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VACANCY CHAINS

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Abstract

The concept of vacancy chains, originally developed in Harrison White's pioneering analysis of organizational mobility processes, has been extended to phenomena as diverse as national labor and housing markets, the historical development of professions, gender and ethnic group discrimination in job and housing markets, organizational demography, and the mobility of hermit crabs to empty snail shells. In all populations in which they occur—whether human or animal—vacancy chains appear to organize a variety of social processes in nearly identical ways. This chapter provides a broad and relatively nonmathematical review of the vacancy chain literature covering basic definitions and formulations, main theoretical ideas and assumptions, comparisons of social processes in different vacancy chain systems, and several conceptual and methodological extensions to vacancy chain analysis. The review concludes by discussing a number of outstanding problems, present limitations, and promising areas for future research using the vacancy chain approach to mobility.

INTRODUCTION

Sociologists as well as economists and biologists often consider individuals who gain material resources or social positions as theoretically independent, virtually isolated entities. In this view what is done by one individual does not affect other individuals except in a simple negative way: If one individual gets a resource unit, other individuals do not; mobility is a zero-sum game. But in

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those cases where material resources or social positions are distributed through vacancy chain processes, things work differently. Here the mobility of several individuals is linked together: What happens to one individual at one point in time and space redounds to affect other individuals at other points in time and space. Because of this fact, studies of mobility through vacancy chains rely upon different theoretical conceptions and methodological techniques than do studies considering individuals as independent units of analysis. Application of the more standard theoretical concepts and methodological techniques to systems in which individuals actually move through vacancy chains can, consequently, produce misleading analyses of causes and patterns of mobility.

This chapter provides a broad and relatively nonmathematical review of the vacancy chain literature. It begins with basic definitions, moves to the common properties of all vacancy chain systems, continues with a variety of extensions based upon the vacancy chain concept, covers some outstanding problems in data collection and methodology, and concludes by contrasting the theoretical underpinnings of the vacancy chain approach to mobility with those of more standard approaches in sociology. This chapter suggests that resource distribution through vacancy chains organizes a variety of social processes in similar ways in any population in which it occurs—whether human or animal. So individuals who ostensibly have nothing in common—such as Methodist ministers moving to new and better pastorates, state police officers in Michigan gaining new jobs, buyers and renters acquiring new dwellings, people buying new and used cars, and hermit crabs occupying empty snail shells—are all alike in that they gain new physical resources or social positions through vacancy chain mobility processes (citations for these and other points will be given in the sections following this Introduction). Underneath all the apparent diversity of behavior, culture, and cognitive ability in these different systems, vacancy chains produce similar patterns of short-term mobility, generate about the same average number of mobility opportunities per chain, affect career and demographic distributions in the relevant systems in about the same way, and influence analogous patterns of aggregate benefits for mobile individuals as well as for other individuals connected to those moving.

In addition to these structural similarities in all the vacancy chain systems investigated, researchers have applied vacancy chain analysis to the study of other central problems in sociology including the operation of national, regional, and organizational labor markets; national and regional housing markets; gender and ethnic group discrimination in job and housing markets; the tracing of elite groups within professions; and the historical development of professional groups. Building upon the recent demonstration of the use of vacancy chains in animals, researchers have shown the importance of vacancy chain theory for a more adequate understanding of the behavior, demography, and ecology of species using this type of resource acquisition process.

BASIC DEFINITIONS AND FORMULATIONS

What Is a Vacancy Chain?

In a vacancy chain, a new resource unit coming into a population is taken by a first individual who leaves his/her old unit behind, this old unit is taken by a second individual leaving his/her old unit behind, and so forth. For example, if the president of a company retires, her job may be taken by a vice-president, his job by the head of sales, and so on. Eventually a chain has to end, usually when a new recruit enters the system—someone moving into the job or housing market for the first time—or the last unit in a chain is abandoned, merged, or destroyed—the last house in a chain is torn down, left empty, or the duties of a vacant job are distributed among other employees. Vacancy chains are started when an initial vacancy comes into a population—a new house is built, a new car manufactured, or a new job created—or an existing unit is vacated by someone leaving the system under consideration—an employee retires, a hermit crab dies leaving the snail shell it occupied intact, or a home owner goes to a nursing home.

A vacancy chain is simply the sequence of moves that a vacancy makes from initial entry into a system to final termination. Figure 1 shows a vacancy chain in the Methodist church taken from White's (1970: 68) study of mobility in three American churches. This chain starts with a retirement and ends with the recruitment of a newly ordained minister. The vacancy in this chain moves five times, starting with the initial move from the church on the extreme left and ending with the final move out of the mobility system. This chain provides mobility opportunities for five ministers—not counting the move to retirement for the minister creating the chain.

Conditions Required for Vacancy Chain Mobility

The distribution of material resources and social positions through vacancy chain processes requires that the things distributed possess a number of abstract qualities. These qualities include that the resource units in question are reusable, discrete, identifiable, and utilized by one individual or social group at a time. Further, in vacancy chain mobility systems, a unit must be vacant before it can be taken by a new occupant; individuals must need or want new and usually "bigger" or "better" units from time to time; vacant units must be scarce (the number is small compared to the number of individuals who want them); and most individuals in a group already must

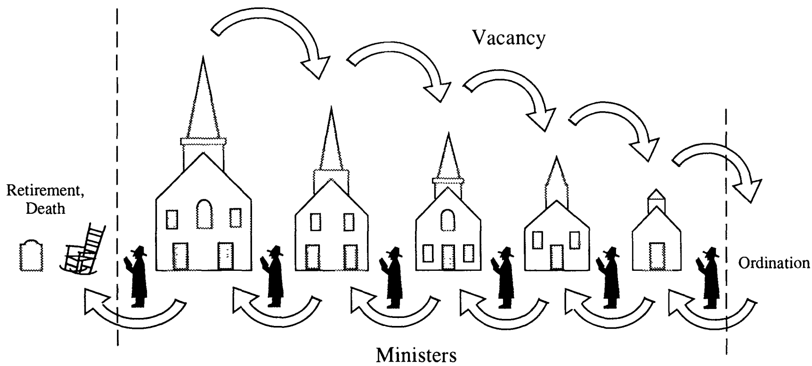

Figure 1 A sample vacancy chain from the Methodist church, from White (1970: 68).

have units so they can leave one behind when they move to a new one (the number of recruits is relatively small compared to the number of individuals already in the system). Combinations of social conventions, economic considerations, or the physical nature of the resource units can produce the general conditions required for distribution through vacancy chain processes. White (1970), Sørensen (1983), and Sørensen & Tuma (1981) discuss the nature of jobs in bureaucracies that allow them to be distributed through vacancy chains. Sørensen (1983) grounds his work on the earlier discussions of Boudon (1974), Thurow (1975) and Hirsch (1976). Later in this paper I suggest a variety of physical resources and social positions that possess the requisite qualities for distribution through vacancy chains but which have not yet been investigated.

