SEARCH BEHAVIOR IN URBAN
HOUSING MARKETS

by

PETER DOUGLAS HALL

B.A., McMaster University
(1974)

M.A., McMaster University
(1976)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(May 1980)

© Peter Douglas Hall

Signature of Author

Department of Civil Engineering, May, 1980

Certified by

Thesis Supervisor

Accepted by

Chairman, Departmental Committee on Graduate
Students of the Department of Civil Engineering

ARCHIVES
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

JUL 1 1980

LIBRARIES
The author hereby grants to M.I.T. permission to reproduce and distribute copies of this thesis document in whole or in part.
ABSTRACT

SEARCH BEHAVIOR IN URBAN HOUSING MARKETS

by

PETER DOUGLAS HALL

Submitted to the Department of Civil Engineering on May 23, 1980 in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Residential mobility is a multi-stage decision process that has traditionally been defined in terms of three interacting stages: the decision to move, the search for residential alternatives and the choice of residence. It is a process, however, that lends itself readily to observation only at the first and third stages since, in each case, a change has occurred that is permanent and recognizable. Perhaps for this reason, theories and models of residential mobility behavior have traditionally examined these two components of the mobility decision, but have largely ignored the search process as a determinant of mobility and choice. It is the contention of this dissertation that such an oversight is inappropriate since search behavior characterizes the limitations to human perceptual abilities and to subjectively defined knowledge about the urban spatial environment, limitations that severely constrain choice.

The purposes of this research effort are to articulate a paradigm for locational choice that explicitly recognizes choice as an outcome of search, and to test this paradigm on survey data collected on the residential search and choice decisions of a sample of intra-urban migrants to provide empirical support for its behavioral precepts.

Building upon a review of the theoretical and empirical literature on residential mobility, the dissertation argues that although the search process has been articulated in conceptual models of mobility, most theoretical models have failed to recognize it, and thus fail to reveal the biases inherent in the location decision that result from information constraints and costs, and human perceptual limitations. Here, an alternative paradigm is offered that characterizes residential choice as the outcome of a residential sampling and evaluation process. This paradigm is first conceptually developed and is then formalized within a mathematical framework to evaluate how the individual responds to uncertainties and costs expected to be encountered during search.

Following preliminary tests on hypotheses inferred from it, the theoretical framework is then reformulated into an empirical model of search behavior which is more in accordance with the realities of empirical measurement than behavioral concepts embodied in the stopping rule framework used to mathematically characterize the theory. The
empirical model, which is based upon choice-theoretic principles, retains
the structural characteristics of search activity proposed in the con-
ceptual and theoretical frameworks by explicitly accounting for the
sequential nature of the search and selection process. Furthermore, its
behavioral assumptions are consistent with the theoretical model, as the
specified random utility formulation is consistent with the principle of
utility maximization, yet coincidentally exhibits satisficing behavior
\( \sim \) the part of the individual over the sequence of observations, yield-
ing a form of bounded rationality in the decision making process. A
property of the model's maximum likelihood estimator is utilized to de-
velop a statistically efficient estimator for simultaneously estimating
the coefficients of utility associated with all conditional choices made
in the sequence of observations.

The model is estimated upon data derived from a survey of residen-
tial search and choice behavior of a sample of households in Metropoli-
tan Toronto, supplemented by data collected in the 1971 Census of
Canada. Estimation results provide tentative support for most behavioral
relationships embodied in the theoretical framework, and demonstrate,
by comparing model predictions to observed search behavior, that a
workable empirical construct exists for characterizing search behavior
in urban housing markets.

THESIS SUPERVISOR: Dr. Steven R. Lerman

TITLE: Associate Professor of Civil Engineering
ACKNOWLEDGEMENTS

Though signifying accomplishment, acknowledgements are the historical medium of a dissertation, a moment for recognizing the assistance and encouragement given by the many individuals who have witnessed and facilitated its evolution. The opportunities for retrospection on the "path with heart" that I have pursued over the past five years have been few. Yet in those moments, I have accumulated the deepest respect for the people I have been involved with. Pirsig was so correct when he said that life is sustained by the sides of the mountain, not the top. Reaching the conclusion of an effort that has consumed so much time and energy over so many years has yielded only the realization of how pathetically little one knows or has managed to contribute. Fortunately, this realization has been compensated by the experiences lived and the friendships engendered along the way -- the facets of this educational process from which I have benefited most -- and the outlook on life that has resulted from these events.

I have been guided intellectually by several colleagues who have allowed me to explore an area of research that, perhaps, is not among their primary fields of interest, but who have patiently and actively participated in its evolution. To my committee members -- Steven Lerman, Michael Webber, Marvin Manheim and Clifford Winston -- I would like to express my appreciation for the advice and support that they have given me. I wish, particularly, to thank my chairman and supervisor, Steve, who has persevered with me from the beginning, advising, counselling and prodding me along (but not too hard) over the ups and downs of dis-
covery and failure. Also, Mike, who has provided long-distance support during the past several years, for his criticisms, suggestions and continuing interest. I must apologize to him for my stylistic plunderings which, despite his efforts, still live on throughout most of the text. I regret involving Cliff so late in this work's genesis; his comments and enthusiasm have provided me with much needed support near the conclusion of this effort.

Others who have contributed to my research pursuits over the years deserve mention as well. Terry Friesz helped to motivate the topic of the dissertation and commented on Chapter 3. Tony Blackburn suggested a proof to a lemma in Chapter 4, the results of which considerably enhanced my findings concerning the impacts of competition on search behavior. I benefited substantially from discussions with Bill Moss about choice theory and its applications. A particular note of thanks goes to Ruth Fincher, a friend I have known and respected for so many years, for her continuing interest in my pursuits, and for her comments and criticisms which she has freely given at every stage of this research effort. More importantly, I owe her an unquantifiable debt for teaching me how to articulate and organize my thoughts when putting pen to paper.

Various organizations have provided financial support over the course of this research. An earlier version of the literature review (Chapter 2) was sponsored by the Office of University Research of the U.S. Department of Transportation. Initial research funds were provided by the Canada Council (now Social Sciences and Humanities Research Council of Canada) and by the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University. Computer funds
were provided by the Department of Civil Engineering at M.I.T. I would like to express my gratitude to all of these organizations for their support. A special note of thanks should go to Urban Systems Research and Engineering, Inc., both for freely lending its resources to enable me to produce this dissertation and for providing me with a research environment that encouraged its completion.

Two individuals were instrumental in transforming my incoherent scribblings into final documentary form. Tina Cutino typed the final draft of the dissertation under what could only be considered to have been sub-optimal circumstances; and, under similar conditions of duress, Kelly Clauson produced an excellent set of graphics. My appreciation for their efforts is particularly acute knowing the little amount of spare time they have for themselves under normal circumstances, and seeing the dedication with which they undertook this formidable task of production.

Finally, I would like to express my gratitude to a special group of individuals at "The Urb", whose support, which could only be called spiritual, has sustained me over the past two years. They are friends who have sympathized and encouraged, as have others, but who, more importantly, have provided that essential element of distraction from the artificial world of analytical thought and formalized knowledge. Their examples of living, sharing and commiserating make me look forward to my journey down the other side of the mountain.

H.H.
May 1980
to
de Selby
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title Page</td>
<td>1</td>
</tr>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>5</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>9</td>
</tr>
<tr>
<td>List of Tables</td>
<td>12</td>
</tr>
<tr>
<td>List of Figures</td>
<td>14</td>
</tr>
<tr>
<td>CHAPTER 1: INTRODUCTION</td>
<td>16</td>
</tr>
<tr>
<td>CHAPTER 2: REVIEW OF THE LITERATURE ON RESIDENTIAL MOBILITY</td>
<td>24</td>
</tr>
<tr>
<td>2.0 Introduction</td>
<td>24</td>
</tr>
<tr>
<td>2.1 Theories and Theoretical Models</td>
<td>28</td>
</tr>
<tr>
<td>2.1.1 Economic Perspectives on Residential Mobility</td>
<td>32</td>
</tr>
<tr>
<td>2.1.2 Sociological Perspectives on Residential Mobility</td>
<td>39</td>
</tr>
<tr>
<td>2.1.3 Summary</td>
<td>54</td>
</tr>
<tr>
<td>2.2 Empirical Evidence</td>
<td>55</td>
</tr>
<tr>
<td>2.2.1 Socioeconomic Characteristics</td>
<td>57</td>
</tr>
<tr>
<td>2.2.2 Locational Attributes</td>
<td>62</td>
</tr>
<tr>
<td>2.2.3 Standards</td>
<td>74</td>
</tr>
<tr>
<td>2.2.4 Summary</td>
<td>77</td>
</tr>
<tr>
<td>2.3 Search Behavior in the Context of Residential Choice</td>
<td>81</td>
</tr>
<tr>
<td>2.4 Summary</td>
<td>88</td>
</tr>
<tr>
<td>CHAPTER 3: A CONCEPTUAL MODEL OF RESIDENTIAL SEARCH BEHAVIOR</td>
<td>90</td>
</tr>
<tr>
<td>3.0 Introduction</td>
<td>90</td>
</tr>
<tr>
<td>3.1 Information Aspects of Residential Search Behavior</td>
<td>94</td>
</tr>
<tr>
<td>3.1.1 Cognitive Structure and Change in Residential Search</td>
<td>94</td>
</tr>
<tr>
<td>3.1.2 Information Agents in Residential Search</td>
<td>101</td>
</tr>
<tr>
<td>3.2 Evaluation and Choice Among Residential Opportunities</td>
<td>110</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS (cont'd)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.1 Cognition and Discrimination of Residential Opportunities</td>
<td>113</td>
</tr>
<tr>
<td>3.2.2 Evaluation Rules and Choice Behavior</td>
<td>116</td>
</tr>
<tr>
<td>3.3 A Conceptual Model of Search Behavior</td>
<td>132</td>
</tr>
<tr>
<td><strong>CHAPTER 4: A MATHEMATICAL MODEL OF RESIDENTIAL SEARCH BEHAVIOR</strong></td>
<td></td>
</tr>
<tr>
<td>4.0 Introduction</td>
<td>141</td>
</tr>
<tr>
<td>4.1 Residential Search as a Stopping Rule Problem</td>
<td>142</td>
</tr>
<tr>
<td>4.2 Residential Search Behavior in a Mathematical Framework</td>
<td>149</td>
</tr>
<tr>
<td>4.3 Properties of Search Models</td>
<td>158</td>
</tr>
<tr>
<td>4.3.1 Search Costs and Search Behavior</td>
<td>162</td>
</tr>
<tr>
<td>4.3.2 Perceived Variations in Housing Quality</td>
<td>168</td>
</tr>
<tr>
<td>4.3.3 Competition for Housing Opportunities</td>
<td>175</td>
</tr>
<tr>
<td>4.3.4 Finite Sampling Strategies</td>
<td>189</td>
</tr>
<tr>
<td>4.3.5 Adaptive Search Behavior</td>
<td>201</td>
</tr>
<tr>
<td>4.3.6 Search Activity With Recall</td>
<td>221</td>
</tr>
<tr>
<td>4.4 Summary</td>
<td>246</td>
</tr>
<tr>
<td>4.5 Bibliographic Notes</td>
<td>257</td>
</tr>
<tr>
<td>Appendix 4.1</td>
<td>261</td>
</tr>
<tr>
<td>Appendix 4.2</td>
<td>262</td>
</tr>
<tr>
<td><strong>CHAPTER 5: EMPIRICAL TESTS ON THE THEORETICAL FRAMEWORK</strong></td>
<td>265</td>
</tr>
<tr>
<td>5.0 Introduction</td>
<td>265</td>
</tr>
<tr>
<td>5.1 Data</td>
<td>270</td>
</tr>
<tr>
<td>5.1.1 Characteristics of the Sample</td>
<td>270</td>
</tr>
<tr>
<td>5.1.2 Limitations to the Analysis</td>
<td>277</td>
</tr>
<tr>
<td>5.1.3 A Profile of Sample Households</td>
<td>281</td>
</tr>
<tr>
<td>5.2 Hypotheses for Testing</td>
<td>288</td>
</tr>
<tr>
<td>5.2.1 Disutility of Search</td>
<td>289</td>
</tr>
<tr>
<td>5.2.2 Variation of Utilities in the Opportunity Set</td>
<td>291</td>
</tr>
<tr>
<td>5.2.3 Forced Mobility</td>
<td>296</td>
</tr>
<tr>
<td>5.2.4 Summary</td>
<td>297</td>
</tr>
<tr>
<td>5.3 Empirical Tests on Hypotheses</td>
<td>299</td>
</tr>
<tr>
<td>5.3.1 Disutility of Search</td>
<td>301</td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>5.3.2</td>
<td>Variation of Utilities in the Opportunity Set</td>
</tr>
<tr>
<td>5.3.3</td>
<td>Forced Mobility</td>
</tr>
<tr>
<td>5.3.4</td>
<td>Summary of Hypothesis Tests</td>
</tr>
<tr>
<td>5.4</td>
<td>Summary</td>
</tr>
<tr>
<td>6</td>
<td>AN EMPIRICAL MODEL OF RESIDENTIAL SEARCH BEHAVIOR</td>
</tr>
<tr>
<td>6.0</td>
<td>Introduction</td>
</tr>
<tr>
<td>6.1</td>
<td>A Theory of Individual Choice Behavior</td>
</tr>
<tr>
<td>6.2</td>
<td>Specification of the Empirical Model</td>
</tr>
<tr>
<td>6.3</td>
<td>Summary</td>
</tr>
<tr>
<td>7</td>
<td>ESTIMATION OF THE EMPIRICAL MODEL</td>
</tr>
<tr>
<td>7.0</td>
<td>Introduction</td>
</tr>
<tr>
<td>7.1</td>
<td>Data Development</td>
</tr>
<tr>
<td>7.2</td>
<td>Specification of the Utility Function</td>
</tr>
<tr>
<td></td>
<td>7.2.1 Continuation of Search</td>
</tr>
<tr>
<td></td>
<td>7.2.2 Termination of Search</td>
</tr>
<tr>
<td></td>
<td>7.2.3 Summary</td>
</tr>
<tr>
<td>7.3</td>
<td>Estimation Results</td>
</tr>
<tr>
<td></td>
<td>7.3.1 Preliminary Estimation Results</td>
</tr>
<tr>
<td></td>
<td>7.3.2 Estimation Results from Final Model Specifications</td>
</tr>
<tr>
<td>7.4</td>
<td>Reconstruction of the Empirical Model of Residential Search</td>
</tr>
<tr>
<td></td>
<td>7.4.1 Comparison of Model Predictions</td>
</tr>
<tr>
<td></td>
<td>7.4.2 Comparison of Model Expectations</td>
</tr>
<tr>
<td></td>
<td>7.4.3 Synthesis</td>
</tr>
<tr>
<td>7.5</td>
<td>Summary</td>
</tr>
<tr>
<td>8</td>
<td>SUMMARY AND CONCLUSIONS</td>
</tr>
<tr>
<td></td>
<td>REFERENCES</td>
</tr>
</tbody>
</table>

11
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Functional and Spatial Biases of Information Agents</td>
<td>105</td>
</tr>
<tr>
<td>3.2</td>
<td>Characteristic Properties and Biases of Major Information Agents</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>Employed in the Residential Search Process</td>
<td></td>
</tr>
<tr>
<td>3.3</td>
<td>Sequencing of Information Channels in Search Activity</td>
<td>111</td>
</tr>
<tr>
<td>4.1</td>
<td>Simulation Values for Search Over $X \sim N(1,1)$</td>
<td>214</td>
</tr>
<tr>
<td>4.2</td>
<td>Relationships Between Environmental Variables and Aspiration Utilities in Sequential Decision Models of Search</td>
<td>252</td>
</tr>
<tr>
<td>5.1</td>
<td>Spatial Distribution of Households in the Sample of Recent (1971) Movers in Metropolitan Toronto</td>
<td>272</td>
</tr>
<tr>
<td>5.2</td>
<td>Variable Definitions in Survey Data on Recent Movers in Metropolitan Toronto</td>
<td>278</td>
</tr>
<tr>
<td>5.3</td>
<td>Profile of Socioeconomic Characteristics of Households in the Survey of Recent Movers in Metropolitan Toronto</td>
<td>282</td>
</tr>
<tr>
<td>5.4</td>
<td>Profile of Mobility Characteristics of Households in the Survey of Recent Movers in Metropolitan Toronto</td>
<td>284</td>
</tr>
<tr>
<td>5.5</td>
<td>Profile of Search Characteristics of Households in the Survey of Recent Movers in Metropolitan Toronto</td>
<td>285</td>
</tr>
<tr>
<td>5.6</td>
<td>Profile of Households' Residential Choices in the Survey of Movers in Metropolitan Toronto</td>
<td>287</td>
</tr>
<tr>
<td>5.7</td>
<td>Hypotheses to be Tested in the Empirical Analysis</td>
<td>298</td>
</tr>
<tr>
<td>5.8</td>
<td>Cross-tabulation of Duration of Search Activity with Number of Houses Searched</td>
<td>302</td>
</tr>
<tr>
<td>5.9</td>
<td>Cross-tabulation of Income (Measured by Price Paid for Chosen Alternative) and Number of Houses Searched</td>
<td>304</td>
</tr>
<tr>
<td>5.10</td>
<td>Cross-tabulation of Income (Measured by Price Paid for Chosen Alternative) and Duration of Search Activity</td>
<td>305</td>
</tr>
<tr>
<td>5.11</td>
<td>Cross-tabulation of Duration of Search Activity with Number of Houses Searched Controlling for Income (Measured by Price Paid for Chosen Alternative)</td>
<td>307</td>
</tr>
<tr>
<td>5.12</td>
<td>Cross-tabulation of Number of Information Channels Used During Search and Number of Houses Searched</td>
<td>311</td>
</tr>
<tr>
<td>5.13</td>
<td>Cross-tabulation of Number of Information Channels Used During Search and Duration of Search Activity</td>
<td>312</td>
</tr>
<tr>
<td>5.14</td>
<td>Cross-tabulation of Number of Children in Household and Number of Houses Searched</td>
<td>313</td>
</tr>
<tr>
<td>Table No.</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>5.15</td>
<td>Cross-tabulation of Number of Children in the Household and Duration of Search Activity</td>
<td>314</td>
</tr>
<tr>
<td>5.16</td>
<td>Cross-tabulation of Average Distance of Household's Search Cluster and Number of Houses Searched</td>
<td>315</td>
</tr>
<tr>
<td>5.17</td>
<td>Cross-tabulation of Average Distance of Household's Search Cluster and Duration of Search Activity</td>
<td>316</td>
</tr>
<tr>
<td>5.18</td>
<td>Cross-tabulation of Mobility Stimulus with Number of Houses Searched</td>
<td>318</td>
</tr>
<tr>
<td>5.19</td>
<td>Cross-tabulation of Mobility Stimulus with Duration of Search Activity</td>
<td>319</td>
</tr>
<tr>
<td>5.20</td>
<td>Summary of Empirical Tests of Hypotheses</td>
<td>322</td>
</tr>
<tr>
<td>7.1</td>
<td>Cross-tabulations Drawn from 1971 Census of Canada for Variable Specification</td>
<td>360</td>
</tr>
<tr>
<td>7.2</td>
<td>Independent Variables Associated with the Searcher's Continuation Alternative</td>
<td>373</td>
</tr>
<tr>
<td>7.3</td>
<td>Independent Variables Associated with the Searcher's Termination Alternative</td>
<td>381</td>
</tr>
<tr>
<td>7.4</td>
<td>Estimated Coefficients of Model I</td>
<td>387</td>
</tr>
<tr>
<td>7.5</td>
<td>Estimated Coefficients of Model II</td>
<td>398</td>
</tr>
<tr>
<td>7.6</td>
<td>Estimated Coefficients of Model III</td>
<td>402</td>
</tr>
<tr>
<td>7.7</td>
<td>Estimated Coefficients of Model IV</td>
<td>403</td>
</tr>
<tr>
<td>7.8</td>
<td>Estimated Coefficients of Models I and IV</td>
<td>411</td>
</tr>
<tr>
<td>7.9</td>
<td>Comparison of Observed Search Behavior with Choices Predicted by Models I and IV</td>
<td>413</td>
</tr>
<tr>
<td>7.10</td>
<td>Matrix of Observed Search Behavior versus Search Behavior of Households Predicted by Model I</td>
<td>415</td>
</tr>
<tr>
<td>7.11</td>
<td>Matrix of Observed Search Behavior versus Search Behavior of Households Predicted by Model IV</td>
<td>416</td>
</tr>
<tr>
<td>7.12</td>
<td>Comparison of Observed Search Behavior to that Expected from Probability Estimates Aggregated from Models I and IV</td>
<td>419</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Observed Causal Relationships Between Socioeconomic Characteristics, Tenure and Intended Mobility</td>
<td>60</td>
</tr>
<tr>
<td>3.1</td>
<td>Satisficing Decision Rule Over Two Attributes</td>
<td>121</td>
</tr>
<tr>
<td>3.2</td>
<td>Satisficing Principle as Modified by Brown and Moore (1970)</td>
<td>124</td>
</tr>
<tr>
<td>3.3</td>
<td>A Conceptual Model of Residential Search Behavior</td>
<td>133</td>
</tr>
<tr>
<td>3.4</td>
<td>A Conceptual Model of Residential Search Behavior with No Recall of Prior Residence or Previously Sampled Opportunities</td>
<td>139</td>
</tr>
<tr>
<td>4.1</td>
<td>Residential Search as a Stopping Rule Model</td>
<td>148</td>
</tr>
<tr>
<td>4.2</td>
<td>Relationship Between Aspirations and Search Costs</td>
<td>165</td>
</tr>
<tr>
<td>4.3</td>
<td>Aspirations as They Relate to the Marginal Impatience of the Searcher</td>
<td>167</td>
</tr>
<tr>
<td>4.4</td>
<td>Relationship Between Aspirations and Variations in the Opportunity Distribution for Alternative Search Costs</td>
<td>174</td>
</tr>
<tr>
<td>4.5</td>
<td>Impact of a Downward Shift in the Opportunity Distribution on Aspiration Utilities</td>
<td>183</td>
</tr>
<tr>
<td>4.6</td>
<td>Relationship Between Success Probability Functions when Number of Competitors for Vacancies in the Opportunity Set is Varied</td>
<td>185</td>
</tr>
<tr>
<td>4.7</td>
<td>Relationship Between Aspiration Utility of the Searcher and Number of Searchers Competing for Vacancies in the Opportunity Set for a Given Marginal Disutility Towards Search</td>
<td>190</td>
</tr>
<tr>
<td>4.8</td>
<td>Relationship Between Aspiration Utility, $\xi_j$, and the Number of Opportunities which Remain to be Sampled, $j$, from the Opportunity Set</td>
<td>200</td>
</tr>
<tr>
<td>4.9</td>
<td>Aspiration Utility in an Adaptive Search Process</td>
<td>212</td>
</tr>
<tr>
<td>4.10</td>
<td>Significant Components of Behavior in Adaptive Search</td>
<td>213</td>
</tr>
<tr>
<td>4.11</td>
<td>Adaptive Search: An Example of Increasing Aspiration Utilities in Response to Declining Updated Means</td>
<td>217</td>
</tr>
<tr>
<td>4.12</td>
<td>Comparison of Adaptive to Non-Adaptive Aspiration Utilities</td>
<td>219</td>
</tr>
<tr>
<td>4.13</td>
<td>Comparison of Aspiration Utilities in a Finite Sampling Process When Different Types of Recall Are Allowed</td>
<td>245</td>
</tr>
<tr>
<td>5.1</td>
<td>The Municipality of Metropolitan Toronto, 1970</td>
<td>271</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES (cont'd)**

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Conceptual Framework for Developing the Empirical Model</td>
</tr>
<tr>
<td>7.1</td>
<td>Census Geographical Units over which Independent Variables Defined</td>
</tr>
<tr>
<td>7.2</td>
<td>Impact of Number of Vacancies Sampled (Expressed as the Dummy Vector, N) on the Probability of Continuing Search</td>
</tr>
<tr>
<td>7.3</td>
<td>Comparison of Observed Number of Households Terminating Search at Each Observation with Expected Number of Households Estimated by Models I and IV</td>
</tr>
<tr>
<td>7.4</td>
<td>Comparison of Number of Households in Sub-population Excluded from Estimation Sample that Terminated Search at Each Observation with Expected Number of Households Estimated by Model IV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>336</td>
</tr>
<tr>
<td>7.1</td>
<td>358</td>
</tr>
<tr>
<td>7.2</td>
<td>404</td>
</tr>
<tr>
<td>7.3</td>
<td>420</td>
</tr>
<tr>
<td>7.4</td>
<td>423</td>
</tr>
</tbody>
</table>
Chapter 1
Introduction

Residential mobility is one of the fundamental social processes underlying the urban activity system. The movement of individuals and families from one dwelling to another is an event that occurs thousands of times daily in U.S. cities and towns. For the individual or household, residential mobility is the most important mechanism for change, to meet changing family needs and circumstances and to fulfill personal or social goals. But mobility is also a process that, in the aggregate, alters the social, economic and physical characteristics of the city. The suburbanization of metropolitan areas, ghetto formation and more recently, the gentrification of inner city neighborhoods are among the many changes that have occurred in urban areas which are consequences of the residential mobility process.

To the individual decision maker, mobility is a consequence of both internally generated and exogenously imposed forces. Changing housing needs, brought on by the household's progression through the life-cycle, income changes and other factors have long been recognized as major stimulants to mobility. Similarly, exogenous changes, such as those in the physical and social environment in which the household
operates, job mobility, and unanticipated events, such as eviction, profoundly impact the mobility decision.

Residential mobility is a multi-stage decision process that has traditionally been defined in terms of three interacting stages: the decision to move, the search for residential alternatives and the choice of residence. It is a process, however, that lends itself readily to observation only at the first and third stages, since, in each case, a change has occurred that is permanent and recognizable. Perhaps for this reason, theories and models of residential mobility behavior have traditionally examined these two components of the mobility decision, but have largely ignored the search process as a determinant of mobility and choice. It is the contention of this dissertation that such an oversight is inappropriate, since search behavior characterizes the limitations to human perceptual abilities and to subjectively articulated knowledge about the urban spatial environment, limitations that severely constrain choice.

Residential search behavior is an aspect of mobility that has received little theoretical or empirical attention. It is a process that has been given conceptual definition (Brown and Moore, 1970), but little formal treatment in the literature. Yet search is the activity that actually determines residential choice. It is an activity whereby a choice set is defined, but, more importantly, an activity which reveals the uncertainties inherent in the choice situation. By failing to recognize these uncertainties, traditional theories of residential mobility have neglected fundamental behavioral responses of the individual to the urban environment which manifest themselves in locational outcomes. Although these theories and related empirical studies have
provided insight into individual motivations and constraints which affect decision making, they are limited to the extent that their conclusions are incomplete.

It is the purpose of this dissertation to bring the search process, as it relates to the mobility and residential choice decisions, into perspective. Specifically, it intends to articulate a paradigm for locational choice that explicitly recognizes choice as an outcome of search, where search is characterized as a sampling and evaluation process which is constrained by uncertainty in information, sampling costs and human perceptual limitations. This paradigm is first conceptually developed and is then formalized within a mathematical framework to evaluate how the individual responds to uncertainties and costs expected to be encountered during search. It is then empirically tested on survey data on the residential search and choice decisions of households in Metropolitan Toronto.

To motivate the analysis of residential search behavior, the dissertation first reviews the literature on residential mobility (Chapter 2). It first defines the scope to be covered in this research by limiting the review to intra-urban mobility only, a process which is argued to be distinct from migration between regions and within rural areas. The review examines both theories and theoretical models articulated in the literature to explain the stages of the residential mobility process, and supporting empirical research. From this review, it is shown that, although the search process has been articulated in conceptual models of mobility, most theoretical models have failed to recognize it, since the incorporation of constraints related to search
impedes mathematical exposition of the outcomes of choice. Similarly, empirical studies have tended to consider mobility as conceived in theoretical models, shedding little insight into the role of information, its acquisition, cost and uncertainty in locational choice.

Because of their failure to recognize the search process in the mobility decision, we argue that traditional models are limited in that they fail to reveal the biases inherent in the location decision which result from information constraints and costs, and human perceptual limitations. Here, an alternative paradigm is offered that characterizes residential choice as the outcome of a sampling and evaluation process. Recent theoretical developments concerning residential search behavior are reviewed to motivate the development of a conceptual model of search behavior in the following chapter.

In addition to developing the conceptual model, Chapter 3 examines two concepts that are fundamental to the characterization of residential search behavior: the role of information in search, how it is recognized and processed by the searching household and how it is transmitted from the supply-side of the housing market to the demand-side; and the residential evaluation process adopted by the searcher as information is gained. Because search is conducted both to identify potential opportunities and to define more precisely the range of opportunities available to the searcher, the chapter argues that, rather than optimizing over a set of alternatives in a well-defined choice set, the individual must compare the utilities of alternative housing opportunities to a subjectively defined standard, or aspiration utility. This utility is formulated upon the basis of the searcher's beliefs about the housing
market, beliefs that are contingent upon information held prior to, and gained subsequently in, the search process. Residential choice behavior, although still rational (i.e. utility maximizing), is "intend-edly rational" (Wolpert, 1965), and decision making resembles the satisficing principle proposed by Simon (1957).

Some terminological distinction is required to clarify this decision making process from the traditional paradigm. In the traditional modeling framework, the set of alternatives, or choice set, over which the locational decision is made is defined a priori. In search models, the choice set is identified (through search) by the individual from a set of potential opportunities, or opportunity set, which constitutes the searcher's spatial search field, a subjectively defined image of the urban environment, conditioned by daily activity patterns, socio-economic characteristics, institutional constraints and other factors. The content of the opportunity set essentially summarizes the individual's beliefs of what is attainable in the urban housing market. The relationship between cognition and evaluation is discussed in depth in Chapter 3. From this is outlined a conceptual model that casts search as a sampling process that allows the searcher to refine his/her prior perceptions about the housing market through observation to enable choice to be made.

Chapter 4 then translates these concepts into a mathematical framework for characterizing search behavior in urban housing markets. Casting residential search as a sequential decision problem permits relationships between the individual's aspiration utility (the criterion for choice) and variables associated with information and cost to be investi-
gated analytically. Although it simplifies the search process to one which is a strictly sequential sampling process, the framework retains the fundamental decision rule proposed in Chapter 3 to characterize decision making under conditions of uncertainty. It thereby recognizes the inherent uncertainties in the location decision faced by households in the mobility process. Relationships between aspiration utility and search costs, variability of alternatives in the searcher's opportunity set and competition are analytically derived in an elementary stopping rule model of residential search behavior. The elementary model is then restructured to examine how search behavior changes when sampling is constrained, when information about housing quality, imparted by observations in search, are factored into the searcher's aspirations, and when past observations made during search (but rejected) are retained in the searcher's choice set. Relationships inferred from these analyses form the basis for hypotheses tested empirically in the following chapter.

