972) uses instantaneous rates of transitions between states to deduce the transitions between states in probabilistic terms. The result is the probabilities take on different values at different points in time. The probabilities usually take the form of a modified decay function. Mayer has developed three models that elaborate on these ideas (see Appendix A). The first allows instantaneous moves only to adjacent states, the second allows moves to any state weighed by a decay factor, and the third associates conditions of permanent retention or some degree of non-retention for each state. Though these models relax the assumption of stationarity, they still assume homogeneity since the transition rates are identical for all members of the population.

Conner (1969) has used a continuous time model to see how an individual's degree of commitment to an occupation, after being in a state of indecision as to remaining in the occupation, results in the probability of leaving the occupation. In substantive terms, Conner is asking how social psychological factors induce the propensity to be mobile. Simulations involving the analysis of Mexican-Americans whose first occupation is farm labor revealed a fit between the actual and predicted proportion of the sample still in agriculture as a function of time.

The significance of Conner's work is the attempt to represent substantively the determinates of the parameters of stochastic models of mobility as a function of social psychological states. This attempt has been generalized and extended by Tuma (1972) by seeking macro level sociological factors that determine the parameters of stochastic models.

Tuma (1972) analyzed mobility in terms of two subprocesses, leaving a job and being attracted to an alternative job. By relaxation of the homogeneity, stationarity and Markov assumptions, Tuma showed most models of mobility are composed of specific mathematical functions termed probability laws which are special forms of basic equations for the two subprocesses. Tuma compared the laws in terms of identification of future states, subsets of homogeneous individuals, best representation of time (duration in a state, age of the individual, or time when a move is made), and validity of the Markov assumption. She found the probability laws which best fitted her data imply a heterogeneous, non-stationary, non-Markovian process.

As we are concerned with how substantive factors determine mobility, we view our work as an extension of Tuma's research. First, we extend the list of possible factors to include some aspects of the status-role of the individual and the industrial location of the individual's occupation for all occupations. Then we argue the status-role of the individual continuously affects the experiences of the individual which affect the parameters of the mobility process. Consequently, our research is an example of the cumulative nature of model-building, since, like Tuma, we argue for the importance of studying how time-varying sociological factors result in a heterogeneous population. Our approach involves a formalization known as the semi-Markov model.

2.3 The Semi-Markov Model and Waiting Time Distributions

The use of the semi-Markov model has been proposed for studies of migration (Ginsberg, 1971), housing turnover (Gilbert, 1972) and occupational mobility (McGinnis, 1968). The semi-Markov model seems fruitful for the construction of a formal theory of mobility since it allows us to see how the time spent in a state modifies transitions between states.

Mobility is conceptualized to be a series of moves between any two states within a set of states. Hence the career of an individual is composed of a series of moves between pairs of states, such that the state of destination for a given move becomes the state of origin for the next move, if any subsequent moves occur. The only requirement is that the states of origin and destination are different states. We are especially interested in the duration in the state of origin, the time an individual waits in the state of origin before a move to the state of destination occurs. We feel that since mobility is a life-chance, aspects of the status-role of the individual relevant to the world of work affects the duration in the state of origin.

The semi-Markov model postulates that movement among a set of states is a function of the probability of movement between any two states and contingent on the time spent in the prior, original state. Two sets of relationships are involved: the simple Markov Chain or conditional probability of moving between states and a set of functions specifying the probability of making a move between any pair of states given a specific length of duration in the state where the move originates or waiting time in a state. The set of functions is a mathematical representation of the status-role and world of work of the individual. The semi-Markov model, when compared to the vacancy chain model, allows us to investigate the determinants of the waiting time till a move is made. These factors, especially aspects of the status-role that reflect duration at the job and seniority, may determine the rate at which vacancies are created and filled (Tuma, 1972). If we stress the substantive advantage of the vacancy chain approach, namely the consideration of the structural determinates of mobility, we see the semi-Markov model's use of waiting times allows us to incorporate this set of considerations in terms of the industrial setting of the occupation and the status-role of the individual. That is, the semi-Markov model will allow us to ask theoretical questions about the specification of conditions of change of the mobility process, a need in mobility research stressed by Stewman (1975).

Tuma's (1975) re-analysis of data on Mexican-Americans employs a semi-Markov model to attempt to model the causes of social mobility. Mobility is viewed by Tuma to be composed of two subprocesses: leaving a state and being attracted to a new state. Specifically, Tuma mentions the duration of an individual in a position does not depend on the previous history of the individual, but may depend on characteristics of the person's present position and his destination. Tuma also realizes the pattern of duration in a state need not necessarily be a monotonically decreasing pattern as duration increases.

Tuma tried to oversome two faults of her model, the omission of the effects of population heterogeneity, and the Markovian nature of part of the model, the embedded chain. In contrast, we will argue that in the semi-Markov model the analysis of the duration of time in a state, which we term the waiting time, shows the effects of population heterogeneity. In addition, the Markovian nature of the embedded chain is modified by the nature of the mathematical distribution of the waiting time (see Appendix A).

Tuma developed a multivariate, linear model to analyze her two subprocesses, leaving a state and being attracted to a new state. She also investigated the impact of the duration in a state on these subprocesses. Our approach is similar since we explicate how factors antecedent to mobility affect the distributions of waiting times in the state of origin before a move to the state of destination.

Since the semi-Markov model is closely related to Tuma's analysis, we should explicate the differences between the two approaches. With respect to the type of formalization involved, the semi-Markov model does not represent mobility in terms of two subprocesses of duration in a state and moving among a set of states, but incorporates both subprocesses in the waiting time function and the embedded Markov chain. The unit of analysis in the formalizations differ since Tuma is concerned with how attributes of a specific job affect rates of mobility, while we examine how the attributes of the status-role of an individual in the occupational structure affect rates of mobility. In addition, we are explicitly concerned with the state of destination and the state of origin. Tuma's ignores the implicit link between current and future states. This ignores the process implicit in the individual's decision to change his state: a decision to move implies the comparison of the current and future occupational state, which implies at least a vague knowledge of the future occupational state. Finally, the existence of vacancies is non-problematic in the semi-Markov formulation since the factors behind a move, if a move occurs, depend on the state where the move commences and terminates. Therefore, we assume that a vacancy must have existed in the state where the move terminates.

In substantive terms, the scope of Tuma's model and the semi-Markov model differ. In the former, one can change a job without changing an occupation, but in the latter a change in an occupation implies a change in a job. In addition, our approach is more comparable to traditional sociological approaches to studying mobility because we conceive mobility in terms of a state of origin and of a state of destination. Analysis of the waiting time distributions in the semi-Markov process allows us to examine the determinants of duration in a state, which, given a state of destination, governs the propensity to be mobile.

These considerations, however, do not mean the semi-Markov model solves all problems of formalization. The idea of waiting time distributions in the model has a caveat: though the distributions need not be identical, the distributions are independent of each other. In substantive terms this means waiting in one occupation does not affect waiting in other occupations, probably a very strong assumption given the various mutual effects of technology on white and blue collar occupations in industrial societies and the modern organization of the industrial state. The possible interactions of the distributions may result in alternative interpretations of our findings, but this is beyond the scope of our research. At the same time, the model does not make the assumption of stationarity since the mathematical properties of the model result in a non-stationary process. Finally, the semi-Markov model, due to the use of waiting time distributions, incorporates heterogeneity into the model despite the homogeneity of the underlying Markov chain of the model.

In this dissertation we limit ourselves to a simple case, a closed occupational system with three states: professional-manager, non-manual workers, and manual workers. Rather than representing mobility in terms of the probabilities of moving among these states we are interested in the determination of these probabilities. Although our unit of analysis is the general occupational category of the individual, we are concerned with how sociological factors, such as the status-role of the individual and the economic milieu of the occupation determine these probabilities. We also argue that patterns of inequality in industrial societies set parameters which affect the level of job satisfaction of the individual which in turn determines the life chances or the propensity to be mobile of the individual over time (i.e., in his career). These patterns of inequality are represented in our study by three background factors.

The first factor, sex, represents some of the ascribed characteristics of the status-role. If the waiting time distribution of males differs from females we conclude sex gives different opportunities for mobility. If the distributions are similar we conclude sex is not relevant for the given data. The second factor, self-employment status, reflects the achieved characteristics of the status-role. If the waiting time distribution of self-employed workers differs from salaried workers we conclude self-employment gives different opportunities for mobility. If the distributions are similar, we conclude that this factor is not relevant. The third factor, industrial growth rate of the location of the occupation, incorporates the effect of economic milieu on mobility. If the waiting time distribution of expanding industries differs from contracting industries we conclude the type of industry gives different opportunities for mobility. If the distributions are similar we conclude that this factor is not relevant. We are not examining the interactions of these factors, nor are we including other factors in the analysis.

Of the three factors, the industrial growth rate of the location of the occupation needs the most clarification. Speaking in terms of the growth rate of the industrial location of an occupation may sound confusing since location is usually used to refer to the site of employment. We do not mean location in the spatial sense. We feel location is a component of the occupation of an individual, since, in many cases, occupations are situated in more than one industry. For example, an engineer may be employed in a steel mill, an automobile factory, a government agency, or in research and development organizations. The extent to which each of these locations of employment expands or contracts may affect the mobility of the engineer (Keyfitz, 1973).

Growth may be measured in terms of industrial output or the size of the labor force. We are concerned with growth as measured by the increase or decrease of the size of the labor force over time. Hence the location of the industry in which the individual is employed refers to how the economic milieu is represented in the semi-Markov model. We are concerned with the part of the economic milieu termed the labor market. Continuing with our example, the number of engineers in the automobile industry may be increasing, while the number in the steel industry decreases. This is postulated to result in differential mobility patterns. Hence we are concerned with the relative growth rate of the industry where the occupation is located, which we term the growth rate of the industrial location of the occupation. This variable, like sex and self-employment status, takes on one of two values, growth and non-growth.

By a process of formal theory construction using the semi-Markov model we will assess the feasibility of explicating and explaining observed empirical regularities of mobility, for example increasing immobility with increased tenure in a state (Morrison, 1973; Tuma, 1972). This would permit us to predict the nature of mobility in industrial societies. In other words, we are asking if mobility can be represented by a stochastic process such that the time till a move is made is contingent on the occupation from which the move originates and in some cases also contingent on the occupation to which the move will be made, given information about factors that result in varying degrees of retention of the individual in the initial occupation.

Our reasoning is as follows: mobility is determined by the time spent in an occupation which reflects commitment to the world of work of the individual and salient features of social differentiation. For example, we want to see if it is possible to represent the status-role of the individual in a dichotomous manner, male and female, and then to see how sex determines the length of time spent in an occupation. Hence, in our example, we are asking the probability of moving between occupations given a length of duration in the initial occupation that reflects and depends upon the sex of the individual rather than simply asking the probability of moving between occupations.

Since we are processually oriented, we need to stress the various meanings of time in our analysis. We are assuming that mobility over a time period is contingent on the time spent in the state from which the move originates. We called the time spent in a state the waiting time. We distinguish among the chronological age of an individual, the time period in which a move may occur, and the waiting time in a specific state before a move occurs.

Ideally our data would be a continuous monitoring of the individual during his working life, looking at ascribed factors, such as sex, age, or race, and achieved factors, such as level of education, level of income, supervisory status, and economic factors. With this type of continuous data we could examine the waiting time till a move is made and see how these factors modify the waiting time. We must be content with existing data sets despite their inadequacies. One of these sets, on Great Britain, is described in Chapter 3. As waiting time is the time till a move is made, we need to observe the occupation from which a move occurs and the occupation to which a move occurs, contingent on the time spent in the original occupation. (The idea of waiting time between events is called time till a failure occurs, or failure time, in a branch of probability theory called renewal theory. The idea of waiting time does not incorporate an idea of multiple-step dependency. Only duration in the current state is involved. Perhaps the label semi-Markov model is misleading since this type of model is actually a multi-state renewal model. Sometimes waiting time is called duration time.)