Collecting Vacancy Chain Data

In order to trace a vacancy chain, a researcher notes a vacancy coming into a system and then follows this vacancy as it moves to a number of resource units in turn and then finally leaves the system. Because vacancy chains in humans often take considerable periods of time, on the order of months, to move from beginning to end and because the chains often involve people widely scattered geographically, researchers usually trace the chains by reconstructing them from organizational records or from series of linked interviews. For example, White (1970) used yearbooks listing ministers and their churches to trace chains, and Lansing et al (1969) followed chains across the United States by interviewing families moving into new houses, the families replacing them at their old addresses, and so forth. In contrast, vacancy chains in snail shells utilized by hermit crabs move from beginning to end in about an hour within a restricted physical area, and researchers (Chase & DeWitt 1988, Chase et al 1988) directly observed these chains and were able to record some on videotape. Hermit crabs do not have protective exoskeletons completely covering their bodies as regular crabs do, so they must live in and continually carry around empty snail shells as portable shelters. The observers traced vacancy chains in this species by introducing an empty snail shell into a tidal pool and recording the sequences of moves initiated as a first crab took the new shell and left its old one behind.

Transition Matrix

A transition matrix summarizes the raw data from a set of vacancy chains; in the form of a transition frequency matrix it shows all the movements that a set of vacancies make, including the terminal moves—those outside the system that end chains (when new recruits take final units or final units are abolished, abandoned, or destroyed). Table 1 gives a matrix showing the frequencies of moves made by a set of 92 vacancy chains for hermit crabs moving to empty snail shells (Weissburg et al 1991). Taking the first row of the matrix, for example, vacancies moved two times from old shells of size 1 to new shells also of size 1, seven times from size 1 to size 2 shells, etc, while one vacant size 1 shell was abandoned and left unclaimed. In contrast to other kinds of mobility studies, this matrix shows the moves of vacancies rather than individuals, because in vacancy chain systems vacancies are causal: they must exist first, before individuals can move. But the movements of individuals can be inferred from the movements of vacancies, for example, in cell (1,3) of the matrix, vacancies moved nine times from size 1 to size 3 shells, and the same number of individuals moved in the opposite direction, from old size 3 shells to new size 1 shells.

If the cell entries in a matrix showing frequencies are divided by their respective row totals, a new matrix showing the maximum likelihood estimates of the probabilities of a vacancy moving between various strata of resource units results. These matrices are referred to as transition probability

Table 1 Transition frequency matrix for vacancy moves in snail shells by hermit crabs from Weissburg et al (1991)[a]

	Destination state							
	Transient states					Absorption states		
Origin state	1	2	3	4	5	Naked[b]	Abandoned[c]	Total
1[d]	2	7	9	2	0	0	1	21
2	0	3	19	17	1	0	2	42
3	0	2	20	11	10	4	23	70
4	0	0	10	26	26	6	24	92
5	0	0	0	5	22	2	30	59

[a] Reproduced with permission from *Evolutionary Ecology*
[b] Termination by crabs without shells taking the last shell in a chain
[c] Termination by the last shell in a chain not being taken
[d] State 1 shells are the largest and state 5 shells are the smallest.

Table 2 Transition probability matrix for vacancy moves in snail shells taken by hermit crabs from Weissburg et al (1991)[a]

	Destination state						
Origin state	1	2	3	4	5	naked[b]	abandoned[c]
1[d]	.10	.33	.43	.10	.00	.00	.05
2	.00	.07	.45	.40	.02	.00	.05
3	.00	.03	.29	.16	.14	.06	.33
4	.00	.00	.11	.28	.28	.07	.26
5	.00	.00	.00	.08	.37	.03	.51

[a] see footnote *a* in Table 1
[b] see footnote *b* in Table 1
[c] see footnote *c* in Table 1
[d] see footnote *d* in Table 1

matrices in the Markov formulation, to be explained below, and substantively they summarize the typical short-term mobility movements of individuals in vacancy chain systems. Table 2 shows Table 1 converted into a transition probability matrix.

Markov Models of Vacancy Chain Data

Most researchers working in the vacancy chain tradition use simple Markov models as tools to describe further their raw vacancy chain data and to make a number of predictions that can be compared with observed data. These models are usually embedded, first-order Markov chains with absorbing states. Markov chains are used because these models assume that a process moves from state to state, as a vacancy moves from one resource unit to another, and that a distinct probability can be assigned to each possible transition. "First-order" means that the researcher assumes that the next position to which a vacancy moves is determined solely by the position that it is currently in; an individual thinking about moving evaluates only the vacant position; he/she does not care about, and probably does not even know about, the positions that the chain was in before the current one. "Embedded" refers to the fact that the model does not consider how long it takes a chain to move in terms of clock time; the model treats the sequence of moves that a chain makes but not how long is required for it to do so. The absorbing states are in the model because all chains eventually end; they do not go on indefinitely. A chain is absorbed when it terminates because the last vacant unit is abandoned, destroyed, or merged with an existing unit, or when the last unit is taken by an individual who does not leave an opening behind, e.g. new recruit, an adult child departing his/her parents' home for a first apartment, or a divorcing husband leaving his wife and children behind in the family house.

In the model vacancies move between units (positions) characterized by states (strata). States, as in other sociological studies of mobility, are often determined by simple attributes of positions relevant to status within the particular system of concern. For example, White (1970) used income and membership size to divide churches into states; Sands & Bower (1976) used sale or rental price for housing units; and Weissburg et al (1991) used physical size for the snail shells occupied by hermit crabs. Some researchers have combined different qualities to determine state boundaries: Marullo (1985) studied housing using both sales price and race of owner, and Weissburg et al (1991) used both size and quality for snail shells. In studies of national and regional labor markets, Harrison (1988, 1990) and Stewman (1985) allocated states by type of occupational grouping.