Chapter 5 presents an initial attempt to provide empirical support for the relationships established in the theoretical framework. Data tabulated by Barrett (1973) from a survey of the search and residential choice decisions made by a sample of households in Metropolitan Toronto are analyzed to test hypothesized relationships between aspiration utility and search costs, competition and constraints on sampling. Though empirical support is limited, the chapter demonstrates a fundamental problem of characterizing search behavior in the sequential decision framework. Variables in the stopping rule model of search and empirically observable phenomena (i.e., measurable by survey techniques) are definitionally incompatible: this suggests that search models, as
currently conceived, are limited in that their behavioral relationships cannot be tested meaningfully in empirical contexts. This problem leads to the development of an empirical model of search behavior in Chapter 6 based upon choice-theoretic principles. It is a model, based upon the work of Sheffi (1979), which retains the structural characteristics of search activity proposed in the conceptual and theoretical frameworks (Chapters 3 and 4) by explicitly accounting for the sequential nature of the search and selection process. Furthermore, its behavioral assumptions are consistent with those of the theoretical model, as the specified random utility formulation is consistent with the principle of utility maximization, yet coincidentally exhibits satisficing behavior on the part of the individual over the sequence of observations, yielding a form of bounded rationality in the decision making process. A property of the model's maximum likelihood estimator is utilized to develop a statistically efficient estimator for estimating simultaneously the coefficients of utility associated with all conditional choices made in the sequence of observations. The model incorporates variables associated with the search process into its framework by specifying them as attributes of the searcher's utility function.

Chapter 7 then presents estimation results based upon the survey of search and residential choice behavior of a sample of households in Metropolitan Toronto (used in Chapter 5), supplemented by data collected in the 1971 Census of Canada. Results provide tentative support for the behavioral relationships embodied in the theoretical framework and demonstrate, through the model's comparison with observed search behavior, that a workable empirical construct exists for characterizing search
behavior in urban housing markets.

Finally, Chapter 8 summarizes the findings of this research effort, its limitations and directions for future research.
Chapter 2
Review of the Literature on Residential Mobility

2.0 Introduction

Residential mobility and locational choice behavior have long been subject to theoretical and empirical investigation in a variety of disciplines. Although perspectives from these disciplines on the mobility process have differed and are still diverse, it can be reasonably argued that from these efforts has evolved a more complete understanding of individual motivations and aspirations which manifest themselves in observed locational patterns. This chapter is a review of the relevant literature on residential mobility and choice. The purposes are to motivate the forthcoming analysis of residential search behavior and to set this element of the location decision into an appropriate context. By doing so, we aim not only to recognize the potential that search theory has for furthering our understanding of the residential location process, but also to acknowledge the unfinished nature of the research undertaken in this dissertation. A truly integrating framework for incorporating search activity into residential choice theory has yet to be developed.

The literature review proceeds in this chapter on two fronts. One traces the progression of theories and theoretical models of residential mobility and locational choice behavior to their current states.
The other examines supporting evidence from empirical studies and significant empirical models which have been developed and estimated to test various hypotheses deduced from theory.

Before proceeding, however, we defined a limit to scope of research to be covered in this review. Although ultimately related to the more general phenomenon of population migration, we focus in this study upon population movement in an intra-urban context only. To clarify the distinction, we consider residential mobility as a process of relocation within the same metropolitan area, where Speare et al's (1974, p.2) convention of defining the metropolitan area's spatial boundaries to encompass its associated labor market is adopted.

The distinction between residential mobility and population migration is appropriate for several reasons. First, while migration research has typically involved the analysis of aggregate flows across politically defined boundaries, 1 residential mobility studies, on the most part, have considered households or individuals as the basic units of analysis. This scale difference has resulted in the consideration of different types of independent variables to explain the two phenomena, with residential mobility variables typically being disaggregate and the analysis more behavioral in approach.

A second reason for distinction is that the literature on intra-urban mobility has traditionally emphasized motivations and constraints on moving behavior which have not been emphasized in studies of interregional migration. Migration has usually been associated with job related

---

1 Notable exceptions to this approach to migration analysis include the works of DaVanzo (1977) and Bartel (1979).
factors, such as regional labor market variations (Bartel, 1979, p.785), while local movement has more often related to social mobility, life-cycle changes and other, more varied and discretionary factors (Rosen, 1979, p.18). Census data tend to support this contention. Whereas 66.8 percent of between-county movers in the 1970 Census of Population cited job related reasons for moving, only 11.4 percent of within-county movers did the same. Conversely, 82 percent of within-county movers changed residences for housing or family reasons compared to only 21.5 percent of between-county movers (U.S. Bureau of the Census, 1974, p.140). Although not indicating the two phenomena to be totally independent, these statistics, and the empirical studies alluded to earlier, suggest the existence of fundamental behavioral differences between them and enables us to isolate residential mobility as a separate field of study.

A final reason for considering residential mobility separately from migration relates to the magnitude of this phenomenon. Nearly 20 percent of the population changes residences annually in the United States, and nearly half of this total moves within the same Standard Metropolitan Statistical Area (SMSA) (U.S. Bureau of the Census, 1977, p.1). Over the 1975 to 1976 period, residential mobility within SMSA's involved over 17 million persons, or 8.3 percent of the total U.S. population (U.S. Bureau of the Census, 1977, p.5). Given the large numbers of families redistributing themselves in urban areas, residential mobility appears of sufficient importance and identity to consider distinctly from more general population migration behavior. As a result, reference in this review is made only to the residential mobility literature, except in those cases where migration studies are obviously of relevance to both inter- and intra-urban contexts.
The structure of this chapter, then, is as follows. Section 2.1 reviews the relevant theories and theoretical models which have attempted to describe or explain residential mobility and locational choice behavior. This literature forms the basis upon which most operational and planning models of residential location have been developed.\footnote{The class of studies which describe attempts, particularly during the 1960's, to operationalize urban models in the U.S. and Britain are not discussed in this chapter since they have been exhaustively reviewed by several authors. For an overview of these efforts, the reader is referred to Butler et al. (1969), Batty (1972), Lee (1973) and Putman (1975).} Section 2.2 then reviews major empirical research that has been conducted in this area. This section considers both studies which have statistically analyzed data to identify individual preferences and the characteristics which distinguish mobile from stable households, and studies which have estimated parametric models to more precisely quantify the relationships between explanatory variables and household mobility and/or locational choice decision. Synthesis of the theoretical and empirical literature at the end of this section provides the opportunity for identifying those aspects of mobility behavior which are still poorly understood. At this point, particular emphasis is placed upon the location decision, the conditions which usually govern choice of residence, and the failure of most mobility research to recognize the dynamics and uncertainties associated with residential relocation. Here, an alternative paradigm is offered which is argued to be a more realistic characterization of the residential choice process than that assumed in more traditional formulations. Recently published theoretical developments in characterizing the residential search process are then briefly appraised in Section 2.3 from which the shortcomings of current theoretical
frameworks are identified. The chapter is finally summarized in Section 2.4 where the agenda for research in the following chapter is motivated.

2.1 Theories and Theoretical Models

Although initial conceptions of the process are attributed to the socio-ecological perspectives of Burgess (1925) and Park (1936), reference to traditional theoretical formulations of residential mobility and locational choice behavior has usually alluded to the structural economic frameworks of Wingo (1961), Muth (1961) and Alonso (1964).

Similar in structure to a von Thünen model of agricultural land rent, the framework's central tenet concerns the trade-off between the demand for accessibility and the demand for land. As stated by Alonso (1964, p.18), households are assumed to choose their locations by trading-off travel costs to the CBD, the quantity of land they prefer to consume and consumption of a composite good. As such, it is a standard micro-economic model, except to the extent that land rents are endogenously determined. Individuals are assumed to behave as if they possessed a utility function (with the composite consumption good, quantity of land and commuting costs being its identified components), but are constrained by limited incomes. Simplifying assumptions about the form of the city (monocentric), information costs and externalities are incorporated into the framework to make it analytically tractable. The constrained utility maximizing solution yields the usual marginal rates of substitution between different components of utility. The theory explains, in an economic sense, the locational strategies of different sub-groups in the population by assuming accessibility to be an inferior good in relation to land. Higher income families therefore substitute land
for accessibility, which results in the familiar spatial population pattern observed in metropolitan areas.

This neoclassical economic framework has been extended to a considerable degree by several authors. Casetti (1971) has mathematically derived continuous functions relating equilibrium land values and population densities to distance from a city center, which could not be obtained within Alonso's framework. Papageorgiou (1971) has extended this analysis to a multi-centered city, and Yamada (1972) has incorporated leisure time and environmental quality (as a function of distance) into the utility function to derive more complex equilibrium relationships in this extended framework. Other important contributions have been made by Beckmann (1969) and Muth (1969).

However, the neoclassical framework encompasses several restrictive assumptions about location behavior which many have claimed oversimplify the residential mobility process (Huff, 1979, p.135), and this argument has provided much of the incentive for reconceptualizing the process in the more recent literature. For example, Alonso assumes the household to directly evaluate access (commuting distance) as a consumption good to be traded-off with a composite good and the quantity of land. In the transportation literature, it has long been recognized that travel demand is derived (Quandt and Baumol, 1966; Brand, 1973), and as such, should be regarded as an intermediate, rather than final good. It is unclear, even in the empirical literature, how transportation levels of service should be treated in the residential location decision, but it is doubtful that it can be conceptualized as simplistically as in Alonso's theory. Also, the theory assumes an idealized location process where all house-
holds are assumed to be simultaneously locating in the urban area with perfect information about alternative choices. The creation of an "instant metropolis" is clearly a gross approximation, and research has shown that spatial biases in perception influence the household's travel and mobility decisions considerably (Hanson, 1976; Adams, 1969). Interaction among competing land uses is completely ignored, and housing and neighborhood amenities are excluded from the analysis. Although not intended to furnish the definitive understanding of all aspects of the residential location decision, the nature and severity of its assumptions have caused critics to suggest that theoretical insights into locational patterns within the metropolitan areas afforded by the neoclassical framework are, at best, limited in scope.

Partly as a response to the difficulties involved in working in a traditional microeconomic framework and the severe assumptions concerning the decision processes of the household imposed by such models, much recent research in residential location theory has taken a different perspective. Although many of these formulations are still economic, more attention has been paid to the sociological aspects of mobility and the household's response to a changing environment. As a result, less emphasis has been placed upon the development of a general theory of residential location and more upon the component parts of the mobility decision. Such a conceptualization has been reviewed in Moore (1972), where the decision to move, the search for available alternatives, and the evaluation of alternatives have been separated for both empirical and theoretical reasons.

Much of the recent theory is due to Wolpert (1965), who developed three central concepts in mobility behavior: place utility, search
strategies and life-cycle effects. Residential mobility is postulated to
be a form of group adaptation to perceived changes in the (personal) envi-
ronment. The household is assumed to be "intendedly" rational in its
mobility decision; in other words, it is assumed that the household's
perception of opportunities is limited due to imperfect information
concerning the urban environment, but the decision unit is still capable
of differentiating choices according to relative or expected utilities.
Wolpert defines place utility to be the net composite of utilities from
the household's integration at some point in space (Wolpert, 1965, p.162),
which is evaluated through an aspiration level that adjusts itself of
the basis of experience. Dissatisfaction, which is identified with a
negative place utility, serves as the stimulus to search behavior which,
if successful, results in a locational change by the household. Wolpert
associates place utility with not only measurable environmental variables,
but with perceived stimuli and expected future rewards associated with
alternative locations. The domain over which households search is limited,
or spatially biased, due to the limited perception of the surrounding en-
vironment. This bias leads to a clustered sampling of residences proximi-
mate to the household's present location. The search domains of house-
holds are distinct, however, each being a function both of socioeconomic
characteristics and present residential location.

Two major lines of inquiry have evolved from Wolpert's place utility
approach to residential mobility. On the one hand, economic derivatives
have focusses upon explaining discrepancies between housing demand and
housing consumption. Mobility, in this framework, is considered as a
mechanism for adjusting housing consumption, and the stimulus to move
is related directly to changes in housing demand and disequilibrium in consumption. On the other hand, the sociological literature has attempted to relate moving behavior and moving expectations to levels of satisfaction and locational stress, and to link these psychological responses to the residential environment. Each of these perspectives is discussed below.

2.1.1 Economic Perspectives on Residential Mobility

The basic argument which has evolved in the economic literature is that the market clearing, or equilibrium locational patterns associated with neoclassical theories of the urban land market do not exist in the presence of transactions and search costs that normally accompany the mobility process. Thus, even though, at the aggregate level, equilibrium housing conditions may appear to be observed, they result from the aggregation of individuals who are underconsuming or overconsuming housing.

Sub-optimal consumption arises when the household's demand for housing changes to a new desired level. With limited ability to transform the attributes of the current dwelling, in the absence of transactions and search costs, the household responds by changing residences. But transactions and search costs impose a threshold upon the household which acts to discourage mobility unless it is exceeded by the expected utility gain from moving. In general, the trade-off between mobility costs and the welfare gain from moving is not exact, since the potential exists for substitution between housing services and consumption goods when the household is forced by these costs to underconsume housing (Hanushek and Quigley, 1978, p.414). However, the theory maintains that the incentive to move remains a monotonic function of the change in equili-
Several variations on the disequilibrium theory have been developed into models in the literature. Goodman (1976) has taken Wolpert's conception of place utility to articulate a probability model of mobility which is a function of the discrepancies between actual and optimal housing consumption, and moving costs. The household is assumed to possess a utility function composed of consumption levels of housing services per time period and the composite commodity, with the usual income constraints binding on the allocation of resources. Optimal, or equilibrium housing consumption is conditional upon the household's utility function, its disposable income and the relative price of housing. Housing services are factored into several dimensions of housing quality and locational attributes. Discrepancies between actual and optimal housing consumption can therefore either exist overall, or in a subset of housing attributes. And since the household may be over-consuming some components of housing services and under-consuming others, disequilibrium in consumption will thus not necessarily lead to residential mobility.

Rothenberg (1975) formulates a theory similar in many respects to Goodman, but is more comprehensive in its consideration of the household's decision to seek another residence. Although both Goodman's and Rothenberg's models assume the same utility function for the household, Rothenberg assumes that the component parts of housing quality are individually assessed by households and, under competitive market conditions, these components can be implicitly priced. In maximizing utility, the household simultaneously decides on both the optimal composition of the housing package and the optimal level of housing consumption (the
latter being traded-off with the composite commodity). Disequilibrium in locational choice is characterized by the degree of discrepancy between ideal and actual budget allocations, and affects both housing and composite good consumption.

Rothenberg identifies two components of loss due to disequilibrium. The first is related to the optimal composition of housing while the second concerns the optimal level. The welfare loss associated with each of these components can be calculated from the differences in the optimal levels of consumption and prices derived from the marginal conditions in the utility maximizing framework, and the actual levels of consumption. Since the model is dynamic, the welfare loss is discounted to present value terms. Lags and non-adjustment in mobility are accounted for by costs associated with search and moving, as well as the costs of conducting a market transaction. The latter two are assumed to be functions of the wealth position of the household and an interest rate. Search costs are assumed to be a function of the discounted value of the expected decrease in equilibrium loss due to the discovery of suitable alternative housing. The household will therefore commence searching if the expected decrease in welfare loss exceeds the expected total cost of participating and transacting in the market.

A more precise characterization of the notion of disequilibrium in housing consumption has recently been developed by Hanushek and Quigley (1979). In this framework, mobility is considered as an adjustment process which allows households to attempt to minimize the gaps which develop over time between their actual and equilibrium consumption levels. This adjustment process is assumed to occur at a constant rate...
over a specified time interval. In this way, expected housing consump-
tion over the next time period can be estimated by factoring the differ-
ence between desired consumption over this next period and actual con-
sumption during the current period by the adjustment rate, and adding
the current consumption level inflated by a housing price inflation
rate over the time interval.

Because the dimension of time is explicitly recognized in the ad-
justment process, disequilibrium in consumption is hypothesized to be
composed of two distinct disequilibrium components in this model, which
are slightly different from those proposed by Rothenberg. The first is
the gap between actual consumption at time $t$ and the consumption level
actually desired at that time, a structural disequilibrium component.
The second is the change in the equilibrium level of housing consumption
which takes place over the interval from time $t$ to $t+1$.

Hanushek and Quigley (1979, p.93) suggest that households are likely
to adjust over time more rapidly to changes in their equilibrium consump-
tion levels than to their structural disequilibrium gaps, i.e. exogenous
changes in housing demand are more likely to cause adjustment immediately
rather than in successive periods, while only changes in the equilibrium
level of consumption over time provide continuous motivations to move.
Another assumption in the model concerns the asymmetrical impacts dis-
equilibrium is likely to have on moving. Hanushek and Quigley (1979,
p.94) incorporate a "ratchet" effect of disequilibrium upon housing con-
sumption by parameterizing the model to enable the underconsumption of
housing services to exert a stronger influence on housing demand than
overconsumption.

Although conceptually, the properties of models embracing the dis-
equilibrium theory of housing demand are more in accordance with the conditions which accompany residential mobility in urban areas, they have been difficult to confirm since many of the concepts utilized in the theory, such as equilibrium consumption levels, are not observable and because, as referenced earlier, aggregate market conditions tend to obfuscate the individual deviations from equilibrium that the theory seeks to address. Furthermore, the theory is not directly comparable to earlier neoclassical efforts because it addresses only one aspect of the mobility decision, the decision to change residences. Theories of residential location, which are amenable to comparison, have not begun to incorporate more realistic assumptions concerning constraints on mobility until recently.

Richardson's (1977) is probably the most comprehensive specification of a general theory of residential location. It is one which is still based upon the traditional paradigm, as it considers the locational choice decision but not the initial mobility decision, and assumes utility maximizing behavior on the part of the individual during the trade-off of location with other goods. However, the theory generalizes the neoclassical framework by including multiple employment centers and characteristic utility functions for a stratified population which, in the location decision, differentially values housing and neighborhood amenities (including environmental quality), accessibility to non-work destinations, alternative public services packages (including taxes) offered by local jurisdictions, and time for leisure activities. But the theory deviates even further from the neoclassical model by recognizing additional constraining factors on locational choice behavior, such as those suggested
in the conceptual frameworks of Wolpert (1965) and Brown and Moore (1970).

Constraints on choice are of two types. One type concerns resource constraints on the household in the forms of income, time, and capital/mobility costs. Income constrains the budget allocation process and affects the trade-offs between housing and accessibility in the usual way. A time constraint allows additional trade-offs between accessibility to the workplace (thus location) and leisure time, and between leisure and work activities. Although the importance of the trade-off in the former constraint has often been noted in the literature (see, for example, Lisco, 1974), the latter is also important because the substitution of work for leisure increases the household’s ability to spend more on housing (Richardson, 1977, p.259). On the other hand, capital constraints, which primarily affect homebuyers through the setting of entry prices and mortgage availability, essentially determine how much the household must allocate to housing expenditures.

The other major type of constraint on choice in the theory relates to the search for housing. Here, the number of vacancies available in the urban area is constrained by the existing housing stock and the prevailing vacancy rate. However, the number of vacancies actually subject to consideration by any household is additionally constrained by either endogenously or exogenously imposed limits to the household's spatial search field. Constraints on the time available for searching and resources available to the household further reduce the number of potential opportunities for relocation.

The effects of search process constraints on locational choice are reasonably self-evident, since they are defined so as to either functionally or spatially restrict the choice set of the household. But what is
important is their subsequent impact on measured behavior. Search process constraints tend the household to sub-optimal choice behavior relative to that in an unconstrained environment by forcing the household, through lack of information, to accept a different type of dwelling than originally desired or to locate in an area which would otherwise have been by-passed. This characteristic allows Richardson (1977, p.259) to identify the fundamental distinction between the two classes of constraints in his theory. Whereas resource constraints determine the fundamental parameters of the location decision, such as housing expenditure, neighborhood amenities and structural characteristics, search constraints, through spatial biasing (limiting the choice set), determine the extent to which actual choices deviate from the ideal.

That the theory is considerably more complex than the elementary neoclassical model is evident from its detailed utility function and additional constraints on choice. Richardson (1977, p.261), in fact, doubts whether a general equilibrium version of the theory can be solved. But the set of marginal conditions on locational choice which can be deduced bear comparison to those derived from earlier theory. Of significance is the finding that, rather than inducing regular and continuous population density and bid-rent surfaces from the city center, Richardson's framework generates a series of rent surfaces which are highly irregular due to the trade-offs resolved among income, leisure, accessibility, neighborhood quality, time and residential space. Search process constraints influence the aggregate residential land rent surface further by transforming these continuous rental gradients to discrete patches coinciding with spatial search fields. That discontinuous land value
gradients and irregular bid-rent surfaces, both of which are derived in
the theoretical framework, co-exist has serious implications for neoclas-
sical economic approaches to residential location (Richardson, 1977,
p.264). Unlike initial formulations which allowed equilibrium rent and
density gradients to be co-determinant with individual equilibrium con-
ditions, individual locational equilibrium conditions are not necessarily
reconciled with simultaneously determined market prices when the theory
is generalized to a state more reflective of economic processes actually
occurring in the urban housing market. It is thus possible, or even
likely, that equilibrium solutions are not unique or, indeed exist
under the specified economic conditions.

2.1.2 Sociological Perspectives on Residential Mobility

While not independent of economic arguments, sociological approaches
to mobility theory have tended to define the disequilibrium concept in
socio-psychological terms and, as a result, have tended to emphasize
psychological forces which give rise to the mobility decision that have
not been given much recognition in the economic literature.

The sociological literature embraces two major themes relating to
residential mobility. One concerns the concept of residential dissatis-
faction or locational stress and the factors which give rise to it. Most
arguments about this concept derive from Wolpert (1965) and are primarily
related to the characteristics of the household and their changes over
time. The life-cycle model of residential mobility posits that discrete
events in the family's life-cycle have major impacts on the probability
of moving. Similar to disequilibrium arguments, these events precipitate
changing housing needs during transitions from one stage in the life-
cycle to another. (This hypothesis is consistent with the conception of mobility as an independent trials process (Spilerman, 1972) in aggregate analyses, whereby stratified population classes are assigned characteristic moving probabilities.) The second theme in the literature concerns the household's resistance to moving and the variables which influence it. It argues that psychological attachments to the dwelling and neighborhood, through interpersonal relationships and community ties, intensify over time, resulting in the phenomenon of cumulative inertia, which effects the lowering of moving probabilities from what would normally be expected in locational stress models. While these two themes are not mutually independent, and while the recent literature has begun to integrate them into a single consistent framework, the development of these ideas has essentially evolved along two different paths, and for this reason, they are discussed separately below.

The notion of locational stress as the underlying factor in residential mobility is one which concerns how changes in socioeconomic traits and characteristics of the residential environment relate to the degree of satisfaction experienced by the household at a given time and location, compared to what might be attainable elsewhere. Originally suggested by Rossi (1955), the stress-threshold model of mobility is conceptualized by Brown and Moore (1970) as a continuous (or near-continuous) process of evaluation by the household as its characteristics and surrounding environment change. Locational stress, when inflated beyond a given threshold value, prompts the household to act, either by reducing the stress in situ or by seeking an alternative residence. The decision of whether or not to remain in the current dwelling depends
upon the degree of locational stress experienced by the household and
qualitative evaluations of the likely success of *in situ* adjustments
versus the likelihood of finding a suitable alternative at another
location.

While conceptually intuitive, there have been few attempts outside
of economic ones to place this framework in a more operational mode.
Speare *et al.* (1975) have approached the problem by considering mobility
as a three-stage process, consisting of the development of a desire to
consider moving, the selection of an alternative location, and the deci-
sion to stay or move.¹ They claim that the desire for mobility is initi-
atated by a growing dissatisfaction with the current residence which, when
strong enough, prompts comparative evaluations of stress-relieving alter-
natives in terms of potential costs and benefits. Therefore, instead
of characterizing mobility on the basis of differences between housing
consumption and equilibrium housing demand, Speare *et al.* embrace the
more subjective notion of satisfaction, a concept which includes individ-
ual, housing and location characteristics, and social bonds.

The first stage of the mobility decision is characterized as a tran-
sition process from satisfaction to dissatisfaction, and is expressed as
the probability of considering moving (a function of composite satisfac-
tion and dissatisfaction threshold measures). The probability of moving
is then calculated for those who consider moving. Here, a cost-benefit

¹The interdependencies among these stages, both in terms of causal
factors and the sequencing of events are recognized by the authors
(Speare *et al.*, 1975, p.175).
framework is invoked, as probabilities of moving to given locations are calculated as functions of the differences in residential satisfactions expected between alternative and current locations, and a threshold value related to mobility costs. The specification of a functional form for the joint probability of desiring to move and then actually moving is then attempted by integrating the sub-models associated with the two previous stages. But rather than calculating it as the product of conditional and marginal probabilities, to recognize the interdependencies between stages (and to avoid cross-product terms in the specification), the joint probability function is specified independently as a function of both the relative residential satisfactions among alternative locations and the costs of moving.

Compared to the conceptual framework, the above formalization of the mobility process is an elementary one, as only few of the concepts suggested by Wolpert, and subsequently developed by Brown and Moore, are actually specified in the model. However, it has been argued that problems associated with sociological approaches, such as Speare et al.'s, are actually much more fundamental than this. For example, Clark (1976) has criticized their failure to cast the mobility decision into a more systemic context, where the individual is cognizant of the trade-offs among alternative bundles of both housing and non-housing goods, and Brumwell (1977) has commented on their neglect of the role that uncertain or imperfect information plays in the determination of residential satisfaction. But although seemingly symptomatic of fundamental problems in theoretical approach, many of these problems have actually resulted from the less than rigorous fashion in which the central element in the theory,
residential satisfaction, has been defined.

Brummell (1977) has attempted to overcome this tendency by explicitly relating the concept of satisfaction, or equivalently, locational stress,¹ to operational definitions of place utility and attainable aspirations which, in turn, are related directly to the more familiar notion of individual (or household) utility. In doing this, he assumes the household to possess a utility function identified by attributes of the residential environment and all other goods. In this respect, the model is similar to economic formulations reviewed earlier. However, instead of the single budget constraint as in economic models, the household is hypothesized to be influenced by three types of constraints. One is a set of minimum need levels which relate to physical subsistence levels and socio-psychological needs. Another is a set of upper need levels beyond which trade-offs among substitutable goods are meaningless. And a third is the usual income constraint which binds the allocation of resources among goods and housing. The theory assumes that within these constraints, the household attempts to maximize its utility by selecting an optimal combination of housing and consumption goods.

¹The terms satisfaction, utility and locational stress have been used interchangeably in the sociological literature, although some distinctions can be made. The concept of satisfaction is essentially consistent with that of utility as both reflect the degree to which the needs and desires of the household are accommodated at a particular place. Satisfaction or utility can be both experienced at the current residence and perceived attainable at other locations (Brummell, 1977, p.34), with the difference between the two constituting stress (Clark, 1975, p.168), a measure of disparity between the household and its environment (Brummell, 1977, p.33). Weinberg (1975, p.5-6) suggests the difference between the two concepts to be one of perspective rather than one of substance with satisfaction characterizing the sociological approach (Speare, 1974; Michelson, 1977) and utility the economic one (Weinberg, 1975; Goodman, 1976). The concept of utility, however, has received the most formal (i.e. mathematical) treatment in the literature.
The concept of locational stress evolves from the recognition of two fundamental types of utility levels which are simultaneously experienced by the household at any point in time. At any given moment, the household is fixed at some point in space and occupies a dwelling having reasonably stable characteristics over the short term. During its tenure there, to maximize utility, it allocates part of its income, within maximum and minimum need levels, to all other desired consumption goods. This quasi-optimal allocation of resources constitutes the household's experienced place utility at that point in time.

At the same time that it resides at the current dwelling, however, the household, through social or other contacts, is assumed also to be continuously gathering information about other residential opportunities in areas of which it is aware. This enables it to develop expectations of housing prices in these areas. Once these expectations are formed, the household can then estimate what would constitute its optimal consumption pattern (housing and other goods) at each location. Consistent with Wolpert (1965), these optimal bundles define the set of attainable place utilities which the household believes it could experience if it were to relocate there. Brummell (1977, p.45) then defines the household's aspiration place utility at any point in time to be equivalent to the maximum of the attainable place utilities of which it is aware. Residential stress is then simply the difference between the maximum attainable place utility the household currently believes it could be receiving and the experienced place utility from its present locational situation. As with other theoretical models, residential mobility results from the response of the household to increasing locational
stress levels that have exceeded some characteristic threshold value which quantifies its resistance to moving.

Although similar in many respects to the economic disequilibrium frameworks discussed previously, Brummell's model is distinguished for its conception of how disequilibrium conditions for the household actually come about. Economic theorists have typically failed to define precisely what they means by the term disequilibrium, but considering their almost exclusive attention to socioeconomic change in both theoretical specifications and subsequent empirical tests (Goodman, 1976, p.865; Hanushek and Quigley, 1979, p.98), they have tended to portray it as an absolute measure of deviance from the optimal consumption pattern which is endogenously defined by the household's socioeconomic characteristics.

But according to Brummell, locational stress is a relative concept which follows from a continuous evaluation process throughout portions of the urban environment. It relates only to the viable alternatives (those which fall within maximum and minimum need levels) of which the household is aware. Thus, households with identical preferences, incomes, needs and experienced place utilities may be subject to significantly different stress levels if their information about alternative housing opportunities is qualitatively or quantitatively different, since aspirations depend critically upon what is known to be attainable. Because of this, the concept of equilibrium in housing consumption does not really exist in this framework. The theory does recognize the household as a goal-seeking entity (Brummell, 1977, p.51) which may adopt incremental strategies to achieve longer term objectives (see Michelson, 1977). But the utility derived from following any given incremental strategy may be
nowhere near the household's "equilibrium" utility; it may simply be greater than the utility currently experienced, and this difference might be large enough to prompt a locational change.