If we talk in terms of waiting times we can introduce determinants of mobility into the model by specifying the nature of the mathematical representations that reflect the idea of waiting time. For example, the mathematical function may represent the idea of cumulative inertia, increased immobility as length of stay in a state continues (McGinnis, 1968).

Ideally we may consider our data to be a set of individuals where the individual is represented as a vector, a set of multidimensional elements, such as age, sex, race, and level of education. Our analysis can be conceptualized as a rearrangement of the elements of these vectors for all individuals in our sample. The specific elements of the vectors that interest us are the sex, self-employment status, industrial location of the occupation, occupation, and length of time in the occupation of the individual. From this information, we could compute the embedded Markov chain of the semi-Markov model and plot the distribution of waiting times. However, our main concern is what determines these distributions.

We will be concerned with a simple case, consisting of three occupational states, professional-manager, white-collar, and blue-collar workers. Since we are concerned with what a move looks like, if a move occurs, we need to specify the number of different moves that may occur among a set of states. A move means going from a state of origin to a state of destination in a countable period of time. Hence the number of different moves among a set of states is equal to the number of possible combinations between pairs of dissimilar states. This is formally computed, in counting theory, as the number of combinations of a finite number of objects taken two at a time.

In our simple case, there are six possible transitions between any pair of dissimilar states. Our first step in reordering the elements of the vectors is to determine whether a move occurs, and, if it does, to ascertain what type of move occurs. Then we have the waiting time, the time in the first state before moving to the second state. This is plotted for all individuals with this pair of states. This type of analysis is detailed in the next chapter. We assume no periods of unemployment between moves and, as we are interested in the move itself, we ignore any intermediate moves. We realize these intermediate moves may be preparatory for future moves, but the issue of intermediate moves is a topic for future analysis if we conclude that the semi-Markov model is worth further consideration.

Information about the waiting time distribution is an important piece of information in studying mobility in a society. Even if a society appears to have a steady state distribution among occupations or appears to be non-fluid with respect to movement between social strata, different patterns of moves may be occurring and the steady state or non-fluid aspects of the mobility system may be artifacts of the statistical aggregation of two or more different patterns. It is for this reason that we ask what background factors may determine mobility patterns. In terms of our model, we are asking what happens when we disaggregate the waiting time distribution by using the various elements of the vectors of individuals. It may very well be that disaggregation results in dissimilar patterns of waiting times. This would indicate the importance of the variables along which the disaggregation was conducted. This point can be illustrated by an example. Suppose we disaggregate self-employed from salaried individuals among individuals moving from non-manual to professional-manager states. Self-employed individuals may stay in the non-manual state longer than salaried individuals since the former may leave their occupation only after failure is evident which may involve a long period of time, while salaried individuals may have a constant rate of leaving non-manual occupations.

To conduct this type of analysis we use the set of individual vectors to determine the time till a specific type of move is made. Then we search the vector for sociological factors of interest, such as sex, self-employment status, and the industrial location of the occupation as represented by the growth rate, and compute the disaggregated waiting time distribution. If different distributions occur for the two states or conditions of the disaggregated variable, we conclude these factors are relevant in determining the waiting time distribution and therefore a possible reason why mobility occurs. If different distributions do not occur we can conclude only that the factor is not relevant for the data being analyzed for the given time period.

This chapter has discussed the mathematical aspects of our research. We began with an overview of types of mathematical models of mobility, concentrating on the stochastic model. After discussing the cumulative development of the stochastic model we focused on the semi-Markov model, which represents mobility as the probability of moving between occupations given a waiting time spent in the occupation from which the move originates. We stressed how the determination of the waiting time distribution may lead to a theoretical representation of mobility if we conceive of the effects of the world of work and of the status role of the individual as influencing the waiting time distribution. This, in turn, implied the semi-Markov model is a cumulative model of mobility and is also inclusive in a substantive sense. The next chapter of the dissertation discusses the sample used to test these ideas and the empirical procedures to be used.

CHAPTER III

SAMPLE AND METHOD OF ANALYSIS

This chapter of the dissertation describes the data which was collected in Great Britain from 1963-1970. Notes are given on the uses and misuses of precollected data, with an emphasis on time-dependent data, since our data set is of this type of data. Finally, the computer procedure employed to generate the waiting time distributions is discussed, concentrating on the creation of a subsample that meets our scope conditions and operationalizes our background variables of sex, self-employment status, and the industrial location of the occupation. We also discuss our operationalization of the occupational state. The original wording of the questions to gather this information and ways this information is coded is located in Appendix B. We do not claim that the background factors are exhaustive. We only assume that they are exclusive of each other and that they are sufficient to permit an assessment of the semi-Markov model for mobility analysis.

3.1 The Butler and Stokes Data: Great Britain from 1963 to 1970

The Butler and Stokes study is a longitudinal behavioral analysis of voting in Great Britain. Individuals were interviewed over a seven year period commencing in 1963. Subsequent interviews were conducted in the election years of 1964, 1966, and 1970. The main advantage of this data is that it has information on the world of work of the individual providing information about factors that impinge on the mobility process at multiple time points. The primary sampling unit is parliamentary constituencies. Interviews were sought with 32 individuals in each constituency according to a random procedure which resulted in 2009 interviews in 1963. No interviews were collected from Northern Ireland which has its own parliament. The first wave of the sample is a self-weighting, multi-stage, stratified random sample of the adult population of England, Wales, and Scotland.

Butler and Stokes (1969) argue that this multi-stage random sample yields smaller sampling error than a simple random sample since the former type of design reduces the cost of interviewing, yielding a larger sample with a smaller sampling error. For a sample of this size, an interval the width of two sample errors (where the maximum sample error is approxmately 3.8%) contains the true value 95% of the time.

As one of our scope conditions is a closed system, we are interested only in information about individuals who are interviewed at all time points, 1963, 1964, 1966, and 1970. The result is a high rate of attrition. Out of the initial sample size of 2009 in 1963, 718 remain in 1970, which results in a sample size of 511 after individuals who violate additional scope conditions are eliminated. The procedure employed to create the subsample of 511 individuals who meet the scope

conditions of our research is discussed in the third section of this chapter.

The major sources of attrition in panel studies include the death of an interviewee and/or the failure of the interviewer to obtain subsequent interviews with the same interviewee because the interviewee was out of the country, did not leave a forwarding address after a move, or refused to be reinterviewed. Unfortunately, Butler and Stokes (1969) do not indicate the rates of attrition due to each of these categories.

It is necessary to survey the economic history of Great Britain during this period since exogenous economic forces may give us insight into alternative interpretations of our analysis. Hence we will give a general economic survey of Great Britain from 1963 to 1970 and a detailed examination of the composition of the labor force by industrial categories since 1939, concentrating in the 1963 to 1970 period. The labor force analysis is a necessary part of our study since this provides the information needed for our operationalization of the industrial growth rate.

Analysis of Great Britain has a few substantive advantages for an exploratory analysis of mobility. First, Great Britain is more racially homogeneous than other nations. With the exception of racial disturbance against non-white immigrants from overseas in 1968, the period under investigation has minimal racial strife. More importantly, the non-whites in our data are less than one percentage of the sample. Because of this, we eliminated non-white from analysis. This reduced the sample from 718 to 714.

Second, the 1963 to 1970 period exhibits no dramatic change in the distribution of the labor force among industrial categories although between 1950 and 1965 the proportion of manual occupations declined by only 5% (Butler and Stokes, 1969).

Third, the period 1963 to 1970 exhibited relatively low unemployment. Great Britain during this period is representative of an industrial nation near full employment. However, from 1963 to 1970 wage and salary increases were greater than the increase in productivity, resulting in demand-push inflation and a foreign exchange crisis. This resulted in an imbalance of payments and a devaluation of the pound by 14% in 1967. This may have a secondary effect on the distribution and growth rates of workers in industrial categories and partly explain the decrease in the growth of individuals in distributive trades from 1964 to 1970 as presented in Table 4 of this chapter.

Fourth, Great Britain is almost an ideal type industrial society. Manufacturing and trade are the largest segments of the industrial work force with the majority in metal-related industries producing heavy durable goods, especially tools, machinery, and transportation equipment.

Fifth, and finally, due to social planning Great Britain does not have its work force as concentrated in specific areas as other industrial nations. Since we are not studying how geographic factors may modify mobility processes and since the British work force is geographically diffuse, the interaction effect of these two factors is minimized. For example, textiles are concentrated in Lancashire, coal and electricity in the Scottish Highlands, heavy industry in the Midlands, light and middle industry in the suburbs of London and Liverpool, etc.

There is one major characteristic of Great Britain from 1963 to 1970 that may confound our analysis and interpretation of the rate of expansion presented in this chapter: industrial production in the 1963 to 1970 period is undergoing decline or is at best stagnant. As Table 2 shows, only one index, crude steel does not decline during this period. This may be a result of nationalization of 90 percent of the steel industry.

TABLE 2

INDICES OF INDUSTRIAL PRODUCTION IN GREAT BRITAIN, 1964-1970

Index	Year			Growth Rate[a]
	1964	1967	1970	
Coal[b]	185.4	172.2	150.5	-0.19
Crude steel[b]	26.2	23.9	26.4	0.00
Automobiles[c]	1868	1552	1717	-0.08

SOURCE: _Whitaker's Almanack, 1965, 1971_ (London, Eng.: Whitaker's, 1965, 1971).

NOTES: [a]Growth rate is 1970 figure minus 1964 figure divided by 1964 figure.

[b]In millions of tons.

[c]In thousands of units.

The negative growth rates may reflect the less than one percentage growth rate of the entire labor force during the 1963 to 1970 period. This would imply a stagnant economy in terms of per capita production. The growth of the number of workers in an industrial category is our operationalization of the growth rate of the industrial location of the occupation.

One of the possible problems of our analysis is the possibility of a delayed effect of the expansion of an industry. For example, upward mobility in the 1963 to 1970 period may be due to possession of the states of the status-role that were operating prior to 1963. Hence our analysis is open to multiple interpretations. Because of the possibility of delayed effects, it is necessary to present data before the 1963 to 1970 period. In addition, the older segment of the labor force had the unique experience of the post World War Two recovery. Hence data is presented for a series of years.
Table 3 presents data for the industrial composition of the civilian force for 1939, 1953, 1960, 1964, and 1970. The cited date is taken to be as of 30 June for each year. 1939 was selected as a pre-war, post-depression year. 1953 was selected as a point midway between 1939 and 1970 and long enough after the conclusion of World War Two to minimize the effects of a post war reconstruction. 1960 was selected to see the entire decade of the 1960's and to detect whether or not any short run delay factor may have existed in the years immediately before 1963. 1964 was used as data for 1963 was unavailable.

TABLE 3

DISTRIBUTION OF THE CIVILIAN LABOR FORCE
OF GREAT BRITAIN: 1939-1970
(as of 30 June)
(in thousands)

Industry	Year				
	1939	1953	1960	1964	1970
Agriculture, horticulture, and fishing	950	1092	971	886	391
Mining and quarrying	873	876	765	657	419
National government	539	595	501	539	580[b]
Local government	846	725	740	813	805[b]
Gas, water, and electricity	242	373	370	398	386
Transportation and communication	1233	1726	1652	1617	1552
Manufacturing	6815	8723	8834	8831[c]	9388[c]
Building and construction	1310	1448	1541	1720	1343
Distribution trades	2887	2641	3265	3404	2702
Professionals, finance and miscellaneous services	2252	3991	4954	5375	4851[d]
Males			15478	15798	1746[a]
Females			8115	8442	
Total	17947	22190	23593	24240	24267

SOURCE: Whitaker's Almanack, 1954, 1957, 1961, 1965, 1971, 1974 (London, Eng.: Whitaker's, 1954, 1957, 1961, 1965, 1971, 1974).