In deciding upon the number of states, researchers must balance two opposing trends. First, the mathematical model assumes that any two vacancies in the same state are identical in terms of their probabilities of movement to the other states. In general dividing the positions into many states makes for more homogeneous categories, but this is balanced by a second consideration. Using many states requires many observations in order to estimate transition probabilities accurately, and having many observations requires assembling large and often expensive and time-consuming data sets. In practice most researchers have used between three and seven states except in large-scale studies of national or regional labor markets where more have been used (Stewman 1985, Harrison 1988, 1990).

Decisions about where to draw boundaries between statuses, as in other kinds of mobility studies, are often somewhat arbitrary in vacancy chain studies. Often the attributes used to rank the states are continuous, like salary or shell size, and researchers utilize a combination of exploratory data analysis and their own intuitive knowledge of the particular system to mark boundaries (see White 1970 and Weissburg et al 1991 for discussions of how to draw boundaries among states). Developing rigorous statistical techniques to form state categories is a difficult statistical problem, but a technique developed by Rosenzweig (1986) in another context may be adaptable for use in separating states (Weissburg et al 1991).

COMMON PROPERTIES OF VACANCY CHAIN SYSTEMS

Short-Term Mobility Movements

The general patterns of short-term mobility are virtually identical in all the vacancy chain studies reviewed for this paper. Tables 3 and 4 give additional transition probability matrices for studies of job (White 1970) and housing mobility (Marullo 1985), to go with the matrix for hermit crabs (Table 2). In these and other matrices reviewed, vacancies usually move to other positions within the same state or they move downward one or sometimes two states in

Table 3 Transition probability matrix for vacancy moves in the Methodist church 1922–1937 from White (1970 : 125)[a]

Origin state	Destination state: Big	Medium	Small	Outside[b]
Big	.46	.33	.05	.16
Medium	.11	.41	.12	.36
Small	.02	.16	.24	.58

[a] Reproduced with permission from Harvard University Press

[b] Indicates probability of absorption by all ways of terminating chains combined

status. Vacancies rarely move to higher ranking states, and vacancies are most often absorbed from lower-ranking states.

Looked at from the point of view of individuals rather than vacancies, individuals affected by chains starting in a given state usually are upwardly mobile in small to moderate jumps in status or laterally mobile within their same status; they rarely experience downward mobility. In addition, chains are much more likely to terminate from a low-status than from a high-status position. Recruits are much more likely to enter a mobility system near the bottom, and low-ranking positions are much more likely not to be taken by any individual (abandoned), to be destroyed, or to be merged with existing positions. To look at these matrices in yet another way, vacancy chains typically flow from higher-ranking or larger resource units to lower-ranking or smaller ones as individuals trade upward to higher-status or more commodious positions.

Table 4 Transition probability matrix for vacancy moves in owned housing units, 1976–1977, from Marullo (1985 : 371)[a]

Origin state	Destination state: High	Medium	Low	Outside[b]
High ($50,000 plus)	.45	.38	.09	.08
Medium ($30,000–49,999)	.08	.39	.35	.19
Low ($0–29,999)	.01	.09	.38	.52

[a] *Urban Affairs Quarterly,* volume 20, issue number 3, page 371, copyright © 1985 by Sage Publications, Inc. Reprinted by permission of Sage Publications, Inc.

[b] Indicates probability of absorption by all ways of terminating chains combined

Length of Vacancy Chains

The length of a vacancy chain is the number of moves a vacancy makes after its entrance into a system, and this includes the terminal move to the absorbing state. Borrowing from input-output economics, White (1970) refers to the length of a vacancy chain as its multiplier effect: The impact of the appearance of a vacancy is multiplied as it makes several movements through a mobility system. For example, the multiplier effect for the chain in Figure 1 is 5.0.

In mobility systems in which researchers have traced vacancy chains from initiation to termination, the multiplier effects reported are remarkably similar in size. Usually average chains have a length around 3.0; chains begun with elite resource units produce chains of length from nearly 4.0 to nearly 5.0. Chains with lengths in these ranges have been reported for mobility systems as ostensibly diverse as those for people gaining jobs in bureaucracies (White 1970, Stewman 1975a, 1985), hermit crabs acquiring snail shells (Weissburg et al 1991), and people buying houses (Lansing et al 1969, Marullo 1985) and cars (Smith 1941). A number of other researchers have reported chains with smaller multiplier effects, but in these studies the researchers did not trace chains from beginning to end but terminated their chains prematurely when they went beyond some arbitrary boundary such as a local housing market or a particular job market (Kristof 1965, Watson 1974, Sands & Bower 1976, Smith 1983, Smith & Abbott 1983).

Researchers often determine how well a Markov model fits observed vacancy chain data by comparing observed and predicted average multiplier effects. The predicted distribution of expected vacancy chain lengths is given by what is referred to as the fundamental or multiplier matrix in the Markov formulation:

$$\mathbf{N} = (\mathbf{I} - \mathbf{Q})^{-1}, \qquad 1.$$

where $\mathbf{Q}$ is an $m \times m$ submatrix of the transition matrix including only the probabilities of transitions among the various transient (nonabsorbing) states, and $\mathbf{I}$ is an $m \times m$ identity matrix. Each element n_{ij} of $\mathbf{N}$ equals the expected number of times a vacancy starting out in state i will be in resource units in state j before it is absorbed. Most standard texts discussing Markov chains with absorbing states give the derivation of this equation (e.g. Kemeny et al 1966, Fararo 1973, Roberts 1976, Heyman & Sobel 1984). For matrices of up to moderate size, this calculation is easy to program and perform on any microcomputer.

The row sums of $\mathbf{N}$ give the expected multiplier effects for chains starting in each of the possible transient (nonabsorbing) states. In matrix notation

$$\mathbf{n} = \mathbf{N}\mathbf{l} \qquad 2.$$

where $\mathbf{n}$ is a column vector giving the predicted multiplier effects and $\mathbf{l}$ is a column vector of 1's. In most vacancy chain studies which have compared actual empirical estimates of multiplier effects with predictions made by Markov models, fits have been very close (e.g. White 1970, 1971, Stewman 1975a, Smith 1983, Smith & Abbott 1983, Weissburg et al 1991).