Because the concept of stress is explicitly related to the individual's utility function, the theoretical model is receptive to qualitative analysis of its significant properties. As a result, Brummell has investigated how stress levels relate to changes in housing prices, and to changes in household income, needs and preferences in a comparative statics framework. His findings are revealing for they demonstrate the conditions under which stress is exacerbated by change and, conversely, those conditions which ameliorate stress. In analyzing the effects on stress from an income change, for example, Brummell (1977, p.59) shows its differential impacts on experienced and aspiration utilities. Experienced place utility increases because the household's budget line is shifted to allow greater consumption, thus enabling the household to exist at a higher utility level than previously. Similarly, aspiration place utility rises because hypothetical consumptions levels associated with all perceived residential alternatives are anticipated to increase as well. The relative change, however, depends upon current consumption levels and trade-offs among housing attributes and other goods. If the household's current situation is optimal, an income change will increase stress since, although consuming more, the household, because housing attributes cannot be easily changed, is forced into a consumption pattern which imbalances its allocation of resources; the increment in income must be devoted to consumption goods only. On the other hand, the household can easily re-allocate its additional income among consumption
goods and housing in an optimal manner when considering its hypothetical alternatives by altering the characteristics of perceived opportunities, reorganizing the choice set or redefining it altogether. These actions, then, tend to widen the gap between experienced and aspiration utilities, and thus increase stress. Similarly, if the household is currently over-consuming housing, an increase in income adds further stress to already existing levels because of the relative invariance of housing consumption over the short term. An increase in income for the household which is underconsuming housing, however, reduces stress since it allows the household to approach a more optimal consumption pattern.

That stress is impacted in the above ways in response to income changes under the specified consumption patterns is not, in itself, unexpected. But the theoretical framework is nonetheless significant since it clearly states the mechanics of the behavioral concept of stress and how the household's changing environment affects this perceived state of consciousness. Analyses which ascertain the impacts of changes in other behavioral and market parameters reveal similar relationships which yield to intuition in most cases, although some consumption patterns and stimuli lead to indeterminate qualitative results (Brummell, 1977, p.67).

Concurrent with the concern for understanding the factors which encourage mobility has been a similar one for understanding those which inhibit it. This has motivated the other major theme in the sociological literature and is one which has utilized a completely different set of techniques for representing the mobility process. The class of models which have evolved from this literature is more limited in scope than the
locational stress models discussed above, but has concerned the effects of a change in residence upon the household's subsequent mobility. Introduced in the more general context of social mobility theory by McGinnis (1968), the theoretical perspective was originally based upon empirical observation (McGinnis, 1968, p. 716) that there appear to be duration of stay effects in mobility situations which influence the likelihood of further movement by the individual. McGinnis transformed this observation into a theoretical axiom of cumulative inertia to elaborate upon a Markov chain framework for analyzing mobility patterns (see DeCani, 1961, for an early application of Markov models in mobility). The resulting Cornell Mobility Model has since served as the major reference point in subsequent mobility studies of this type.

The underlying behavioral explanation for the cumulative inertia hypothesis is that as time progresses, the household develops stronger emotional and physical ties to the current residence because of the establishment of interpersonal relationships within the community (Huff and Clark, 1978, p. 1106) and the progressive biasing of the household's cognitive image of the urban environment around the home. But despite this rationale, the importance of duration of stay effects on mobility has never been satisfactorily established, as inertial tendencies are always confounded in data by a second, and concurrent phenomenon. Originally suggested by Goldstein (1954), McFarland (1970) has theoretically shown that duration of stay effects in Markov models of mobility can be produced and explained simply by postulating varying mobility rates in an heterogenous population. Although empirical research has shown population heterogeneity and inertial effects to both exert some influence
upon the resistance to move (Clark and Huff, 1977), little progress has been made in determining how psychological attachments to dwelling and neighborhood are retained or utilized in mobility decisions. Different model formulations in this branch of the literature have thus generally considered alternative duration of stay assumptions in the Markovian framework.

McGinnis' (1968) model is perhaps the most elementary. In its simplest form, the distribution of the population among alternative locations is represented by a row vector, in which each element defines the number of households residing in a given area of the city at an arbitrary reference time. The mobility process is then characterized as a sequence of probabilistic events over a series of discrete, equal time intervals. During each event, a proportion of the population in each location migrates to another location according to a transition matrix whose elements distinguish the probabilities of migrating from one location to another over the specified time interval. These transition probabilities are assumed to remain constant over time.

McGinnis elaborates this system by partitioning the household location vector at the end of each mobility event into a set of classes according to their current residential histories. Households are thereby identified in the model by location in space and time, and by the number of time periods they have remained immobile. The axiom of cumulative inertia is invoked by assuming that the probability of moving from one location to another declines as the number of time periods in which the population remains immobile increases. This means that for the set of transition matrices which are applied to households that have remained at their current residences for \( k = 0, 1, \ldots, n \) time periods, the sets of transition
probabilities, \( \{P_{ij}(0)\}, \ldots, \{P_{ij}(n)\} \), decrease with increasing \( k \).

McGinnis (1968, p.718) also assumes that any household which moves in any given interval erases all memory of previous locational stability and, before the next mobility event, transfers to the population class which has remained at the current residence for no previous time periods (i.e. the most mobile population class).

Although the model, as described, embodies only one behavioral aspect of the mobility decision, it is extremely complex and its properties have never been analyzed exhaustively. McGinnis (1968, p.719) has shown that the aggregate household location vector (obtained by aggregating over durations of residence) converges to a limiting distribution which is different from the limiting distribution of an equivalent Markov chain model. Furthermore, this limiting distribution, under certain conditions, is dependent upon the initial distribution, which is in contrast to properties of the standard Markov model (Boudon, 1973, p.92).

However, many properties of the model are dependent upon assumptions concerning the rate of immobilization of the population as duration of stay increases, a concept which has yet to be given empirical meaning. Furthermore, the model has been criticized for its complexity, as it contains a countably infinite number of states, and embodies rather primitive assumptions regarding the total cancellation of duration of stay effects following mobility. As a result, most research efforts in this area since have attempted to address these issues.

Modifications to the behavioral assumptions which characterize cumulative inertia in McGinnis' (1968) model have been suggested by Boudon (1973). Rather than eliminating all duration of stay effects when a move is made, alternative forms of memory are placed on duration,
deriving a class of models from the original Cornell mobility framework. The two variants of the model formulated by Boudon (1973, p.87-88) both include measures on the sequence of moves and on the household's residential history prior to the last move. A "rigid" memory form of the model assumes past periods of stability to be remembered by the household throughout the period of analysis. (Recall that the original model "forgets" periods of stability as soon as a move is made.) This model is shown to converge to a limiting distribution over the location vector of households which is distinct from that derived by McGinnis. A second variant, a "gradual forgetting" form of the model, is proposed, although not completely developed. It assumes that earlier periods of stability are remembered, but with decreasing intensity as time progresses.

Shinnar and Stewman (1978) have extended Boudon's work to a more general formulation of discrete time Markov models by conceptualizing mobility along dimensions of both location-space and duration memory-space. Thus, a move symbolizes a transition not only to another location but also to another defined psychological state which determines the type of duration memory, and thus duration of stay effects, that influence mobility thereafter until the next move. Memory patterns which are formalized in the model include total loss of memory (duration of stay effects which are independent of previous mobility), memory with barriers to recall, rigid memory and gradual loss of memory. Additional enhancements extend the framework to include heterogenous populations having different duration memory patterns.

An alternative approach to modeling the mobility process has been taken by Ginsberg (1971). Arguing that the treatment of time as discrete
intervals in Markov mobility models severely limits their utility, mobility is instead formulated as a semi-Markov process. By doing so, both the timing of moves and destination selection are explicitly recognized in the framework. Waiting times until the next move are represented by arbitrarily defined probability distributions which can be structured to depend upon origin and destination states, and the length of time since the last move. Destination choices are characterized in the transition matrix of a simple embedded Markov chain. Thus, the model is capable of exhibiting all of the standard properties of McGinnis' earlier formulation plus additional properties related to duration of stay effects and mobility propensities among heterogeneous populations, but in a more consistent manner through the added dimension of time in the semi-Markov framework. Note, however, that casting mobility as a semi-Markov process revives the assumption that moving probabilities are independent of the household's mobility history prior to the last move (Huff and Clark, 1978, p.1105). Higher-order Markov process which might be specified to relax this assumption have not been proposed in the literature, probably because of their expected structural complexity.

As can be inferred from the above review, sociological investigations of residential mobility behavior, in contrast to the economic literature, have typically been diverse and fragmented. While theories concerning those factors which encourage mobility have generally been structured around accepted behavioral paradigms, those addressing the other side of the issue (the resistance to moving) have tended toward more macroscopic conceptions of the process and have developed more from empiricism than deduction. Because of these fundamental differences
in approach, the mutual study of the affirmative and inertial effects on mobility has been largely ignored. Although suggested as early as Ginsberg (1972), only one major attempt has been found in the literature which integrates the locational stress conception of mobility with duration of stay concepts investigated in the Markovian framework.

Huff and Clark (1978) have posited a residential history model which extends the Speare et al. (1975) concept of residential satisfaction to a composite one which recognizes both stress formation and resistance-to-moving forces which influence the mobility decision (see also Clark et al., 1979). The probability of moving is assumed to be a function of the difference between residential stress and resistance to mobility experienced by the household at time t. Furthermore, both stress and resistance factors are given explicit functional recognition with respect to time. This allows duration of stay effects to be directly considered in the model through an exponential decay function on an initial resistance level. It furthermore introduces the notion of temporal discounting of residential stress measures, which contrasts with simple cumulative stress indicies contemplated in Speare et al.'s formulation.

Although still naively specified (only aggregate stress and resistance measures are defined), the importance of this development is apparent in the complex mobility behavior the model produces (Huff and Clark, 1978, p.1110; Clark et al., 1979, p.696-697). Qualitative analysis reveals four general classes of temporal behavior which depends upon the relative discount rates applied to resistance and stress measures. These classes have been found to correspond roughly to different sub-populations.
of mobile households in empirical analyses, and different parameterizations of the model have produced complex, but realistic mobility patterns in simulation tests.

2.1.3 Summary

A review of the literature has traced the evolution of theoretical conceptions of the residential mobility process to their current states. From a neoclassical economic foundation which considered only the trade-offs between accessibility and land in the locational choice decision, the theory has been successively broadened conceptually to consider mobility as a multi-stage event encompassing an initial mobility decision, an evaluation stage and a residential selection process by the household. Developments of a theoretical nature have been identified in both the economic and sociological literature, where marginally different but generally non-competing conceptions of the mobility process have evolved.

Theoretical frameworks addressing the mobility decision have generally considered it to be an event which results from an increasing discordance between the housing and consumption bundle the household is currently consuming versus what it believes it could consume if it were to relocate elsewhere. Several approaches have further investigated the inertial effects of settlement which tend to immobilize households, even when substantial inconsonance exists between current and desired consumption levels.

Locational choice theory, though not completely reformulated from its neoclassical origins, has been progressively generalized by its incorporation of information bias and transactions and search costs as
constraints, and by its recognition of the multidimensional preferences of individuals actively participating in the housing market. These developments have led to the articulation of more complex behavioral patterns in models of the mobility process which are generally not reconcilable with those of neoclassical theory.

Concurrent with theoretical developments has been the growth of another body of literature concerned with empirical research into residential mobility behavior. Although sometimes undertaken to confirm various hypotheses deduced from theory, much of this research has taken place because of our still incomplete understanding of the factors which influence the household's mobility decision and its residential choice strategies. As a result, empirical studies have often suggested directions for further theoretical research and, accordingly, have come to exert considerable influence. The next section of the chapter reviews these important empirical contributions; it considers exploratory analyses of data and empirical models of selected mobility phenomena.

2.2 **Empirical Evidence**

Empirical studies reviewed in this section are those which have attempted to investigate the significance of selected sociological and environmental variables on the household's mobility and residential choice decisions. Although not always strictly comparable, most empirical findings reported in this review have received considerable substantiation and have formed the basis for most modeling efforts subsequently undertaken.
Speare (1974) has suggested a convenient framework for organizing the empirical evidence presented in this section. Consistent with the theoretical literature, mobility is considered as a response to three types of stimuli acting upon the household: needs generated by changing socioeconomic circumstances, the social and physical attributes offered by particular locations, and the standards the household uses to evaluate its situation. These three stimuli interact to influence the household's assessment of the present residential environment, and its expectations and desires associated with alternative environments.

In reviewing the literature, we note that measures of mobility, particularly those related to intended mobility, have not been standardized in empirical studies. However, three distinct variables relating to Rossi's (1955, p.102) conception of the mobility decision have been applied most often: desired, expected and actual mobility. And although the exact interpretation of each term has varied with the specific wording on survey questionnaires, conveying to respondents different impressions regarding what is meant by "wishing to move" or "planning to move" (see, for example, Speare, 1974, p.178), a general consensus has emerged as to their meaning. Desired and expected mobility have been interpreted in this review as different degrees of moving potential, the former reflecting the household's mobility preferences and the latter its more precisely articulated plans for moving (Butler et al., 1969, p.49). The dichotomy is important because, although they are positively interrelated, the greater "reality content" (Pickvance, 1974, p.185) of expected mobility has been found to provide a better predicate to actual mobility (Van Arsdol et al., 1968); desired mobility, on the other hand, has been
shown to be more indicative of residential dissatisfaction (Speare, 1974). Further references to mobility will attempt to remain consistent the meanings attributed to types of mobility described here.

2.2.1 Socioeconomic Characteristics

The importance of socioeconomic characteristics in mobility behavior has long been established in the empirical literature. Rossi (1955) was one of the first to articulate a direct relationship between mobility rates and socioeconomic status, a finding that has since been substantiated in other studies of mobility patterns in urban areas (Moore, 1972; Simmons, 1974). Research of more relevance to this study, however, is that which has attempted to transform these empirical regularities into substantiated behavioral hypotheses. From these latter studies has evolved a set of household characteristics which distinguish the different elements of the mobility decision.

Of the parameters which can be defined to characterize the socioeconomic status of households, one which has been consistently cited throughout the literature to be a major influence on mobility behavior is family life-cycle. Defined as the stages through which the family ages, from formation to final dissolution (Glick and Parke, 1965), most empirical studies have found strong associations between the family life-cycle and mobility. Expected mobility has been found to be most prevalent among younger families, particularly those with the oldest child at a pre-school age (Bulter et al., 1969), small families (Roistacher, 1975, p.263) and very large families (with seven or more members) (Roistacher, 1975, p.263). Although not as strongly related, empirical evidence has also shown actual mobility to be positively associated with the family
life-cycle (Chevan, 1971; Roistacher, 1975).

Age, although considered by some to be a surrogate for life-cycle, has also been studied independently for its influence on mobility. Defined in most research as the age of the household head, the hypothesis which has usually been tested is that age is a deterrent to residential mobility. The empirical studies of Rossi (1955), using desired mobility as the dependent variable, Speare (1974) using desired and actual mobility, Roistacher (1975), using expected and actual mobility, and Menchik (1971), Duncan and Newman (1975) and Schnare (1979), using actual mobility, have all supported this hypothesis. Although found to be an important variable in the mobility decision, however, it has been shown not to have more than a minor impact on locational outcomes (Butler et al., 1969).

Tenure is another characteristic of the household which has been repeatedly substantiated as having an important socioeconomic influence on mobility. Universally, the finding has been that those who own homes are far less likely to move than are renters (Rossi, 1955; Butler et al., 1969; Brown and Kain, 1972; Speare, 1974; Roistacher, 1975; Goodman, 1976). Data from the Panel Study of Family Income Dynamics found renters to be three times more likely to move than owners and, to be more likely to fulfill their expectations than homeowners with identical plans (Duncan and Newman, 1975). Relationships of similar magnitude have been observed between tenure and desired mobility.

Although statistically significant in most empirical tests, the role that tenure plays as a stimulus to mobility, in relation to those of other socioeconomic characteristics, has not been substantiated to
the same degree. Pickvance (1974) has suggested that tenure acts as an intervening variable between both desired and expected mobility and household characteristics such as life-cycle, age and income, thereby exerting the only direct influence of all socioeconomic factors on the mobility decision.

Using cross-sectional data from a 1968 survey of West Indian and Asian residents in Manchester, England, Pickvance tested for significance seven possible path coefficients to desired and expected mobility. The analysis found that of the household characteristics defined, only life-cycle and age were significantly related to desired mobility, but only indirectly through the intervening tenure variable. Tenure was found to be the only variable acting directly upon desired mobility (Figure 2.1, top). Causal linkages were significantly different when expected mobility was considered, with tenure being one of three direct socioeconomic linkages to the mobility variable (Figure 2.1, bottom). Findings of tenure's central role as a mobility stimulus have also been supported by Speare (1974) and Michelson (1977).

Two other socioeconomic characteristics, race and income, have been found to play more complex roles in the mobility process. With regard to race, non-whites in the United States have been found in a number of studies to possess a markedly higher incidence of expressed desire to move than whites, but have not been found to possess higher mobility rates. Income, though hypothesized to be an important mobility variable, has rarely shown the significance nor sometimes anticipated relationship intuitively expected from data on residential mobility.

That non-whites have been found more often to express moving desires,
(a) Causal Sequence Associated with Desire Mobility

Life-cycle stage | (unexplained variation) | Desired Mobility
---|---|---
Life-cycle stage | (unexplained variation) | Expected Mobility
Life-cycle stage | (unexplained variation) | Expected Mobility
Income | +ve (or -ve) | Expected Mobility

1Life-cycle is defined as a dichotomous variable (married/not married); interpret, for example, the positive association between life-cycle stage and tenure as "being not married induces rental tenure status".

2Tenure is the dichotomous variable "rent/own"; the positive association between tenure and mobility implies that renters are more likely to be considering moving than owners.

3Income of the household head.

4When income is measured as total family income.

Figure 2.1 Observed Causal Relationships Between Socioeconomic Characteristics, Tenure and Intended Mobility. (Source: Pickvance, 1974, p. 185)
but less often to express moving expectations than whites, has usually been attributed to anticipated housing or price discrimination (Roistacher, 1975; Weinberg, et al., 1977). On the other hand, Roistacher has found that when actual mobility rates are adjusted for socioeconomic characteristics, moving rates of blacks are similar to whites, and has countered discriminatory arguments with hypotheses related to social differences in planning horizons, eviction rates (Roistacher, 1975), and motivation (Duncan and Newman, 1975). None of these latter hypotheses have been satisfactorily substantiated in the literature, however.

Results are somewhat less ambiguous with respect to residential choice. Butler et al. (1969) found distance of the move to be related to both race and income, with low income non-whites tending to rent cheaper housing in central cities and to experience more crowded conditions. McAllister et al. (1971) found blacks less likely to move outside their neighborhoods, although neither this nor the previous study determined whether observed locational behavior was attributable to racial discrimination in the housing market or sociologically motivated preferences related to the neighborhood. More recent evidence, however, indicates that distance biases associated with race are likely attributable to perceived racial discrimination in search, or the spatial contraction of search in anticipation of discrimination by black households, rather than individual preferences (Weinberg et al., 1977).

Relationships of income to mobility have not been consistently demonstrated in the literature, though often because housing costs have not been controlled. For example, its relationship to desired mobility has ranged from slightly positive and significant in one study
(Speare, 1974), to insignificant in another (Pickvance, 1974). Generally, a small positive relationship has been detected between income and expected mobility (Speare, 1974; Pickvance, 1974; Roistacher, 1975) but income has been found to have little to do in translating moving expectations into actual mobility (Duncan and Newman, 1975). Goodman (1976), however, has found the probability of moving to be significantly related to a change in income. With respect to residential choice, although it has been found to be an important determinant of how much families spend on housing, income does not appear to influence the amount of space consumed (McCarthy, 1976).

The association of income and housing costs is an interesting one whose effects on mobility are not totally understood. Schnare (1979) has found, for example, that mobility rates from urban homesteading neighborhoods are positively related to incomes of homeowners, but negatively related to those of renters. Rather than income, it is suggested renters that are sensitive to housing costs and would be induced to move if rent increases were expected. Relationships among income, tenure and mobility have also been investigated by Pickvance (1974).

2.2.2 Locational Attributes

Locational attributes are the objective characteristics of the environment, as perceived by the household, which influence the household's satisfaction with a given place. If these amenities deviate from their expected levels or are perceived to be attainable at another location at an acceptable cost, they may stimulate the household into considering relocation. Butler et al. (1969) define four basic dimensions of location upon which mobility behavior can be discussed: neigh-
borhood characteristics, housing characteristics, accessibility and neighborhood services. To these can be added a fifth component, related to all four of these dimensions, housing cost.

All studies have shown neighborhood characteristics to be important elements of the household's environment and significant determinants of mobility and choice decisions. With respect to the decision to move, almost universally it has been observed that households living in poorer quality neighborhoods are more likely to express moving desires than families in better areas of the city. However, the relative importance of neighborhood quality has not received a consensus in the literature.

For example, Rossi (1955), Barrett (1973) and Michelson (1977) have found it to be less important than housing characteristics, while Schnare (1979) has shown that neighborhood quality may only be important for owners. On the other hand, Dutlor et al. (1969) have found it to be the most important of the four dimensions of residential satisfaction they define. Similar results have been reported by Speare (1974), who found neighborhood cited as the most important or next most important factor in housing satisfaction by more than 56 percent of the respondents in his survey of Rhode Island residents. Analysis by Stegman (1969) and Morrison (1972) have shown neighborhood quality to be more important than accessibility.

Neighborhood quality is also important in residential choice. Retrospective responses by households to questions concerning the important attributes the household considered when looking for a place to live have consistently shown neighborhood attributes to be one of the most frequently cited criteria. Butler et al. (1969), for example,
found that an overwhelming majority of metropolitan households preferred better neighborhood quality with a less desirable housing unit or a less accessible location, to a less desirable neighborhood with either a better housing unit or better accessibility.

Although accepted in the literature to be important, few studies have attempted to define the components of neighborhood quality which are actually evaluated by households. Instead, mobility has usually been related to measures of satisfaction or other indirect evaluative indices of neighborhoods. Studies which have attempted to identify these components have usually done so by interpreting the loadings of independent variables on a reduced set of factor scores related to neighborhood quality (Butler et al., 1969; Atkinson and Phipps, 1977; Cadwallader, 1979) or by analyzing regression equations estimated on mobility or choice data (Levin and Mark, 1977; Schnare, 1979).

Empirical evidence reveals that neighborhood quality is typically evaluated in terms of two major cognitive categories, comprising the physical and social attributes of the neighborhood (Johnston, 1973). Significant physical attributes that have been identified in the empirical literature include the exterior conditions of dwellings and lots, conditions of public facilities such as streets, sidewalks, and curbs (Butler et al., Atkinson and Phipps, 1977; Schnare, 1979), and characteristics related to lot size, privacy and traffic noise (Butler et al., 1969; Cadwallader, 1979). Identified social attributes of importance have included measures of friendliness and interaction with neighbors (Butler et al., 1969; Schnare, 1979), crime (Levin and Mark, 1977; Atkinson and Phipps, 1977; Cadwallader, 1979) and the demographic
composition of the neighborhood (Levin and Mark, 1977; Cadwallader, 1979). In addition, a residual neighborhood quality or satisfaction dimension has usually retained some statistical significance (Butler et al., 1969; Schnare, 1979).

Housing characteristics, and their relationship to household satisfaction and mobility, have been studied by several authors and have been found to be of major importance throughout the literature (Rossi, 1955; Michelson, 1977). Though characterized by several dimensions, usually relating to quality, distinctiveness and conveniences (Levin and Mark, 1977; Cadwallader, 1979), the primary housing-related determinant to mobility and choice has pertained to interior space. Rossi found 51 percent of the movers in his sample citing living space as contributing to their moving desires, and 44 percent responding that space was the primary reason for moving. Similarly, interior dimensions of space and quality were cited by 24 percent of respondents, second only to life-cycle changes, as the primary reason for moving in McCarthy's (1976) study. Butler et al. (1969) found the highest component loadings on satisfaction with the dwelling to be the number of rooms and number of bedrooms.

Although objective measures of space have proven to be significant variables in the mobility decision, Moore (1972) has suggested that the reaction to living space is more one of individual perception than objective reality. To this end, using Rossi's data, he finds a predominant association between family size and movement desires, with only a small additional influence from dwelling size. From this, he infers the direct relationship between dwelling space and mobility to be spurious. However,
the contradiction is likely due to variable specification. Chevan (1971) has suggested a more appropriate measure of interior space demands is household density, and has shown it to exhibit an independent influence on moving behavior. Both Chevan (1971) and Schnare (1979) have found greater mobility to be related to higher household densities.

Dwelling unit attributes also play an important role in the selection of a new residence. Rossi (1955) found space and design to be the most frequently cited set of criteria in the residential choice decision, each attribute being mentioned by half the movers surveyed. Similar findings have been reported by Menchik (1971); 25 percent of the respondents cited space, and 42 percent claimed design to be primary considerations in their choice of dwelling. Cadwallader (1979) has shown spaciousness to be a major evaluative dimension in residential preferences, while Levin and Mark (1977) have suggested that households tend to increase the number of rooms they occupy, particularly bedrooms or bathrooms, when they relocate. Although this tendency is generally characteristic of both owners and renters, McCarthy (1976) has suggested that the adaption to larger residences by the former is usually less precise (McCarthy, 1976, p.44).

Households also exhibit definite design preferences for housing. In addition to the universal preference for home ownership (Rossi, 1955; Butler et al., 1969; Frieden, 1978), Butler et al. (1969), in their national survey, found households to prefer modern architecture over traditional (barely) and to prefer, paradoxically, a new house in a well-established neighborhood. Other measures of housing quality, concerning structural (i.e. single versus multiple family) and convenience features
(i.e., air conditioning), have found to be important as well (Levin and Mark, 1977).

Although traditionally hypothesized to be a major determinant of mobility and choice, accessibility is perhaps the most ambiguous of the major dimensions considered in this review. Inspired by neoclassical location theory, almost every empirical study has examined the impact of accessibility upon moving behavior. However, much of this literature has found it to be less important than originally conjectured.

For example, Rossi (1955) and Barrett (1973) both found space complaints to be a more frequent reason for households wanting to move than locational complaints, and Stegman (1969) and Morrison (1972) found neighborhood considerations to be more important in locational choice than accessibility to place of work. Barrett notes that only 2.7 percent of the respondents in his sample stated that living closer to the workplace was even one of the deciding factors in the decision to move, and households in Michelson's (1977) survey cited general access as one of their reasons for moving only about 7 percent of the time. McCarthy (1976) found only 4.7 percent of the households he surveyed in Brown County, Wisconsin moving primarily because they wanted to live in a more convenient location. And in the national survey analyzed by Butler et al. (1969), satisfaction with accessibility accounted for the least variance of the four major components of satisfaction considered.

But other studies have found accessibility's role in the location decision to be more important. Weinberg's (1975) analysis of the mobility histories of residents in the San Francisco Bay area, for example, identified a significant association between journey-to-work and actual
mobility. Hypotheses that workplace change affects residential mobility and that residential change affects workplace mobility were both supported by the data in his study, suggesting a direct interdependence between residence and workplace locational changes. Furthermore, Mayo (1973) and Friedman (1975) found journey-to-work costs significantly related to the locational decisions of households in their samples, although Mayo found the relationship to be significant only for single worker households. Distance to the workplace (but not travel time) was found to be a significant component of the household's preference structure towards neighborhoods in Levin and Mark's (1977) study of mobility in St. Louis.

Journey-to-work considerations appear to intensify in locational preferences when accessibility is constrained by distance or other factors. Butler et al. (1969) for example, found that households living forty or more minutes away from the workplace were more likely to be intending to move than those living closer to work. This correlates with Menchik's (1971) study of residential preferences of households living in the suburban fringes of Philadelphia. Accessibility preferences were the second most articulated response of households, behind space preferences. Butler et al., also found satisfaction with accessibility to be moderately associated with generalized cost to most activities, and strongly associated with the auto-ownership level of the household and its usage of public transportation. Dissatisfaction was found to increase in those households with few or no vehicles available and those having increased dependency on public transportation. However, the latter relationship was found not to be significant in another study involving low income households (Weinberg et al., 1977, p.A-38).
One reason for the ambiguous findings concerning accessibility in the empirical literature has been suggested by Redding (1970), who has posited that the accessibility-locational choice relationship is not always apparent because accessibility benefits are often obfuscated by proximity costs. He has argued that proximity costs often outweigh the benefits of locating near major destinations, such as workplaces or shopping areas, because of the externalities they generate. Thus, when these costs are combined with the traditional relationship between accessibility and residential satisfaction, the result is a U-shaped association between dissatisfaction and distance. Since we cannot usually dissociate the simultaneous consideration of the costs of proximity from the benefits of accessibility, apparently negligible impacts of accessibility or movement desires are observed in statistical tests.

This hypothesis has received partial substantiation in the literature. Empirical studies which have isolated several distinct components of accessibility (related to the types of destinations the household is accessible to) have generally found positive associations between residential satisfaction and accessibility to destinations that generate fewer externalities. For example, Butler et al. (1969) observed residential satisfaction to be positively and significantly influenced by accessibility to convenience locations containing retail and personal services, but not to be influenced by accessibility to the workplace or to schools. And Weinberg et al. (1977) found neighborhood satisfaction to be significantly associated with accessibility to grocery stores and places of worship.

But whether these considerations precipitate household mobility
decisions has not been conclusively established. Though Speare (1974) found satisfaction with distance to schools, shopping and work to be moderately important to respondents in his survey (in terms of the proportion of respondents citing them as the first or second most important items relating to satisfaction), he failed to find any statistical significance in the relationships between the relative importance of the variables (as defined above) and either desired or actual mobility. These results suggest that relationships between accessibility measures and mobility are still far from clear.

The impacts of neighborhood services on mobility and choice behavior have been investigated by a number of authors. These services are the local public goods and services provided to constituents of local jurisdictions by government and quasi-government agencies. Typically, measures of public services have included fire, garbage and police services (Butler et al., 1969; Atkinson and Phipps, 1977; Levin and Mark, 1977), recreational facilities (Mayo, 1973; Atkinson and Phipps, 1977; Cadwallader, 1979) and schools (Mayo, 1973; Friedman, 1975; Weinberg et al., 1977; Levin and Mark, 1977; Atkinson and Phipps, 1977).

Hypotheses pertaining to their effects on mobility are those originating from the Tiebout hypothesis (Tiebout, 1956), which conjectured that households tend to settle in communities in accordance with their incomes and preferences for outputs of local public services (Friedman, 1975, p.18). Both out- and in-migration phenomena have been studied in the context of this hypothesis.

Moore (1972) has suggested that public goods are likely less responsible for stimulating mobility than they are for attracting households
to locations, and this contention has received some support in the empirical literature. Butler et al. (1969) found neighborhood services to explain only a small amount of variance in satisfaction levels expressed by respondents in their national survey. Of the consideration given to services, only fire and police protection, sewage and water systems, and parks and playgrounds were of any relevance to residential satisfaction levels.