NOTES: [a]Employers and self-employed.

[b]In 1967. 1970 is an aggregation of National and Local Government of 1378.

[c]Sum of all manufacturing categories since data is disaggregated.

[d]Sum of all professionals et al. categories since data is disaggregated.

An examination of Table 3 reveals a picture similar to most industrial nations. The agriculture, mining and related industrial categories seem to decline in their number of workers while manufacturing, energy producing, professionals and related industrial categories increase. Surprisingly, building and construction, and government workers are relatively constant in the period although the fluctuation in the former may be due to completion of the "new towns" by the early 1960's. The sharp decline in distribution trades at 1970 may be a result of the balance of payment problem and devaluation of the pound in 1967. (The reader of the table should note that transportation and communication includes the government run railroad, telephone, and postal services. The figures given for government workers do not count double government workers in other industrial categories.)

The growth rate of industrial categories provides the information needed to compare rates of expansion. The growth rate is equal to the size of the labor force in the year at the end of the period minus the size of the labor force at the beginning of the period divided by the size of the labor force at the end of the period. The size of the labor force for a given industry is in Table 3.

Growth rates for the industrial categories are presented in Table 4. The rate given means (1 - g) x 100% of the figure at the end of the period is equal to the figure at the beginning of the period, where g is the growth rate. Thus, unlike Table 2, we are using the final year as the base year, which makes our growth rates in Table 4 oriented forward in time.

Examination of Table 4 reveals the 1964 to 1970 period exhibited no expansion. The entire labor force for this period exhibited no measurable growth. Agriculture and mining exhibit sharp declines. Gas, water, and electricity, transportation and communication, building and construction, distribution trades, and professionals, exhibit moderate to slight declines. The slight decline in professionals may reflect the disaggregation of the 1970 data. National government and manufacturing exhibit slight increases. Looking at Tables 2, 3, and 4 together seems to imply most movement was to manufacturing and most new entrants to the labor force were to manufacturing.

Table 4 gives other growth rates due to the possible delay factor. The 1939/70 rate is given to see the long run pattern of growth. Long run growth is exhibited in utilities, transportation and communication, manufacturing, and professionals.

The 1939/70 period is split into 1939/53, 1953/64, and 1964/70 periods. This analysis reveals the majority of the

TABLE 4

GROWTH RATES OF INDUSTRIAL CATEGORIES IN GREAT BRITAIN: 1939-1970

Industry	Time Period[a] 1939/70	1939/53	1953/64	1964/70	1939/60	1960/70
Agriculture, horticulture, and fishing	-1.42	.13	-.23	-1.26	.02	-1.48
Mining and quarrying	-1.08	.00	-.33	-.56	-.14	-.82
National government	.07	.09	-.10	.07	-.08	.14
Local government	-.06	-.17	.11	.00	-.14	.08
Gas, water, and electricity	.37	.35	.06	-.03	.39	.04
Transportation and communication	.20	.28	-.04	-.04	.25	-.06
Manufacturing	.27	.22	.01	.06	.23	.06
Building and construction	.02	.10	.16	-.28	.15	-.15
Distribution trades	-.07	-.09	.22	-.26	.12	-.21
Professionals, finance and miscellaneous services	.54	.44	.25	-.11	.54	-.02
Total	.26	.19	.08	.00	.24	.03

NOTE: [a]The / means the period; for example, 1964-70 means the 1964 to 1970 period.

long run growth in utilities, transportation and communication, manufacturing and professionals occurred before 1953.

Alternatively, the 1939/70 period is split into 1939/60 and 1960/70 periods. This reveals the bulk of the decline in agriculture and mining occurred in the early 1960's. However, the national government seems to be undergoing a rapid growth in the same period. The bulk of the increases in utilities, transportation and communication, manufacturing, building and construction, and professionals occur before 1960 or in the early 1960's.

The result of this analysis of the industrial labor force of Great Britain is information that enables us to operationalize one of our variables that may impinge on the mobility process, the variable of the industrial location of the occupation. This will be discussed later in the chapter, along with the discussion of the operationalization of the other variables.

3.2 Problems of Using Pre-Collected Panel Data

Although the data we propose to use is a voting study of political change in Great Britain, the data provides information about factors that impinge on the mobility process as information on background variables was collected to explicate the voting behavior. The use of the panel technique involves the administration of the same set of questions on the same group of individuals at multiple time points. In other words, panel studies are replicated interviews. The panel technique is superior to one step observations or collecting data at one point because we can see the change in patterns of responses or the type of phenomena being studied at various time points. This allows us to make longitudinal statements about social phenomena without having to make strong assumptions about the regularity of the phenomena. The panel technique is employed here to identify the dynamics of the regularities. By having data representing change over a period of time, especially net change, one can hopefully begin to explain social processes such as mobility in terms of dynamic regularized and recognized patterns. Panel studies tend to minimize the problems of induction of dynamic social processes (Galtung, 1967).

There are no techniques other than panel techniques to see the dynamics of intragenerational mobility. There are some techniques, usually involving cohort analysis, that attempt to synthesize a dynamic process. For example, Mayer (1972), used the Blau and Duncan (1967) data to develop data amenable to dynamic analysis by dividing the data into four groups of individuals aged 25, 35, 45, and 55 years of age. The older groups are considered to be the younger groups after a duration of time equal to the differences between the ages of the two groups. Individuals aged 35, 45, and 55 are considered to be the individual aged 25 after 10, 20, and 30 years respectively. For example, the pattern of moves observed for the 45 year old group would be considered to be the pattern of moves for individuals who have a duration of 20 years in their state of origin, given the state of origin is the state where the individual is located when the individual is 25 years old. By this method, the same group can be synthetically analyzed at future time points, simulating the effects of duration. Any changes in the social structure are negated by assuming social forces of change are equally salient to all individuals at all time points. This negates the intent of processual analysis in sociology; namely, studying how changes in the social structure affect social processes. The results of any mobility study using cohort analysis probably would be erroneous, especially in periods of economic change and different rates of expansion of industries.

The panel technique is not without its disadvantages (Galtung, 1967). Since the panel study is a replicated interview, the disadvantages of the panel combine the disadvantages of all interviews and all longitudinal studies. With respect to the disadvantages of interviews, the panel study does not have pre-specified independent or antecedent variables, and does not have a control group. Usually the types of questions asked and manner responses are recorded are incongruent with the needs of the user of the data. The user of panel data for secondary analysis must compromise his need for data with the data available. Usually this compromise involves using the pre-collected data to attempt a falsification of the postulated relationship. To do this, the postulated relationship should have a level of abstraction such that its scope includes the observations represented by the pre-collected data. The pre-collected data, not the postulated relationship, is in a fixed time and space.

In addition, the panel study involves a social psychological process since it is an obtrusive form of research and subject to experimental effects that may invalidate the data collected. This may be amplified in the panel study, since subjects may attempt to recall previous responses (Galtung, 1967).

Finally, the panel study usually has an attrition factor due to the death of some individuals and the failure to obtain subsequent interviews. Hence analysis of data collected by a panel study may be a confounding of real changes and a sample bias, since the individuals who contribute to attrition may have characteristics distinct from the entire sample population.

These problems can be partly overcome. The lack of control and pre-specified independent variables can be minimized by multivariate analysis. The extent of experimental effects can be studied by examining the degree of incongruity in answers to questions concerning non-varying factors, like the level of education of one's spouse, or the age difference between a respondent's parents. Experimental effects can be minimized by triangulation. The extent of the discrepancy of real change and sample bias due to attrition may be measured by assessing whether or not the part of the sample that contributes to attrition possesses characteristics different from the rest of the sample population. Attrition can be minimized by introducing a panel weight factor to the remaining part of the sample.

With respect to the problems of longitudinal analysis, the panel study results in an aggregation problem. Specifically, the problem when applied to mobility, is asking whether observed changes in the transition matrix are due to structural factors acting on all individuals or statistical artifacts due to the behavior of individuals. This problem of panel studies is a specific example of one type of response uncertainty (Coleman, 1973).

This type of response uncertainty asks if individuals analyzed at multiple time points may give erroneous answers to questions, i.e., be uncertain of their responses. Hence observed change, for example transitions between states, may not be an index of the expected proportion of all individuals who make a specific transition but may be due to an uncertain response as to current and/or past location in a specific state. Studies of perceived social class and class consciousness continually exhibit such response uncertainty (Landecker, 1963).

Response uncertainty confounds actual change and human forgetfulness resulting in an apparent heterogeneity of movement at the macro level being partly due to response uncertainty at the micro level. This contributes to the problem of aggregation in mobility models: the heterogeneity of mobility patterns may be due both to response uncertainty (Coleman, 1973) and possible actual different patterns of behavior

(McFarland, 1970). This results in a dilemma: the degree of change can never be completely identified at the structural level.

Out of all the problems that arise in using pre-collected data we believe the major problem is the researcher must compromise his desires since the way a variable is recorded may not always be in a desired or usable format. For example, the Butler and Stokes data fails to differentiate between public and private workers in all industrial categories, or individuals who work in small or large organizations, two factors that affect the world of work of the individual. We also note we only know the individual's occupation is his or her chief occupation; we do not know if it is a full time or part time occupation.

3.3 Operationalization of Variables

The scope conditions of our research are determined by our interests. Since we are interested in the feasibility of using the semi-Markov model, we are dealing with the simplest case of applicability of the model: an adult, civilian, full-time employed working population in an industrial society at multiple time points. As mentioned above, we are interested in whites only. All non-whites were excluded from analysis. This resulted in a reduction of our original sample of 718 to 714.

The Butler and Stokes data is recorded so that it is possible to differentiate the respondent from the head of household. This led us to believe we may be able to increase our sample size; for, if interviews were conducted during the day, it is likely the respondent would be a "non-worker" and out of the scope of our research. The data is also recorded such that we can easily examine only individuals interviewed in 1963, 1964, 1966, and 1970. We assume if the head of household is not the respondent, the head of household is the same individual at all time points. This ensures the continuity of our panel. We also assume that all individuals are continuously employed in years between the interviews. Since information about changes in marital status and periods of unemployment is unobtainable, these assumptions are untestable. Moreover, the head of household, if not the respondent, is the respondent's father or husband, and is not retired. All other heads of household who are not respondents were excluded from subsequent analysis since it is impossible to determine the sex of individuals in this group, as it may include wives, siblings, and mothers, and the sex of any sibling is not given.

Occupational states are operationalized as the occupational grade of the respondent <u>and</u> head of household. If a respondent is a state pensioner, or a "non-worker," or does not give information as to his or her occupational state in any year, the individual was excluded from our sample. We constructed three graded occupational states, the states of our model, from this information, by using criteria suggested by Goldthrope and Hope (1974).

Goldthrope and Hope contend that any set of graded occupations is a scale of recognized prestige differences such that the elements of this scale are large homogeneous subgroups that are presumed to be similar with respect to socioeconomic characteristics. We note certain occupations may overlap these gross states such as a skilled craftsperson who sells wares in his or her shop, while some occupations are heterogeneous, especially white collar occupations in an advanced industrial society like Great Britain. Goldthrope and Hope recommend that when one collapses categories one should maintain differences among states, collapse adjacently ranked states, try to maintain the symbolic meaning of a state, and try to collapse states such that individuals are involved in similar work tasks. Using these guidelines, we ended up with three states: professional-manager, non-manual, and manual. This is discussed in detail in Appendix B.

The head of household is operationalized as the individual who is financially responsible for the place where the interview is conducted. Knowing if the respondent is different from the head of household enables us to prevent double counting of individuals who may be housepersons and heads of households. Working heads of households may be males or females. However, these individuals, if not the respondent, and if not the respondent's father or husband, are all lumped together. Since this category is only 6.3% of all heads of households in 1963, we excluded this category from further analysis. Note it is possible to be female and in this category, such as a wife, mother, or sister. The result of this procedure is all heads of households, if not respondents, are males, while respondents can be males or females.