The Number of Individuals Experiencing Mobility in a Chain

The number of individuals experiencing mobility in a vacancy chain is closely related to a chain's multiplier effect, and the exact relationship depends upon the way in which a chain terminates. If a chain terminates (is absorbed) when an individual without a resource unit, e.g. a new recruit, enters the mobility system, the multiplier effect of the chain equals the number of individuals experiencing mobility in the chain. This is the case in Figure 1 where the multiplier effect is 5.0 and the number of mobile ministers is also 5.0. If instead a chain terminates because the last position in the chain is abandoned, destroyed, or merged with another position, the vacancy is considered to make the last move to an absorption state without a corresponding mobility event by an individual. In this case the number of mobile individuals is one less than the multiplier effect.

Most vacancy chain studies do not specifically report the average number of mobile individuals for chains starting in various states (but see Weissburg et al 1991). However, the fact that researchers report similar multiplier effects in mobility systems involving jobs (White 1970, Stewman 1975a), snail shells (Weissburg et al 1991), houses (Lansing et al 1969, Marullo 1985), and cars (Smith 1941) implies that remarkably similar numbers of individuals have mobility in typical vacancy chains in all these systems because, as indicated above, the multiplier effect and the number of mobile individuals in a chain are equal or differ at most by unity.

It is quite easy to calculate the expected number of mobile individuals in chains starting in various strata using the standard Markov model. First, the probabilities of a chain terminating in absorption states which do and which do not provide one final mobility opportunity for an individual are calculated as follows:

$$\mathbf{B} = \mathbf{N}\mathbf{R} \qquad 3.$$

where $\mathbf{R}$ is an $m \times 2$ submatrix of the original transition matrix, with the first column giving the combined probability of absorption in those states providing one final mobility opportunity for individuals and the second column giving the combined probability of absorption for those states not doing so.

The matrix **B** then shows the probabilities of a chain terminating in either kind of absorption state given the initial state of the chain.

The average number of individuals experiencing mobility for chains started in the various states is given as:

$$\text{Avg } I_i = (b_{i1} \times n_i) + [(1 - b_{i1}) \times (n_i - 1)] = b_{i1} + n_i - 1 \qquad 4.$$

where b_{i1} is the probability that a chain starting in state i is absorbed in a state generating one final mobility event, $1 - b_{i1}$ is the corresponding probability of termination in any state not providing a last mobility opportunity, and n_i is the expected multiplier effect for a chain starting in state i.

Detailed Predictions of Individual Mobility

A common set of techniques provides detailed predictions of individual mobility in any vacancy chain system (see Stewman 1986a for the derivation of these methods). Using these techniques, a researcher can predict the number of individuals moving from positions in one state to those in any other state, including absorption states, given a distribution of vacancy chains starting in the various states of a system. For example, a researcher can answer questions of this sort: What specific mobility movements would result if 12 new chains were begun in the highest stratum of units, 43 chains in units of the stratum just below, etc.

One of the most useful techniques for making detailed mobility predictions starts with the creation of a simple from-to matrix which shows the expected number of times a vacancy will move from one particular state to any other particular state, given the state in which the chain started. Each element of such a matrix can be calculated as $m_{i(jk)} = n_{ij} \times t_{jk}$, where n_{ij} is an element from the fundamental matrix and t_{jk} is one from the full transition matrix (including absorbing states). Thus, the element $m_{i(jk)}$ is the product of the number of times a vacancy starting in state i will be in state j before absorption and the probability that a vacancy in j will move to state k. In matrix form

$$\mathbf{M}_i = \mathbf{D}_i \, \mathbf{T}, \qquad 5.$$

where $\mathbf{D}_i$ is a diagonal matrix of elements from the ith row of the fundamental matrix.

The from-to matrix $\mathbf{M}_i$ shows all the movements of one vacancy starting in state i as it moves through and finally out of the mobility system. If several chains start in state i, then $\mathbf{M}_i$ must be scalar multiplied by the number of chains in order to predict all the mobility movements deriving from these chains. The resulting matrix shows the detailed from-to movements for vacancies resulting from these chains, and the transpose of this matrix gives the detailed predictions of mobility movements for individuals. If the basic from-to matrix ($\mathbf{M}_i$) for each possible starting state for a vacancy chain is scalar multiplied by the number of chains starting in each state, and if the resulting matrices are added together and then transposed, a grand matrix of detailed from-to mobility predictions for individuals results. Although these calculations are easy to carry out, comparisons between observed and predicted from-to mobility patterns have rarely been carried out in published studies of vacancy chain mobility. Exceptions are found in Stewman (1985) and Weissburg et al (1991), both of which show good fits between predicted and observed mobility movements in job and hermit crab mobility systems, respectively.

Because various attributes of individuals are correlated with their positions in a mobility system, from-to matrices could also be used to make detailed predictions about the number and characteristics of mobile individuals. For example, in human vacancy chain systems, income level and age are often correlated with position, and in hermit crab systems body size is closely correlated with shell size (Chase et al 1988). Using this information, a researcher could predict not only how many individuals would be mobile from specific states to specific states but also what are the individual attributes of those individuals making the transitions. Researchers have not yet reported such predictions, but vacancy chain theory can easily be advanced into this area.

Other detailed mobility predictions can be derived from the matrix of from-to predictions or can be calculated independently. For example, Stewman (1986a, 1985) derives and predicts the number of promotions, transfers (lateral moves), demotions, and new recruits hired as a result of a set of chains begun in the various states of a model.

Aggregate Benefits and Deficits Resulting from the Initiation of Vacancy Chains

In all vacancy chain systems the introduction of an initial set of vacant resource units has predictable, aggregate impacts for those individuals experiencing mobility. These impacts can be benefits in some systems—for example, humans getting new jobs often increase their salaries, and hermit crabs acquiring new shells grow larger and produce more offspring. In other systems mobile individuals may suffer deficits, as in housing chains where individuals moving often pay greater housing costs (Lansing et al 1969) than they did previously (they also may benefit by having more space, being nearer their places of work, having better school systems for their children, etc).