On the other hand, with regard to residential choice, Atkinson and Phipps (1977) and Levin and Mark (1977) have both shown that movers tend to relocate to areas providing more or better public services. Atkinson and Phipps, in comparing scores given to neighborhood services both before and after the move, generally found households to assess higher scores to public services, school quality and recreational facilities associated with their new neighborhoods. Levin and Mark similarly found significant associations between neighborhood choice and both per pupil expenditures, and student-teacher ratios in the local school system, and the crime clearance rate for the police district in which the neighborhood was located.

Not all studies have concurred with these findings, however. Mayo's (1973) analysis of residential choice behavior of mobile households in Milwaukee found local government variables to be insignificant in his locational choice model, and Friedman, though finding most public goods and services to be statistically significant, concluded that these services play only a minor role in residential choice (Friedman, 1975, p.84).

The impacts of local public goods and services become less ambiguous, however, when income is taken into consideration. Weinberg et al., found public services to bear significantly upon the residential satisfaction levels
of low income households over almost every measure of public services 
considered in that analysis (Weinberg et al., 1977, p.A-38). Studies of 
residential location decisions have found lower income households to 
prefer greater quantities of public services, tending to locate in areas 
characterized by high effective tax rates (Friedman, 1975, p.81), middle 
class areas (Mayo, 1973, p.40) and areas with high per capita educational 
expenditures. Friedman has suggested that low income households pursue 
this locational strategy in order to increase their real incomes, avoid-
ing full payment for these services by consuming smaller quantities of 
housing in the community (Friedman, 1975, p.82).

A final locational attribute investigated in this section is housing 
cost. Moore (1972) has asserted that the overall effect of housing cost 
on the mobility decision is weaker than might be expected. Furthermore, 
when cost is cited, it is more often articulated by renters than by own-
ers.

Cost considerations have been cited by movers in surveys, but gener-
ally, the empirical literature has found them to be a minor importance. 
McCarthy (1976), for example, found only 6.5 percent of all households 
in his survey attributing their mobility primarily to housing cost. And 
only 7.9 percent of the households in Michelson's (1977) study mentioned 
fiscal considerations as even one of their reasons for moving. The dif-
ferential impacts of housing cost upon owners and renters have been less 
thoroughly investigated. Schnare (1979), however, has found that while 
neither owners nor renters are particularly sensitive to past changes in 
housing cost, an expected change in rent exerts a significant influence 
on the likelihood of a move (Schnare, 1979, p.23).
Cost has been shown to be even less of a factor in locational choice. Respondents in Michelson's (1977) survey cited fiscal considerations as one of the reasons for choosing their new residence only 6.3 percent of the time, compared with nearly 8 percent citing them in the mobility decision. (The significance of the difference was not tested.) Also, Lansing et al. (1964) report most of the moves in their sample were upgrading moves (in terms of housing and locational quality), where significantly more was spent on housing after the move than before (Lansing et al., 1964, p.22).

The influence of housing cost on mobility is difficult to determine since, as discussed previously, it is dependent to a great extent upon household income. Few studies have attempted to address these interdependencies and how they influence subsequent mobility behavior. Goodman (1976) has shown that households whose housing expenditures are less than average for its economic status are more likely to move than families whose expenditures are greater, but his analysis is only suggestive since income considerations in relation to housing cost were not explicitly considered. Schnare (1979), however, has attempted to quantify these relationships more precisely. Her analysis of mobility data for forty different neighborhoods in 23 demonstration cities in the Urban Homesteading Demonstration Program finds income and housing cost to exhibit significant interdependent effects upon the mobility rates of homeowners only. Homeowners whose housing costs required half their incomes had estimated mobility rates which were 50 percent higher than those who spent only 10 percent of their income on housing. Renters responses to housing cost, however, were essentially independent of income; their
mobility, instead, was predicated upon expected increases in rents, as described earlier.

2.2.3 Standards

Standards relate to the attitudes and values held by the household which in some way influence its mobility or residential choice. They are factors which, though to some extent correlated with the household's socioeconomic status and current residential environment, influence the way in which the current locational situation is evaluated and the dimensions over which alternative residential opportunities are considered.

Moore (1972, p.8-9) has discussed standards in terms of "push" and "pull" factors acting upon the household. He has argued that push factors relate to how the household feels towards its present locational environment. These feelings, which are translated into action (mobility), are typically manifested in the attitudes the household possesses towards the social composition of the neighborhood. Thus, complaints about the neighborhood composition observed in most mobility studies (see McCarthy, 1976, p.63; Atkinson and Phipps, 1977, p.105; Weinberg et al., 1977, p.A-38) are thought to arise from the neighborhood undergoing a social change which the household deems undesirable or the household's changing expectations for the social environment in which it operates (Moore, 1972, p.8).

Although several authors have found these attitudinal factors to be important in neighborhood satisfaction ratings (Atkinson and Phipps, 1977; Weinberg et al., 1977) and actual mobility (Rossi, 1955), they have typically been shown to be less important than objectively defined attributes of the residence, such as public services provided to the neighborhood (Weinberg et al., 1977), specific characteristics of the
dwelling (Rossi, 1955; McCarthy, 1976), and changes in the household's socioeconomic circumstances (McCarthy, 1976).

Pull factors relate to the household's perceptions of alternative residential environments and are usually expressed through its lifestyle aspirations. Bell (1958) identified three kinds of aspirations which appear to motivate the household into changing residence: consumption-oriented aspirations, social prestige-oriented aspirations and family-oriented aspirations. To this, Moore (1972, p.9), upon the suggestion of Gans (1967), has added a fourth, community-oriented aspirations. And although empirical research has not resolved whether, according to competing theories of social behavior, households utilize mobility as a form of status enhancement (Feldman and Tilly, 1960) or self-selection (Bell, 1958), usually one type of aspiration has been found to dominate the mobility decision in household surveys asking respondents why they moved (Gans, 1967; Feldman and Tilly, 1960; Bell, 1958; Levin and Mark, 1977; McCarthy, 1976). However, little in the way of empirical evidence has managed to quantify the relative importance of these aspirations or the context and conditions under which they become significant. Michelson (1977, p.160) has furthermore found little empirical support for Gans' (1967) conjecture that community-oriented aspirations lead to suburban settlement in single family dwellings.

Suggestions that lifestyle aspirations are only manifested in the mobility behavior of homeowners have also been refuted in the empirical literature. In fact, this is the central argument in Michelson's (1977) research. He asserts that renters, rather than lacking long term aspirations, are actually adopting incremental strategies of achievement toward
their goals, since the attainment of an ideal is currently constrained by the stage in the family-mobility cycle in which they find themselves (Michelson, 1977, p.33-34).

In support of this, Butler et al. (1969) found no significant differences between the aspirations of movers and non-movers. Their study defined seven attitudinal scales relating to familism, neighborhood perception and social mobility, urban-suburban orientation, mental well-being, neighborhood factors, housing and neighborhood preferences, and housing characteristics of current place of residence, and found no relationship between these scales and residential mobility. However, by differentiating according to age, they did find several significant characteristics. For younger households, families who did not define important factors in choosing a neighborhood or who desired a change in accessibility were more likely to be residentially mobile. Older households who had one of the following attributes -- familistic consumer-oriented, high social mobility commitment, non-interaction with neighbors, little regard for the reputation of the neighbors or the neighborhood, or dissatisfaction with public services -- were more likely to be residentially mobile than those without these attitudes.

A final factor which has been indirectly related to standards is the previous mobility of the household. As was theoretically postulated in McGinnis' (1968) axiom of cumulative inertia, most studies have observed an inverse relationship between duration of residence and residential mobility. Behavioral explanations for this phenomenon have usually centered around the household's establishment of interpersonal relationships near the home and the progressive spatial biasing of the
household's cognitive image of the urban environment. Weinberg et al. (1977) found, for example, previous mobility to be the only significant influence on the moving probabilities of two samples of searching households, and attributed its influence to the better developed information channels and more extensive spatial search fields of previously mobile households.

However, Clark and Huff (1977) maintain that although tests have supported the existence of duration-of-stay effects, they have not necessarily proven that they result from cumulative inertia. In opposition to prescribing duration-of-stay effects to cognitive differences, McFarland (1970) has suggested that the observed decline in mobility with duration-of-stay could simply be attributed to heterogenous mobility rates associated with different population groups. Clark and Huff (1977) have attempted to distinguish between the two phenomena by controlling for heterogeneity in the population and testing whether the effects of cumulative inertia on mobility rates are identifiable. Their analysis suggests cumulative inertia to only weakly influence mobility and that duration-of-stay, as currently defined, is an inadequate indicator of the effects of prior residential history on mobility behavior. Quigley and Weinberg (1977, p.53) have gone one step further by suggesting the relationship between previous mobility and moving probabilities is entirely due to a spurious correlation.

2.2.4 Summary

Empirical evidence reviewed in this section has revealed what appear to be the major determinants of residential mobility and residential choice behavior. It has characterized these determinants in terms
of three generic types of stimuli associated with the household's socioeconomic composition, the social and physical attributes offered by particular locations and the standards by which the household evaluates its situation, to ascertain their impacts upon both the various stages of intended mobility the household passes through before actually deciding to move and the residential choice decision subsequently made.

Socioeconomic characteristics found to be important in the mobility and choice decisions include family life-cycle, age of the household head and tenure, although the causal relationships among these variables and mobility decisions are still far from clear. Race and income, also hypothesized to be significant, have not received as conclusive substantiation. Here, it has been argued that ambiguous findings concerning race have resulted from constraints on household activity not observed in the data, and those pertaining to income from its interdependence with housing costs. Evidence from empirical studies has also suggested that changes or anticipated changes in selected socioeconomic characteristics, particularly family life-cycle, age and income, are likely more appropriate precipitators of the mobility decision than current levels of these variables associated with the household.

Locational attributes associated with the current dwelling and alternative living environments have been found to be important considerations in both the mobility and residential choice decisions. Attributes of the residential unit, particularly living space, and those related to neighborhood quality have consistently been revealed to be major determinants of satisfaction levels associated with the household's current locational situation, and important criteria in residential choice.
Accessibility and public service provision appear to play more ambiguous roles in the relocation process, although accessibility to retail and social services and to the workplace, when constrained by distance or number of automobiles, has been found to bear some significance in mobility and choice decisions. The importance of public service provision in residential choice appears to intensify with declining income. Housing costs, when considered independently of income, have been found to be of more concern to renters than owners, stimulating mobility when cost increases are anticipated in the near future.

Standards over which present and alternative housing opportunities are evaluated have received less explicit attention in the residential mobility literature. Attitudes toward neighborhood composition have been found to have some influence on residential satisfaction levels although typically less than objectively defined amenities offered by particular locations. Similarly, lifestyle aspirations of the household appear to play a role in residential choice, although defining the ways in which these aspirations are manifested in choice has barely progressed beyond conceptual arguments. Previous mobility or, conversely, duration-of-stay has been found to influence the mobility decision, but it has been argued that its significance is generally overstated because its relationship to mobility is obfuscated by heterogeneous population mobility rates, a factor which has usually not been controlled in the empirical literature.

Although not all empirical hypotheses examined in this section derive directly from theory, empirical analysis of mobility and choice behavior is generally supportive of the theoretical paradigm that
has evolved in the mobility literature. It is a paradigm that has considered residential mobility as a process which is separable into the decision to move and the choice of a new residence, and as such, has developed the contexts in which empirical analyses have been directed.

But the paradigm upon which most analyses of residential choice have been based is an incomplete representation of human activity in the relocation process. It is important to recall that theories and theoretical models examined in this chapter are but simplifications of the more general conceptual framework that has been developed to outline the series of decision problems encountered by the individual during relocation. As conceived by Brown and Moore (1970), residential mobility is an adjustment process whereby one residence is substituted for another. To effect this substitution requires three phases of activity by the decision maker comprising the initial mobility decision, search for feasible alternatives, and finally, residential choice. And while models of the decision to move have remained consistent with their conceptual foundations, those of residential location have not, subtending the decisions and uncertainties associated with search under simplified assumptions relating to information and choice. That constraints attributable to the search process have been incorporated into recent theories of residential location (Richardson, 1977; Rothenberg, 1975) is significant, for they indicate a recognition of the impacts search activities have on both residential choice and the mobility decision.

But beyond its recognition in neoclassical theories of location, the search process, as it relates to residential choice, has not been comprehensively analyzed for its role in residential decision making.
This is partly attributable to the complexities that arise when it is considered, as was demonstrated in Richardson's (1977) generalized model. But it is also indicative of the absence of both a well-developed theory of search behavior, as it relates to residential decision making, and sufficient data upon which to test its behavioral hypotheses. Only recently has a body of literature developed which attempts to analyze residential choice in the context of vacancy search. Before defining the issues to be investigated in the remaining chapters, then, we first review these studies to motivate the subject of this dissertation.

2.3 Search Behavior in the Context of Residential Choice

Though recognized in some theoretical models of residential choice, characterization of search behavior as a distinct element of the mobility process has not been subject to a great deal of research. Recent activity in the area parallels mathematical developments in the economics of information and its application to other fields. An earlier application to residential search by Schneider (1975) is not considered in this review, since it cast the search process as space searching for randomly located targets on a grid, similar to defense applications for locating enemy targets, and yielded no substantive behavioral hypotheses concerning search behavior.

Theoretical frameworks which are of relevance to this study have been developed by Weibull (1978) and Smith et al. (1979). Of the two, Weibull's is more limited in scope as it considers search activity only;

---

1Search theory has been applied to problems involving gasoline purchases (Goldman and Johansson, 1978; Johansson and Goldman, 1979), shopping center choice (Hay and Johnston, 1979), job search (Kahn, 1978; Pissarides, 1974; many others), and several other issues.
Smith et al., on the other hand, attempt to integrate residential search into the existing mobility choice framework discussed above.

Weibull (1978) characterized the search process as a sequence of residential opportunities observed by the searcher over a specified period of time. Each opportunity is characterized by its value, or utility, to the searcher, and sampling involves a fixed cost per observation. The distribution of values in the population from which the sample is drawn is assumed to be known to the searcher and the interarrival times between observations are stochastic. Residential decision making is characterized by the searcher choosing one of two alternatives at each observation: either he/she accepts a given opportunity or continues search for a better prospect knowing the costs and benefits involved in the decision; once an alternative is forgone, it can never be retrieved.

The specification of the problem is essentially a mathematical one designed to exploit the properties of a persistency problem in optimal stopping theory investigated by Elfving (1967). However, a context is developed which is applicable to particular conceptions of residential and job search activities, and by relating model parameters to housing market conditions and the searcher's characteristics, a coherent framework for theoretically investigating residential search behavior is advanced.

Weibull generalizes the model through several modifications. The searcher's perception of competition for vacancies in the market is introduced through a modification of the perceived distribution of utilities in the vacancy population. Spatial dimensions of search are incorporated through the assignment of locational attributes to resi-
dential opportunities or, alternatively, through the probabilistic 
arrival function which characterizes the sampling process. Further, 
alternative attitudes toward risk are associated with the searcher, which 
affect the benefits expected from further search.

Since the problem specification relates to optimal stopping theory, 
solution of the problem yields a stopping criterion, or aspiration uti-

lity, which equates the marginal cost of sampling another vacancy to 
the marginal gain expected from observing it. This stopping criterion 
is a moving standard which is the basis for each binary decision; search 
is discontinued at the first alternative inspected with utility greater 
than or equal to the searcher's aspiration utility. Residential choice 
is thereby characterized by the observation at which search is terminated.

Smith et al. (1979) integrate search activities into the residen-
tial mobility process by relating search behavior to the concept of 
locational stress. In addition to its preferences and income constraints, 
the household is assumed to possess a set of beliefs about the housing 
market. The structure of the housing market and characteristics of in-
formation sources which describe the market are assumed to be such that 
the household perceives housing opportunities in terms of spatially 
identifiable sub-markets, in each of which, housing characteristics are 
relatively homogeneous. Since knowledge of opportunities in each sub-
market is imperfect, individual's beliefs are characterized in terms of 
subjective probability distributions, each of which describes the joint 
distribution of housing characteristics and housing costs in a particular 
sub-market. The household is furthermore assumed to possess a set of 
beliefs which relate to the costs of searching for a new dwelling, costs
which include search costs, opportunity costs of search time, trans-
actions costs (if a vacancy is chosen) and an opportunity cost associ-
ated with losing a potential vacancy to another searcher.

Similar to Brummell (1977), the household's preferences and
beliefs, relating to both the currently occupied dwelling and per-
ceived alternatives, determine whether it will search for a new resi-
dential unit. Since the household is aware of the potential opportu-
nities and costs, it can assign expected utilities to each of the sub-
markets of which it is aware. The mobility decision is then initiated
by comparing the expected utility of the household's situation if
search were to be undertaken to the utility of its present situation
with no active search (Smith et al., 1979, p.11). The differences
between expected and current utilities constitute a set of locational
stress measures; if any differences are positive, search is commenced.

The mode of search employed by households is assumed to be hierarch-
ical, in that search is initiated in the sub-market beholding the highest
locational stress. However, individual dwellings are randomly sampled
within the sub-market. At each observation, the expected utility of
continuing search is recalculated by considering the expected utility
of the situation if the best alternative viewed so far is lost, an event
which occurs with probability p, and the expected utility of the situa-
tion if it is still available. Note that if the best alternative is
lost, the household must consider both potential gains or losses if an
alternative better than the currently occupied dwelling is not found,
and those if a better alternative is found through continued search in this or other housing sub-markets. Solution to this expression yields a reservation utility or aspiration curve upon which the decision to continue or terminate search is made. Termination may involve returning to the original dwelling or choosing the best available alternative of the opportunities sampled.

To simplify the analytical expression, several assumptions are made concerning the household's perception of the search process. First, direct costs of search are omitted from calculations of expected utility. Second, although admitted in the conceptual framework, the searcher is assumed to take no account of the information gained from search in evaluating the expected utility of continuing. Finally, search behavior is assumed to be myopic, meaning that households ignore the expected utility of search in future periods beyond the next. This final assumption transforms the decision problem into an optimal stopping problem from which the reservation utility can be analytically derived.

The major achievements of this model relate to both its consideration of the entire mobility process and the behavioral relationships that its functional form embodies. By calculating the expected utility of searching in each sub-market at every observation, an updated set of locational stress measures is derived. Search (mobility) is initiated if stress associated with any sub-market is positive, and continues until either residential choice is made or all stress measures are non-positive, the latter of which implies unsuccessful search and return to the currently occupied residence. Behavioral relationships forthcoming from the model relate the probability of continuing search to factors
which influence locational stress (such as the probability of losing the best alternative), and aspiration utility to the household's wealth and initial utility level associated with the currently occupied residence. An empirically-oriented model is developed by expanding the searcher's utility function in a Taylor series about the best alternative. When substituted back into the expected utility expression, relationships between the probability of further search, aspiration utility, and the arguments of the searcher's utility function (the latter of which are interpretable as attitudes to risk and housing preferences) are derived, most of which are amenable to empirical investigation (Flowerdew, 1979).

Common to both theoretical frameworks reviewed above is the casting of residential choice as a sequential decision problem, whereby the alternatives available to the searcher at any decision point consist of either terminating search and choosing the best alternative observed to date (which may or may not be still available or constrained to the current observation) or continuing search for at least one more observation. Note how this decision rule differs from that of traditional theories of locational choice. Either implicitly or explicitly stated, choice in traditional models is predicated upon the simultaneous evaluation of alternatives in a choice set (that may include all residential areas). Uncertainties regarding the availability of alternatives are not recognized, nor are the costs associated with search. By characterizing locational choice as a sequential decision problem, then, search-theoretic frameworks add additional dimensions to the mobility process which make them more in accordance with what occurs in reality. These dimensions include an uncertain choice set, competition from other searchers,
search costs, sampling strategies, attitudes towards risk, and many others which change the decision problem from the selection of a global optimum to the search for a local one, even though the mobile household is assumed to be behaving rationally (i.e. maximizing utility) in both cases.

But although conceptually attractive, models of search behavior have been subject to little empirical study. That little empirical work has been done in this area is partly attributable to the absence of an explicit theoretical framework, until recently, for suggesting appropriate hypotheses to test. Smith et al. (1979) are just now collecting data to empirically investigate the relationships established in their model (Smith et al., 1979, p.19). But a problem more fundamental than this is also responsible, since the underlying sequential decision model has been utilized to investigate search behavior in other contexts for several years.

Casting residential choice as the outcome of search process essentially requires the consideration of human activity at a more microscopic level of detail than previous conceptions of choice behavior, since the revealed preferences we wish to establish empirically are embodied not only in what was chosen by the searcher, but also in what was rejected. Few surveys of residential choice behavior have collected such data. Furthermore, variables which describe the search process in sequential decision models, such as expected and aspiration utilities, probabilities of continuing search and subjective multivariate probability distributions describing vacancy sub-markets, are generally impossible to extract from data, no matter how sophisticated the survey.
instrument. (Note that Smith et al. (1979) intend to empirically substantiate their model by testing only selected behavioral relationships which admit empirical interpretation.) Empirical investigations of residential search behavior have therefore typically involved tests of hypotheses that only indirectly relate to search theory. Since a context must be established before their results can be interpreted, review of these investigations is withheld until the conceptual model is developed in the next chapter.

2.4 Summary

In this chapter we have reviewed the theoretical and empirical literature on residential mobility, a literature which constitutes the background for this research effort. After discussing the theoretical paradigms that have evolved, and the empirical support they have engendered, we have argued that, while a theory of residential mobility has been conceptually developed to a form which recognizes the behavior motivations of mobile households and the dynamics of the evaluation process subsequently undertaken, articulated mathematical frameworks have generally focussed upon the decision to move or the determinants and resulting patterns of residential choice, subtending the evaluation process, with its associated uncertainties and costs, beneath more analytically tractable constraints on information and choice. Furthermore, we have argued that empirical analyses have traditionally followed formalized theories, investigating the determinants of the mobility decision or those of the residential choice decision, without regard to the evaluation process required to bridge the former to the latter. And while our understanding of the mobility process has been advanced by the
theoretical and empirical investigations undertaken to date, their failure to explicitly recognize the role of the search process in residential choice (and the decision to move) leaves it incomplete.

While mathematical characterizations of residential search behavior have been published recently, their properties have not been extensively investigated nor have they been empirically substantiated. Empirical investigations of search activity have been limited in number because of the lack of data and, more importantly, because of the absence of a theoretical framework from which empirically substantiable hypotheses are forthcoming. Even recent theoretical developments provide few opportunities for validation, as their specifications are not particularly well focussed upon empirically observable phenomena. That there exists a need to consolidate the theoretical and empirical expositions of search should be apparent from this review.

These issues essentially define the scope of work to be undertaken in the remainder of this dissertation. To fulfill it requires the articulation of a model of search which is both theoretically valid and empirically meaningful, so that behavioral relationships can be established and tested. We initiate it by developing a conceptual model of search behavior in the next chapter, a model which recognizes the evaluation process as an uncertain one and characterizes the individual's reactions to uncertainty which are likely to result.
Chapter 3
A Conceptual Model of Residential Search Behavior

3.0 Introduction

Search behavior has been shown in Chapter 2 to be a relatively recent area of investigation in the intra-urban residential migration process and one still poorly understood. And yet the influence of search on the household's locational choice decision can be profound, particularly when the household is forced to operate under severe physical and psychological constraints. It is the purpose of this chapter to examine the significant components of the search process, determine how these components vary from household to household, and to assess the relationships between search behavior and residential choice in urban housing markets.

We undertake this effort in order to lay the foundations for a conceptual model of residential search behavior, a model which will serve to organize the somewhat disparate notions of search behavior advanced to date into a coherent framework for analysis. Such organization is a prerequisite for translating concepts and conjectures about residential search into the formalized mathematical framework to be developed in Chapter 4. In developing the conceptual model, the chapter first examines two concepts which are fundamental to the characteriza-
tion of residential search behavior. One is the role of information in search, how it is recognized and processed by the searching household, and how it is transmitted from the supply-side of the housing market to the demand-side. These issues are discussed in Section 3.1. The other, reviewed in Section 3.2, is the evaluation process adopted by the searcher as information is gained, but only at the cost of repeated sampling from a market about which he/she is uncertain. These concepts, given a distribution of vacancies and individuals actively seeking them, essentially define the residential search process and they allow us to develop the conceptual model in the concluding section of the chapter.

Residential search behavior is a strategy adopted by the individual or household for the purpose of acquiring information about alternative residential opportunities. The objective of the search is to locate a vacancy which somehow "best" satisfies the household's requirements within constraints imposed by household and market characteristics. Before describing the process in any detail, however, some general points concerning search behavior should be briefly discussed.

First, search, as defined above, is an activity which is conditional upon an initial mobility decision made by the household (even if, eventually, mobility is not actually realized). Because of this, the conditions which precipitated the mobility decision can significantly impact subsequent search strategies. For example, consider the differences between an evicted household and one searching the housing market because of its dissatisfaction with the current residence. The former's opportunities are potentially limited because first, it must choose one of the vacancies sampled (since it cannot return to its current dwelling and must live somewhere) and second, the time period over which a
vacancy must be chosen is severely constrained by exogenous circumstances.

The voluntary mover, on the other hand, faces less serious constraints, since time is less of a factor in the search process, for the household can usually return to its current residence if inadequate housing opportunities are found in the market (unless constraints are imposed through lease termination or sale of the currently occupied residence). Even if dissatisfied with their current residence and unsuccessful in search, these households can improve upon their current environments by taking actions other than migration (Moore, 1972, p.4), such as alleviating accessibility problems through the purchase of an additional automobile, or reducing crowded conditions by adding more living space.

Between categories of voluntary movers, parameters of the search process may be equally distinct. Compare the search behavior of a household dissatisfied with its current residence (i.e. mobility stimulated by "push" factors) with that of a household whose mobility decision is based upon "pull" factors. With regard to the latter, some households make no deliberate attempt to search in the market since "casual" observation of available opportunities through daily activity patterns has both raised expectations relative to the existing dwelling and identified alternative residences in which to live. In less extreme cases, where deliberate search strategies are undertaken by both kinds of movers, evaluation criteria could still differ since the perceived opportunity sets and resulting expectations of both are likely to be distinct.
The conditions which precipitate the mobility decision are therefore expected to alter the context in which search is conducted, particularly with respect to evaluation criteria, temporal constraints on the household, constraints on the choice set, and other factors. We will attempt to amplify these essential differences between mobility types in the following sections.

A second point about search behavior concerns the decision making unit. Behavioral theory generally recognizes the individual as the basic decision making unit, particularly when relationships are formalized by mathematics. However, intra-urban migration concerns the mobility and locational choice decisions of the household, which can be comprised of more than one member. The decision making unit is therefore likely to be a composite body which operates under a particular set of rules and which may or may not involve group decision making, bargaining, and so on. Clearly, intra-household interactions at this level of resolution are unknown at present, and although they may be significant, they are ignored in the following discussion. The household is therefore assumed to operate as if it were a single decision making unit. The term individual, or decision making unit, will henceforth be understood to represent household.

Search behavior can be considered to be composed of two major components: cognition and evaluation. Although considered separately, it should be stressed that these two components are not distinct in practice, but rather are likely to be carried out more or less simultaneously throughout the search. The essential elements of these two components, which, when combined define the relocation decision (Brown and
3.1 Information Aspects of Residential Search Behavior

As defined above, search is an activity undertaken by the individual for the purpose of acquiring information about alternative residential opportunities. It is a process of finding and evaluating alternative locations. The individual's information, however, is not uniform over the entire urban area. Since behavior is affected only by that portion of the environment perceived (Gould and White, 1974, p.48), the locational outcomes of search are often found to exhibit several forms of spatial bias. For example, directional biases in location behavior by particular segments of the population have been noted by Adams (1969), Barrett (1973) and Simmons (1974). Butler et al. (1969) have observed distance of the move to be related to race, and Adams (1969) has found a strong sectoral bias in intra-urban migration fields.

In the context of residential search behavior, it is important to understand why such biases occur and how they are modified. More specifically, it is necessary to ask:

- what are the critical elements which define the perceived information field of the individual?

and,

- what are the types and sequences of information used, and how are they combined with current perceptions over the course of the search process?

These issues are discussed in the following sections.

3.1.1 Cognitive Structure and Change in Residential Search

It is important (and convenient) to distinguish the a priori infor-
information gained and processed during search activity. Whereas the latter essentially defines search behavior, its outcome is highly dependent upon the former. Their integration determines the spatial and temporal characteristics of search activity.

The a priori information base constitutes the individual's cognitive image of the urban area in which he/she is situated. The behavioral process which forms this image has been described as one "composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday environment" (Downs and Stea, 1973, p.9). Although Lueck (1976, p.276) has attempted to distinguish between the terms "cognitive map" and "mental map", attributing to the latter only locational attributes (essentially mental cartography), they are essentially similar concepts involving the storage of information with distinct spatial properties such as location, distance and direction (Kaplan, 1973, p.74).

Two elements are of major importance to the cognitive image of the individual: the process of interaction with the everyday environment, and the limits to the individual's ability to store information. These elements basically determine the spatial dimensions and degree of detail of the individual's cognitive image. Activity paths provide the individual with direct contact to the environment from which an impression of the urban landscape is made. The degree to which any one point in the objective environment is perceived is a function of both the characteristics of the observer and the variability of the environment (Wolpert, 1965, p.163; Lynch, 1960, p.3). Limits to the individual's
perceptual abilities, in effect, reduce the cognitive image to an item of minimal information (i.e., a reduced set of data). This information is supplemented through indirect sources such as news media and social contacts. The filtering of these direct and indirect observations into a cognitive image defines the "awareness space" (Barrett, 1973, p.4) of the individual, or what will eventually be defined as the opportunity set of the individual, established before search is initiated.

That biases in perception exist have been demonstrated by Gould and White (1974), Hanson (1976) and Orleans (1973), among others. Empirical research has generally supported hypotheses that relate awareness (level of information) directly with the spatial dimensions of alternative locations and inversely with distance (Hanson, 1976). The attenuating effects of barriers, particularly political boundaries on the awareness of the individual have also been empirically demonstrated (Gould and White, 1974, p.143-150), an observation which is supportive of the theoretical literature (Gould, 1969). However, the cognitive awareness of the surrounding environment has also been found to be related to social class (Orleans, 1973; Ladd, 1967), e.g. the cognitive image of minorities being more spatially constrained than those of white upper and middle income groups. But whether this latter relationship is the product of racial barriers, poor accessibility, locational characteristics, or socioeconomic factors has not been satisfactorily addressed. Some evidence supportive of Orleans' and Ladd's conjectures can be inferred from Weinberg et al.'s (1977, p.87) study of search behavior, though, where minorities were found to avoid areas in which discrimination was expected to occur.
The importance of a spatially restricted cognitive image lies in the observation that it is only over this limited area that the individual has sufficient information to be able to evaluate alternative opportunities relative to the current residence.