The first background variable to be operationalized is sex. Butler and Stokes do not present any information on the operationalization of the sex of the respondent. We assume this is operationalized by visual inspection since all data was collected in face to face interviews.

One of our interests is if sex reveals different mobility rates. Since sex is a multiple value status characteristic in all societies, that has a preferred state, male, we would expect individuals of different sexes to exhibit different mobility patterns. Since mobility is a life-chance in modern societies, possession of the preferred state, male, should affect the degree to which the individual is mobile. For example, if males and females exhibit different rates of mobility for the same type of move such that males wait shorter for an upward move to be made compared to females, we would have evidence of inequality of opportunity with respect to sex in the population being analyzed.

The second background variable to be operationalized is self-employment status. Butler and Stokes term this variable economic status. Economic status asks if the individual is self-employed with or without employees, or a manager, or a foreman/supervisor, or any other employee with no direct managerial or supervisory responsibility. We would expect different rates of mobility for self-employed individuals since being self-employed usually reflects monetary investment in equipment and the development of a clientele (Ladinsky, 1967). Goldthrope and Hope's guidelines, used in developing occupational states, were applied to economic status. This resulted in two conditions, self-employed and non-self-employed or salaried individuals. Individuals who were unemployed, not in the labor force, or not giving information with respect to their economic status in any year were excluded from subsequent analysis.

The final background variable to be operationalized is the relative rate of growth of the industry in which respondent is employed and the location of the occupation. Butler and Stokes term this information the individual's occupation in contrast to the occupational grade which provided the information to determine the states in our model. Our operationalization is done with the aid of Table 4, which presents the growth rate of occupational categories by industrial location, as measured by the increase or decrease of full-time workers. The operationalization involved using this information in order to dichotomize the industrial setting of the occupation into growth and non-growth categories, which reflect the information termed the individual's occupation by Butler and Stokes. The industries are dichotomized as follows: <u>non-growth</u> (farmers, foresters, fishermen, miners, quarrymen, construction workers, painters, decorators, non-civil service clerical workers, and sales workers) and <u>growth</u> (gas, coke, chemical, glass, ceramic makers, furnace, forge, foundry, rolling mill, electronic, electrical and engineering workers, woodworkers, leatherworkers, textile and clothing, food, drink, tobacco, paper and printing workers, drivers, service, sports and recreation workers, professional and technical workers, transportation and communication workers). Occupations were coded by using the General Registrar's Office Classification of Occupations, the British analogue of the U.S. Department of Labor Occupational Classification. Butler and Stokes note when the occupation is coded the code reflects the individual's usual occupation, or if multiple occupations are given, the occupation with the higher social grade is coded. They also note if the description of the occupation is ambiguous the simplest interpretation of the occupation that seems compatible with remaining details is employed. Finally, professionals with managerial responsibilities are coded as professionals if in an organization germane to the profession, and coded as managers otherwise. Appendix C lists the 25 gross groups of occupations that were used in our analysis of the industrial growth rate of the setting of the occupational state. When determining whether or not an individual is in a non-growth or growth category, if the individual was in the armed forces, or a houseperson, or a student, or unemployed, or retired, or refused to answer, or inadequately described his or her occupation in any year, the individual was excluded from further analysis.

Once our variables were operationalized we were able to conduct some simple analyses by standardizing and editing the Butler and Stokes data tape. Note the operationalizations of our variables involved data standardization in order to make the data meet our scope conditions. Our editing started with the creation of a file using relevant data from the Butler and Stokes voting study. This study has 1244 variables due to its longitudinal nature. This was reduced to 45 variables of interest to us as students of mobility, that include only white individuals interviewed at all stages of the panel. After this file was created, we created a new working file to prevent double counting of heads of household and respondents, that also eliminated non-civilian and non-continuously employed workers. The final data base is presumed to be an adult, civilian working population, continuously employed from 1963 to 1970. This is the closed occupational system that meets the scope conditions of our research. The end result is a sample of 511 individuals.

Finally, a working file for purposes of analysis of the waiting time was created. This file consists of information on the sex, 1963 dichotomized self-employment status, 1963 dichotomized industrial setting of the occupation, and collapsed occupational states of the individual, using data from previous files. Since we are examining the distribution of waiting times for moves where the period of observation starts in 1963, we think this information is necessary and sufficient for our analyses.

Table 5 gives the distribution of the 511 individuals among the three occupational states as of 1963. The disaggregation in Table 5 is with respect to each of the dichotomized background variables. Hence we can see the way individuals having a specific condition of the background variables are represented in the three occupational states. The raw data in Table 5 may be employed to show the proportion of each condition of the three background variables in each of the occupational states, independent of other occupational states. For example, 65 of the 73 professional-managers are males, or 89.0%, compared to 11.0% that are female. Since we are interested in the distribution of our sample of 511 individuals among occupational states, contingent on background variables, we are not interested in this type of analysis. Hence in substantive terms, Table 5 represents the proportion of males, females, self-employed, non-self-employed individuals, and individuals in non-growth and growth industrial locations of the occupation among graded occupational states for our sample as of our initial time, 1963.

Table 5 allows us to see if the various groups represented by conditions of the background variables are over- or underrepresented in a given occupational state. A group is overrepresented if a larger proportion of its members is in a given occupational state than the proportion of the total population in that state. A group is underrepresented if a smaller proportion of its members is in a given occupational state than the proportion of the total population in that state. Hence, in the professional-managerial state, males and females are equally represented, but self-employed individuals and individuals in growing industrial locations of the occupation are

TABLE 5

DISTRIBUTION OF THE SAMPLE AS OF 1963 BY BACKGROUND FACTORS OF MOBILITY

Occupational State	Total	Background Variable					
		Males	Females	Self-employed	Non-self employed	Non-growth	Growth
Professional-Manager	73 (.143)	65 (.147)	8 (.114)	18 (.409)	55 (.118)	16 (.077)	57 (.189)
Non-manual	142 (.278)	112 (.254)	30 (.429)	20 (.455)	122 (.261)	103 (.493)	39 (.129)
Manual	296 (.579)	264 (.599)	32 (.457)	6 (.136)	290 (.621)	90 (.431)	206 (.682)
Total	511	441	70	44	467	209	302

NOTE: Proportions in brackets.

overrepresented. In the non-manual state, females, self-employed individuals, and individuals in non-growing industrial locations of the occupation are overrepresented. In the manual state, males, self-employed individuals, and individuals in growing industrial locations of the occupation are over-represented.

In absolute terms, there are more males than females, and more non-self-employed than self-employed individuals in each occupational state. However, only in the professional-manager and manual states are there more individuals in industries that are growing rather than non-growing.

3.4 Methods of Analysis

The main purpose of our analyses is to determine the waiting time distributions contingent on background factors for various types of moves. It is difficult to specify the exact mathematical nature of the functions that represent the waiting times. The mathematical form of the function is assumed to be a general function, the Gamma distribution (Ginsberg, 1971). This is described in Appendix D. It is possible to describe the various waiting time functions in terms of three statistics, the mean, variance, and time point at which the distribution is maximized, or maxpoint. The formulas to estimate these statistics are given in Appendix D. Knowing any two of the statistics uniquely determines the third.

The mean of the waiting time distribution gives us the average time till a move is made. If, when comparing two conditions of a factor due to disaggregation, such as sex, the means differ, then the distribution with the smaller mean indicates an expected value of mobility at an earlier time point, i.e., a shorter waiting time. The variance gives us the expected dispersion about the mean and indicates the minimum number of observations within a certain boundary of the mean. If, when comparing two conditions of a factor due to disaggregation, the variances differ, the distribution with the smaller variance indicates a greater concentration of mobility in a given time span. The maxpoint indicates the time point at which the greatest number of moves is postulated to occur. If, when comparing two conditions of a factor due to disaggregation, the maxpoints differ, the distribution with the smaller maxpoint indicates a greater chance of mobility at an earlier time point.

In general, we can say what the distributions mean in substantive terms by plotting or tabulating the time till a move occurs for all the various types of moves. Since moves are made by only three time points, 1964, 1966, or 1970, we will tabulate the moves. Thus the aim of our analysis is a tabulation of moves that reflects the time spent in one state before a move to another state occurs, given the initial state is in the 1963 state, no intermediate moves occur, and the final state is the 1970 occupation which is different from the 1963 occupation. We will only consider the wait until a move occurs and be concerned with subsequent immobility at the state of destination. This information would enable us to estimate the parameters of the waiting time distribution, according to Appendix D.

The critical issue is not the mathematical nature of the distribution but rather what the distributions tell us about the nature of mobility. Our reconceptualization of mobility using the ideas of the semi-Markov process goes beyond current verbal and formal representations of mobility. The importance of our research is not in the mathematical relationships but in explicating and possibly explaining mobility in industrial societies. We are interested in mobility in terms of the distribution of waiting times as they reflect, upon disaggregation, aspects of the status-role and world of work of the individual.

There are two ways to incorporate the waiting time distributions into the semi-Markov model. The first, estimation techniques, requires actual data. The second, simulation, generates data. In estimation techniques, one can compute the parameters of the waiting time distribution given the observed data. The parameters of this distribution may be computed by manipulations of the time till a move is made. However, this procedure is highly insensitive to great differences in waiting time for long periods of time, which may result in problems of parameter estimation. Ideally, the parameter estimation approach could involve continual monitoring of the individual to obtain a set of observed times till a move occurs. As we have not been able to locate this type of data, we must utilize data collected at discrete time points, the Butler and Stokes data.

The second approach, simulation, generates the time till a move is made as a random variable such that the random variable is from a probability distribution function that is of substantive interest, for example, the Gamma distribution with different values. Thus we might compare two hypothetical distributions whose parameters are guessed at based on substantive interpretations of the mean, variance, and maxpoint. This does not overcome a dilemma common to all approaches of estimating a function by statistics or simulation: more than one function can satisfy the same set of observations or statistics. Simulation would be an obvious extension of this research, but we will not pursue it here. We will concentrate on the estimation approach.

Our reconceptualization uses two types of time, the year when a move is made, and the duration time in an occupation till a move is made, or job tenure. The semi-Markov model realizes the multiple meanings of time since we speak of the probability of making a move between a dissimilar binary set of states in a given time period conditioned on being in the initial state for a specific period of time, not the probability of making a move between a binary dissimilar set of states in a given time period.

Despite the seemingly mathematical nature of our work, we are starting from substantive considerations and trying to explicate social mobility by using a formal representation. Our reconceptualization of the transition matrix with subsequent disaggregations for background factors of the world of work may seem similar to the procedure used by Blumen, et al., and McFarland, but our disaggregation is sociological and not reductive like McFarland's as we examine moves for all dissimilar binary sets of states and the associated waiting time distribution.

The first step in this type of analysis involved standardizing and editing the Butler and Stokes data to obtain a three state closed system of continually employed, white, civilian workers in terms of their occupational grade at multiple time points, their sex, self-employment status, and industrial location of the occupational grade.

The computational stages of our analysis involved the construction of a series of contingency tables in order to yield information about the embedded Markov Chain of the semi-Markov process and the parameters of the waiting time distribution. This involved the use of a Statistical Package for the Social Sciences (SPSS) routine termed CROSSTAB. CROSSTAB creates tables and can control for variables of interest. In addition, each element of the table is represented as a proportion of the entire table, or the row or column where the element is located. Finally, the total for each row or column is represented as a proportion of the entire table. If the row and column of the table are the three graded occupational states at various time points, the result is an embedded Markov Chain computed by maximum likelihood techniques and the proportion of the population in each state, the distribution vectors, are the proportions of the entire row or column with respect to the entire table for the time point labeled by the row or column. For example, if the rows represented the 1963 and the columns the 1964 occupation, the result of making a table using CROSSTAB would be the first order Markov Chain with the initial distribution the row probabilities and the observed distribution at the first time period the column probabilities. By controlling for the dichotomized background factors of sex, self-employment status, and industrial location of the occupation we can disaggregate the observed Markov Chain and see if different patterns of moves exist.