Although no researcher has yet applied them, the same set of methods can be used to predict aggregate benefits or deficits in different kinds of vacancy chain systems. Given detailed predictions of mobility resulting from an initial set of vacant units, such as provided by the from-to matrices discussed above, and the average increase in benefits or deficits, a researcher could easily predict the aggregate impact for a population. To provide an illustration, assume that a researcher has calculated a grand from-to matrix for all the predicted individual moves in an organization as a result of the retirements, deaths, and new jobs expected to be created in the next year. Each entry in the matrix is then multiplied by the respective increase or decrease in salary associated with such a move. Adding up all these products would give the net aggregate income increase for the individuals in the organization. Organizational managers could use the same kinds of calculations to assay the impact of labor cuts, changes in the retirement age, and creation of new jobs upon labor costs and benefits to be paid (see Stewman & Konda 1981, Konda et al 1981, Stewman 1988).

Vacancy Chains and Associated Individuals and Institutions

Vacancy chains have patterned effects upon other individuals and, in the human case, institutions connected to the primary individuals actually getting resources in the chains. For humans in chains for cars and houses, consider individuals such as real estate agents and car sales personnel and institutions such as banks and state and local governments. The individuals profit from sales commissions and agents' fees and the institutions from taxes, interest, and other payments when vacancy chains move through these mobility systems. Longer chains and more costly resource units generate greater benefits, while shorter chains and less costly units generate smaller benefits, for the individuals and institutions involved. In hermit crab vacancy chain systems, the individuals connected to the crabs are members of the epibiont community of animals and plants such as algae, gastropods, sea anemonies, and hydractinia which compete to live on and in the snail shells occupied by the crabs (Chase & DeWitt 1988). Vacancy chains influence the fates of epibionts: those on larger shells which are more likely to be passed on in vacancy chains live longer and reproduce more than those on smaller shells likely to be abandoned at the ends of chains.

At present researchers have not tried to predict the aggregate benefits received by associated individuals and institutions, but this is yet another area into which vacancy chain theory can be extended. The required techniques are analogous to those described above for estimating aggregate benefits for the primary individuals actually moving in chains. The level of benefits (or deficits) for associated individuals or institutions related to specific vacancy movements would need to be multiplied by the predicted number of such movements (from a from-to matrix), and the resulting products added together. This procedure could predict, for example, the aggregated total sales taxes and registration fees paid to a state government, or the aggregate income to real estate agents as a result of the chains started by the sales of a specified set of new cars or houses, respectively.

Vacancy Chains and Career Processes

In vacancy chain systems the chains themselves, in conjunction with a few other features of the systems, largely determine the career chances of the respective human and animal populations. Consider the set of resource units or social positions occupied by incumbents of a vacancy chain system at some specific point in time. In most systems this set probably looks like a typical organizational pyramid with relatively few units or positions of the largest size or highest status, more of intermediate sizes or statuses, and more yet of the smallest size or lowest status. As vacant units new to the system enter—houses just built, jobs just created, snail shells just emptied—and as the occupants of units already in the system permanently leave—they die, retire, move into institutional housing—vacancy chains are created. These vacancies trickle down to create a variety of mobility opportunities for individuals within the system. The number and initial strata of the vacancy chains created influence the career possibilities of the individuals already in the system and those about to enter. The more chains initiated at higher levels, the more mobility opportunities for individuals throughout the system, as the chains move downward, and the greater the speed with which individuals advance to high status or large units and positions. On the other hand, if chains are mostly initiated at lower levels, individuals already in high status positions will see their careers plateau while only those at lower levels will move comparatively quickly before they reach a career bottleneck caused by the lack of opportunities at higher levels.

Building upon earlier work by White (1970), Keyfitz (1973), and Stewman & Konda (1983), Stewman (1986a) presents the mathematical framework for calculating the probabilities for advancement (and lateral moves and demotions) from stratum to stratum within vacancy chain mobility systems. This framework assumes the input of events starting chains as an exogenous variable. Stewman (1986a, 1985) uses his techniques to draw "Venturi tubes" showing empirical estimates of the probability of advancement in several organizations. Three sample Venturi tubes are shown in Figure 2 for systems with four strata. These Venturi tubes graphically display the probabilities of mobility between various strata: The hourglass shape on the left indicates a system with a restricted probability of upward mobility for individuals at intermediate status levels; the diamond shape shows restriction at the highest and lowest levels but relatively easy movement at the intermediate level; and the pyramid decreasing mobility chances as an individual moves upward.

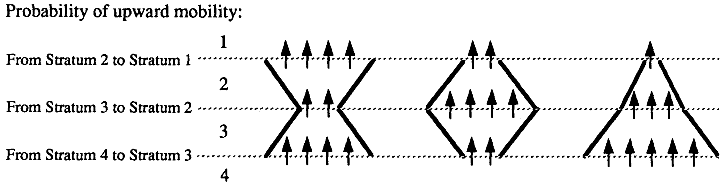

Figure 2 Three possible shapes for Venturi tubes in a mobility system with four strata. Stratum 1 is the highest ranking stratum and stratum 4 the lowest ranking. The widths between the sides of the tubes at the various gateways between strata, marked by the dashed lines, indicate the relative probabilities of upward mobility for an individual moving from one stratum to another. See the text for further details.

In applying his techniques Stewman (1986a) discovered a particularly striking and unexpected finding. Although a large number of Venturi tube shapes are theoretically possible, in real organizations he found only a few actual shapes: different organizations showed similar mobility patterns. Stewman found that the probability of mobility did not decrease the higher an individual rose in an organization, as would seem to be dictated by the shape of the organizational pyramid. Instead, individuals reaching intermediate levels often had greater probability of advancement than individuals at lower levels (see S. Spilerman & T. Petersen, submitted for publication, for a study of upward mobility chances by gender in a large corporation using different methodological techniques).

Other researchers have also explored career movements and attainments in vacancy chains systems. Sørensen (1977) proposes a model of attainment in systems with an exponential distribution of positions in which individuals move upward one stratum at a time through vacancy chains as other individuals leave the system. In contrast with Stewman's empirical investigations of several formal organizations, Sørensen's model suggests rapid growth in attainment at the beginning of careers, slower growth later, and finally a stable plateau. Abbott (1990) uses vacancy chain theory for historical investigations of the careers of managers in psychiatric institutions. He estimates the probability of advancement and the time required for advancement in order to track historical trends and isolate elites within the larger group of managers. Stewman & Yeh (1989) have recently developed a technique that traces out the various occupational positions individuals are predicted to move through during their careers in an organization.