From a mobility viewpoint, information about alternative residences enables the individual to define aspirations through the integration of this information with personal desires and constraints from which relative values, or place utilities (Wolpert, 1965, p.161) can be attached to these opportunities. The differences between experienced place utility (that attached to the current residence) and expected place utility (that attached to alternative residences -- both concepts are attributable to Brown and Moore, 1970) -- constitutes stress, which, if great enough, stimulates the household to attempt to relocate to another residence in the urban area (Brummell, 1977, p.55; Smith et al., 1979, p.7).

Although the awareness space of the individual is sufficiently articulated to enable the individual to make a mobility decision, considerable uncertainty remains with regard to what opportunities are actually available. The initial mobility decision is predicated upon what the individual believes is attainable, beliefs which are articulated through the searcher's aspirations. Search is initiated to determine what is actually attainable (Brummel, 1977, p.55).

Search in the housing market is undertaken essentially to expand the individual's cognitive image, either spatially or substantively. We conjecture that search is, in general, initially restricted to those areas of which the individual is aware. (This does not imply, however,
that search is restricted to areas of which the individual is familiar.) Through the gathering of information, the spatial search field is expanded, and expectations about housing opportunities, and thus aspirations, are modified throughout.

Aspirations may increase or decrease over the course of the search effort, although they are bounded from below by the utility of the currently occupied dwelling plus a utility associated with transactions costs. If the cognitive image of the individual is spatially restricted prior to the search, giving the individual an optimistic outlook upon the housing market, aspirations may be adjusted downward as the spatial search field expands and reveals the housing market to be less attractive than originally perceived, particularly as repeated failures in locating a satisfactory alternative are encountered during search. Conversely, aspirations may adjust upward, leading to the rejection of vacancies which would have previously been perceived as acceptable, if an expanding spatial search field reveals housing opportunities to be more satisfactory (either in quantity or quality) than originally perceived.

The spatial search field will exhibit and, in fact, will likely reinforce spatial biases inherent in the individual's cognitive image. Through continued search, the individual's awareness of spatial opportunities will expand in the direction of current biases. Contiguity with the current image will be constrained only by information gaps, social and economic barriers, and, factors related to individual preferences. The continual modification of the individual's cognitive image will thus likely resemble changing patterns associated with diffusion processes (Gould, 1969) which operate under the same type of constraints.
Search for housing opportunities involves more than the visual inspection of vacancies. Brown and Moore (1970, p.9) describe it as a structured sampling activity where the household samples available information channels, such as newspapers, realty agents and social acquaintances according to a set of implicit rules. The household's choice of channels and degree to which they are utilized have been suggested to be dependent upon three factors (Brown and Moore, 1970, p.9; see also MacLennon, 1979a, for a slightly different conception of the determinants of choice):

- the subjective probability of success of finding a suitable vacancy if a given information channel is employed,
- the perceived costs of utilizing the channel at a given level of intensity, and
- the time which remains before the household must make a relocation decision.

Sampling intensity over a particular channel is hypothesized to be directly related to the channel's subjective probability of success and inversely related to its perceived utilization costs. As time remaining for search declines, households can be expected to bias their selection of information channels toward those offering higher probabilities of success, regardless of perceived cost.

Opportunities or areas within the search space may be hierarchically organized according to such criteria as desirability (relative to aspirations), familiarity with area, or other factors (Brown and Moore, 1970, p.9). This enables the household to utilize more economical sources of information during the initial stages of search activity until a more
precisely articulated opportunity set, which requires a more thorough investigation at greater expense, is defined.

Throughout the search process, information channels which indirectly familiarize the household with opportunities in the housing market are supplemented by direct visual assessments of a subset of those vacancies originally considered. The visual assessment of housing alternatives, then, can be regarded as a final stage in the search and selection process, for it is upon the visual evaluation of housing opportunities that choice among alternatives is finally made.

The a priori information base can be seen to be a significant determinant of the residential mobility and subsequent search decisions of the individual. A cognitive image, conditioned by distance, accessibility, and social and physical barriers, influences the utility the individual associates with the current residence relative to other opportunities. It thus stimulates the mobility decision which, in turn, forces the individual to undertake search in the housing market.

Search is undertaken to enable the individual to both indirectly and directly evaluate perceived opportunities in the housing market. Through the gathering and processing of information, the individual determines whether housing market expectations are actually attainable (whether actual market conditions are close to those perceived), and if so, which alternative to choose. Search will be spatially bounded within the limits of the individual's cognitive image of the area, as modified by information received from sampled agents. That the household's search space tends to possess a distinctly social, economic and spatial character (Brown and Moore, 1970, p.9) attests to the importance of its cogni-

100
tive image and its selection of information channels\(^1\) in the structuring of search activity. In effect, the opportunity set is both unconsciously and intentionally constrained to enable a decision to be made.

The existence of a constrained opportunity set is consistent with the concept of "intended rationality", defined by Simon (1957; 1972) and Wolpert (1965). Choice to the individual is constrained to a subset of perceived alternatives, which is more limited than the whole range of opportunities objectively available (Simon, 1957, p.244), and the process of learning throughout the decision making process is explicitly recognized (Wolpert, 1965, p.163). The awareness space of the individual corresponds to the former and its subsequent modification upon undertaking search, the latter. The importance of the correspondence between constrained choice and intended rationality will be revealed in the following sections.

3.1.2 Information Agents in Residential Search

Information agents have been outlined above as channels of communication which, when sampled by the individual, have their contents selectively combined with an \textit{a priori} cognitive image of the urban housing market. This information enables the individual to more precisely define, evaluate and, finally, choose among vacancies.

Of all agents, empirical studies of residential search behavior have found the following to be most important:

- \textbf{mass media} -- primarily newspapers, but including radio, television and billboard advertising

\(^1\)Biases in information channels are more completely discussed in the following section.
- **localized notices** -- signs posted at the site of the vacancy, plus notices posted on bulletin boards of supermarkets, etc.

- **personal contacts** -- friends, relatives or associates in employment

- **real estate agents**

Other channels of information include "windfall"\(^1\) (Rossi, 1955), builder's reputation (Michelson, 1977), and friend in real estate (Barrett, 1973). These latter agents are not consistently defined across the literature, and, since their significance is usually quite small,\(^2\) they are not considered further.

Associated with each agent are characteristic properties such as cost, information content and likelihood of success which are translated by the individual into perceived measure of what could be termed "cost effectiveness". For example, advertisements concerning vacancies in newspapers are low cost, relatively accessible sources of information to the searcher. However, this information is of relatively low quality.

---

\(^1\)Rossi (1955, p.160) defines "windfall" to be an information resource which presents a favorable housing opportunity to the household unsolicited though no apparent expenditure of effort has been made to locate the opportunity. Rossi (1955, p.216) suggests that windfalls likely result from the household's casual inquiries to acquaintances, who are then alerted for information about vacancies. In that case, the windfall is only perceived to be so by the household.

\(^2\)Rossi (1955, p.161) finds "windfall" to be the most effective agent when utilized by searchers, having an effectiveness index of .81 (the percentage of times this agent is cited to be responsible for locating the chosen vacancy divided by the percentage of times the agent is cited for being used at some stage of the search process). However, this agent is also the least accessible channel of communication (cited only 31% of the time; compare with 63%, 57%, 62% and 50% respectively for the agents defined above). Also, as stated above, this information channel likely involves the utilization of one or more of these four agents before it can be realized by the household.
containing little in the way of factual content, making the channel only marginally useful to the searcher. On the other hand, informal information channels cannot be bought at any cost by newcomers to an area, (MacLennan, 1979a, p.83), although they often, if obtained, convey high quality information through the source's living experience in the area.

These characteristics must be evaluated by the individual within constraints of time, income and housing needs, and desires to enable him/her to determine which channels should be chosen and to what extent employed. Typically, a combination of information agents is utilized by the individual during search (Rossi, 1955; Barrett, 1973, Michelson, 1977; Weinberg, et al., 1977; MacLennan, 1979a).

However, in addition to these properties are associated with each agent characteristic biases which further constrain the opportunity set of the individual. These biases, although not mutually independent, can be classified as being either spatial, functional or socioeconomic.

Information which is characterized by spatial variations in quality and quantity around the vacancy can be considered to be spatially biased. Biases can range from the extreme, that is, where information about vacancies is highly localized (its distribution exhibiting strong distance-decay relationships with respect to the site), to near insignificance, for example, where information is distributed evenly throughout the area. An example of an information agent which exhibits the former bias is the localized notice posted at the site of the vacancy; only those searchers passing within visual distance of the notice will know of the vacancy's existence, unless information is transmitted through an
intermediate channel. An example of a nearly unbiased channel is the large daily newspaper which disseminates information more or less informally over an expansive, although bounded, area.

Functional biases refer to the types of vacancies covered by the channel. Metropolitan newspapers can generally be regarded as functionally unbiased sources of information, as most housing sub-markets are advertised in the medium. Real estate agents, however, are functionally selective. They deal almost exclusively in the owner market or the renter market -- rarely both. They furthermore tend to specialize within these markets, for example, by concentrating on high-value single-family dwellings, moderately priced rental apartments, or some other sub-market. From the latter functional specialization, spatial biases can result.

Functional biases of information agents, particularly with respect to those cited above, are evident in Michelson's (1977) data (Table 3.1). Real estate agents are cited as an information source more often by those choosing houses. Conversely, newspapers are cited far more often by apartment dwellers than by homeowners. Within the homeowner market, there appears to be a further functional distinction. Real estate agents are by far the most dominant source of information for those choosing to locate downtown, whereas posted information in new developments is the most frequently accessed agent in suburban homeowner markets, particularly those experiencing rapid growth (see Barret, 1973, p.200). Although it is difficult to generalize these results to all urban housing markets, similar functional biases can be expected in most metropolitan areas.
<table>
<thead>
<tr>
<th></th>
<th>Newspaper</th>
<th>Real Estate Agents</th>
<th>Personal Contacts</th>
<th>Localized Notices</th>
<th>Other</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. ALL SOURCES CONSULTED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment Downtown</td>
<td>69.4</td>
<td>21.3</td>
<td>32.4</td>
<td>51.9</td>
<td>5.6</td>
<td>108</td>
</tr>
<tr>
<td>House Downtown</td>
<td>69.6</td>
<td>94.6</td>
<td>43.5</td>
<td>54.3</td>
<td>1.1</td>
<td>92</td>
</tr>
<tr>
<td>Apartment Suburbs</td>
<td>71.1</td>
<td>12.7</td>
<td>32.4</td>
<td>55.6</td>
<td>5.3</td>
<td>284</td>
</tr>
<tr>
<td>House Suburbs</td>
<td>57.9</td>
<td>61.7</td>
<td>42.1</td>
<td>77.1</td>
<td>12.4</td>
<td>266</td>
</tr>
<tr>
<td>Downtown</td>
<td>69.5</td>
<td>55.0</td>
<td>37.5</td>
<td>53.0</td>
<td>3.5</td>
<td>200</td>
</tr>
<tr>
<td>Suburbs</td>
<td>64.7</td>
<td>36.4</td>
<td>37.1</td>
<td>66.0</td>
<td>8.7</td>
<td>550</td>
</tr>
<tr>
<td>House</td>
<td>60.9</td>
<td>70.2</td>
<td>42.5</td>
<td>71.2</td>
<td>9.5</td>
<td>358</td>
</tr>
<tr>
<td>Apartment</td>
<td>70.6</td>
<td>15.1</td>
<td>32.4</td>
<td>54.6</td>
<td>5.4</td>
<td>392</td>
</tr>
<tr>
<td><strong>II. MOST EFFECTIVE SOURCES CONSULTED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment Downtown</td>
<td>38.9</td>
<td>16.7</td>
<td>11.1</td>
<td>24.1</td>
<td>4.6</td>
<td>108</td>
</tr>
<tr>
<td>House Downtown</td>
<td>20.7</td>
<td>79.3</td>
<td>14.1</td>
<td>14.1</td>
<td>1.1</td>
<td>92</td>
</tr>
<tr>
<td>Apartment Suburbs</td>
<td>44.0</td>
<td>10.2</td>
<td>21.0</td>
<td>32.4</td>
<td>4.9</td>
<td>284</td>
</tr>
<tr>
<td>House Suburbs</td>
<td>16.7</td>
<td>39.4</td>
<td>15.7</td>
<td>44.7</td>
<td>12.0</td>
<td>266</td>
</tr>
<tr>
<td>Downtown</td>
<td>30.5</td>
<td>45.5</td>
<td>12.5</td>
<td>19.5</td>
<td>3.0</td>
<td>200</td>
</tr>
<tr>
<td>Suburbs</td>
<td>31.8</td>
<td>24.3</td>
<td>18.4</td>
<td>30.3</td>
<td>8.3</td>
<td>550</td>
</tr>
<tr>
<td>House</td>
<td>19.2</td>
<td>49.7</td>
<td>15.3</td>
<td>36.8</td>
<td>9.2</td>
<td>358</td>
</tr>
<tr>
<td>Apartment</td>
<td>42.6</td>
<td>12.0</td>
<td>18.3</td>
<td>30.1</td>
<td>4.8</td>
<td>392</td>
</tr>
</tbody>
</table>

1 Aggregate of "Friends" and "Relatives" as defined by Michelson (1977).
2 Defined as "Driving Around" by Michelson (1977, p.106).
3 Other = "Builder's Reputation".
4 More than one answer permitted.

Table 3.1 Functional and Spatial Biases of Information Agents
(Source: Adapted from Michelson, 1977, p.107-108)
Socioeconomic biases are those which limit the access of particular socioeconomic groups to particular housing sub-markets. Metropolitan newspapers, due to their low cost and wide circulation are, theoretically, unbiased in this respect, since this information is accessible to all literate individuals, regardless of income or class. Information about vacancies from personal acquaintances, however, is likely to be extremely biased since channels which are regularly maintained through friendship, employment or personal relationships tend to be stratified along distinct social, cultural and economic dimensions (Himmelstrand, 1960; Coleman, 1959; Murdie, 1969).

The characteristic properties and biases of these information channels are summarized in Table 3.2. Mass media are seen to be low cost and relatively unbiased sources of information, but of low quality (as defined) to the searcher. The effectiveness of this medium for locating vacancies is therefore relatively low. Real estate agents generally operate within narrower functional and socioeconomic ranges (although not necessarily spatial ones). However, it is a source of high quality information and in therefore an effective medium, especially in the single family, owner-occupied sub-market.

Localised displays, although of low monetary cost to the seller, impose other costs, particularly in terms of time and effort, upon the searcher, since vacancies must be actively sought before evaluation. The spatial dimensions of this information agent are highly localized and, though not restricted to any set of sub-markets, it is more commonly associated with urban rental and suburban single-family dwelling sub-markets. The medium is furthermore socioeconomically biased in the
<table>
<thead>
<tr>
<th>INFORMATION CHANNEL</th>
<th>PROPERTIES</th>
<th>BIASES</th>
<th>EFFECTIVENESS^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Media (newspaper, radio, television)</td>
<td>low</td>
<td>low</td>
<td>uniform coverage of extensive, bounded area^2</td>
</tr>
<tr>
<td>Real Estate Agents</td>
<td>variable; costs depend upon local institutional arrangements and may be assessed to buyers or sellers</td>
<td>high (factual and visual)</td>
<td>usually limited</td>
</tr>
<tr>
<td>Localized Notices</td>
<td>moderate; costs are a function of mobility of searcher, type of sub-market, etc.</td>
<td>high (visual)</td>
<td>extremely localized around vacancy</td>
</tr>
<tr>
<td>Personal Contacts</td>
<td>low</td>
<td>variable</td>
<td>--</td>
</tr>
</tbody>
</table>

^1Proportion of searchers citing agent as leading source of information which led to chosen vacancy divided by proportion of searchers using the agent. Indices are not strictly comparable because of definitional differences.

^2Coverage more spatially confined and information more functionally and socioeconomically biased in local or community newspapers.

^3Source: Rossi (1955).


^5Source: Weinberg et al. (1977, p.78), Pittsburgh data.

^6Source: Weinberg et al. (1977, p.78), Phoenix data.

Table 3.2 Characteristic Properties and Biases of Major Information Agents Employed in the Residential Search Process
sense that individuals are likely to search only those areas perceived to be suitable and attainable (in terms of an a priori cognitive image—see Michelson, 1977, on this point), or those areas close to vacancies discovered through another medium to be close to expectations (Brown and Moore, 1970, p.9). Although information transmitted through this medium, because of the direct visual element, is of high quality, its characteristic spatial bias prevents it from being any more than moderately effective to searchers. Only when searchers are reasonably mobile and these localized opportunities highly clustered, as is the case in new suburban development, is this information agent found to be effective (Michelson, 1977, p.108).

Personal contacts provide low cost (to searchers with an established network of contacts in the area), variable quality information to the searcher (depending upon the number of intermediate contacts between informant and searcher). This information does not necessarily exhibit any functional or spatial biases. However, vacancies are likely to be socioeconomically constrained within the norms of these personal contacts. Given that the individual is likely to possess values similar to those of his/her contacts, information about housing opportunities can be considered to be socioeconomically biased. To the extent that socioeconomic groups are spatially identified, this socioeconomic bias may translate itself into one with spatial dimensions as well. This agent appears to be a moderately effective source of information.

The differential characteristics of information agents suggest that an hierarchical sampling scheme may be appropriate for the organization of search activity by the individual. Within this framework,
search is initially conducted over inexpensive, spatially extensive, but low quality information agents, such as newspapers, to assist the individual in clarifying expectations to a point where more localized and factual information is necessary. At this point, information channels possessing these characteristics, such as realtors and notices posted in areas identified in initial stages of search, are employed to more precisely define the aspirations and expectations of the individual.

Clearly, the hierarchical sampling procedure described above represents an ideal, as the exact choice and sequencing of information channels, and intensity of use will depend upon constraints placed upon the searcher (see MacLennan, 1979a) and type of dwelling desired. For example, time constraints will require more expensive, high quality information sources to be utilized during the course of the search; preference for these agents will likely intensify as time remaining until a relocation decision must be made runs short. The degree to which time is a factor will, as described above, be dependent upon conditions precipitating the mobility decision. Furthermore, monetary constraints may preclude the use of particular information agents altogether. Even though many factors are likely to intervene in the sequencing of information agents, there is some evidence in the empirical literature, as discussed below, to support the basic tenet of the proposition, i.e. that spatially extensive information channels of low cost and quality are utilized prior to the employment of more costly, high quality sources by searchers.

Barrett (1973, p.105) found that of all major information channels sampled by households, only newspapers are sampled proportionately less in
subsequent search activity (Table 3.3). In all other cases, more visually and factually intensive information channels are cited more frequently later in search than at the beginning. That search activity is hierarchically structured with respect to the sampling of information channels is consistent with the hierarchical organization of search described by Brown and Moore (1970, p.9), and is furthermore logically consistent with the proposition that, in the final analysis, search, evaluation and choice must involve the personal assessment of vacancies by the intended migrant. How these alternatives are actually evaluated is the subject of the next section.

3.2 Evaluation and Choice Among Residential Opportunities

Search activity has, as its ultimate objective, the facilitation of choice among alternatives perceived to be attainable by the individual. But for choice to be made, residential opportunities must in some way be evaluated and a decision rule enacted. As developed in the introductory chapter, decision problems such as those characteristic of residential choice are seldom as clearly defined as theories and models, particularly those related to theories of revealed preference, would have us believe (Pirie, 1976). Behavior is modified by the psychological limitations of decision makers (Miller, 1956; Ewing, 1971), their alternative objectives and desires (Golledge, 1970), time-space schedules (Hägerstrand, 1969), and imperfect information about the choice set (Hanson, 1976). This section examines search behavior in light of the first two of these factors, that is, how residential opportunities are perceived by the individual given particular psychological limitations, and how alternatives are then evaluated over different objectives and desires.
<table>
<thead>
<tr>
<th>INFORMATION CHANNEL</th>
<th>INITIAL (^1) METHOD</th>
<th>PERCENT</th>
<th>SUBSEQUENTLY (^2) USED</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newspaper</td>
<td>104</td>
<td>27.37</td>
<td>59</td>
<td>15.53</td>
</tr>
<tr>
<td>Real Estate Agency</td>
<td>117</td>
<td>30.79</td>
<td>145</td>
<td>38.16</td>
</tr>
<tr>
<td>Localized(^3) Notices</td>
<td>95</td>
<td>25.00</td>
<td>310</td>
<td>81.58</td>
</tr>
<tr>
<td>Personal(^4) Contacts</td>
<td>39</td>
<td>10.26</td>
<td>104</td>
<td>27.37</td>
</tr>
<tr>
<td>Other(^5)</td>
<td>25</td>
<td>7.58</td>
<td>4</td>
<td>1.05</td>
</tr>
<tr>
<td>Total</td>
<td>380</td>
<td>100.00</td>
<td>622</td>
<td>N/A</td>
</tr>
</tbody>
</table>

\(^1\) Information channel first utilized by each household in sample.
\(^2\) Number of times channel cited by households as being used subsequent to initiation of search (more than one answer per household permitted).
\(^3\) Aggregate of "Walking", "Driving" and "Sign on Property" as defined by Barrett (1973).
\(^4\) Aggregate of "Friend", "Relative", "Fellow Employee" as defined by Barrett (1973).
\(^5\) Other = "Friend in Real Estate" as defined by Barrett (1973).

Table 3.3. Sequencing of Information Channels in Search Activity
(Source: Derived from Barrett, 1973, p.105)
The same basic behavioral paradigm which was used to describe the individual's development of a cognitive image of the urban area is applicable to the evaluation of specific residential opportunities during the search activity. A given residential package can be considered to be composed of a vector of attributes, $\bar{X}$, where $X = \{x_1, x_2, \ldots, x_n\}$. These attributes may relate to characteristics of the dwelling, neighborhood, location or a host of other factors.

Behavioral theory states, however, that individual behavior is a response, not to the stimulus as it objectively exists, but rather as it is perceived (Brummell, 1977, p.14). Therefore, the objective attributes of the alternative, $\bar{X}$, are transformed by the individual $t$ through the processes of perception and cognition into a perceived set of attributes, $Z_t = \{z_{1t}, z_{2t}, \ldots, z_{mt}\}$. Evaluation is then based on the mapping of $Z_t$ onto an evaluation function $U_t$, upon which choice among alternatives is made (see, for example, Lerman, 1975).

The behavioral paradigm upon which models of individual choice are based can therefore be stated mathematically as follows:

\begin{align}
  Z_t^i &= Z_t(\bar{X}_i) \\
  U_t^i &= U_t(Z_t^i)
\end{align}

(3.3.1)

(3.3.2)

where $\bar{X}_i = \{x_1^i, x_2^i, \ldots, x_n^i\}$ is a vector of attributes which objectively characterize the alternative, $i$; $Z_t^i = \{z_{1t}^i, \ldots, z_{mt}^i\}$ is a vector of attributes of alternative, $i$ as perceived by individual $t$; $U_t^i$ is a vector which represents individual $t$'s evaluation of alternative $i$. $Z_t$ is referred to as a cognition function; $U_t^i$ an evaluation or utility function.
function. Note that \( Z_t \), when defined in a more general sense, is the
cognitive image discussed previously (Lueck, 1976).

Two characteristics of this theory should be emphasized. The first
relates to the objective and subjective dimensions of the stimuli which
enable alternatives to be discriminated. The second concerns the form
of the evaluation function and what this implies in terms of individual
choice behavior.

3.2.1 Cognition and Discrimination of Residential Opportunities

We have defined an alternative, or stimulus, \( i \), by a vector of
attributes, both as it objectively exists, \( \mathbf{X}^i = \{x_1^i, x_2^i, \ldots, x_n^i\} \), and
as subjectively perceived and cognized by the individual \( t \), \( \mathbf{Z}_t^i = \{z_1^t, z_2^t, \ldots, z_m^t\} \). The human species, however, is one of limited computa-
tional ability, and cognition, therefore, involves the reduction or
simplification of each stimulus into a reduced form. The individual
accomplishes this by considering only a subset of attributes which
characterize the alternatives, \( i.e. \) for the vectors \( \mathbf{X}^i \) and \( \mathbf{Z}_t^i \), \( m < n \).
In fact, the psychological literature has shown that although stimuli
are better discriminated as the number of dimensions over which they
vary increases, the marginal improvement in discrimination increases at
a decreasing rate, and is approximately zero beyond seven dimensions
(Miller, 1956). Hence, the translation from object to percept involves
the implicit reduction of information (Posner, 1964).

However, the way in which this reduction is accomplished can only
be speculated at present, but may involve the disregard for some of the
dimensions ("filtering", see Posner, 1964), the combination of attrib-
utes into fewer dimensions ("reduction", see Coombs et al., 1970, p.344),
or the hierarchical ordering of attributes based upon their relative importance, thereby enabling sequential comparisons\(^1\) (Brown and Moore, 1970, p.7). Although not conclusive, empirical evidence appears to support the proposition that, in the search for housing, at least, some form of information reduction does take place. For example, Chapter 2 identified several factors which are consistently reported throughout the literature as being significant determinants of either the mobility or relocation decisions.\(^2\)

Other studies which address the issue of cognition reduction more directly are supportive as well. For example, Peterson (1965) used factor analytic techniques to reduce a set of nine objectively defined attributes of residential alternatives to just two, "newness-expensiveness" (involving factors such as age of dwelling and cost), and "closeness-to-nature" (related to the amount of open space, privacy, etc.), which, based upon stated preferences, appeared to be key indicators used by respondents to evaluate opportunities (see also Johnston, 1973; Cadwallader, 1979). Lueck (1976), although concerned with a different set of stimuli, the perceived attributes of American cities, found information to be reduced by indi-

---

\(^1\)For example, initial criteria, such as accessibility, neighborhood, etc., are used to eliminate a subset of vacancies. Remaining opportunities are then compared over another set of (possibly) related or more specific criteria to further reduce alternatives, and so on. Zeleny (1976, p.160) and March (1978) suggest that the simultaneous development of choice criteria with the choice set is common to many decision making situations.

\(^2\)Note that such evidence may be inappropriate in the above context, particularly if survey instruments did not employ open-ended questions regarding mobility or location determinants. Revealed preference data are, by definition, invalid evidence, and retrospective responses may contain significant biases. See Pirie (1976) for an excellent discussion on revealed preferences and spatial behavior.
viduals in this choice situation as well. Using multidimensional scaling (MDS) techniques to evaluate respondents' perceptions, he found American cities to be characterized by three major attributes: "excitement" (related to the physical amenities of cities), "cleanliness and safety", and "social milieu" (social and cultural characteristics of the cities' populations).

These latter studies should be interpreted with caution, however, since they involve small samples and restricted choice situations. Attributes used in the evaluation of residential opportunities are likely to differ between housing sub-markets (Michelson's, 1977, data appear to clearly support this conjecture), neighborhoods (Cadwallader, 1979) and by socioeconomic status of searchers. The current location of the intended migrant is likely to further influence evaluation criteria used in search. With regard to these latter two relationships, Lueck (1976) found the cognitive dimensions used to evaluate U.S. cities to be both demographically and locationally invariant. However, given the more intensive nature of search in the housing market and the cognitive biases observed in urban residents, it is conceivable that such findings may not be applicable to problems of residential search. Finally, it is not particularly clear whether, in either of the empirical studies, choice criteria derived from preference data are more the products of the cognition function of the individual or the analytic techniques used to estimate them.

What is most apparent from the above discussion is that the cognition function of the individual is essentially unknown. Although it can be suggested that the structure and mechanics of MDS models may be appro-
appropriate surrogates for the cognitive aspect of human behavior (Harman and Betak, 1976; Lueck, 1976), there is no strong empirical basis for such a representation. Given these limitations, the analysis of choice behavior must typically involve relating the objective attributes of the stimulus, \( \underline{x}^i \), directly to the evaluation function, \( \underline{u}^i_t \), through the composite operator, \( V_t \):

\[
\underline{u}^i_t = u_t[z_t(\underline{x}^i)] \\
= v_t[\underline{x}^i]
\]

which only implicitly recognizes the psychological processes actually undertaken in the choice situation. This latter concept, as defined in (3.3.3), will henceforth be adopted to describe the evaluation of alternative vacancies in the residential search process.

3.2.2 Evaluation Rules and Choice Behavior

Given information about alternative residential opportunities, the individual must somehow now use it for evaluative purposes. This evaluative aspect of search behavior involves the rules used to combine information and the criteria employed to compare alternatives.

Evaluation, in the context of residential search and relocation, however, does not simply involve the identification of the "best" (in an absolute sense) among a set of alternatives. Search is predicated upon an initial mobility decision by the household which is either forced or voluntary. In either case, the household undertakes search to locate a residential alternative which, at a minimum, satisfies its basic needs. Preferably, the chosen alternative will more than satisfy its needs and
fulfill some or all of the household's established goals. Regardless of this distinction, it must be assumed that the criteria upon which residential choice is made are defined upon the decision to migrate. Search activity, in addition to its identification function, serves to modify these choice criteria and, by doing so, resolves the differences between what is actually attainable in the housing market and what was initially believed by the household to be available when the mobility decision was originally made. Choice, then, is made relative to a set of standards or aspirations held by the household. These standards are initially based upon an a priori cognitive image of housing opportunities but are dynamically adjusted to reflect changing information brought on through search activity.

Aspirations are subjectively determined quantities influenced not only by such psychological factors as preferences and needs, but also by economic constraints, such as income, and supply-side constraints, such as the set of opportunities available to the individual and their corresponding prices. As they relate to needs, aspirations are relatively well defined. Whereas needs represent the minimum levels of a quantity of attribute required to sustain the household, aspirations characterize maximum, or at least desired or satisfactory levels (Brummell, 1977, p.25).

Relationships between aspirations and goals, however, are less direct, since it is recognized that usually not all goals of the household are fulfilled upon relocation to a new residence. Some form of constraint, be it income, vacancy availability or non-substitutability among attributes which characterize vacancies in the opportunity set,
is likely to inhibit the household from realizing all goals at any given point in time. Because of this, households tend to organize their goals consistently into the short and longer terms, respectively, some goals serving simply as means to other ends (Michelson, 1977, p.34-35).