Finally, proper selection of controls will enable us to get the information needed to estimate the parameters of the waiting time distribution. We are interested in the time spent in the initial occupational state, the 1963 occupational state, before a move to a different state occurs, the waiting time, counting only individuals who remain at this new and subsequently final occupation. Hence multiple moves are excluded from our analysis thereby satisfying our mathematical definition of the waiting time distribution given in Appendix A. This means our use of CROSSTAB involves creating a series of tables where the rows are the 1963 occupation and the columns the 1970 occupation, controlling on the following conditions, showing individuals who move at most once:

1. For all changes made by 1964, with no subsequent changes, control for 1963 occupation dissimilar from all other occupations and 1964 occupation similar to remaining occupations.

2. For all changes made by 1966, with no subsequent changes, 1963 occupation similar to 1964 occupation, and 1966 occupation different from 1964 occupation and similar to 1970 occupation.
3. For all changes made by 1970, with no subsequent changes, control for 1963 occupation similar to all occupations but 1970 occupation.

Similarity of occupation is operationalized by being in the same state. The result of this set of controls is the time spent in the 1963 occupation before a move is made for all observed time points, eliminating multiple moves. If we apply additional controls with respect to the dichotomized background variables, we obtain all the information needed to estimate the parameters of the semi-Markov process. In formal terms, we can compute the embedded Markov Chain and parameters of the waiting time distribution. In substantive terms, we can see the effect of aspects of the world of work and status-role of the individual on mobility patterns. Table 6 gives the distribution of waiting times for all types of moves according to the disaggregations.

3.5 Computation of Parameters of the Waiting Time Distribution

The parameters of the Gamma distribution, which represents the waiting time distribution, may be computed from the data in Table 6. By using this data, maximum likelihood techniques given in Appendix D may be used.

TABLE 6

NUMBER OF ONE-TIME MOVES MADE BY DIFFERENT TIME POINTS

Moves	By Year	Total	Variable					
			Male	Female	Self-employed	Non-self-employed	Non-growth	Growth
Upward								
Non-manual to Professional-manager	1964	6	4	2	0	6	1	5
	1966	5	5	0	0	5	3	2
	1970	16	13	3	1	15	11	5
Manual to Professional-manager	1964	2	2	0	0	2	0	2
	1966	2	2	0	0	2	0	2
	1970	7	7	0	0	7	3	4
Manual to Non-manual	1964	9	8	1	2	7	7	2
	1966	5	4	1	0	5	1	4
	1970	19	16	3	1	18	11	8
Downward								
Professional-manager to Non-manual	1964	7	4	3	4	3	4	3
	1966	3	3	0	0	3	1	2
	1970	5	3	2	2	3	2	3
Professional-manager to Manual	1964	0	0	0	0	0	0	0
	1966	2	2	0	0	2	1	1
	1970	1	1	0	0	1	0	1
Non-manual to Manual	1964	4	3	1	1	3	2	2
	1966	9	8	1	1	8	8	1
	1970	4	1	3	0	4	3	1

Since we are interested in movement over time, the events represented by the random variable is whether or not a move occurs by a given time. In turn, Table 6 can be interpreted as the observed frequency with which each of the random variables occur for different types of moves, disaggregated with respect to the background variables of sex, self-employment status, and the industrial location of the occupation. The random variable, X_i, has the value of 1, 3, and 7 years respectively for the index i having the value 1, 2, or 3. The value is the number of years since the initial point of observation, 1963. For example, among males moving from the non-manual to professional-manager state the frequencies are 4 for X_1, 5 for X_2, and 13 for X_3. The information given in Table 6 is necessary and sufficient to compute the maximum likelihood estimates of the waiting time distribution.

Table 7 lists the estimated maximum likelihood mean for each of the distributions assuming the distribution takes the form of a Gamma function. Knowing the value of each random variable, and the frequency of each random variable from Table 6, the mean value, of $\bar{X}$ can be computed. Next the natural logarithm of each value of the random variable is computed. These values and $\bar{X}$ are then used to compute the right hand side of the equation in Appendix D which gives the value of $\hat{r}$. This computed value falls within the range of 0 to 1. This value is compared to different values of $\hat{r}$ that are manipulated to compute the left hand side of the same equation. Some of these values are listed in Appendix D. The value of $\hat{r}$ is

TABLE 7

MEANS OF THE WAITING TIME DISTRIBUTION

Type of Move	Total	Variable					
		Male	Female	Self-employed	Non-self-employed	Non-growth	Growth
Upward							
Non-manual to Professional-manager	0.609	0.600	0.652	0.429	0.619	0.862	0.783
Manual to Professional-manager	0.579	0.579	-----	-----	0.579	0.429	0.706
Manual to Non-manual	0.630	0.637	0.400	1.000	0.609	0.655	0.600
Downward							
Professional-manager to Non-manual	0.882	0.882	0.882	1.000	0.817	1.000	0.800
Professional-manager to Manual	1.386	1.386	-----	-----	1.386	1.000	1.200
Non-manual to Manual	0.865	2.827	0.400	2.000	0.817	0.828	1.000

approximated by seeing the closeness of the right hand side of the equation to the manipulated value of r given the left hand side of the equation. If this estimated value, $\hat{r}$, is divided by $\bar{X}$, from the right hand side of the equation, the result is $\hat{\alpha}$, the other parameter of the Gamma distribution. When $\hat{r}$ is divided by $\hat{\alpha}$, the result is the mean of the waiting time distribution, given in Table 7.

Using the estimated values of $\hat{r}$ and $\hat{\alpha}$, the variance of the waiting time distribution can be computed as $\hat{r}$ divided by the square of $\hat{\alpha}$. The results of these computations are given in Table 8, the variance of the waiting time distributions. The maxpoint of the waiting time distribution may be computed by computing $\hat{r}$ minus 1 and dividing this result by $\hat{\alpha}$. Table 9 gives the number of years post 1963, in which the number of moves were maximized. Finally, Table 10 presents the values of $\bar{X}$ for each type of move. In substantive terms, Table 10 gives the observed average waiting time in years for a given type of move. Since the intent of our work is the substantive meanings of these findings, the results of Tables 7 to 10 cannot be discussed independently from the rest of our work. Hence we defer a discussion of our findings until the next chapter.

TABLE 8

VARIANCES OF THE WAITING TIME DISTRIBUTION

Type of Move	Total	Variable					
		Male	Female	Self-employed	Non-self employed	Non-growth	Growth
<u>Upward</u>							
Non-manual to Professional-manager	0.123	0.120	0.142	0.061	0.128	0.149	0.204
Manual to Professional-manager	0.112	0.112	-----	-----	0.112	0.061	0.166
Manual to Non-manual	0.132	0.135	0.080	0.333	0.124	0.143	0.120
<u>Downward</u>							
Professional-manager to Non-manual	0.259	0.259	0.259	0.333	0.223	0.333	0.213
Professional-manager to Manual	0.320	0.320	-----	-----	0.320	0.333	0.240
Non-manual to Manual	0.249	0.999	0.080	1.000	0.223	0.229	0.333

TABLE 9

TIME AT WHICH THE MAXIMUM NUMBER OF MOVES OCCURS OF THE WAITING TIME DISTRIBUTION IN YEARS POST 1963

Type of Move	Total	Variable					
		Male	Female	Self-employed	Non-self-employed	Non-growth	Growth
Upward							
Non-manual to Professional-manager	3.284	3.333	3.067	4.662	3.238	4.640	2.554
Manual to Professional-manager	3.454	3.454	-----	-----	3.454	4.662	2.833
Manual to Non-manual	3.174	3.140	5.000	2.000	3.284	3.053	3.333
Downward							
Professional-manager to Non-manual	2.268	2.268	2.268	2.000	2.448	2.000	2.500
Professional-manager to Manual	3.608	3.608	-----	-----	3.608	2.000	4.166
Non-manual to Manual	2.312	2.476	5.000	1.500	2.448	2.415	2.000

TABLE 10

OBSERVED AVERAGE WAITING TIMES IN YEARS

Type of Move	Total	Variable					
		Male	Female	Self-employed	Non-self-employed	Non-growth	Growth
Upward							
Non-manual to Professional-manager	4.93	5.00	4.60	7.00	4.85	5.80	3.83
Manual to Professional-manager	5.18	5.18	----	----	5.18	7.00	4.25
Manual to Non-manual	4.76	4.71	5.00	3.00	4.93	4.58	5.00
Downward							
Professional-manager to Non-manual	3.40	3.40	3.40	3.00	3.67	3.00	3.75
Professional-manager to Manual	4.33	4.33	----	----	4.33	3.00	5.00
Non-manual to Manual	3.47	2.83	5.00	2.00	3.67	3.62	3.00

This chapter of the dissertation has discussed methodological issues. We initially discussed the substantive aspects of our analysis, modifying information obtained as part of a voting study in Great Britain from 1963 to 1970 by Butler and Stokes. We indicated how this data met the scope conditions of our research and indicated how editing of the data resulted in a closed system of mobility. Since this is pre-collected panel data, we noted the possible hazards involved in the use of this data. After the data was operationalized according to the variables of occupational state, sex, self-employment status, and the industrial location of the occupation, we mentioned how a series of contingency tables could be created to give us all the information needed to estimate the parameters of the semi-Markov process, especially the waiting time distribution.

The next chapter of the dissertation discusses the results of our analyses. We then draw some summaries and conclusions as to the further use of the semi-Markov model in the study of mobility.

CHAPTER IV

FINDINGS OF THE RESEARCH

This final chapter of the dissertation discusses our analysis of the waiting time distribution and draws conclusions with respect to the feasibility of this approach for the development of a formal theory of social mobility. Initially we will discuss our findings with respect to the axiom of cumulative inertia (mobility decreases as the time spent in a given occupation increases). This will be followed by an analysis of the statistics of the waiting time distribution considering the background factors of sex, self-employment status, and growth rate of the industrial location of the occupation, differentiating between upward and downward moves. Finally, this type of analysis will be repeated but within upward and downward moves and between the conditions of the background factors.

There is a difference in these three types of analyses. The analysis of the number of one-time moves made by different time point, given in Table 6, allows us to see if there is any consistent pattern in the frequency of increase or decrease of moves over time. This will allow us to test the axiom of cumulative inertia. The second and third types of analyses attempt to substantively interpret the statistics of the waiting time distribution, given in Tables 7 to 10. The second type of analysis compares the statistics for upward and downward moves for the same pair of states. For example, we will ask if there is a difference in the statistics for moves upward from the non-manual to professional-manager state, compared to moves downward from the professional-manager to non-manual state. The third type of analysis compares the statistics of males and females, self-employed and non-self-employed individuals, and non-growth and growth industrial locations of the occupations of the individual. The three analyses are not meant to be causal analyses. The analyses only deal with the association of background variables and mobility patterns for given types of moves. After our analysis, we will discuss how the research reflects upon the feasibility of this approach.

Our research is different from previous studies of mobility since we have studied structural aspects of career mobility that are antecedent or concurrent with mobility, such as sex, self-employment status, and the growth rate of the industrial location of the occupation. Unlike the majority of most studies of mobility, we have considered the industrial location of the occupation to be problematic.

Since the number of moves that occur is small when information about the three background factors is introduced, we will present only a qualitative and descriptive account of our findings. As the number of moves is small, statistical tests of significance are not appropriate.

4.1 Analysis of the Waiting Time Distribution

One of the central axioms of mathematical models of mobility is the axiom of cumulative inertia (McGinnis, 1968). In formal terms, the axiom of cumulative inertia states 'the probability of remaining in any state increases as a strict monotonic function of duration of prior occupancy of that state' (McGinnis, 1968). This would mean the frequency of the number of moves from a state of origin to a state of destination should decrease as the time waiting in the state of origin increases.