Vacancy Chains and Organizational Demography

In systems in which they operate, vacancy chains have a strong influence upon organizational demography: Such factors as length of service distributions for individuals within the organization, rates of advancement within the system, the age distribution of individuals within particular strata, cohort effects for mobility within the system, and waiting times for advancement (Stewman 1981). Stewman's (1988) recent review in this same series provides a detailed discussion of the interrelationship of organizational demography and vacancy chains examining both empirical results and theoretical developments in four areas: intraorganizational demography, interorganizational demography, individual careers, and linkages between organizations and external populations. Although the techniques of organizational demography have been developed for the analysis of human populations, these methods promise more adequate understanding of the demography, behavior, and ecology of animals getting resources through vacancy chains than do traditional biological formulations (Weissburg et al 1991).

ELABORATIONS AND EXTENSIONS OF VACANCY CHAIN THEORY

Researchers have extended and elaborated the underlying theory of vacancy chains to explore a variety of important issues in sociology. Harrison (1988, 1990) has expanded the basic conception of vacancy chains to reconceptualize our understanding of occupational mobility in the national labor market. Harrison does this by going from the idea of a vacancy chain to that of an opportunity chain. His data do not allow him to trace specific vacancy chains, but they do allow him to tabulate the occupational type of a worker's present job by that of his previous one. From this information he forms a transition matrix showing the probabilities that a job vacancy in one type of occupational grouping will move to a job in the same or another occupational grouping. A vacancy in one grouping "calls" a worker from another grouping, which calls yet another worker, and so on to create a chain of opportunities for advancement. Harrison's (1988) findings corroborate those of other researchers (Stewman 1986b, Sommers & Eck 1977, Rosenfeld 1979) by indicating that for the national labor market often about two workers experience occupational mobility for every vacancy occurring, and that there is some indication that a multiplier effect of 2.0 may be a lower bound on the average number of workers experiencing mobility (Stewman 1988).

Harrison (1990) uses opportunity models to investigate "structural" mobility in the national labor force, exploring the impact of economic development, the change in demand for various kinds of occupational groupings, on worker mobility. The great contribution of this work is that it moves nearer to the actual mechanisms behind mobility than many previous studies of occupational mobility in the national labor market. He builds upon this contribution by analyzing the recent development of the urban underclass and develops a new analysis suggesting, in contrast with the prevailing wisdom, that the rise of the underclass is not rooted in the simple absence of mobility opportunities but in the nature of the opportunities themselves (low-paying with short or unstable tenures) and the lack of historically occurring mobility pathways out of low-status occupational groupings (Harrison 1990).

Stewman's (1985) analysis of mobility within the civilian work force of the federal government takes a similar path. He does not trace individual vacancy chains but puts together data indicating the probabilities of a vacancy in one occupational grouping calling a replacement from another grouping. Using this technique he finds that none of the occupational groupings in the government's civilian work force are independent: Job events in one grouping reverberate to affect other groupings, and all are interconnected by the flow of mobility opportunities.

Several researchers have used vacancy chain studies to investigate equal opportunity of access by different groups to mobility opportunities. Lansing et al (1969) and Marullo (1985) have investigated the access of income and racial groups to available housing units, and both conclude that African Americans are relatively disadvantaged in housing chains. Abbott & Smith (1984) have examined vacancy transitions to determine if the probability of filling positions is the same across gender. Abbott (1990) discusses the use of vacancy chain analysis to track elite groups within professions, reasoning that vacancies in elite positions should produce longer chains, and he uses these techniques in charting the historical development of the supervisory profession for mental health hospitals in the eastern United States.

Vacancy chain theory has also been used to explore issues at the border of sociology and economics. Smith (1983) uses vacancy chain analysis to investigate market segmentation for college athletic coaches and shows that there are two markets—one core and the other peripheral—that spread across firms (colleges) rather than being internal to separate firms. Akerlof et al (1988) incorporate the concept of vacancy chains into a series of microeconomic models explaining cycles of labor turnover.

OUTSTANDING PROBLEMS IN VACANCY CHAIN ANALYSIS

One of the main obstacles to vacancy chain analyses of mobility is the scarcity of data sets. As mentioned above, researchers following vacancy chains in humans usually reconstruct chains from labor- and time-consuming reviews of organizational records. Some of these records are public, such as yearbooks for ministers (White 1970) and athletic coaches (Smith & Abbott 1983), but others, particularly for private organizations, are not, and access is a problem. Some researchers (e.g. Harrison 1988, 1990, Stewman 1985, Marullo 1985) have avoided the problems of tracing chains from beginning to end by gathering data just on transitions—comparing a person's present and former positions—from large, previously collected data sets. Inexpensive optical scanners available for microcomputers could help those researchers assembling complete chains from organizational records. These scanners could directly read records and transfer their contents to computer files for tracing of chains (Abbott 1990 mentions the use of computer routines for assembling chains from lists of positions entered and left).

Data on car registrations are already on computers for probably all states, and in New York at least, there is public access via computers to these data. Similar data sets appear to be available for private airplane and pleasure boats, which are also probably distributed via vacancy chains. These data sets would make it possible to trace chains in major consumer goods without the extensive interviews used previously (e.g. Lansing et al 1969).

Studying vacancy chains in animals presents fewer problems of access, but the trade-off is that it is often difficult to permanently identify either individuals or their resource units. The studies of vacancy chains in hermit crabs (Chase & DeWitt 1988, Chase et al 1988, Weissburg et al 1991) solved this problem by choosing an animal in which chains progressed quickly. Recently developed, insertable and computer readable microchips promise help in permanently identifying individuals and resources (BioMedic Data Systems, Maywood, N.J.).

A second outstanding problem is the provision of detailed predictions about career dynamics such as the length of service distributions for individuals at various strata, the distribution of waiting times for advancement for individuals at various strata, and the distribution of times at each strata for individuals completing their careers. Finding general analytic solutions for these problems of career dynamics appears difficult, but some more elaborated versions of queuing theory, such as network queuing models, look helpful (M. Sobel, personal communication). Such models could also provide information on the analogous but untouched problem of the "career" dynamics of resource units and social positions: the distributions of occupation times and life spans of jobs, cars, houses, shells, etc.