Residential choice, then, is predicated upon the attainment of the former, or short term objectives. Aspirations formulated prior to and modified throughout search therefore conform to these short term objectives, objectives constrained by the household's ability to obtain a particular type of residential opportunity.¹

The distinction between household needs and aspirations in relation to residential choice can now be established. Needs are relatively well-defined phenomena representing minimum sustainable levels of housing consumption. In the context of search activity, they can be considered to be exogenously determined. Aspirations, on the other hand, since they depend upon household preferences, objectives and constraints, are necessarily endogenously determined in the search and selection process. Choice is predicated upon the short term objectives of the household; these short term objectives are conditioned by the household's knowledge of what is actually available in the housing market. Since search is the means by which knowledge of the market is derived, aspirations must adjust themselves throughout the process in order to characterize the household's beliefs as to what is actually attainable. Aspirations essentially involve the individual's response to the known residential environment.

The development of evaluation criteria enables each residential opportunity to be assessed by the household. However, choice can be

¹Empirical support for the establishment of short and long term goals in the mobility decision can be found in Michelson (1977, p.294-302).
made only upon the implementation of a decision rule which involves both how information about the alternative's attributes is combined to characterize it, and how each of the alternatives, themselves, are compared.

We have characterized the alternative i by a vector of attributes \( \mathbf{x}_i = \{x_1^i, x_2^i, \ldots, x_n^i\} \) which are evaluated by the individual \( t \) through the operator, \( V_t \). The resulting evaluation function, \( u_{ti} \), may be either a scalar or vector quantity from which a variety of decision rules can be formulated.

But the residential relocation decision has been shown to be one constrained with respect not only to the environment (or supply side) but also to the capabilities of the individual decision maker. Spatially limited opportunities are only approximately perceived and defined by the individual at the outset through a set of aspirations which are continuously refined during the search process. The problem the individual faces is one of adopting a decision rule which, under significant psychological and environmental constraints, results in the "rational" selection of a residential opportunity.

One decision rule which is claimed to approximate these conditions of "bounded rationality" is that of satisfying (Simon, 1957). Satisfying behavior assumes that the individual \( t \) reduces the decision problem to one within his/her computational capabilities by associating with each attribute \( k \) of a set which characterizes the alternatives, an aspiration level, \( \xi_t^k \), which represents a satisfactory, or sufficient quantity of the attribute. Upon observation of a given alternative \( i \), choice is invoked through the individual's valuation of each of its attributes,

\[
V_t(x_1^i, x_2^i, \ldots, x_m^i) = [V_t(x_1^i), V_t(x_2^i), \ldots, V_t(x_m^i)]
\]  

(3.3.4)
and their comparison to aspirations. Satisficing behavior regards a payoff (through choice) to the individual as being satisfactory if and only if:

\[ V_t(x_k^i) \geq \xi_t \quad \text{for all } k \quad (3.3.5) \]

As an example, conditions under which alternatives possessing two attributes would be considered satisfactory are shown in Figure 3.1.

Choice, then, is made through the following decision rule: search the perceived set of alternatives, \( S_t \subseteq S \), and accept the first opportunity which satisfies (3.3.5), where \( S \) is the set of all alternatives.

Although there is general agreement that, in many situations, satisficing is a more realistic descriptor of decision making behavior than "rational optimizing" (Keen, 1977, p.32) or "perfect rationality" (March, 1978, p.589), the concept still exhibits shortcomings with respect to important behavioral aspects of the choice decision, particularly as applied in a multi-attribute context.\(^1\)

It has been suggested above that aspirations function as goals for the individual which reflect what he/she believes is attainable in the housing market. In the search and selection process, these goals are expected to act as standards of comparison to facilitate the choosing of an opportunity. But it is questionable whether all aspirations are required to be satisfied in order for choice to be made in real-life

\[^1\] An alternative paradigm developed for multi-attribute decision problems is Zeleny's (1976) theory of the displaced ideal. Here, the reference point for decision making is initially an infeasible, ideal alternative which is successively displaced toward the attainable during information gathering and alternative-generating activities until it merges with a feasible solution.
Figure 3.1  Satisficing Decision Rule Over Two Attributes
(Source: Adapted from Simon, 1957, p. 251)
mobility situations, as postulated by the satisficing model, for such assumed behavior ignores the role of needs in residential choice and their relationships to aspirations, and the potential for tradeoffs among attributes considered by the household.

As above, needs define minimum sustainable levels of housing services and must always be satisfied by the residential opportunity. Aspirations define goals which the household attempts to attain through residential selection. It is not clear why the universal attainment of all aspirations should be other than a sufficient condition for the acceptance or rejection of the opportunity. A household may find an alternative which offers twice the living space aspired to, but less than desired accessibility. Should this alternative be rejected in the hope that both of these criteria will be sufficiently satisfied in a future observation, or are there likely to be implicit trade-offs among attributes considered in the assessment of a given opportunity? Although in some respects putting the cart before the horse, the locational choice literature reviewed in the previous chapter appears to support the latter argument. Trade-offs among attributes are likely to be made by the individual in the search and selection process, which may preclude the satisfaction of all aspirations through residential choice (Brummell, 1977, p.51).

Decision rules which attempt to incorporate these behavioral realities are typically modifications to the traditional satisficing paradigm. For example, Brown and Moore (1970) introduce the concept of an "aspiration region" which serves as the criterion of choice rather than the unique quantity defined by Simon (1957). For each attribute $k$, the
region, or range of acceptable attribute values, is determined through the individual's definition of their lower and upper limits, $\xi^k_t(\text{min})$ and $\xi^k_t(\text{max})$, respectively, which essentially reveal the lower and upper limits to the individual's needs (Brumwell, 1977, p.27; see Chapter 2).

A given alternative $i$ may be determined satisfactory if each attribute of the alternative is perceived to fall within the acceptance region (Figure 3.2). That is:

$$\xi^k_t(\text{min}) \leq V_t(x_k) \leq \xi^k_t(\text{max}) \quad \text{for all } k \quad (3.3.6)$$

A decision rule which results in a chosen alternative is, therefore, search the perceived set of alternatives, $S_t \subseteq S$, and accept the first opportunity which satisfies (3.3.6).

Under this paradigm, minimum sustainable needs in housing services are explicitly defined. Furthermore, since aspirations are not uniquely defined, trade-offs among attributes are possible, providing their values fall within their respective acceptable regions. However, the non-uniqueness of aspirations leads to a degree of fuzziness in the solution since the individual's residential goals are left unstated, and trade-offs, even if they do exist, are implicit rather than explicit, i.e. explicit relationships between aspirational dimensions cannot be quantified. It is also not clear why alternatives are rejected if any of their attributes exceed $\xi^k_t(\text{max})$.

The individual's uncertainty with respect to opportunities in the housing market will undoubtedly lead to uncertainties in aspirations over the criteria dimensions. But it still must be believed that the individual possesses some overall situational goal in the search and selection process. Such a goal may be expressed through the concept
Figure 3.2 Satisficing Principle as Modified by Brown and Moore (1970)
of place utility (Wolpert, 1965).

Under this construct, the individual's valuation of each alternative's attributes is assumed to be expressible as a single metric, or utility, from which preference orderings among opportunities can be derived. Place utility, which is so termed to explicitly recognize the spatial dimensions of residential alternatives, can either be experienced, expected or perceived as a goal, the latter defining the aspiration utility of the individual. Experienced place utility is that associated with the current residence which Wolpert (1965, p.162) describes as "the net composite of utilities which are derived from the individual's integration at some position in space". Expected utilities are those ascribed by the individual to potential opportunities, and are more anticipatory in nature since considerable uncertainty is associated with the net benefits likely to accrue from each. Aspiration utility is simply the composite of those aspiration levels defined above, weighted by their relative importance to the individual. Thus, mobility is based upon the relative values of experienced and aspiration utilities, and choice upon the relative values of aspiration and expected utilities.

Choice behavior is thereby defined by assuming the individual t to possess an aspiration utility which functions as a general residential goal throughout both the mobility and the search and selection processes. Such a utility would be defined:

$$\xi_t = \xi_t(x_1, x_2, \ldots, x_m)$$  \hspace{1cm} (3.3.7)

Vacancies observed during search activity are assigned an expected utility which essentially defines the alternative's anticipated value to
the individual.

\[ U_t^i = v_t(x_1^i, x_2^i, \ldots, x_m^i) \]

If we invoke a satisficing rule to these sets of subjective valuations, then a residential opportunity \( i \) will be regarded as satisfactory if and only if:

\[ U_t^i \geq \xi_t \]  \hspace{1cm} (3.3.8)

A satisficing choice rule under these conditions would then require the household to search the perceived set of alternatives and accept the first opportunity which satisfies (3.3.8).

Although essentially a form of satisficing behavior, the decision rule explicitly recognizes potential trade-offs among attributes. That is, \( U_t^i \geq \xi_t \) does not necessarily imply that \( v_t(x_1^i) \geq \xi_t^1, v_t(x_2^i) \geq \xi_t^2, \ldots \), etc. Providing the utility function of the individual satisfies a set of basic axioms (Henderson and Quandt, 1958, p.13), these trade-offs can, furthermore, be mathematically defined. Note that although needs are not explicitly recognized by the decision rule, their implicit relationships to aspirations, as described above, are still maintained. If necessary, they could be explicitly incorporated as constraints in the formulation of the decision rule.

We have developed a decision rule which postulates residential choice to be the product of satisficing behavior whereby the expected utilities of residential opportunities are compared by the individual to a subjectively determined aspiration level throughout the course of search. The chosen alternative is the first opportunity encountered in
search with expected utility greater than the search's aspiration utility. This represents a fundamental change in approach to the modeling of residential location. Instead of choosing that alternative which is perceived "best", the individual chooses an alternative which is "good enough". It is advocated because we contend that, in the residential evaluation process, the indeterminacy of the choice set and the uncertainties that beset the decision maker make global optimization behavior, implied by the traditional paradigm, impossible.

But what does this alternative decision rule imply about the rationality of the individual? By transforming the choice situation to one in which the opportunity is compared to a subjectively defined evaluation standard, we are explicitly recognizing the individual's attempt to simplify the surrounding environment, and thereby the choice situation, under conditions of partial knowledge and uncertainty. Although alternative maximizing principles can be established under uncertainty conditions, such as maximin, generalized maximin and minimax regret (see Ackoff and Sasieni, 1968, p.39-43), these models require all alternatives to be evaluated before choice is made, for if the choice set is not completely revealed to the individual, _ex post_ sub-optimal choice can be expected. A satisficing principle, on the other hand, requires alternatives to be sequentially evaluated for its solution to be unique (Simon, 1957, p.252)\(^1\), and thus requires the choice set to be only partially

\(^1\)Several operational approaches to the satisficing principle, which do not require alternatives to be sequentially evaluated, have been discussed by Keen (1977). These include several goal programming formulations which operate by attempting to minimize the sum of deviations from specified objectives, \(y^*\). For example, two goal programming formulations suggested applicable to satisficing decision situations are of the form:
known by the decision maker. The chosen alternative, again, is suboptimal from a global perspective (Flowerdew, 1976, p.50). Under conditions of uncertainty and incomplete information, then, the difference in choice between maximizing and satisficing principles may simply be, as Ackoff and Sasieni (1968, p.443) succinctly describe, the approximate attainment of an optimal alternative (maximizing) versus the exact attainment of an inferior one (satisficing).

That both satisficing behavior in a sequential evaluation process and maximizing behavior over an incomplete choice set are ex post suboptimal from a global perspective, however, does not necessarily imply irrational behavior on the part of the individual in decision making situations. Rather, the results demonstrate the consequences of the individual acting rationally under constraints associated with imperfect information, sampling costs, risk aversion and other factors. In these situations, the decision maker is still optimizing, but is optimizing a different decision problem. Behavioral differences between perfect rationality and bounded rationality are viewed simply as the consequences of constraints (March, 1978, p.590).

It is important to note how this interpretation differs from Keen's (1977, p.41), who conjectures that even though the individual may operate

\[
\minimize \sum_{i=1}^{l} (y_i - y^*_i)^\rho \quad (0<\rho<\infty), \text{ or } \sum_{i=1}^{l} |y_i - y^*_i|
\]

However, Keen (1977, p.48) argues that although these programming frameworks appear to correctly represent the decision rule, their mathematical approaches do not seem behaviorally grounded, because they fail to reflect the entire decision process of which satisficing is only a part. One element of this process of concern to us here is the way in which alternatives are sampled and the choice set identified.
under a well-defined decision framework, satisficing behavior may involve not the approximation of rational search for the ex ante optimal alternative, but rather the attempt to "best" adapt to the environment. As stated by Keen (1977, p.41) "[a] suboptimal decision that provides for aspiration and understanding may be preferable to the attainable optimum", which appears to run counter to Simon's notion of constrained rational behavior on the part of the satisficer. Hence, instead of being the intendedly rational economic man, the satisficer may well be, as Keen (1977, p.45) defines, the "apprehensive man", one who approaches decision making situations without well defined objectives but rather with aspirations incrementally adjusted from past experience so as to avoid opportunities which involve excessive risk. Presumably, under his precept, satisficing does not define "intended rationality". It represents a notion of incrementalism and risk aversion.

That interpretations differ about the implicit rationality of the process is probably attributable more to perspective than substance, however, for Keen is simply articulating another set of constraints on the decision maker in an uncertain choice situation which may be further concealing or, more appropriately, bounding rationality. As stated by Savage (1954), "rational choice involves two kinds of guesses: guesses about future consequences of current actions and guesses about future preferences for those actions" (March, 1978, p.589). We take Keen to be describing a choice situation when both the former, which we have considered, and the latter types of constraints, which we have not, are binding, a choice situation that has not been widely researched in the literature (see, however, March and Olsen, 1976).
Though not universally recognized, bounded rationality and the satisficing principle it yields, has been widely recognized as a more appropriate descriptor of choice behavior than other paradigms in many decision making situations (Radner, 1975; Radner and Rothschild, 1975; Keen, 1977; Connolly, 1977). Evidence from the psychological literature on the choice behavior of subjects in controlled experiments (Kahan, Rapoport and Jones, 1967; Rapoport and Tversky, 1966; 1972), and from the residential choice literature, which has observed households to adopt conservative strategies when searching for new residences, as characterized by their taking the first acceptable opportunity which presents itself (Butler et al., 1969; Lyon and Wood, 1977; Barrett, 1973; Michelson, 1977, MacLennan, 1979b), lend empirical support for the adoption of a satisficing decision rule in the modeling of the residential search and selection process.

Note, however, that by adopting a satisficing decision rule, we have imposed a particular sampling rule upon the situation as well. The sequential observation of alternatives, while representative of some aspects of search activity, is clearly inappropriate for others. For example, it has been suggested that during the initial stages of search, households refine their aspirations and choose a subset of the housing market to investigate more intensely through the employment of low cost, low quality, but spatially expansive information agents. Indeed, this approach may be repeated at regular intervals during search to identify new subsets of vacancies to examine (Smith et al., 1979). Sampling at these stages is neither sequential nor is choice necessarily deduced from satisficing, for with the choice set essentially revealed (as much as it
is going to be through this agent), the subset of opportunities chosen for further examination could as easily and more appropriately be defined through a maximizing decision rule as through a satisficing one.

But alternatives will be sampled sequentially at some stages of search, and will be associated with perhaps the most important stage of the process, the visual inspection of vacancies, for it will usually be at this point that choice is made. Given the limits upon the individual's time and resources, the significance of these elements at this stage of the activity and the inherent uncertainties in the housing market from the perspective of the searcher (because of a lack of knowledge of potential opportunities and competition for vacancies from others), make the conception of the search and selection process within the satisficing framework particularly appropriate.

From an overall perspective, then, evaluation and choice behavior, though not necessarily consistent throughout search activity, can be reasonably characterized by a satisficing principle. Upon observation of an opportunity, choice is predicated upon its expected utility to the individual relative to a subjectively determined aspiration utility which is continuously updated as more information about the housing market is gained through search. (Meyer, 1980, has demonstrated empirical support for information updating during search.)

What now remains to be done is to take each of the elements of search discussed in this chapter -- the cognitive dimensions of the individual, the sampling and utilitization of information, and the evaluation and choice behavior of the decision maker -- and combine them into a conceptual model of the relocation process. This is the
subject of the following section.

3.3 A Conceptual Model of Search Behavior

Search has been defined as an investigative activity which, through the acquisition of information about housing vacancies, enables the household to identify and evaluate residential opportunities. It is a process which dynamically adjusts the household's aspirations by revealing actual market conditions. And it is the means by which choice among candidate opportunities is made.

Though likely to be distinct for each individual undertaking the activity, search behavior, in its most general form, can be conceptualized as in Figure 3.3. As illustrated, we assume search to be predicated upon an initial mobility decision, whether stimulated by push factors, pull factors or some combination of both. This decision has been described as a product of the individual's cognitive image of the urban housing market from whence has been established an initial set of evaluation criteria and a composite aspiration utility against which to assess potential vacancies. Conditional upon the type of residential package desired (a function of aspirations) and prior perceptions of the housing market, the individual is assumed to selectively sample information agents in order to better acquaint him/herself with residential opportunities. From these agents is selected a subset of candidate alternatives to be more carefully evaluated. Typically, less factually specific, but more spatially extensive information agents are utilized to broaden the individual's information base and identify these subsets of opportunities. Because of the low factual content of information used at this stage, feedbacks to the individual's aspirations, defined evaluation
Figure 3.3 A Conceptual Model of Residential Search Behavior
criteria and cognitive image of the area are not considered significant. Actual choice among residential alternatives cannot be made by the individual until more extensive assessments of candidate opportunities are undertaken, which must usually involve visual appraisal. Thus, search among an identified subset of alternatives must typically involve the sequential sampling and evaluation of vacancies, with evaluation being made in relation to the individual's aspirations. But both visual appraisal and the employment of more factual information agents provide the individual significant information about housing attributes, the environmental characteristics of residential neighborhoods and, possibly, additional vacancy opportunities not originally perceived in the opportunity set. These data are assumed to be used by the searcher to update his/her information base upon which search is being conducted (the cognitive image), to refine evaluation criteria over which alternatives are assessed, and to revise aspirations to better represent what the individual believes is an attainable goal through residential relocation. These three psychological characteristics of the search: his/her cognitive image of the urban area, evaluation criteria over which to establish potential opportunities, and aspirations against which to compare alternatives, are all seen as dynamically adjusting elements of residential search. Their behavior essentially determines which opportunities are acceptable at their time of evaluation. Note, however, that rejection upon initial evaluation does not preclude an opportunity from being acceptable at a future point in time, since aspirations, in their adjustment to attainable levels realized through continued observation, may decline to levels below that alternative's perceived utility.
Search activity, particularly that aspect involving visual inspection, imposes significant costs in terms of time, money and effort upon the potential migrant (see MacLennan, 1979b). Upon the completion of each evaluation, the individual must decide whether to continue the search or choose amongst alternatives already observed. In some, but not all cases, the choice set will include the no-move alternative, *i.e.*, the individual may choose to remain at the current residence and attempt to mitigate any stressful circumstances that might have initially precipitated the mobility decision.

The decision of whether or not to continue the search will depend upon many factors. The individual must weigh remaining resources against both opportunities already observed through search and opportunities likely to be discovered if search is continued. To a large extent, this latter set of expectations will depend upon the individual's initial beliefs about residential opportunities and how subsequent search activity has reinforced or refuted these beliefs. In the conceptual model, these expectations are characterized by the searcher's aspirations. Thus, repeated failures in the attempt to locate suitable vacancies are expected to lower aspirations to levels below the perceived utilities of previously observed opportunities or even the stress threshold associated with the current residence, which initially prompted the decision to move. On the other hand, the identification of attainable alternatives valued significantly higher than original aspirations is expected to raise evaluation standards and encourage further search activity if resources permit. Diminishing resources, of course, are expected to discourage further search activity, although other more binding constraints, such
as forced mobility, may preclude the immediate curtailment of search.

If search is continued, the most recently observed vacancy may be assumed to be placed in a pool of searched alternatives, even though it may currently be considered unacceptable. These unacceptable opportunities must still be considered eligible simply because further investigation of the market may reveal them to be preferable in relation either to general submarket conditions (reflected in a lowering of the individual's aspiration utility) or to other alternatives in the pool (which would be a result of changes in the relative importance of evaluation criteria). Alternatively, competitive pressures in the market could conceivably eliminate more preferable alternatives from the vacancy pool and thus leave the individual with an inferior choice set from which to select an alternative. Although all observed vacancies could be considered to be placed in the vacancy pool, it is likely that only a small proportion are actually maintained in the choice set. Only those opportunities considered sufficiently close to aspirations at the time of observation are likely actively considered later in the search and selection process if recall of previously observed vacancies is deemed necessary.

If the continuation decision is made, the searcher may continue sampling from a previously identified subset of potential opportunities (if any remain in this pool) or may choose to develop a new choice set from which to sample more intensively. The choice of sampling strategy will depend to a large extent upon changes to the psychological characteristics of the individual in response to conditions perceived in the housing market through prior observation. For example, a household
initially desiring a centrally located single family dwelling may decide after a round of intensive searching that opportunities perceived in this submarket do not meet expectations, because either alternatives are perceived not to be attainable or desired residential amenities were incorrectly specified in the formation of aspirations. Rather than continuing to search in this submarket, the household might instead revise its aspirations and commence active search in another sub-market, for example, in the sub-market of suburban single family dwellings. In order to acquaint itself with potential opportunities in this sub-market, the household would be expected once again to select a subset of candidates from less factual information sources before engaging in more intensive sampling methods. Such "retreats" from the sequential appraisal element of search might be expected to occur on several occasions during search activity.

Upon discontinuation of search, an alternative is assumed to be chosen from the choice set of candidate opportunities considered acceptable to the individual. Choice may or may not include the current residence. Choice is assumed to be made by comparing the expected utility attributed to a given opportunity to the current aspirations of the individual.

However, the chosen alternative may no longer be available to the individual, as it may have been removed from the choice set, while search was being continued, by competitors for residential opportunities in the housing market. If, in fact, the chosen alternative has been taken off the market, a decision must be made either to recommence search activity or choose another acceptable alternative from the individual's
choice set. This decision will depend upon the psychological and environmental factors discussed above: resources, perceptions and aspirations of the search, and the perceived availability of suitable alternatives.

The degree to which recall of previously observed vacancies is permitted in the choice framework, as applied to residential search and selection, is problematic in the conceptual model. Uncertainties regarding available opportunities in the market attributable to the finite perceptual capacities and resources of the searcher, and external market forces such as competition, tend to restrict choice to the consideration of a very few recently observed vacancies. In the limit, the choice can be reduced to one of accepting the current opportunity if its expected utility exceeds the individual's aspiration utility, or of continuing search activity otherwise (Figure 3.4). Though obviously a simplification of actual search behavior, this chapter has found empirical evidence to support the contention of choice (as well as search) to be a sequential activity rather than a simultaneous one.

That a sequential evaluation and decision framework may be appropriate in the modeling of the search and selection process is important, since traditional models of residential location have typically described the process within a static equilibrium structure. This latter approach has been shown in Chapter 2 to overlook many important behavioral elements in the relocation process as described in this chapter which are likely to significantly influence locational choice. Thus will be developed in the following chapter a mathematical model of residential choice which explicitly recognizes the sequential nature of search.
Figure 3.4 A Conceptual Model of Residential Search Behavior With No Recall of Prior Residence or Previously Sampled Opportunities
activity and the modes of evaluation and choice likely to be pursued by the individual under these conditions. This model will be shown to be applicable to the search and selection process through an investigation of its properties and, finally, through its application to data.
Chapter 4
A Mathematical Model of Residential Search Behavior

4.0 Introduction

It is usually difficult to transform a conceptual model into its mathematical counterpart, since the phenomenon under investigation must be more precisely defined and relationships must be explicitly formalized. Yet search behavior is a phenomenon of widely divergent characteristics depending upon what conditions precipitated the mobility decision, upon the amount of information possessed initially, and gained during search, and upon competitive pressures for vacancies in the housing market. Although it would be desirable to develop a theoretical model which captures these aspects of search behavior within a single, consistent mathematical statement, such a task is beyond the bounds of this research effort. Instead, this chapter undertakes the development of a mathematical framework from which is derived a class of models which are used to represent different variations of search behavior. Within this framework are commonly held by this class of models two major characteristics of the search process developed in Chapter 3: search is represented as a sequential activity, and each alternative is evaluated by comparing its ascribed utility to currently held aspirations.

Although several related analytical frameworks could potentially
characterize the search and selection process, this chapter suggests that sequential decision theory is the most appropriate, since it explicitly recognizes the sequential nature of search activity hypothesized above, and is sufficiently flexible to incorporate alternative behavioral and environmental assumptions about search activity. In order to relate search to the sequential model, the chapter proceeds by first introducing the sequential decision framework and its characteristic features, to which the elements of search activity defined in the conceptual model are then related. From these basic relationships is developed a simple model of search behavior which is the basis upon which more sophisticated models are built. Following an assessment of the simple model's properties, the behavioral and environmental conditions imposed in this framework are selectively relaxed through the development of more complex models, which enable the effects of more realistic factors in the search process to be evaluated and compared to observed search behavior. The chapter concludes by summarizing the hypotheses suggested by the theoretical framework, of which some are tested in the empirical analysis that follows.

4.1 Residential Search as a Stopping Rule Problem

The analysis of search behavior within the framework of sequential decision analysis has its origins in the economics of information, from which have been developed models of employment search, and consumer search for lowest priced goods (see Flowerdew, 1979).

The model most commonly applied in the context of search is a stopping rule model (McCall, 1965; Lippman and McCall, 1976a; 1976b; Weibull, 1978). Stopping rule problems form the simplest sub-class of problems
in the field of sequential decision analysis (Breiman, 1964, p.284).

They are problems in which a decision is made on the basis of a sequence of observations, and possess two essential features:

- There exists a probabilistic mechanism which moves from state to state under known, partially known, or unknown probability laws, and

- The payoff and decision structure is such that, after observing the current state, there are at most two decisions:
  (a) take the accumulated payoff to date, or
  (b) pay an entrance fee for the privilege of observing another transition.

(Breiman, 1964, p.285)

Each state in the problem represents an observation of a given phenomenon, which possesses a value to the observer. Both the interarrival times between observations and the corresponding values are governed by a probabilistic mechanism. At each observation, a choice must be made by the decision maker to either discontinue observing the sequence and accept a terminal payoff, which is some function of the values of the states observed to date, or pay an entrance fee, which is a function of the state the observer is in, and observe one more state. The decision to be made by the observer is simply in which state to stop and accept the accumulated payoff. The objective of the observer, however, is to use the "best" stopping rule among all rules, so that the expected net payoff is maximized.

Given an observation in the sequence, the decision maker is affected by past observations only to the extent of the total entrance fees paid to date. But since these fees can never be recovered, the decision of whether or not to continue depends only upon the terminal payoff of that observation versus the expected gain from continuing. Thus, stopping rule problems exhibit a characteristic Markovian property, where
the entire future probabilistic development depends only upon the state
currently under observation.

Rapoport and Tversky (1970, p.107) and Flowerdew (1976, p.48) have
suggested a classification of stopping rule problems from which the
components of the stopping rule model can be identified. Five basic
elements characterize this class of models: the distribution function,
type of recall, entrance fee structure, sample size, and the evaluation
and decision rules. In stopping rule problems, each state or alternative
in the sequence of observations possesses a set of attributes which define
its value to the observer. The distribution function relates to the
probabilistic mechanism governing the distribution of these attributes
over the sample. It furthermore defines the probability function which
describes the distribution of times between observations in continuous mo-
dels. Upon the decision to discontinue sampling, the observer chooses one
of the alternatives inspected. Recall refers to the choice the decision
maker has. Models without recall permit only the most recently observed
alternative to be chosen. Those with recall extend the choice set to
some or all of those alternatives previously sampled. Entrance fees are
the costs borne by the observer to continue sampling. These costs may be
constant from state to state, or a function of the number of states ob-
served by the individual. The sample size defines the maximum number of
observations which can be made by the decision maker; the number of
alternatives in the sequence may either be finite or infinite. Evalu-
a-
tion and decision rules are the criteria over which the alternatives are
evaluated, and the objective(s) defined by the decision maker with which
to formulate the "best" stopping rule. These rules, in conjunction with

144
the other components of the model, essentially determine the choice of state along the stopping sequence.

In a stopping rule model, residential search is characterized by the sequential observation, or sampling of states. Each state can be thought of as characterizing a particular housing/location package, which is defined by a set of attributes whose distribution is governed by a known, partially known or unknown probability law. The consideration of each alternative bears some cost, though not necessarily in monetary terms, to the decision maker, and only one alternative can be chosen from the sample. Given the distribution of attributes over alternative dwellings, the value, or utility, of alternatives will also follow some probability law (Flowerdew, 1976, p.48). The objective of the decision maker is to discontinue search at that point in the sequence of observations where the gains to be made from further search are less that the gains to be made from discontinuing.

The components of the stopping rule model are well defined in terms of residential search. The distribution function relates to the probability law governing the distribution of utilities in the individual's opportunity set, where utilities are functions of the attributes of the alternative vacancies. The distribution thus indirectly reflects the supply-side characteristics of the housing market. The degree of recall defines the choice set of housing opportunities available to the individual throughout search. The extent to which previously observed alternatives may be included in the choice set is dependent upon conditions precipitating the move (whether forced or voluntary); if mobility is forced, or if the previous residence of the voluntary mover has been sold
or rented, the choice set cannot include the former dwelling) and market-related factors such as the supply of vacancies and intensity of competition. Entrance fees are the costs associated with searching for replacement housing. Costs are a function of the information channels used and the evaluation criteria defined by the individual. The sample size refers to the number of potential opportunities available to the individual in the search process; clearly, conditions of housing supply and limited resources for searching impose an upper bound on the number of vacancies that can be inspected in the sequence.

The evaluation and decision rules of the model essentially define the behavior of the decision maker under consideration, and under the conditions of observation. Following our analysis of evaluation and decision behavior in Chapter 3, we expect the individual to combine the attributes into a cardinally-scaled metric, which defines the alternative's utility. 1 Similarly, decision rules which characterize the individual as a satisficer are expected to define the means by which choice is based. Both of these features are operative within stopping rule frameworks, although other evaluation and decision rules can be incorporated as well. Stopping rule models provide the opportunity for examining alternative behavioral formulations related to evaluation, such as that of Brown and Moore (1970), and to choice (eg. Chow et al., 1964; Gilbert and Mosteller, 1966). 2

---

1 We require a cardinal measure of utility because utilities are characterized in terms of expected values.

2 The decision rule postulated and applied by Chow et al. (1964) assumes the decision maker to attempt to minimize the expected rank of the alternative selected; that by Gilbert and Mosteller (1966) assumes the individual to maximize the probability that the best opportunities are placed on a shortlist, or subset, from which final choice is made. The evaluation concept of Brown and Moore (1970) has been described in Chapter 3.
Although little empirical research has been undertaken, most tests of the stopping rule model have supported it as a valid representation of choice behavior over a sequence of alternatives. Evidence from the psychological literature (Kahan, Rapoport and Jones, 1967; Rapoport and Tversky, 1966; 1970) has revealed that, under controlled experimental conditions, subjects faced with hypothetical choice situations over a sequentially revealed opportunity set more often follow optimal stopping policies than not, i.e. they stop at the same point in the sequence and make the same choice of alternative as predicted by a stopping rule model. Although other behavioral search policies could conceivably produce the same choices, these results suggest stopping rule models to be appropriate descriptors of search behavior in a residential context, particularly if the sequential nature of residential search activity hypothesized above can be accepted.