The axiom of cumulative inertia has at least two formal interpretations. First, since it is a strict monotonic function, any part of its domain will be a strict monotonic function. Hence the frequency of moves from the state of origin to a given state of destination should decrease over time. (Since the Gamma distribution is not a strict decreasing monotonic function, we did not bias our analyses by trying to estimate a function that will have the strict monotonic property.)

For example, the first interpretation of the axiom of cumulative inertia, as applied to our data, would imply the number of moves by 1970 would be less than the number of moves made by 1966 for a given state of origin and destination. Likewise, the number of moves made by 1966 would be less than the number of moves made by 1964 for a given state of origin and destination. The first formal interpretation of the axiom of cumulative inertia means given the fact a move occurs, the frequency of this type of move occurring decreases over time. This means the time waiting in the state of origin increases over time. Hence, the first interpretation of the axiom is conditioned on the fact a move occurs.

Alternatively, the axiom of cumulative inertia may be interpreted as not being conditioned on the fact a move occurs. From this viewpoint, our data supports the axiom since most individuals do not move, although we have observed them for a long period of time, seven years. Of our sample of 511 individuals, only 106, or 20.7% of our sample made moves to a state of destination different from the state of origin and remained at the state of destination.

We feel the axiom of cumulative inertia is ambiguous since it does not explicitly state whether or not a move occurs. The findings that support the axiom, for example Morrison's work on migration (Morrison, 1973) and Tuma's work on occupational mobility (Tuma, 1972, 1975), indicate the axiom holds. These findings do not assume the axiom is conditional on whether or not a move occurs, since they look at the entire sample. We are asking if a move occurs, what does it look like, and what is the pattern of the frequency of occurrence of these moves as the waiting time in the state of origin increases.

If we collapse the data in Table 6 by disregarding the type of move, we find 71 of the 106 moves, 67.0% of the moves, are upward, and 35 of the 106 moves, 33.0%, are downward. For the 71 upward moves, 17 occurred by 1964, 12 by 1966, and 42

by 1970, which is not decreasing over time. This violates the axiom of cumulative inertia. Likewise, for the 35 downward moves, 11 occurred by 1964, 14 by 1966, and 10 by 1970. This also violates the axiom of cumulative inertia. If we combine the upward and downward moves, of the total of 106 moves, 28 occurred by 1964, 26 by 1966, and 52 by 1970. This also violates the axiom of cumulative inertia.

In general, we observe in Table 6 a basic violation of the axiom of cumulative inertia. Indeed, the opposite pattern seems to hold: moves are maximized rather than minimized as time goes on.

This indicates the scope of the 'axiom' of cumulative inertia may be limited. To our knowledge, this is the first test of the axiom over a variety of background factors. Again, we note we may be over-emphasizing the significance of our findings since we are dealing with small sample sizes and a limited number of time points, 1963, 1964, 1966, and 1970. However, we feel the axiomatic status of the idea of cumulative inertia should be questioned and further tested.

The only type of move that seems to follow the pattern of the axiom of cumulative inertia is downward moves between the professional-manager and non-manual states. Upward moves reveal the opposite type of pattern: a non-monotonic pattern with the exception of self-employed individuals moving from the manual to non-manual state. The dominant pattern in downward mobility seems to be a convex or non-monotonic pattern, with the exception of females, self-employed individuals, and individuals in non-growing industries moving from the non-manual to manual states. Within the background variables, the same patterns hold with the exceptions noted above. Other exceptions occur for upward moves from the manual to non-manual state, and from the non-manual to professional-managerial state in non-growing industries.

Our main conclusion is the number of moves over time is not a monotonic decreasing function of time, which would be a formal consequence of the axiom of cumulative inertia. However, there is no consistent pattern between the background variables or between the types of moves that would allow us to adduce a counter axiom.

In many cases the addition of one move to a specific state may result in different conclusions. Hence, any statements made with respect to the waiting time distribution are speculative. This would especially apply to moves between the professional-manager and manual states, since they occur infrequently. In addition, we are considering the self-employment status and industrial location of only the 1963 occupation. This should not confound our analysis since we are concerned only with moves that originated in 1963 and have no intermediate states. Finally, we are not concerned with the possible interactions of the background factors. This may explain some of the observed patterns of moves but would further reduce the number of cases analyzed.

Analysis of the distribution of moves by years in Table 6 indicates the period from 1963 to 1970 was a period of more upward than downward moves. There are a total of 71 upward and 35 downward moves. Even within the conditions of the background variables of sex, self-employment status, and industrial location of the occupation, the same pattern seems to hold: there are more upward than downward moves, with the exception of self-employed individuals. Within each type of move, moves between non-adjacent states occur the least, or are non-existent for females and self-employed individuals. This may be an artifact of the under-sampling of these groups compared to the entire sample. Finally, the total of 106 moves without intermediate states is 20.7% of the 511 individuals in our sample. All of this information is concurrent with the belief modern industrial societies are dynamic, with a tendency toward upward mobility.

Within the background variables the number of observed moves can be compared to the expected number of moves by comparison with what would be expected if we computed the proportion of individuals in each condition of the background variables for each type of move.

We can compute the proportion of the sample in each condition of the background variables from Table 5. Of the sample of 511, 441 or 86.4% are male, and 13.6% of the sample are female. Forty-four of the 511, or 8.6% are self-employed, and 91.4% of the sample are non-self-employed. Finally, 209 of the 511, or 40.9%, are in non-growth industrial locations of employment, and 59.1% of the sample are in growth industrial locations of employment. Hence under the assumption the conditions of background variables have no bearing on mobility, we would expect 86.4% of all moves to be made by males, and 13.6% by females. Likewise, we would expect 8.6% of all moves to be made by self-employed individuals, and 91.4% by non-self-employed individuals. Finally, we would expect 40.9% of all moves to be made by individuals in non-growth industrial locations of employment, and 59.1% by individuals in growing industrial locations of employment.

We can compute the actual proportion of moves for the conditions of the background variables from Table 6. Of the 71 upward moves, of the total of 106 moves, 61 of the moves, or 85.9% are made by males. Of these moves, 14.1% are made by females. Four of the 71 moves, or 5.6% of the moves are made by self-employed individuals. Non-self-employed individuals made 94.4% of these moves. Of the 71 moves, 37 or 52.1% are made by individuals in non-growth industrial locations of the occupation; 47.9% of the moves are made by individuals in growing industrial locations of the occupation.

In addition, there are 35 downward moves. Twenty-five of the 35 moves, or 71.4% are made by males. Of these moves 28.6% are made by females. Eight of the 35 moves, or 22.9% are made by self-employed individuals. Twenty-one of the 35 moves, or 60.0% are made by individuals in non-growth industrial locations of the occupation; 40.0% are made by individuals in growing-industrial locations of employment.

Hence, with respect to sex, females seem to slightly over contribute to upward moves, which is contrary to our expectations about sexism. However, consistent with these expectations, females also over contribute to downward moves. With respect to self-employment status, the pattern of upward moves is near what is expected, but self-employed individuals contribute more to downward moves than non-self-employed individuals. This seems to go along with the idea industrialization means the end of the self-employed individual. Finally, with respect to the industrial location of the occupation, non-growth industrial locations of the occupation seemingly over contribute to all types of moves. If we examine this pattern in greater detail, we observe non-growing industries over contribute to one step upward moves but are under represented in moves between states one and three. This may reflect the limited number of vacancies in the non-growing industry at the upper level compared to the growing industry. With respect to downward mobility, the only finding contrary to our expectation is for moves from the non-manual to the manual state, which are over represented by individuals in non-growing industries. This is surprising, since due to the increased tendencies toward automatic controls and skilled labor we would expect little or no moves of this type.

We have argued that the waiting time distribution follows a Gamma distribution. The finding that the pattern of moves does not follow the axiom of cumulative inertia does not prohibit us from using the Gamma function, since the Gamma function is non-monotonic over its entire domain. Only the special form of the exponential function is monotonic. Hence we can analyze the distribution in terms of the mean, variance, and maxpoint, which are all partial consequences of the observed average waiting time. Note the Gamma distribution is not the only function that may satisfy these statistics. This is a problem of identification which is beyond the scope of this dissertation. Again, we note any findings based on these statistics must be regarded as tentative and possibly artificial due to the limited number of data points and small sample size.

Before we detail our findings with respect to the statistics of the Gamma distribution we can state our findings in terms of the observed average waiting time, Table 10, since this information is central to the estimation of these statistics. Although the observed average waiting time is a summary statistic, it involves some idea of the distribution of moves over time. We note that the observed average waiting time for upward moves to occur is longer than for downward moves with the exception of moves between non-adjacent states. Hence, coupled with the findings given earlier for the number of moves in Table 6, more upward than downward moves occur, but they occur at later time points. Within each type of move, moves between non-adjacent states have the longest average waiting time, with one exception. We also see there is no relationship between the frequency of the move and the average waiting time until a move of that type occurs.

The maxpoint in Table 9, the time at which the number of moves is maximized, follows the same pattern with two minor exceptions: males and non-self-employed individuals in moves between non-adjacent states. These exceptions occur when these types of moves are infrequent so this observation may be an artifact of the small sample size.

With respect to the remaining statistics of the Gamma distribution, the mean, in Table 7, and the variance, in Table 8, a consistent pattern occurs: downward moves have larger means and variances than upward moves. This is a logical consequence of the observed average waiting time since the mean and variance is mathematically related in a reciprocal manner to the observed average waiting time. This would imply upward moves are more concentrated than downward moves.

Our final set of findings to be reported involves the use of background variables to ascertain whether different patterns of mobility exist for males versus females, for self-employed versus non-self-employed individuals, and for individuals in growth and non-growth industrial locations of the occupation. With respect to sex we find males wait longer than females for upward moves between the top two states and females wait longer than males for downward moves between the two bottom states. This seems surprising given the last-hired, first-fired belief regarding the career patterns of females independent of the level of the occupation. This would lead us to believe a consistently higher average waiting time for females in upward moves and lower average waiting time for females in downward moves compared to males.

The same pattern is obtained for the variable of self-employment status as for sex with the exception that self-employed individuals always exhibit shorter average waiting times if downwardly mobile than non-self-employed individuals. This is a surprise finding since we expected the opposite pattern due to the nature of self-employment. Personal investment in equipment and the development of a clientele are necessary to the self-employed individual which would lead us to believe a downward move would be made as a last resort. However, the opposite patterns seem to hold.

The same patterns hold for the statistic of the maxpoint as for the observed average waiting time: males and self-employed individuals maximize their frequency of upward moves from state two to state one at later time points than females and non-self-employed individuals respectively while the opposite pattern holds for downward moves between states two and three. The opposite set of patterns holds for the mean and variance. This indicates upward moves between states two and one for males and self-employed individuals and downward moves between states two and three for females and non-self-employed individuals are more concentrated than for the opposite conditions of the variables involved.

The background variable of the industrial location of the occupation in terms of the growth of the number of full time workers reveals a more complex pattern than the pattern for the variables of sex and self-employment status. Individuals in non-growing industries who make upward moves, make these moves at later time points and have a greater frequency of moves at the later time point than individuals in growing industries making the same kind of move. Conversely, this also holds for individuals in growing industries making downward moves compared to individuals in non-growing industries making the same type of move. The only exception to this pattern is moves between the two bottom states. Likewise, with this same exception, individuals in non-growing industries making downward moves and individuals in growing industries making upward moves wait longer for these types of moves than individuals in growing and non-growing industries respectively making the same type of move. The maxpoint, with slight exceptions, follows this pattern while the mean and variance follow the opposite pattern.

This seemingly conflicting set of findings seems to indicate some pattern with respect to the creation of vacancies as a function of the industrial location of mobility. If mobility occurs, there must be a vacant position to which one moves. Non-expanding industries have few vacancies, hence upward mobility will be restricted, while growing industries create vacancies. At the same time, the contraction of non-growing industries may account for the volatile nature of downward moves.