A third problem is the identification of state boundaries for Markov models. How should a researcher group various levels of resource units or social positions so as to provide homogeneous strata? As mentioned above most researchers have used a combination of exploratory data analysis and their knowledge of a particular system in selecting boundaries. Harrison (1989) has recently developed an innovative new approach to this problem using blockmodeling techniques borrowed from the studies of networks, and the adaptation of Rosenzweig's (1986) methods to forming boundaries was mentioned above.

THEORETICAL ASSUMPTIONS AND IMPLICATIONS OF VACANCY CHAIN ANALYSIS

We now have empirical demonstration that vacancy chains are responsible for the distribution of several resources important for humans: jobs, houses, and cars. Although they have not yet been investigated, many other resource systems appear to have the qualities necessary for distribution through vacancy chains: major consumer goods such as pleasure boats and private airplanes and major pieces of industrial equipment such as pile drivers and state-of-the-art medical imaging devices. Further, Sørensen (1983) suggests that vacancy mechanisms apply to mobility in educational systems for tracks and other educational grouping, and Stewman (1988) argues vacancy formulations can apply to flows involving prison populations, voluntary groups, church memberships, nursing homes, and school districts. We also know that at least one type of nonhuman animal, hermit crabs, gets resources through vacancy chains. A variety of other animal species utilize resources with the requisite qualities for vacancy chain allocation including some that are exotic by usual sociological standards: snails living in barnacle shells and rock crevices, snapping shrimp living in sea anemones, mantis shrimp occupying burrows, octopuses inhabiting gastropod shells, and blennies living in holes on coral reefs (see Chase & DeWitt 1988 for a review).

The analysis of mobility in all these systems begins with a deceptively simple assumption: movement is contingent upon the presence of vacant positions. The actual, concrete mechanism of mobility in vacancy chain systems is the filling of vacant positions, and the filling of one vacant position means that another is opened and must be filled in turn. Vacancy chains are linkages of causes and effects in the mobility of individuals, and a good theory of mobility in those systems must incorporate this most basic of understandings. As Harrison White (1970: 328) indicates: "The core idea behind vacancy models is the need to trace social processes at a microscopic level of social structure to obtain valid causal theory." Similarly, Sørensen (1977, 1983) and Sørensen & Tuma (1981) argue in the strongest terms that in order to understand the processes of inequality and attainment, we need to develop a more adequate "sociological conception" of mobility, one based upon the actual vacancy mechanisms by which positions are allocated in many systems. They suggest that, when we examine mobility systems with "closed positions", i.e. systems in which vacancy mechanisms operate, we need to reformulate fundamentally our standard models in which isolated, independent individuals attain positions contingent upon their personal characteristics. They see the more usual sociological models of attainment and economists' theories of human capital as applying in systems with "open positions", i.e. those with market competition for positions where individuals are in fact selected contingent upon their personal attributes in comparison with all other eligibles (also see Abbott 1990 for a discussion of independent individuals versus interdependent ones in contingent mobility processes).

If in many systems individuals do not get resources as independent and isolated entities, but their mobility opportunities are contingent upon the movements of other individuals and linked together in lawful ways, then adequate theoretical conceptions and methodological techniques must reflect these facts. Much of the standard theory and methodology in status attainment, including the newer developments incorporating structural variables, such as characteristics of firms, and life event history analysis do not yet take into account the contingent nature of mobility opportunities. This present lack of response to the underlying mechanisms of mobility may unnecessarily limit our understanding of the important processes that these approaches investigate (see Stewman 1975a,b, 1978, Konda & Stewman 1980, Stewman & Konda 1983 for similar points and tests of vacancy versus other mobility models).

Vacancy chain models themselves are not immune to criticism, however (White 1970). First, the present Markov models do not treat the actual, detailed influences at work in selecting particular individuals for particular vacant openings. For humans these influences include reputations, networks of acquaintance, information, and having the right attitudes; for animals, individual differences in searching behavior, aggressiveness, ability to process sensory stimuli indicating the presence of vacant resource units, and overall physical condition would be important. Second, the Markov models presently used are quite crude. Positions are roughly grouped into a few broad strata, probabilities of a vacancy moving between the various states have to be measured empirically and cannot be predicted from first principles. In most studies the distribution of vacancies entering a system is treated as an exogenous variable and not predicted within vacancy chain theory (but see Stewman 1988, Weissburg et al 1991 for some ideas about theoretically predicting the entrance of vacancies into a system). Third, vacancy chain theory, in its present formulation, does not lend itself to answering questions about the equality of access of various groups to mobility opportunities, and these questions motivate, in part, some of the more traditional approaches to mobility (but see the exceptions noted above).

While meeting these criticisms would further strengthen the present methodology, vacancy models have already demonstrated remarkable similarities in the social organization of several human and animal mobility systems, and vacancy chains are the central concept in linking together a wide range of social processes. The present successes suggest the future contributions of the vacancy conception for understanding the distribution of inequality, career development, organizational demography, and mobility processes for humans and animals. I suggest that the most valuable of these future contributions would be the extension of vacancy chain theory in two areas: (*a*) further investigations of the common properties of all vacancy chain systems including in particular those topics described above but not yet treated: aggregate effects for primary and associated individuals and institutions and the career dynamics of individuals and their resource units and social positions, and (*b*) studies of the fundamental, underlying structural properties causing the already observed similarities among several human and nonhuman vacancy chain systems.

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Literature Cited

Abbott, A. 1990. Vacancy models for historical data. In *Social Mobility and Social Structure*, ed. R. Breiger, pp. 80–102. New York: Cambridge Univ. Press

Abbott, A., Smith, D. R. 1984. Governmental constraints and labor market mobility. *Work Occup*. 11:29–53

Akerlof, G. A., Rose, A. K., Yellen, J. L. 1988. Job switching and job satisfaction in the U.S. labor market. In *Brookings Papers on Economic Activity*, ed. W. C. Brainard, G. L. Perry, pp. 495–582. Washington, DC: Brookings Inst.