By applying the model to residential search, however, we are implicitly restructuring the process as described in Chapter 3. Search is still predicated upon an initial mobility decision, from which are established evaluation criteria and aspirations, represented by a distribution function of perceived values (Figure 4.1). These characteristics of the individual can be revised in particular variants of the model through systematic modification of the above probability distribution. Choice of housing is taken over a choice set which may contain only one, some or all previously sampled alternatives, depending upon the degree of recall permitted by the model.

However, the sampling of opportunities is strictly sequential. Furthermore, the search and evaluation processes are essentially com-
Figure 4.1 Residential Search as a Stopping Rule Model
bined into a single stage; by definition, a vacancy is presumed evaluated upon observation, and the decision of whether to continue search or choose an alternative vacancy from the sample is defined to occur immediately following the evaluation of each alternative.

Casting search and selection within the framework of a stopping rule model explicitly arranges the behavioral mechanics of the process that, in many cases, are left purposely vague in the conceptual model because of the extreme variation expected among subsets of movers, or simply because little is known about the underlying behavioral actions which are manifested into a chosen residential package. However, theoretical and empirical reasons suggest that stopping rule models are appropriate. Providing the limits to the model's capabilities are recognized, its application should lead to insights into the location decision that are not addressed in current theoretical formulations.

4.2 Residential Search Behavior in a Mathematical Framework

Much understanding of residential search behavior can be gained through an examination of stopping rule models in their simplest form, since they are both analytically tractable and exhibit properties which are similar to those of their more complex derivatives. This section explores the characteristics of search models by first introducing the basic model and examining its properties. The relationships between stopping rule models and the satisficing principle discussed in Chapter 3 are then explored and evaluated in the context of residential choice. The section following this assesses the model's properties in relation to observed search behavior from whence more complex models are introduced by relaxing particular assumptions. In this way, the impacts of
more involved stimuli on the search behavior of the individual are ascertained.

Before introducing the models, however, some theoretical preliminaries should be stated so that the behavioral context in which the models are based is explicitly recognized.

Corresponding to the theory of consumer behavior, we assume the individual to possess a set of preferences for different combinations of attributes, which define the set of goods in the market (Lancaster, 1966). Behavior is determined by preferences through the existence of a utility function which represents the individual's evaluation of available attributes in the market. However, instead of choice involving the evaluation of the attributes of all goods simultaneously, we adopt the behavioral concept of rational irrationality (van Praag, 1968), whereby the individual considers only the attributes of commodities relevant to the situation at hand. Thus, in the modeling of relocation behavior, rather than determining the optimum mix of attributes of both the residential environment and all other goods over a p-attribute space, as in traditional theoretical formulations (see, for example, Alonso, 1964; Casetti, 1971; Brummell, 1977), we assume the relocation decision to depend only upon the characteristics of the housing/location package; that is, the relevant set, $\mathcal{F}_n$, which constitutes an n-attribute space (n<p). By adopting this convention, we are explicitly recognizing an inherent non-homogeneity between housing and most other consumption goods; substitutions between housing services and attributes which characterize other goods are simply not defined. We are furthermore acknowledging the limited perceptual capabilities of the individual for evaluating
the characteristics of all consumption goods simultaneously (van Praag, 1968, p. 5). Consistent with behavioral processes postulated by Simon (1957, p. 243) and Posner (1964), and observed in empirical research (see Chapter 3), the individual is assumed to simplify the choice situation by considering only those attributes relevant to the decision at hand. We are, in effect, assuming the individual possesses a separable utility function (Gorman, 1959).

The relevance process (van Praag, 1968, p. 4), which determines the relevant set, \( I_n \), over which evaluation is based, is assumed to be determined exogenously. For the evaluation of housing opportunities, this means that the individual defines a range of alternatives over which to search, and a set of attributes relevant to the evaluation process, upon the initial mobility decision. This range of relevant attributes maintains a desired consistency between the consumption of housing and the consumption of all other goods. Perceived opportunities in this preliminary screening process, which require significant shifts in consumption between housing services and other goods, are simply considered as infeasible alternatives. ¹

We assume, however, that once the relevance set, \( I_n \), is established by the individual, it remains constant over search. This, in effect, enables opportunities to be evaluated over a common set of dimensions (van Praag, 1968, p. 11).

¹The definition of an appropriate relevance set in the residential search context is problematic, since a wide range of consumption decisions must still be made in the housing/location decision. For example, Lerman (1975) has shown that significant trade-offs exist between locational choice and auto-ownership levels.
The Basic Model

We begin by defining the essential elements of the search model in terms of the components identified in Section 4.1. In particular, we assume the following:

- the distribution function is known and invariant over time
- recall of all previously observed alternatives except the one currently being evaluated is not permitted
- entrance fees are constant from state to state
- there is no limit on the number of alternatives which can be inspected in the sequence
- the decision maker evaluates alternatives in terms of a cardinally-scaled utility function

Consider the individual engaging in search for housing.\(^1\) Over each unit of time, one vacancy is observed, and for this privilege, the individual incurs a cost, \(c\), a vector which remains constant over the search effort. Costs may include fees paid to information agents, transportation costs, costs in terms of time and effort, and a number of other components, as discussed in Chapter 3. We assume the individual, \(t\), associates a disutility, \(U_t(c)\), with these components, which must be incurred in order to secure alternative housing.

Housing can be considered a multi-dimensional commodity comprising, among other things, components related to neighborhood and housing quality, accessibility and public services. We can denote a given vacancy, \(i\), then, by a vector \((x_1^i, x_2^i, \ldots, x_n^i)\). Similar to the components of cost, we assume the individual, \(t\), ascribes a utility, \(U_t(x_1^i, x_2^i, \ldots, x_n^i)\) to

\(^1\)At this point, we are not concerned with circumstances precipitating the move (the mobility decision may be voluntary or involuntary, and search may be active or passive). We accept the mobility decision as given.
the vacancy, \( i \), upon evaluation. We define utility such that, for the vector of attributes \( \mathbf{x} \in \mathbb{R}^n \), \( u: \mathbb{R}^n \rightarrow \mathbb{R}_0^+ \). Since housing vacancies can be expected to vary along their respective quality dimensions, the corresponding utilities associated with vacancies in the market will vary as well. We assume the variation in utilities follows a probability distribution which remains invariant throughout the search, and which is assumed to be known by the individual.\(^1\) The utility associated with vacancy \( i \) can therefore be considered a random variable with distribution function, \( F(\cdot) \).\(^2\)

For simplicity, the individual engaged in residential search is assumed to be risk neutral. We also assume rational behavior on the part of the individual in that he/she attempts to maximize utility when deciding whether to continue or discontinue the process.

Now assume the individual has sequentially observed \( k \) vacancies in the housing market. If the \( k^{\text{th}} \) opportunity was chosen, the net gain in utility to the searcher would be:

\[
U_t^k(x_1^k, x_2^k, \ldots, x_n^k) - k \cdot \bar{u}_t(c) = y_t^k
\]  

(4.2.1)

Since the objective of the individual is to maximize his/her net gain from sampling, the problem is one of finding a stopping rule which maxi-

\(^1\)Note that several of the assumptions made for the development of the basic stopping rule model are relaxed in later sections.

\(^2\)\( F(\cdot) \) can be considered to be a subjective probability distribution over the utilities of vacancies in the searcher's opportunity set, as it incorporates the individual's beliefs about future observations and, possibly, his/her sampling strategy (Kohn and Shavell, 1974, p.94). Although assumed to remain invariant over the search process in the basic model, conditions on the distribution function are relaxed in later sections.
\[ E(Y^K_t) = E\left[ u_t(x^K_1, x^K_2, \ldots, x^K_n) - K \cdot \bar{u}_t(c) \right] \]  

(4.2.2)

where \( K \) is the random number of vacancies inspected until one is accepted.

Define \( \xi_t \) to be the maximum expected utility that can be achieved by the individual if a best stopping policy is adopted throughout the search. After the first observation, search may be discontinued and the vacancy accepted with utility gain,

\[ u^1_t(x^1_1, x^1_2, \ldots, x^1_n) - \bar{u}_t(c) \]  

(4.2.3)

or continued with expected utility, \( \xi_t \). The optimal procedure for the individual to follow is to:

- Reject the vacancy and continue searching if \( u^1_t < \xi_t \)  

(4.2.4)

- Accept the vacancy and stop searching if \( u^1_t \geq \xi_t \)

The expected gain from following the optimal search strategy after just one observation can be easily calculated as:

\[ E[\max\{u^1_t, \xi_t\} - \bar{u}_t(c)] \]  

(4.2.5)

But note that \( \xi_t \) was defined previously to be the expected return from pursuing the "best" stopping rule. By definition, both expressions are equivalent, yielding the identity:

\[ \xi_t = E[\max\{u^1_t, \xi_t\} - \bar{u}_t(c)] \]  

(4.2.6)

We submit the following definition to advance our arguments.
DEFINITION 4.1: A function $F: \mathbb{R}^+ \rightarrow [0,1]$ is called an opportunity distribution (of utilities) if it is non-degenerate over the range $[a, b]$, where $b = \inf \{ u | F(u) = 1 \}$ and $a = \sup \{ u | F(u) = 0 \} \geq 0$.

Then, the expected value of the argument in (4.2.6) can be decomposed as follows:

$$E[\max \{ U_t, \xi_t \}] = \int_{\xi_t}^b u_t dF(u_t) + \int_{\xi_t}^b dF(u_t)$$

$$= \int_{\xi_t}^b u_t dF(u_t) + \xi_t \int_{\alpha}^b dF(u_t) - \int_{\xi_t}^b dF(u_t)$$

$$= \int_{\xi_t}^b (u_t - \xi_t) dF(u_t) + \xi_t$$  

(4.2.7)

Substituting back into (4.2.6) yields:

$$\tilde{U}_t(c) = \int_{\xi_t}^b (u_t - \xi_t) dF(u_t)$$  

(4.2.8)

Since $\tilde{U}_t(c) > 0$, there is a unique number, $\xi_t \in (a, b)$, which satisfies (4.2.8), and therefore, at any stage, $k$, in the search process, the optimal stopping rule remains:

Reject the vacancy and continue searching if $\tilde{U}_t^k < \xi_t$  

Accept the vacancy and stop searching if $\tilde{U}_t^k \geq \xi_t$  

(4.2.9)

That an optimal stopping rule exists in sequential decision problems under quite general conditions has been shown by several authors (DeGroot,
1970; Kohn and Shavell, 1974; Lippman and McCall, 1976a). Specifically, for the problem at hand, it can be shown that if the variance of the distribution function, \( F \), is finite, then the maximum gain, \( \xi \), among all stopping rules is finite, and there exists an optimal stopping rule (with expected gain, \( \xi \)) which is of the form defined in (4.2.9) (Lippman and McCall, 1976a, p.161). This condition for ensuring the existence of such a decision rule is assumed in all theoretical expositions that follow; the condition is also one that is likely to be satisfied (and is assumed satisfied) in actual circumstances pertaining to residential search.

The decision rule defined by the model in (4.2.9) reveals choice among alternatives to follow the satisficing principle described in Chapter 3. \( \xi_t \) defines the individual's aspiration utility, which is used as the standard of comparison against which alternatives are evaluated. At the first acceptable vacancy (i.e. one having utility greater than or equal to the individual's aspiration utility), search is discontinued and that vacancy chosen.

However, of greater interest is how the satisficing behavior of (4.2.9) is derived. In the previous chapter it was suggested that satisficing behavior could be considered either as the individual's attempt to optimize under conditions of uncertainty and incomplete information, or as non-optimizing behavior which, instead, represents risk avoidance, by considering only alternatives which deviate marginally from an established norm. The satisficing principle defined in (4.2.9) supports the former viewpoint; by its relationship to the objective function of (4.2.2), the satisficing decision rule results from the
individual's attempt to maximize his/her perceived gains (in terms of net utility) under significant behavioral and environmental constraints and conditions of uncertainty. Sequential sampling of opportunities from a known probability distribution essentially constitutes a random drawing.\(^1\) Since search imposes real costs upon the individual, it cannot be conducted indefinitely. In order to maximize net utility, the searcher must trade off expected returns from continuing search with the returns which can be realized by accepting the current opportunity. The constraints result in the formation of a standard of evaluation by which the individual judges alternative vacancies, a standard which identifies the decision framework as a satisficing one.

The rationale of the optimal search strategy can be seen by interpreting (4.2.8). Expanding the right-hand side yields:

\[
\int_{\xi_t}^{\beta} (u_t - \xi_t) dF(u_t) = \int_{\xi_t}^{\beta} u_t f(u_t) du_t - \xi_t \int_{\xi_t}^{\beta} f(u_t) du_t
\]

\[
= \int_{\xi_t}^{\beta} u_t f(u_t) du_t - \xi_t \cdot \Pr\{U_t > \xi_t\}
\]

\[
= \Pr\{U_t > \xi_t\} \left[ \int_{\xi_t}^{\beta} \frac{f(u_t) du_t}{\Pr U_t > \xi_t} - \xi_t \right]
\]

\[
= \Pr\{U_t > \xi_t\} \cdot \left[ \mathbb{E}(U_t | U_t > \xi_t) - \xi_t \right]
\]

\(^1\)We assume, in fact, that vacancies are drawn independently from an infinite population.
\[ = H(\xi_t) \]

The first factor, \( \Pr(U_t > \xi_t) \), is the probability that the utility of an arbitrary vacancy exceeds the individual's aspiration utility; the second is the expected increment in that utility over the individual's aspiration utility. \( H(\xi_t) \) can therefore be interpreted as the expected marginal utility to the searcher, gained from observing one more vacancy in the sequence, and is formally defined as follows.

**DEFINITION 4.2:** A function \( H: \mathbb{R} \rightarrow \mathbb{R}_0^+ \) is called an **expected marginal utility** if:

\[
H(s) = \int_s^\beta (x-s) dF(x) = c
\]

where \( c \) is a non-negative constant. \( H \) is a convex, non-negative and strictly decreasing function which satisfies the following relationships (Lippman and McCall, 1976a, p.160):

\[
\lim_{s \rightarrow \beta} H(s) = 0; \quad \frac{dH(s)}{ds} = -[1-F(s)]; \quad \frac{d^2H(s)}{ds^2} \geq 0
\]

Therefore, implicit in the stopping rule of (4.2.9) is the intuitive economic result: the individual's aspiration utility, \( \xi_t \), equates the marginal perceived cost of search with the expected marginal utility of observing one more vacancy in the sequence of opportunities.

**4.3 Properties of Search Models**

Thus far, a model of residential search behavior has been introduced which operates upon an extremely simple, yet intuitively appealing principle. Search over a sequence of opportunities is discontinued, and
the most recently observed opportunity is chosen, at that vacancy having utility greater than or equal to the individual's aspiration utility. Furthermore, this aspiration utility equates the marginal perceived cost (or disutility) of searching with the expected utility to be gained from taking one more observation.

We wish now to examine the properties of the stopping rule model to assess what the relationships that it embodies mean in terms of residential search behavior. Specifically, we are interested in the search and choice behavior of the individual in response to changes in particular environmental variables: search costs, variations in housing quality and competition for available housing opportunities from other households. Furthermore, we are interested in how search behavior changes when the searcher's sampling activities are constrained. Finally, we are interested in how changes to particular behavioral or psychological assumptions affect search and choice behavior: how the individual adapts to additional information gained during search, and how choice is affected by the expansion of the choice set to include some or all previously observed alternatives. Through these developments can a better assessment of the sequential decision framework's capabilities for representing residential search behavior be made.

The critical decision variable associated with the search sequence has been shown in Section 4.2 to be the searcher's aspiration utility, \( \xi_t \). However, it has not been revealed in a general sense, beyond the decision rule derived for the basic model in (4.2.9), how aspirations condition choice. The existence of an aspiration utility essentially determines which vacancies from the original opportunity distribution,
\( F(*) \), are considered acceptable by the searcher. Aspirations thus impose a lower bound on the opportunity distribution, as is shown below.

First, define the random variable, \( U_t^* \), to be the utility ascribed to the chosen opportunity by individual, \( t \). Since, by definition, \( U_t^* \geq \xi_t \), the distribution function of the variable \( U_t^* \) can be derived as follows:

\[
F_{U_t^*}(\lambda) = \Pr\{U_t^* \leq \lambda \mid U_t \geq \xi_t\} \cdot \Pr\{U_t \geq \xi_t\}
\]

\[
= \Pr\{U_t \leq \lambda \cap U_t \geq \xi_t\}
\]

\[
= \int_{\xi_t}^{\lambda} f(u_t) \, du_t
\]

\[
= F_{U_t}(\lambda) - F_{U_t}(\xi_t)
\]

\[
\leq F_{U_t}(\lambda) \quad (4.3.1)
\]

where \( U_t \), as before, denotes the utility ascribed to a given alternative by individual, \( t \). Truncation of the lower range of the opportunity distribution by the aspiration curve means that the expected utility of the chosen alternative will always be at least as great as the perceived mean utility of all housing opportunities considered by the searcher.

That is:

\[
E(U_t^*) = E(U_t \mid U_t \geq \xi_t)
\]

---

1In order to differentiate between distribution functions for \( U_t^* \), the utility of the chosen alternative, and \( U_t \), the utility associated with any given alternative in the sequence, we adopt, for this section only, the notation \( F_X(*) \) to represent the distribution function of the random variable, \( X \).
\[ E(K) = \frac{1}{1 - F_{U_t}(\xi_t)} \]
Taking the derivative reveals:

\[
\frac{\partial E(K)}{\partial \xi_t} = \frac{1}{1 - F_{U_t}(\xi_t)^2} \frac{\partial F_{U_t}(\xi_t)}{\partial \xi_t} \geq 0
\]  

(4.3.6)

A decline in the individual's aspiration utility decreases the number of vacancies searched before a suitable opportunity is located since, *ceteris paribus*, a declining aspiration utility increases the probability that a given alternative's utility will exceed it. The expected gain from searching, since equivalent to aspiration utility [see (4.2.6)], declines directly with decreasing aspirations.

Relationships between behavioral variables implicit in the model can be seen to correspond to the expected behavioral patterns of households undertaking search in the housing market. Search is an activity which enhances the choice set of the individual by screening alternatives below an aspiration threshold. Changing aspirations modify expectations of searchers and the amount of effort which must be expended in order to locate acceptable housing. What must now be investigated are the degrees to which other conditions related to the household or surrounding environment are of significance to both search and choice behavior.

### 4.3.1 Search Costs and Search Behavior

One set of major environmental constraints facing households searching for alternative residential opportunities is that which relates to search costs. These costs are usually expressed in terms of time, financial resources and effort required to identify and evaluate a set of residential opportunities; they may also include transactions costs that
result from successful search activities (Smith et al., 1979). However, significant psychological costs, for example, those associated with apprehension and uncertainty, may be involved as well.

The stopping rule model of search behavior postulated above defines these costs in terms of a single numeraire, or disutility, $\bar{u}_t(c)$, perceived by the individual, t. Therefore, residential search behavior is conditioned both by the magnitude of costs faced by the individual, and by the relative importance attached to each element of the cost vector.

The relationship between aspirations and the individual's disutility for searching is defined in (4.2.8), where:

$$
\bar{u}_t(c) = \beta \int_{\xi_t}^{\beta} (u_t - \xi_t) dF(u_t)
$$

Taking the derivative with respect to $\xi_t$ yields

$$
\frac{\partial \bar{u}_t(c)}{\partial \xi_t} = \frac{\partial}{\partial \xi_t} \left[ -\int_{\xi_t}^{\beta} u_t f(u_t) du_t + \xi_t \int_{\xi_t}^{\beta} f(u_t) du_t \right]
$$

$$
= -\xi_t f(\xi_t) - \left(1 - F(\xi_t)\right) + \xi_t f(\xi_t)
$$

$$
= -F(\xi_t)
$$

$$
\leq 0 \quad (4.3.7)
$$

Furthermore,

$$
\frac{\partial^2 \bar{u}_t(c)}{\partial \xi_t^2} = \frac{\partial}{\partial \xi_t^2} \int f(u_t) du_t
$$

163
\[ = f(\xi_t) \]
\[ \geq 0 \quad (4.3.8) \]

\( H(\xi_t) \), the expected marginal utility gained from observing an additional vacancy which is, by definition, equated to the marginal perceived cost of search, can be seen to be a non-increasing, convex function in \( \xi_t \). By (4.2.10), it is also non-negative for all \( \xi_t \). This relationship, plus the definition of the search disutility function, lead to two fundamental observations.

First, since \( \xi_t(0) \) can be assumed to be monotonically related to costs incurred through search (i.e., the disutility of time, money, etc. is increasing in these variables), the aspirations of the individual decline and, if linear, decline at a decreasing rate, as the marginal cost of searching increases (Figure 4.2). In effect, higher search costs define higher marginal utilities which must be gained from successive observations in the sequence of opportunities. (This is a direct consequence of 4.2.10.) The individual attains these higher margins by lowering his/her aspiration utility.

Second, aspirations decline as the individual increases his/her valuation of each of the components of search cost. Different valuations of identical search costs may represent socioeconomic variations across groups of individuals or the changing attitudes of a single individual over time. If attitudes are assumed to change over time, an increasing valuation of one or more cost factors reflects an increasing "marginal impatience" by the searcher as successive vacancies in the sequence of opportunities are rejected, demonstrating the deterrent effects of post-
Figure 4.2 Relationship Between Aspirations and Search Costs
poning choice among the set of vacancies already inspected.\footnote{The marginal impatience of the individual may also be represented by a discount function applied to the utility of the individual (Weibull, 1978, p.52; Lippman and McCall, 1976a, p.171) and represents a form of risk aversion.} Here, equal marginal search costs, \( c^* \), give rise to different utility levels, depending upon the number of opportunities rejected or, equivalently, the point in the sequence in which the individual is situated. If we let \( T_i \) represent the cumulative number of periods devoted by the individual to residential search activity, this statement may be defined as follows:

\[
\hat{u}_t(c^*;T_2) \geq \hat{u}_t(c^*;T_1) \quad \text{for } T_2 \geq T_1 \quad (4.3.9)
\]

Therefore, given equal marginal expenditures of time, money, effort and other costs associated with search activity, greater marginal impatience, brought upon by the postponement of choice, effectively reduces the aspiration utility of the individual as search is continued (Figure 4.3). This, again, is a direct consequence of (4.2.10).

By the relationships between aspirations and choice defined in the previous section, then, increasing search costs, either experienced or perceived, reduce the number of opportunities likely to be evaluated before aspirations are exceeded and search is discontinued. By lowering aspirations, the expected gain to the individual, achieved through relocation, is correspondingly reduced. High search costs are therefore seen by the model as inhibitors to the search process and to the subsequent relocation decisions made on the basis of this sampling and evaluation strategy.
Figure 4.3 Aspirations as They Relate to the Marginal Impatience of the Searcher
4.3.2 Perceived Variations in Housing Quality

Throughout the course of search for housing, the individual possesses a cognitive image of the housing market, a concept which is essentially defined in the stopping rule model by the opportunity distribution, $F(\cdot)$. This function, combined with the marginal perceived cost or disutility toward search, is posited to supply sufficient information to enable the searcher to formulate an aspiration utility, $\xi_t$, which serves as the criterion for choice among the set of sequentially observed alternatives. Since aspirations are dependent upon the opportunity distribution, it is of interest to determine the extent to which choice behavior is influenced by changes to perceived variations in housing quality. This can be shown by examining the relationships between the parameters which characterize the spread of the opportunity distribution and the aspiration utility, $\xi_t$.

In order to characterize changes to perceived variations in housing quality and what these changes mean to the individual, we need to advance a definition which unambiguously identifies whether a given distribution is more variable, or is "riskier", to the individual than another. To do this, we restrict our attention to a particular transformation which maintains a constant mean value of $U_t$, but shifts the probability density from the center of the distribution to the tails. Such a transformation is termed a mean preserving increase in risk (Rothschild and Stiglitz, 1970), which can be operationally defined as follows (Diamond and Stiglitz, 1974, p.340).

**DEFINITION 4.3:** Let a shift in the distribution function $F(\cdot)$ be characterized by a change in the shift parameter, $z$. Without loss of
generality, the function \( F \) may be symbolically represented by \( F(\cdot; z) \), and a shift in \( F \) by \( \frac{dF(\cdot; z)}{dz} = F_z(\cdot; z) \). Then an increase in \( z \) causes a mean preserving increase in risk if:

\[
\int_{\alpha}^{\beta} F_z(u; z) du = 0 \quad (4.3.10)
\]

\[
\int_{\alpha}^{y} F_z(u; z) du \geq 0 \quad \text{for all } y \text{ such that } \alpha \leq y \leq \beta \quad (4.3.11)
\]

The first condition, defined in (4.3.10), ensures that the two distributions, which differ only by the shift parameter, \( z \), have the same mean; the second, (4.3.11), essentially measures the degree of shift in the distribution, brought about through the change in \( z \).

An individual searching for housing opportunities can therefore be said to be facing a more variable or riskier housing market if the opportunity distribution, \( F(u; z) \), satisfies equations (4.3.10) and (4.3.11), where \( z \) defines the amount of variability added to the original distribution. The problem is now one of finding how the individual's aspirations change as this distribution function undergoes a mean preserving increase in risk. This is addressed in the following theorem (see also Kohn and Shavell, 1974, p.114).

**THEOREM 4.1:** A mean preserving increase in risk in the opportunity distribution can only raise, or maintain at its current level, the aspiration utility, \( \varepsilon_t \), of the individual, \( t \).

**PROOF:** Assume sampling costs remain constant throughout search. Then, a change in aspiration utility brought about by a change in the variability of the opportunity distribution can be assessed by differentiating, by the shift parameter, \( z \), the expected marginal utility, \( H \).
Therefore,

\[
\frac{dH(\xi_t)}{dz} = \frac{d}{dz} \int_{\xi_t}^{\beta} (u_t - \xi_t) dF(u_t; z)
\]

\[
= \int_{\xi_t}^{\beta} (u_t - \xi_t) dF_z(u_t; z)
\]

\[
= (u_t - \xi_t) F_z(u_t; z) \bigg|_{u_t = \beta}^{u_t = \xi_t} - \int_{\xi_t}^{\beta} F_z(u_t; z) d(u_t - \xi_t)
\]

\[
= 0 - \int_{\xi_t}^{\beta} F_z(u_t; z) du_t
\]

\[
= -\int_{a}^{\beta} F_z(u_t; z) du_t + \int_{a}^{\beta} F_z(u_t; z) du_t
\]

(4.3.12)

But since the transformation of $F$ is a mean preserving increase in risk, then, by Definition 4.3,

\[
-\int_{a}^{\beta} F_z(u_t; z) du_t = 0 \quad \text{and} \quad \int_{a}^{\xi_t} F_z(u_t; z) du_t > 0
\]

Therefore, \(\frac{dH(\xi_t)}{dz} \geq 0\). The aspiration utility of the searcher is a non-decreasing function of the variability of the opportunity distribution.

Thus, we expect households to prefer sampling from more variable distributions in perceived housing quality, since the expected marginal gain from search increases as the variability of the opportunity distribution
increases,\(^1\) even though the expected utility associated with the sampling distribution remains constant.\(^2\) As a consequence of (4.3.6), however, the duration of search activity can be expected to increase with a corresponding increase in variation. It is of interest to note that the above statements may be further generalized by the finding that even risk averse individuals prefer to sample from a more variable distribution (Kohn and Shavell, 1974, p.94).

That aspirations change in response to changes in variability in the opportunity distribution can be more clearly seen in the following example. Consider search being conducted over a set of vacancies having a single, known quality dimension which is uniformly distributed between the limits \(\alpha\) and \(\beta\), i.e.

\[
f(u_t) = \frac{1}{\beta - \alpha}, \quad \alpha \leq u_t \leq \beta
\]

\[
= \frac{1}{2z}
\]

where \(\beta = \bar{u}_t + z\) and \(\alpha = \bar{u}_t - z\). Note that \(E(U_t) = \bar{u}_t\) and \(\sigma_{U_t} = \frac{z}{\sqrt{3}}\). Since \(F\) is now defined, the aspiration utility of the individual can be solved by substituting (4.3.13) into (4.2.8) to yield,

\[
u_t(c) = \int_{\xi_t}^{\beta} \left( \frac{u_t}{2z} \right) \, du_t - \xi_t \int_{\xi_t}^{\beta} \frac{1}{2z} \, du_t
\]

\(^1\)Providing that inspection cost conditions remain the same.

\(^2\)This is consistent with David (1974).
\[ = \frac{1}{2z} \left[ \frac{u_t^2}{\xi_t} \right] - \frac{\xi_t}{2z} \left[ \frac{u_t}{\xi_t} \right] \]

\[ = \frac{\beta^2 - \xi_t^2 - 2\xi_t\beta + 2\xi^2}{4z} \quad (4.3.14) \]

Rearranging the terms of this expression reveals:

\[ \xi_t^2 - 2\beta \xi_t + \left( \beta^2 - 4z\bar{u}_t(c) \right) = 0 \]

Solving the quadratic defines the aspiration utility of the individual to be,\(^1\)

\[ \xi_t = \bar{u}_t + z - 2\sqrt{\bar{u}_t(c) \cdot z} \quad (4.3.15) \]

Two properties of this expression should be noted. First, when the opportunity distribution, \( F \), is uniform, aspirations are, in general, non-linearly related to variations in perceived quality, as measured by the standard deviation of the distribution. This observation can be directly inferred from (4.3.15), since \( z \) is a linear function of \( \sigma_{\bar{u}_t} \). Only when the individual's disutility towards search is identically zero (\( \bar{u}_t(c) = 0 \)) is the relationship between aspirations and variation linear.