We can substantively summarize our findings by grouping them into three sets, findings with respect to the distribution of moves over time, findings of upward versus downward moves, and findings of various conditions of the background variables:

A. Findings with respect to the distribution of moves:

1. More upward than downward moves occur, independent of background factors.

2. Females are more overrepresented in moves than males. Self-employed individuals are overrepresented in downward moves compared to non-self-employed individuals. Individuals in non-growing industries are overrepresented in moves between adjacent states if the move is upward or downward from the nonmanual to the manual state. However, individuals in non-growing industries are underrepresented in other types of downward moves.

3. There is a basic violation of the axiom of cumulative inertia. Observed patterns of moves are not a monotonic decreasing function of time. They are non-monotonic, and in many cases convex functions.

B. Findings with respect to the type of move:

1. With one exception, the average time to wait until an upward move occurs is longer than the wait until a downward move occurs.

2. With one exception, the average time to wait until a move between non-adjacent states occurs is longer than the wait until a move between adjacent states occurs.

3. There is no relationship between the frequency of the type of move and the average time to wait until a move occurs.
4. The time at which moves occur with the greatest frequency follows this pattern with minor exceptions.
5. Downward moves are more dispersed over time than upward moves irrespective of background factors.

C. Findings with respect to the background variables:

1. Females are not necessarily "last-hired, first-fired." In many cases, the opposite pattern holds, especially with shortened waits for upward moves and longer waits for downward moves at the extreme ends of the occupational continuum.
2. Non-self-employed individuals seem to wait shorter than self-employed individuals for moves to the top state but seem to wait longer for downward moves than self-employed individuals. Hence being downwardly mobile is abetted by being self-employed, especially if one is a professional-manager. This is contrary to our intuition and may be an artifact of the greater degree of socialism in Great Britain than in the United States.
3. The growth rate of the industrial location of the occupation indicates mobility is related to the creation of vacancies. Upward moves in

growing industries, with one exception, have small waiting times, since vacancies must be filled. Conversely, non-growing industries exhibit more dispersed but earlier moves, with one exception.

This summary of our findings indicates the procedure employed is feasible but raises more substantive issues than it lays to rest. The final section of the dissertation is concerned with future work that should be conducted to further investigate these new substantive issues.

CONCLUSION

Despite the substantive issues implied by our findings, especially with respect to the axiom of cumulative inertia and sex as a background factor, our conclusions are tentative due to the small sample size and the limited number of observed data points. To repeat these findings, first, with respect to the axiom of cumulative inertia, we did not find a tendency for the frequency of a move to decrease as duration in a state increases. This casts doubt on the axiomatic status of the idea of cumulative inertia. Second, we did not find females are always last hired and first fired. Females are not necessarily more immobile than males, nor do females wait longer for upward moves and shorter for downward moves compared to males.

Patterns of mobility have been revealed that are counter intuitive and which should prod further research. The doubt cast on the axiom of cumulative inertia and inconsistent patterns of mobility when information about sex and self-employment status of individuals is introduced forces us to reconceptualize our ideas about mobility.

The findings given information on the industrial location of the occupation in terms of growth of number of employees is a step of analysis needed antecedent to vacancy chain analysis. We observed that if the individual is in a growing industrial location of the occupation, compared to individuals in non-growing industrial locations of the occupation, the first individual usually has a smaller waiting time until an upward move occurs. Growth may be interpreted as a set of vacancies which must be filled. Hence, we would expect the upward mobility of workers in growing industrial locations of the occupation to occur at earlier time periods compared to workers in non-growing industrial locations of the occupation.

Keyfitz (1973) has developed a model of migration that indicates the rate of movement in a society is a function of the general population of that society. In addition, Keyfitz implies his model may be applied to specific organizations. Using this idea, we feel the pattern of upward moves in an industry is a function of the rate of expansion of the industry. An increase in the number of subordinates seems to push individuals in higher positions in the upward direction, while the creation of positions at higher levels pulls individuals at lower levels in the upward direction (Keyfitz, 1973). Hence any future work using our approach should investigate the hypothesis the waiting time in a state of origin is related to the size of the social organization in which the individual is located.

We note our findings may not hold in all sets of data. For example, some of our findings, especially with respect to the axiom of cumulative inertia, are contrary to previously held findings (Tuma, 1972), but, to our knowledge, provide the first test of the axiom of cumulative inertia in an industrial society where possible effects of the social structure and world of work of the individual are considered. In addition, the data set, Great Britain, is a fresh data set that has not been artificially manipulated like other data sets, such as Mayer's (1972) manipulation of the Blau and Duncan (1967) data.

The inadequacy of previous mobility studies resulted in our study of the reconceptualization of mobility in terms of the semi-Markov model. This final part of the dissertation discusses the data requirements of future studies, as well as other implications of our research. In order to do this we need to state the nature of a research program required to develop a theory of mobility. Our work indicates the feasibility of embarking on such a research program.

The data should be longitudinal which would require continual monitoring of individuals. Initially we would record the sex, age, and race of the individual, increasing the age by one year in each subsequent interview. By using Census scales we could record the occupation of the individual, and use Social Security classifications to record the industrial location of the occupation. Any change in either in the past twelve months would be noted and further questioned to determine the duration in the occupation or industry. Since the world of work is central to our analysis, we would ask if the worker is self-employed or salaried, the type of employer, supervisory status, and the size of the organization where the occupation is located. Finally, by means of Department of Commerce information, the growth rate of the industrial location of employment can be calculated.

The result would be a series of vectors for each individual in the work force giving information from which the waiting time distribution could be computed. This distribution would be disaggregated according to the various conditions of the elements of the vector that reflects aspects of the status-role and world of work of the individual such as sex, self-employment status, and growth rate of the industrial location of the occupation, following procedures analogous to those in Chapter 3.

Future work can also extend the rudimentary formal work presented in this dissertation. Since we have estimated the parameters of the Gamma distribution and have the embedded Markov Chain, we can simulate the semi-Markov process. We originally intended to conduct such a simulation as part of our dissertation, but this proved to be beyond our means, given the fact the simulation implies the feasibility of what is to be simulated. This dissertation has indicated the feasibility of simulating the semi-Markov process. The simulation is straightforward given the waiting time distribution and embedded Markov Chain. Mayer (1972) suggests the simulation is realized by sampling from the initial distribution, in our case 1963, then using the embedded Markov Chain to select the next state, and randomly determining the length of time spent in the initial state before a move to next state occurs by the waiting time distribution.

We could also graph the Gamma distribution for various conditions of variables with types of moves, using points estimated from this graph to fit actual data. We have data for the initial time point, and for t_1, t_3, and t_7 for 1963, 1964, 1966, and 1970 respectively, plus an additional point for the maxpoint. Such graphic analysis may reveal the axiom of cumulative inertia exists over only specific time domains.

Finally, one could attempt to get a symbolic solution to the equations of the semi-Markov process given in Appendix A, for specific embedded Markov Chains and waiting time distributions. Cox and Miller (1965) and Gilbert (1972) have presented examples of this using a two state model with simple exponential waiting time functions. Even in this simple case, the algebra is quite laborious.

The use of computers with special symbolic manipulation languages, like MATHLAB, may aid the symbolic analysis. For example, MATHLAB involves direct interaction with the computer giving symbolic solutions to matrix differential equations by treating symbolic strings as partial fractions of rational polynomials (Monove, et al., 1968).

Future work must concentrate on the interactions of background factors. Interaction is important since the status-role of the individual varies in terms of compatibility with different organizational settings of work and different types of rewards due to the investment of the individual in the work role. We have indicated mobility is contingent on the time spent in an occupation which reflects the world of work of the individual and salient features of social differentiation. These factors, for example sex, self-employment status, and economic growth, affect the life style and life chances of the individual due to patterns of inequality in industrial societies. These patterns of inequality affect the level of job satisfaction, which in turn determines the propensity to be mobile. Hence our reconceptualization of mobility is a reformulation that attempts to develop a formal theory of mobility.

The interaction effects are critical to a formal theory of mobility since mobility is defined in terms of criteria based upon a mixture of achieved and ascribed status factors. Ascribed criteria may incur institutionalized inequalities which dominate achieved criteria. For example, a female given a chance to be mobile due to an affirmative action program may not take advantage of the promotion since it may conflict with her self-evaluation or be discrepant with her spouse's work role. Exchange theory in social psychology postulates investment in the work role and adaptation of the individual to different types of organizations determines the level of job satisfaction of the individual (Blauner, 1964).

A formal theory of mobility could be developed from such considerations, coupled with analyses of various disaggregations of the waiting time distribution. Specifically, a theory of mobility must concentrate on the industrial location of the occupation and economic milieu of the industry since, as we have indicated, it may determine the creation of vacancies. Expanding industries require increased manpower which may mean that a high level of achieved criteria is common to all workers, making ascribed criteria the chief determinant of mobility by default, assuming aspects of the individual's status-role determine mobility. The opposite may hold in non-expanding industries. This idea is an expansion of work done on the career-life interests of managers (Goldman and Harry, 1973). Hence our goal would be to develop a theory of mobility around the following counter-intuitive hypotheses which would be analyzed by the formal theory approach to sociology:

> <u>Hypothesis One</u>: Upward mobility is determined by achieved criteria at declining rates in rapidly expanding industries, and
>
> <u>Hypothesis Two</u>: Upward mobility is determined by ascribed criteria at declining rates in rapidly contracting industries.

This would be the result of interactions of aspects of the status-role and world of work of the individual and result in an explanation rather than description of mobility.

Note we have expanded the perspective toward mobility beyond consideration of the structure of the work organization per se, as in vacancy chain models (White, 1970; Stewman, 1975). Our work and the future work outlined earlier is the blending of the sociology of work and organizations with economic sociology. This would result in the development of an empirically based theory of macro-sociology.

Perhaps the lack of cumulative development of a theory of mobility in sociology is due to the failure to concentrate on what mobility looks like if it occurs. We have compensated for this omission by stressing the importance of the waiting time distribution and how the status-role and world of work affect mobility. We have concentrated on the link of theory and model rather than the link of data with theory or data with model since we considered the feasibility of mapping our reconceptualization of mobility using the semi-Markov model. Our use of the model is developed from theoretical considerations and indicates the data that needs to be collected. We have now just proposed a longitudinal research program that concentrates on formal theory construction as directing empirical studies. Hopefully this proposed research program will give us precision in theory construction. But we recognize the potential lack of precision due to the possible interaction of factors that may determine mobility.

The main contribution of our work is its theoretical development, not the sophistication of its formalization. We have asked if the semi-Markov model resulted in a feasible reconceptualization of mobility and, if so, does it tell us more about mobility than current theories and representations? We found positive answers to both questions.

Compared to the substantive importance of our dissertation given in our introduction, our proposed research program and conclusions superficially appear to be a non sequitur. The stated purpose of the dissertation was to determine some of the causes of mobility, given the fact mobility occurs. We argued this is important since mobility is a life-chance in advanced industrial societies and should be affected by socio-economic factors. We selected three of these factors for analysis, the sex, self-employment status, and growth rate of the industrial location of the occupation of the individual. Our analysis did not reveal any significant findings beyond the violation of the idea of cumulative inertia, the unimportance of sex as a factor determining mobility, and the creation of vacancies in an industry as being a plausible reason to explain differential rates of upward mobility.

We can draw three final conclusions from our work. One, we looked at the wrong factors or looked at them in the wrong way, e.g., ignoring interactions. Two, we used the wrong research design, since the empirical requirements of the semi-Markov model are only minimally met by our sample. Three, mobility exists as a social factor, sui generis, like power, the division of labor, conflict, etc.