Boudon, R. 1974. *Education, Opportunity, and Social Inequality*. New York: Wiley

Chase, I. D., DeWitt, T. H. 1988. Vacancy chains: A process of mobility to new resources in humans and other animals. *Soc. Sci. Info*. 27:81–96

Chase, I. D., Weissburg, M., DeWitt, T. H. 1988. The vacancy chain process: A new mechanism of resource allocation in animals with application to hermit crabs. *Anim. Behav*. 36:1265–74

Fararo, T. J. 1973. *Mathematical Sociology*. New York: Wiley. [Reprinted 1978, Melbourne, Fla: Krieger]

Harrison, R. J. 1988. Opportunity models: adapting vacancy models to national occupational structures. *Res. Soc. Strat. Mobility* 7:3–33

Harrison, R. J. 1989. Identifying occupational labor markets in a national economy: A blockmodeling approach. *Res. Soc. Strat. Mobility* 8:129–76

Harrison, R. J. 1990. *Trends in occupational opportunities in markets: Preliminary results from the 1968–1984 Current Population Survey*. Presented at Ann. Meet. Am. Soc. Assoc., 85th, Washington, DC

Heyman, D. P., Sobel, M. J. 1984. *Stochastic Models in Operations Research,* Vol. 2. New York: McGraw Hill

Hirsch, F. 1976. *Social Limits to Growth*. Cambridge, Mass: Harvard Univ. Press

Kemeny, J. G., Snell, J. L., Thompson, G. L. 1966. *Introduction to Finite Mathematics*. Englewood Cliffs, NJ: Prentice-Hall. 2nd ed.

Keyfitz, N. 1973. Individual mobility in a stationary society. *Popul. Stud*. 27:335–52

Konda, S. L., Stewman, S. 1980. An opportunity labor demand model and Markovian labor supply models: Comparative tests in an organization. *Am. Sociol. Rev*. 45:276–301

Konda, S. L., Stewman, S., Belkin, J. 1981. Demographic models for manpower planning and policy. *Policy Sci*. 13:297–344

Kristof, F. S. 1965. Housing policy goals and the turnover of housing. *J. Am. Inst. Planners* 31:232–245

Lansing, J. B., Clifton, C. W., Morgan, J. N. 1969. *New Homes and Poor People*. Ann Arbor, Mich: Univ. Mich. Inst. Soc. Res.

Marullo, S. 1985. Housing opportunities and vacancy chains. *Urban Affairs Q*. 20:364–88

Roberts, F. S. 1976. *Discrete Mathematical Models*. Englewood Cliffs, NJ: Prentice-Hall

Rosenfeld, C. 1979. Occupational mobility during 1977. *Monthly Labor Rev*. 102:44–48

Rosenzweig, M. L. 1986. Hummingbird isolegs in an experimental system. *Behav. Ecol. Sociobiol*. 19:313–22

Sands, G., Bower, L. L. 1976. *Housing Turnover and Housing Policy: Case Studies of*

Vacancy Chains in New York State. New York: Praeger
Smith, T. H. 1941. *The Marketing of Used Automobiles*. Columbus, Oh: Ohio State Univ., Bur. Bus. Res.
Smith, D. R. 1983. Mobility in professional occupational-internal labor markets. *Am. Sociol. Rev*. 48:289–305
Smith, D. R., Abbott, A. 1983. A labor market perspective on the mobility of college football coaches. *Social Forces* 61:1147–67
Sommers, D., Eck, A. 1977. Occupational mobility in the American labor force. *Monthly Labor Rev*. 100:3–19
Sørensen, A. B. 1977. The structure of inequality and the process of attainment. *Am. Sociol. Rev*. 40:456–71
Sørensen, A. B. 1983. Processes of allocation to open and closed positions in social structure. *Zeitschr. Soziol*. 12:203–24
Sørensen, A. B., Tuma, N. 1981. Labor market structures and job mobility. In *Research in Social Stratification and Mobility,* ed. D. J. Treiman, R. V. Robinson, pp. 67–94. Greenwich, Conn: JAI
Stewman, S. 1975a. An application of job vacancy chain model to a civil service internal labor market. *J. Math. Sociol*. 4:37–59
Stewman, S. 1975b. Two Markov models of open system occupational mobility: underlying conceptualizations and empirical tests. *Am. Sociol. Rev*. 40:298–321
Stewman, S. 1978. Markov and renewal models for total system manpower. OMEGA. *Int. J. Mgmt. Sci*. 6:341–51
Stewman, S. 1981. The aging of work organizations: Impact on organizations and employment practice. In *Aging: Social Change,* ed. S. B. Kiesler, J. N. Morgan, V. K. Oppenheimer. pp. 243–90. New York: Academic
Stewman, S. 1985. Interdependent managerial decisions and the opportunity structures of white-collar internal labor markets (revised). Presented at Ann. Meet. Acad. Mgmt. San Diego
Stewman, S. 1986a. Demographic models of internal labor markets. *Admin. Sci. Q*. 31:212–47
Stewman, S. 1986b. Labor markets, aging, and health. In *Age, Health and Employment,* ed. J. E. Birren, P. E. Robinson, J. E. Livingston. pp. 114–57. Englewood Cliffs, NJ: Prentice-Hall
Stewman, S. 1988. Organizational demography. *Annu. Rev. Sociol*. 14:173–202
Stewman, S., Konda, S. L. 1981. *Demographic models of labor squeezes and cutbacks*. Presented at Ann. Meet. ORSA/TIMS, Houston
Stewman, S., Konda, S. L. 1983. Careers and organizational labor markets: Demographic models of organizational behavior. *Am. J. Sociol*. 88:637–85
Stewman, S., Yeh, K. S. 1989. *Structural pathways and switching mechanisms for individual careers*. Presented at Ann. Meet. Am. Soc. Assoc., 84th, San Francisco
Thurow, L. C. 1975. *Generating Inequality*. New York: Basic
Watson, C. J. 1974. Vacancy chains, filtering, and the public sector. *J. Am. Inst. Planners* 40:346–52
Weissburg, M., Roseman, L., Chase, I. D. 1991. Chains of opportunity: a Markov model for acquisition of reusable resources. *Evol. Ecol*. In press
White, H. C. 1970. *Chains of Opportunity: System Models of Mobility in Organizations*. Cambridge, Mass: Harvard Univ. Press
White, H. C. 1971. Multipliers, vacancy chains and filtering in housing. *J. Am. Inst. Planners* 37:88–94