We have not indicated any fixed patterns of mobility, nor have we indicated empirical regularities that may explain the incidence and form of mobility in industrial societies. We have indicated the use and feasibility of the semi-Markov model. We have not indicated the background factors of sex, self-employment status, and the industrial growth rate of the occupation are determinates of mobility. Hence our main conclusion is no conclusion can be given.

We feel mobility is a concept in its own right, like shade in art, bonding in chemistry, and motive in psychology.

We have attempted to explicate the concept of mobility by asking what the concept looks like, if it occurs, and what factors may be antecedent to the occurrence of the concept of mobility. We have only begun to realize our ignorance of the concept of mobility.

APPENDICES

APPENDIX A

MATHEMATICAL MODELS

This appendix presents the basic models that lead up to the semi-Markov model and the semi-Markov model. The appendix assumes the reader has a knowledge of matrix notation and understands some rudiments of stochastic processes. P(t) is the probability transition matrix at the time t and P^t is the t-th power of the probability transition matrix observed at the first interval. $\pi(t)$ is the distribution vector. A is the instantaneous change matrix.

In the simple Markov Chain, $\pi(t) = \pi(0)P^t = \pi(t-1)P$ and $P^t = P(t)$.

In the mover-stayer model, P(t) is disaggregated into a matrix of movers, M, and stayers, S, so

$$P = S + (I-S)M(1), \text{ and } P(t) = S + (I-S)M^t.$$

In McFarland's model there are m different types of individuals, each with a unique transition matrix, P(m). Note m = 2 in the mover-stayer model. To combine the different matrices, McFarland introduces a Boolean matrix, $N_o(m)$, for each m, where the diagonal entry is 1 if the individual is initially in state i, and all other entries are 0. If $N_o = \Sigma N_o(m)$, we get,

$$P(t) = N_o^{-1} \Sigma\ N_o(m)\ (P(m)^t)$$

The McGinnis and Cornell school of models introduces the idea of duration in a state, duration of period r. Hence ${}_rP(t)$ is the transition matrix for people in the t-th interval who have been in their states for r periods. Using a notation like in the mover-stayer model,

$${}_rP(t) = {}_rS + {}_rM$$

There is no general equation for the model although a unique equilibrium exists. Boudon (1973) presents iterative techniques for the model. The techniques recognize at time t there are 2^t types of people who move or stay in different patterns.

In the vacancy chain model, $Q1 + Q_o = 1$, where each element of matrix Q is the probability of a vacancy moving from state i to state j, Q_o is a vector representing the probability of a vacancy in a given state moving outside of the system, and 1 is a vector consisting of all elements equal to one. The probability distribution vector giving the probability a chain starting in state i terminates in n moves is

$$P_n = Q^{n-1}Q_o.$$

In Mayer's continuous time models,

$$P(t) = e^{At}$$

In the first model, the birth-death model, moves only to adjacent states are allowed. In this model,

$$a_{ij} = \begin{cases} \geq 0 \text{ if } |i-j| = 1 \\ \leq 0 \text{ if } i=j \\ = 0 \text{ if } |i-j| > 1 \end{cases}$$

In the second model, each term of A is weighted by a decay factor, so

$$A(t) = e^{-ct}A$$

In the final model each state is decomposed into a transient and absorbing state so 2n states exist. In the model,

$$A = \begin{array}{|c|c|} \hline B & C \\ \hline 0 & 0 \\ \hline \end{array}$$

where C is an absorbing matrix with only diagonal entries and the entire matrix has the properties of an instantaneous transition matrix.

In Tuma's model, the basic factors of interest are $f_j(t)$, the instantaneous rate of leaving state j, and $k_{ij}(t)$, the probability an individual of type i is attracted to state j at time t. The leaving process is uniquely determined by $f_j(t)$, since if $\overline{G}_j(t)$, is the expected proportion of the population in state j at time t, and $\overline{H}_j(t) = 1 - \overline{G}_j(t)$, then

$$\frac{d\,\overline{H}_j(t)}{dt} = \overline{h}_j(t) = f_j(t) \text{ X } \exp.\ (\overline{\ }\int_0^t f_j(u)du).$$

The attraction process is determined by a time-varying attraction factor, $a_{ij}(t)$, and the number of vacancies in state j at time t, $v_j(t)$, such that

$$k_{ij}(t) = a_{ij}(t)\ \frac{v_j(t)}{\sum_{m=1}^{n} v_m(t)}$$

Note if $f_j(t) = f_j$ for all t, Tuma's model is the instantaneous rate model.

The semi-Markov model consists of two sets of factors, the embedded Markov Chain, P, and the waiting time distribution. The latter will be discussed in detail in Appendix D which concentrates on the Gamma Distribution. The waiting time distribution for the relationship between states i and j, $F_{ij}(t)$, is defined as the time spent in state i before a move to state j, or

$$F_{ij}(t) = Pr\{T(t) - T(t-1) \leq \tau | X(t-1)=i, X(t)=j\}$$

The semi-Markov model uses the idea of a renewal density, or a transition from state i to state j associated with a duration in state i, and a sequence of events leading to all n states at time t-u followed by a transition to state j in an interval of length u.

This can be written as the matrix equation,

$$H(t) = M(t) + \int_0^t H(t-u)M(u)du,$$

where M(t) is the term by term concatenation of P and f(t), where $f(t) = \frac{dF(t)}{dt}$. Note if $f_{ij}(t) = f_i(t)$, irrespective of the state of destination, j, the semi-Markov model reduces to the leaving part of Tuma's model. H(t) has a solution that is found by Laplace Transforms since a convolution is involved. The solution, in terms of Laplace Transforms, is,

$$H(s) = ((M(s))(I-M(s))^{-1}.$$

The intent of the semi-Markov model is to compute P(t), whose elements are the probability of moving from state i to state j given a length of time t in state i. The equation for P(t) is similar to the renewal density equation, the probability of moving from i to j after being in i for a period of time t and surviving in j plus a sequence of events leading to all n states at time t-u followed by surviving a transition to state j associated with an interval of length u.

This can be written as a matrix equation,

$$P(t) = N(t) + \int_0^t H(t-u)N(u)du, \text{ where}$$

$N(t) = \int_0^t M(v)\, dv.$

The matrix equation has a solution in terms of Laplace Transforms of,

$$P(s) = (I+H(s))(N(s)).$$

All the results can be combined to get the equation,

$$P(s) = (1/s)\ (I-M(s))^{-1}(P-M(s)),$$

which does not involve computing the renewal density function. Hence P(t) can be computed directly from P and F(t).

Finally, due to a property of Laplace Transforms, the equilibrium distribution can be computed, since

$$P(\infty) = \lim_{s\to 0^+} sP(s).$$

APPENDIX B

QUESTIONS AND CODING OF RESPONSES

The part of the survey entitled "Household Composition and Occupational Details" provides the information used in our analysis. The relevant open-ended questions of the interview include:

- can you tell me who else there is in your household living here besides yourself? (give relationship to respondent, sex, age, whether or not in job, marital status)

- which member of your family living here is actually the owner/ is responsible for the rent?

- what type of firm or organisation (sic) does (householder) work for?

- what job does (householder) actually do? does he/she hold any particular position in the organization?

- (if in public service) what is his/her rank or grade?

- (if proprietor or manager) how many employees are there?

If the respondent is not the head of household, the questions were repeated.

Occupational Grade gives information about the occupational states. After editing out individuals who were not always in the panel, or state pensioners, or housepersons, or failed to give information, the following coded categories remained:

First, for interviews conducted in 1963 and 1964, for respondents only,

1. higher managerial, administrator, or professional
2. intermediate managerial, administrator, or professional
3. supervisory or clerical and junior managerial, administrator, or professional
4. skilled manual workers
5. semi-skilled and unskilled manual workers

Second, for interviews conducted in 1966 and 1970, for respondents only, and for heads of household in all years,

1. higher managerial or professional
2. lower managerial or professional
3. skilled or supervisory non-manual
4. lower non-manual
5. skilled manual
6. unskilled manual

In both scales, the five item and six item scale, the first two categories were grouped for the professional-manager state. Category three and categories three and four of the five and six item scales respectively were grouped for the non-manual state. The remaining states in each scale were grouped for the manual state.

Economic Status gives information about the background variable of self-employment status. After editing out individuals who were not always in the panel, or unemployed in any year, or housepersons, or failed to give information, the following coded categories remained:

1. self-employed with employees
2. self-employed without employees
3. managers
4. foremen/supervisors
5. other employees (includes all employed persons who have no direct managerial or supervisory responsibility)

Categories one and two were combined to designate self-employed individuals. The remaining categories designate non-self-employed individuals.

APPENDIX C

OCCUPATIONAL CODES

The variable of occupation is used to determine the industrial location of the occupation to find the effects of growth and non-growth on mobility patterns. After editing out individuals who were in the armed forces, or housepersons, or students, or unemployed, or failed to give information, or inadequately described their occupation in any year, the following gross categories of occupations remained:

CATEGORY NUMBER	OCCUPATION
I	Farmers, Foresters, Fishermen
II	Miners and Quarrymen
III	Gas, Coke, and Chemical Makers
IV	Glass and Ceramics Makers
V	Furnace, Forge, Foundry, Rolling Mill Workers
VI	Electrical and Electronic Workers
VII	Engineering and Allied Trade Workers
VIII	Woodworkers
IX	Leatherworkers
X	Textile Workers
XI	Clothing Workers
XII	Food, Drink, and Tobacco Workers
XIII	Paper and Printing Workers

CATEGORY NUMBER	OCCUPATION
XIV	Makers of other Products
XV	Construction Workers
XVI	Painters and Decorators
XVII	Drivers of Stationary Engines, Cranes, etc.
XVIII	Other Laborers
XIX	Transportation and Communication Workers
XX	Warehousemen, Storekeepers, Packers, Bottlers
XXI	Clerical Workers
XXII	Sales Workers
XXIII	Service, Sport and Recreation Workers
XXIV	Administrators and Managers
XXV	Professional, Technical Workers, Artists

APPENDIX D

THE GAMMA DISTRIBUTION

In Appendix A we noted the semi-Markov model requires a distribution of waiting times, $F(t)$. $F(t)$ is a monotonic probability distribution function.

In the Gamma distribution,

$$f(t) = \frac{\alpha}{(r-1)!}(\alpha t)^{r-1}(e^{-\alpha t})$$

and

$$F(t) = 1 - \sum_{K=0}^{r-1} \frac{e^{-\alpha t}(\alpha t)^K}{K!}$$

If $r = 1$ we get the exponential distribution. If used in the semi-Markov model, the result is the continuous time model, $P(t) = e^{At}$.

Using maximum likelihood techniques, we can get estimates for α and r, denoted $\hat{\alpha}$ and $\hat{r}$, from the observed time till a move occurs, X_i.

$\hat{r}$ is the solution to the equation

$$\ln r - \frac{\Gamma'(r)}{\Gamma(r)} = \ln \bar{X} - (1/n) \sum_{K=1}^{n} \ln X_i, \text{ where}$$

$\bar{X}$ is the mean time till a move occurs, and $\frac{\Gamma'(r)}{\Gamma(r)}$ is

$$\left[\sum_{K=1}^{r-1} \left(\frac{1}{K}\right)\right] - \gamma$$

where γ is Euler's constant (= .572157...)

The following is a partial table of r and values of

$$\ln r - \left(\frac{\Gamma'(r)}{\Gamma(r)}\right) .$$

r	$\ln r - \frac{\Gamma'(r)}{\Gamma(r)}$
1	0
2	.7295377
5	.1033124
10	.0508276
20	.0252067
50	.010..

Knowing $\hat{r}$, we estimate $\hat{\alpha}$ as $\frac{r}{\bar{X}}$. Hence we need information about the time till a move occurs for our estimation. The mean, variance, and maxpoint of the Gamma distribution is $\frac{r}{\alpha}$, $\frac{r}{\alpha^2}$, and $\frac{r-1}{\alpha}$ respectively.

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