Second, for all defined values of \( \xi_t \), the aspiration utility of the searcher is non-decreasing in \( \sigma_{\bar{u}_t} \), since:

\(^1\)The second root of the quadratic, \( \xi_t = \bar{u}_t + z + 2\sqrt{\bar{u}_t(c) \cdot z} \), is undefined for this problem, since all values of \( \xi_t \) are greater than \( \beta \), the maximum of the distribution.
\[
\frac{\partial \xi_t}{\partial z} = 1 - \sqrt{\frac{\bar{u}_t(c)}{z}} \geq 0 \iff z \geq \bar{u}_t(c) \quad (4.3.16)
\]

Since, by (4.3.15), \( z \) must be greater than \( \bar{u}_t(c) \) for \( \xi_t \) to be greater than \( \alpha \) (the minimum of the opportunity distribution), then:

\[
\frac{\partial \xi_t}{\partial z} \geq 0 \quad (4.3.17)
\]

Aspirations, as they relate to changing variations in a uniform distribution function under alternative cost structures for searching are shown in Figure 4.4. Aspiration utilities are monotonically increasing functions of the standard deviations of the random variable, \( U_t \), as expected. In addition, search costs are shown to influence this relationship in two ways. First, to attain a given aspiration utility, higher marginal search costs require search to be conducted over a more variable distribution than do lower costs, since aspirations are effectively shifted downward as search costs increase (Section 4.3.1). Second, higher marginal search costs reduce the rate at which aspiration utilities increase in response to changing variations in the opportunity distribution, \( F \).

These observations suggest that the variation in perceived housing quality is an important parameter in influencing the individual's behavior throughout the search process. Searchers who perceive and evaluate highly variable opportunity distributions are expected to search longer but gain more than those facing a less variable distribution of opportunities. However, these gains are likely to be highly conditional upon the relative magnitudes of search costs, since aspirations, regardless
Figure 4.4 Relationship Between Aspirations and the Variation in the Opportunity Distribution for Alternative Search Costs
of the variability of utilities in the opportunity set, can be offset significantly by high sampling costs.

4.3.3 Competition for Housing Opportunities

Though influenced by perceived characteristics of the residential opportunity and a general predisposition against searching, the relocation decision of the individual is, in the end, totally dependent upon whether or not the chosen alternative is available for occupancy. That a given residential alternative may no longer be available to the household can, in general, be attributed to one of two major housing market phenomena: discrimination and competition. Whereas in the former case, a vacancy is denied to the individual for socioeconomic, racial or other reasons (and may still be considered available to certain classes of searchers), the latter removes potential vacancies from the individual's opportunity set before he/she has had the chance to either evaluate or claim the vacancy. It is this latter phenomenon which is addressed in this section.

Unlike traditional economic models which abstract competition from a general equilibrium market clearing procedure (Alonso, 1964; Herbert and Stevens, 1960), stopping rule models can be made to explicitly recognize the impacts of competition by appropriately modifying the individual's opportunity distribution. Once these transformations upon F are determined, relationships between competition and aspirations, and therefore choice, can be directly established.

Consider a binary random variable, \( \delta^i \), which indicates whether the \( i \)th opportunity in individual t's sequence of alternatives is still available to this searcher upon its observation/evaluation; that is,
\[
\delta_i^t = \begin{cases} 
1 & \text{if vacancy } i \text{ is available when sampled} \\
0 & \text{otherwise}
\end{cases}
\]

We assume the probability associated with \( \delta_i^t \) to be independent of the availability status of other potential opportunities, but to be dependent upon the alternative's utility to the searcher. Since we are concerned with how a given individual perceives competition to be affecting his/her opportunity set, let the probability of \( \delta_i^t \) depend upon \( U_t^i \), the expected utility of the \( i \)th opportunity (as perceived by individual, \( t \)). We formally define this expression below (Weibull, 1978).

**DEFINITION 4.4:** A function \( \pi: \mathbb{R}^+ \to [0,1] \) is called a **success probability function** if:

\[
\pi_t(u_t) = \Pr[\delta_i^t = 1 | U_t^i = u_t] \tag{4.3.18}
\]

\( \pi_t \) is continuously differentiable, and \( \frac{\partial \pi_t}{\partial u_t} < 0. \)

\( \pi_t \) can be seen to define a set of personal probabilities held by the individual which measures the likelihood of obtaining a vacancy of given perceived quality level, \( u_t^i \). It embodies the searcher's belief that an opportunity perceived to be attractive will also be perceived to be attractive by other searchers, and will thus be in high demand. This will lower the likelihood the individual believes he/she has of obtaining a residential alternative of that utility.

Given the existence of a success probability function, it can now be shown how competition, whether real or perceived, transforms the character of the individual's opportunity distribution (see also Weibull, 1978).
THEOREM 4.2: Let the perceived opportunity set of the individual, \( t \), be characterized by the opportunity distribution, \( F \), and let \( \tau_t \) be a success probability function. Then the distribution of utilities in the opportunity set, perceived available upon the introduction of competitive conditions is equivalent to a transformed opportunity distribution, \( F^+ \), defined (in terms of generalized probability densities) by:

\[
 f^+(u_t) = \frac{f(u_t)\pi_t(u_t)}{\int_s \pi_t(s)f(s)ds} \tag{4.3.19}
\]

PROOF: Define the random variable \( y^i_t = \delta^i u^i_t \) to be the utility individual \( t \) expects to realize from the \( i^{th} \) opportunity in the sequentially defined opportunity set. Therefore, \( y^i_t = u^i_t \) if the alternative is still available upon observation (\( \delta^i = 1 \)), and \( y^i_t = 0 \) if not (\( \delta^i = 0 \)). Then for \( y > \alpha \)

\[
 \Pr(y^i_t > y) = \Pr(\delta^i u^i_t > y)
\]

\[
 = \Pr(U^i_t > y \text{ and } \delta^i = 1)
\]

\[
 = \int_0^\beta \Pr(\delta^i = 1 | u^i_t = u_t)f(u_t)du_t
\]

\[
 = \int_0^\beta \pi_t(u_t)f(u_t)du_t \tag{4.3.20}
\]

The transformed density function \( f^+(u_t) \) can now be easily derived as follows:

\[
 f^+(u_t)du_t = \Pr(y^i_t \in (u_t, u_t + du_t) | y^i_t > 0)
\]
\[
\frac{\Pr(Y^i_t \leq (u^i_t, u^i_t + du^i_t))}{\Pr(Y^i_t > 0)} = \frac{\Pr(U^i_t \in (u^i_t, u^i_t + du^i_t) \text{ and } \delta^i = 1)}{\Pr(Y^i_t > 0)} = \frac{\Pr(\delta^i = 1 | U^i_t \in (u^i_t, u^i_t + du^i_t)) f(u^i_t) du^i_t}{\Pr(Y^i_t > 0)}
\]

Using the result of (4.3.20), we find

\[
f^+ (u^i_t) du^i_t = \int_s \pi^i_t(s) f(s) ds
\]

Q.E.D.

Therefore, competitive conditions in the housing market effect only a simple transformation upon the searcher's opportunity distribution in the stopping rule model, and this transformation is defined in (4.3.19).

Since search is predicated upon the distribution of utilities associated with alternatives in the opportunity set, it is important to quantify this transformation brought about by competitive (demand) forces in the housing market. It is shown in the following lemma that if the success probability function is as hypothesized (i.e. monotonically decreasing in \(u^i_t\)), then, except at the end-points, the transformation effects a downward bias upon the opportunity distribution over the range of \(u^i_t\).

---

1It will be shown later how competition may also be incorporated into the recall component of the model.
LEMMA 4.1: Let π(x) be a success probability function. Then $F^+(s) \geq F(s)$.

PROOF: Define the function $G(s) = F^+(s) - F(s)$, and let

$$K = \int_{\alpha}^{\beta} \pi(y)f(y)\,dy - \int_{\alpha}^{\beta} \pi(y)f(y)\,dy.$$

Note that K > 0, since $\pi(y)f(y) > 0$ for all y. Then

$$G(s) = \int_{\alpha}^{s} \frac{\pi(x)}{K}f(x)\,dx - \int_{\alpha}^{s} f(x)\,dx$$

$$= \int_{\alpha}^{s} \left[ \frac{\pi(x)}{K} - 1 \right] f(x)\,dx$$

Since both $F^+$ and F are distribution functions, then

$$G(\alpha) = G(\beta) = 0$$

Therefore, if we can show that G has only one stationary value on the range $(\alpha, \beta)$ and the value is a maximum, it follows that $G(s) \geq 0$ for all $\alpha \leq s \leq \beta$. Taking the derivative of G with respect to s reveals:

$$G'(s) = \left[ \frac{\pi(s)}{K} - 1 \right] f(s)$$

The solution for $G'(s^*) = 0$ (since $f(s^*) > 0$ for $s \in (\alpha, \beta)$) is:

$$s^* = \pi^{-1}(K)$$

Since π is monotonically decreasing, this inverse exists (Johnson and Klockemeister, 1959, p.254) and $s^*$ is uniquely defined. Hence, G has only one stationary value over the range $(\alpha, \beta)$. The stationary point, $G(s^*)$, is found by taking the second derivative of the function, G.
\[ G''(s) = \left[ \frac{\pi'(s^*)}{K} - 1 \right] f'(s^*) + \frac{\pi'(s^*)}{K} f(s^*) \]

Since \( s^* = \pi^{-1}(K) \), we may eliminate the first term of the expression, leaving

\[ G''(s^*) = \frac{\pi'(s^*)}{K} f(s^*) \]

\(< 0 \quad \text{since} \quad \pi' < 0 \]

Therefore, \( G(s) \geq 0 \) or \( F^+(s) \geq F(s) \) for all \( \alpha \leq s \leq \beta \), (4.3.21)

with equality if and only if \( s = \alpha \) or \( s = \beta \).

Q.E.D.

By definition of expected values, the following corollary is evident.

**COROLLARY 4.1:** The distribution function \( F^+ \) possesses a mean value \( E^+(X) \)

such that \( E^+(X) < E(X) \).

The individual undertaking search, then, has revised his/her perception of what is available in the housing market upon the realization of competition for available housing opportunities. This revision has resulted in a biasing of the opportunity distribution to a new distribution, \( F^+ \), where \( F^+ \geq F \) and \( E^+(U_t < E(U_t) \).

This result enables us to determine how competition affects the actions of the individual throughout the search process. The following theorem shows that a transformation upon the original opportunity distribution, as defined in (4.3.19), brought upon by competitive forces in the housing market, can never increase the searcher's aspiration utility.
And, providing that the marginal disutility towards search is non-zero, this transformation can only depress the aspirations of the individual undertaking search.

**THEOREM 4.3:** If \( \pi_t \) is a success probability function, then

\[
H^+(\xi_t) \leq H(\xi_t)
\]

(4.3.22)

with strict equality if and only if \( \xi_t = \beta \).

**PROOF:** Define the expected marginal utilities associated with continuing search before and after the transformation upon \( F \) for a given aspiration utility, \( \xi_t \), as \( H(\xi_t) \) and \( H^+(\xi_t) \), respectively. Then by (4.2.8),

\[
H(\xi_t) - H^+(\xi_t) = \int_{\xi_t}^{\beta} (u_t - \xi_t) dF(u_t) - \int_{\xi_t}^{\beta} (u_t - \xi_t) dF^+(u_t)
\]

Rearranging terms within each of the integral expressions (Appendix 4.1) allows us to rewrite the difference as:

\[
H(\xi_t) - H^+(\xi_t) = \int_{\xi_t}^{\beta} (1 - F(y)) dy - \int_{\xi_t}^{\beta} (1 - F^+(y)) dy
\]

\[
= \int_{\xi_t}^{\beta} (F^+(y) - F(y)) dy
\]

But, by Lemma 4.1, \( F^+(s) \geq F(s) \) for all \( \alpha \leq s \leq \beta \), and therefore

\[
\int_{\xi_t}^{\beta} [F^+(y) - F(y)] dy \geq 0 \text{ for all } \alpha \leq s \leq \beta \text{, and } H^+(\xi_t) \leq H(\xi_t), \text{ with equality if }
\]

and only if \( \xi_t = \beta \).

\[ \square \]

Q.E.D.

181
Equation (4.3.22) states that, for a given aspiration level, $\xi_t$, the expected marginal gain to be made from search in a competitive situation will never be greater than that expected in the absence of competition; and, in fact, the equality relationship holds only if the expected marginal disutility towards search is zero, since, by (4.2.10), $H^+(\beta) = H(\beta) = 0$. For any search process, then, where $\bar{u}_t(a) > 0$, $H^+(\xi_t)$ is strictly less than $H(\xi_t)$. If this disutility term remains unchanged over the transformation of $F$ and is non-zero, then in order to maintain the equality relationship expressed in (4.2.8), aspirations must necessarily adjust to compensate for the fact that $H^+(\xi_t) < H(\xi_t)$. The following corollary is directly consequent.

**COROLLARY 4.2:** If $\bar{u}_t(a) = H(\xi_t) = H^+(\xi_t)$ and $\bar{u}_t(a) > 0$, then $\xi_t^+ < \xi_t$.

Aspirations must necessarily decline to equate the marginal disutility-expected marginal gain relationship of (4.2.8) and yet compensate for the lower marginal gains which are expected at any given utility level, if competition for alternatives in the opportunity set is anticipated by the individual (Figure 4.5).

That aspirations adjust downward because of competition is an intuitively credible response from the individual. The stopping rule model characterizes this response by assuming that the searcher, through a success probability function, revises his/her perception of the opportunity set to one which is skewed toward vacancies of lower utility levels. This revision leads to a decline in aspirations and induces the individual to accept a vacancy of lower utility than would otherwise have been chosen if competitive forces were not influencing search activity.
Figure 4.5  Impact of a Downward Shift in the Opportunity Distribution on Aspiration Utilities
It now remains to determine how search behavior relates to the intensity of competition. That is, we wish to know how the individual's aspirations change as more and more competitors are perceived to be entering the vacancy market. To do this, we first assume that the number of competitors impacts the searcher's success probability function in the following manner. As more competitors are perceived to be competing for vacancies in the opportunity set, the searcher is assumed to believe that the probability of locating a vacancy of given utility level monotonically declines. Furthermore, this probability declines over the range of utilities in the opportunity set at an increasing rate relative to success probability functions formulated under less competitive situations. These characteristics, which are illustrated in Figure 4.6, are operationalized in the following definition.

**DEFINITION 4.5:** A function $\pi: \mathbb{R} \rightarrow [0, 1]$ is called a $k$-intense success probability function if, for any non-negative integer, $k$, $0 \leq \pi_t(u_t; k) \leq 1$ and $\pi'_t(u_t; k) = \frac{\partial}{\partial u_t} \pi_t(u_t; k) < 0$; and

\[
\begin{align*}
(i) & \quad 0 \leq \pi_t(u_t; k+1) \leq 1; \quad \pi'_t(u_t; k+1) < 0 \\
(ii) & \quad \pi_t(u_t; k+1) < \pi_t(u_t; k), \quad \text{and} \\
(iii) & \quad \pi'_t(u_t; k+1) < \pi'_t(u_t; k) \quad \text{where } \pi'(\cdot) < 0
\end{align*}
\]

(4.3.23)

for all $u_t \in (\alpha, \beta)$ and $k=0, 1, 2,...$

Obviously, $\pi_t(u_t; 0) = 1$ for $\alpha \leq u_t \leq \beta$. Also,
Figure 4.6  Relationship Between Success Probability Functions
When Number of Competitors for Vacancies in the
Opportunity Set is Varied
$$F^+(s; k) = \int_{\alpha}^{s} \frac{\pi(x; k)}{\int_{\alpha}^{\beta} \pi(t; k) f(t) dt} f(x) dx = \int_{\alpha}^{s} \frac{\pi(x; k)}{E[\pi(x; k)]} f(x) dx$$

and

$$F^+(s; k+1) = \int_{\alpha}^{s} \frac{\pi(x; k+1)}{\int_{\alpha}^{\beta} \pi(t; k+1) f(t) dt} f(x) dx = \int_{\alpha}^{s} \frac{\pi(x; k+1)}{E[\pi(x; k+1)]} f(x) dx$$

We can now define the effect of increased competition on the distribution of opportunities in the individual's opportunity set, from which the relationship between aspirations and the intensity of competition can be established.

**LEMMA 4.2:** If \(\pi(x; k)\) and \(\pi(x; k+1)\) are \(k\) (and \(k+1\))-intense success probability functions, then \(F^+(s; k+1) \geq F^+(s; k)\) for all \(\alpha \leq s \leq \beta\) and \(k=0, 1, 2, \ldots\)

**PROOF:** Define, as in Lemma 4.1, the function \(G_{k+1}(s)\), where

\(G_{k+1}(s) = F^+(s; k+1) - F^+(s; k)\). Note that \(E[\pi(x; k)] > E[\pi(x; k+1)] > 0\), and by Lemma 4.1, \(F^+(s; 1) > F^+(s; 0) = F(s)\). Now define the following transformations.

\[ f_k(x) = \frac{\pi(x; k)}{E[\pi(x; k)]} f(x) \]

\[ \pi_{k+1}(x) = \frac{\pi(x; k+1)}{\pi(x; k)} \]

\[ f_{k+1}(x) = \frac{E[\pi(x; k)]}{E[\pi(x; k+1)]} \pi_{k+1}(x) f_k(x) \]
Clearly, $f_k(x)$ and $f_{k+1}(x)$ are proper probability density functions.

Furthermore,

$$
\pi_{k+1}'(x) = \frac{\pi'(x;k+1) \pi(x;k) - \pi'(x;k) \pi(x;k+1)}{[\pi(x;k)]^2} < 0
$$

Therefore,

$$
G_{k+1}(s) = \int_\alpha^s \frac{\pi(x;k+1)}{E[\pi(x;k+1)]} f(x) \, dx - \int_\alpha^s \frac{\pi(x;k)}{E[\pi(x;k)]} f(x) \, dx
$$

$$
= \int_\alpha^s f_{k+1}(x) \, dx - \int_\alpha^s f_k(x) \, dx
$$

$$
= \int_\alpha^s \frac{E[\pi(x;k)]}{E[\pi(x;k+1)]} \pi_{k+1}(x) f_k(x) \, dx - \int_\alpha^s f_k(x) \, dx
$$

$$
= \int_\alpha^s \left[ \frac{E[\pi(x;k)]}{E[\pi(x;k+1)]} \pi_{k+1}(x) - 1 \right] f_k(x) \, dx \quad (4.3.24)
$$

Let $y_{k+1} = \frac{E[\pi(x;k+1)]}{E[\pi(x;k)]]}$ to reduce (4.3.24) to

$$
G_{k+1} = \int_\alpha^s \left[ \frac{\pi_{k+1}(x)}{y_{k+1}} - 1 \right] f_k(x) \, dx \quad (4.3.25)
$$

Since $G_{k+1}^{(a)} = G_{k+1}^{(b)} = 0$, then we must only show that $G_{k+1}$ has only one
stationary value on the range \((a, \beta)\), and the value is a maximum for \(G(s) \geq 0\) for \(a \leq s \leq \beta\). As before, taking the derivative of \(G_{k+1}^\prime\) with respect to \(s\) yields:

\[
G_{k+1}^\prime(s) = \left[ \frac{\pi_{k+1}(s)}{Y_{k+1}} - 1 \right] f(s)
\]

Since \(f(s^\star) > 0\) for all \(s \in (a, \beta)\), solving for \(G_{k+1}^\prime(s^\star) = 0\) reveals

\[
s^\star = \pi_{k+1}^{-1}(Y_{k+1})
\]

and since \(\pi_{k+1}\) is monotonically decreasing in \([a, \beta]\) for all \(k\), the inverse exists. The proof then follows the same arguments as that of Lemma 4.1 to yield \(G_{k+1}^\prime(s) \geq 0\), or

\[
F^+(s; k+1) \geq F^+(s; k) \quad (4.3.26)
\]

for all \(a \leq s \leq \beta\) and \(k=0, 1, \ldots\)

Q.E.D.

The relationship between the aspiration utility of the individual undertaking search and the number of competitors perceived by that individual to be competing for residential opportunities in the opportunity set can now be formally established.

**Theorem 4.4:** If \(\pi(u_t; k)\) and \(\pi(u_t; k+1)\) are \(k\) (and \(k+1\))-intense success probability functions, then

\[
H^+(\xi; k+1) \leq H^+(\xi; k) \quad (4.3.27)
\]

for \(k=0, 1, 2, \ldots\), with strict equality if and only if \(\pi_t = \beta\).
PROOF: The proof of this theorem follows the arguments of Theorem 4.3 and is not repeated here.

A consequence of this theorem is the following corollary.

**COROLLARY 4.3:** If \( a_t(a) = h_t^+(k_t(k+1);k+1) = h_t^+(k_t(k);k) \) and \( a_t(a) > 0 \), then \( k_t(k+1) < k_t(k) \).

The effects of competition on search behavior have now been revealed, from which it is suggested that aspiration utility in the stopping rule model reacts to competition in a manner similar to that which would intuitively be expected of households facing competitive pressures in urban housing markets. Aspiration utility is a non-increasing function of the number of searchers perceived by the individual to be competing for vacancies in the opportunity set (Figure 4.7). As competition becomes more intense, we expect the individual to adjust his/her aspiration utility downward, thereby inducing a curtailment of search activity earlier, and the acceptance of a vacancy of lower utility than would otherwise be the case under less competitive circumstances.

4.3.4 Finite Sampling Strategies

To this point in the analysis, we have examined the characteristics of a model of search behavior based upon some relatively simple assumptions about both the individual undertaking search and the residential environment over which search is being conducted, assumptions which are to be relaxed in subsequent sections of this chapter. The model has assumed search behavior to be constrained only by search costs, the individual essentially being granted unlimited opportunity (within constraints
Figure 4.7 Relationship Between Aspiration Utility of the Searcher and Number of Searchers Competing for Vacancies in the Opportunity Set for a Given Marginal Disutility Towards Search
of cost) to observe and evaluate residential alternatives. This section seeks to examine what happens to aspirations throughout search when a finite limit to the number of vacancies that can be sampled is recognized by the individual.

Consider the model in its present form. Aspirations are adjusted in order to equate the marginal cost of searching with the expected marginal return from continuing the search. But once these aspirations are established, they remain invariant over the course of the search; that is the expected gain from search remains fixed, regardless of the number of vacancies. That aspirations remain constant under these conditions is attributable to conditions on the opportunity distribution, i.e. the distribution is assumed to be completely known by the individual, and to an absence of an upper limit to the number of observations permitted during search. By realizing what can be gained from continuing search, and knowing that search can be continued indefinitely, the individual can conclude that an opportunity at least as great as current aspirations can be attained eventually from the evaluation of alternatives in the sequence. Only by allowing new information about housing opportunities to be acquired from further observation or by imposing an upper bound upon the sample size can a change in initial expectations be anticipated. Both the former (which is discussed in another section) and the latter lead to the same behavioral response: the adjustment of aspirations over the search.

Constraining the number of observations requires only minor respecification of the stopping rule model as defined in (4.2.8). We again assume the opportunity distribution is known and invariant over time. Fur-
thermore, recall of only the current opportunity is permitted, and search costs are constant throughout the search. We assume the individual evaluates vacancies in terms of a risk-neutral utility function, \( U_t \). But now we impose an upper bound, \( k (k \geq 2) \), on the number of observations that may be taken by the individual. This is equivalent to constraining the number of alternatives in the searcher's opportunity set.1

Consider the individual as he/she evaluates the \( i^{th} \) vacancy in a finite sequence of length, \( k \). At this point, there are exactly \( j (=k-i) \) opportunities remaining over which choice may be exercised; at \( j=0 \), we assume that the individual must accept this last remaining vacancy having ascribed utility, \( U_t^k \). At the \( i^{th} \) observation in the sequence, search may be discontinued and the vacancy accepted with utility, \( U_t^i \), or continued with expected gain, \( \xi_t^j \), where this latter expression is simply the expected utility anticipated by the individual, \( t \), if he/she observes one more vacancy in the sequence and proceeds optimally from that point. That is,

\[
\xi_t^j = E[\max( U_t^i, \xi_t^{j-1})] - \bar{u}_t(c) \tag{4.3.28}
\]

Since \( U_t \) is a random variable, the expression can be decomposed using similar arguments to those in the derivation of (4.2.7) to yield the expected gain, or aspiration utility of the individual at the \( i^{th} \) opportunity in the sequence.

\[
\xi_t^j = \xi_t^{j-1} + \int_{\xi_t^{j-1}}^{\beta} (u_t - \xi_t^{j-1}) f(u_t) du_t
\]

1Note that we are constraining only the number of vacancies that the searcher can sample. The individual is still assumed to be sampling from an infinite (for practical purposes) pool of vacancies in the urban area.
\[ \xi_t^{j-1} + H(\xi_t^{j-1}) - \bar{u}_t(c) \quad \text{for } j > 1 \quad (4.3.29) \]

where \( H \) is as defined previously. In order to this expression to hold for \( j = 1 \), we define \( \xi_t^0 = 0 \) since, regardless of the last alternative's utility, it must be accepted if search has not been terminated before then.

Therefore, at the \( i \)th vacancy in the sequence of observations, the optimal procedure for the individual to follow is to:

- Reject the vacancy and continue searching if \( U_t^i < \xi_t^j \)  \( (4.3.30) \)
- Accept the vacancy and stop searching if either \( U_t^i \geq \xi_t^j \)
  or if \( j = 0 \)

where \( \xi_t^j \) is now defined by the expression

\[
\xi_t^j = \begin{cases} 
\xi_t^{j-1} + H(\xi_t^{j-1}) - \bar{u}_t(c) & j > 1 \\
0 & j = 0
\end{cases} \quad (4.3.31)
\]

Note that the individual's aspiration utility at any point in the sequence can be computed recursively from the aspiration level associated with the last observation (defined to be zero).

Aspiration utility is now no longer independent of the number of observations that have been made by the individual nor of the number of opportunities which remain. It is, instead, a dynamic variable that adjusts itself over the sequence of alternatives sampled from the opportunity set. The manner in which aspiration utility changes as search is continued along the finite sequence, and its relation to aspirations formed
in an unconstrained sampling process are both important, for they
distinguish constrained from unconstrained choice. The properties of
aspirations, therefore, as they relate to search as a finite sampling
process, are discussed in detail below.

The characterization of relationships among aspirations during a
finite sampling process is facilitated if we recognize first, that since
\( \xi_t^0 = 0 \), \( \xi_t^1 \) is uniquely determined by the identity

\[ \xi_t^1 = H(0) - \bar{U}_t(c) \]  \hspace{1cm} (4.3.32)

and second, that we can define a number, \( \xi_t^* \), such that

\[ H(\xi_t^*) = \bar{U}_t(c) \]  \hspace{1cm} (4.3.33)

as before in (4.2.8). As previously defined, \( \xi_t^* \) is simply the searcher's
aspiration utility given that no limit is imposed upon the number of
vacancies that can be sampled. Under these conditions, the following
theorem results (see also Leonardz, 1973, Ch. 2).

**THEOREM 4.5:** If \( \xi_t^1 \) and \( \xi_t^* \) are as defined in (4.3.32) and (4.3.33), then
\( \xi_t^* \geq \xi_t^1 \) for all \( \xi_t^1 \geq 0 \), with equality if and only if \( F(\xi_t^-) = 0 \), where
\( F(\xi_t^-) = 0 \) implies that \( F(y) = 0 \) for all \( y \leq \xi_t^* \).

**PROOF:** For analytical convenience, we shall adopt an alternative mathematical expression from (4.2.8) for \( H(\xi_t^*) \), established in Appendix 4.1, i.e.

\[ H(\xi_t^*) = \int_{\xi_t^-}^{\beta} (1-F(y)) dy \]  \hspace{1cm} (4.3.34)

From (4.3.32),

\[ \xi_t^1 = H(0) - \bar{U}_t(c) \]
\begin{align*}
&= \int_{0}^{\beta} (1-F(y))dy - \int_{\xi_t}^{\beta} (1-F(y))dy \\
&= \int_{0}^{\xi_t} (1-F(y))dy \\
&= \xi_t - \int_{0}^{\xi_t} F(y)dy
\end{align*}

Therefore,

\[ \xi_t - \xi_t^1 = \int_{0}^{\xi_t} F(y)dy \geq 0 \quad (4.3.35) \]

with equality if and only if \( F(\xi_t^-) = 0 \).

Q.E.D.

If the latter condition applied, aspirations would be at such a (minimum) level that the individual would, in effect, be indifferent between undertaking search and postponing the mobility decision. Unambiguous search activity requires aspiration utility to be greater than the least which can be gained from the opportunity set, or, equivalently \( F(\xi_t^-) > 0 \). The adoption of this condition, then, implies that \( \xi_t > \xi_t^1 > 0 \) for all \( \xi_t^1 > 0 \), which leads to the following statement.

**THEOREM 4.6:** If \( \xi_t > \xi_t^1 > 0 \), then \( \xi_t > \xi_t^j > 0 \) for all \( \xi_t^j \), where

\[ \xi_t^j = \xi_t^{j-1} + H(\xi_t^{j-1}) - \bar{a}_t(\sigma), \quad j \geq 1. \]

**PROOF:** From the definition of \( \xi_t^j \) above,
\[ \xi_{t}^{j+1} = \xi_{t}^{j} + H(\xi_{t}^{j}) - \bar{u}_{t}(c) \quad (4.3.31) \]

which, by (4.3.33)

\[ = \xi_{t}^{j} + H(\xi_{t}^{j}) - H(\xi_{t}) \]

\[ = \xi_{t} - \left[ \xi_{t} + H(\xi_{t}) - (\xi_{t}^{j} + H(\xi_{t}^{j})) \right] \]

\[ = \xi_{t} - \left[ \xi_{t} + \int_{0}^{\beta} (1-F(y))dy - \left( \xi_{t}^{j} + \int_{0}^{\beta} (1-F(y))dy \right) \right] \]

\[ = \xi_{t} - \left[ \int_{0}^{\beta} F(y)dy - \int_{0}^{\beta} F(y)dy \right] \]

\[ = \xi_{t} - \int_{0}^{\beta} F(y)dy \]

Therefore,

\[ \xi_{t} - \xi_{t}^{j+1} = \int_{\xi_{t}^{j}}^{\xi_{t}} F(y)dy \quad (4.3.36) \]

If \( \xi_{t} > \xi_{t}^{1} > 0 \), then from (4.3.35), \( F(\xi_{t}-) > 0 \), and \( \xi_{t} - \xi_{t}^{j+1} > 0 \) for \( j=1 \).

Now assume (4.3.36) to be greater than zero for \( j=1 \); that is,

\[ \xi_{t} - \xi_{t}^{j+1} = \int_{\xi_{t}^{j}}^{\xi_{t}} F(y)dy > 0 \quad (4.3.37) \]

Therefore, for \( j=1 \),

196
\[ \xi_t - \xi_t^{j+2} = \int_{\xi_t^{j+1}}^{\xi_t} F(y) \, dy \]

But from (4.3.37), \( \xi_t - \xi_t^{j+1} > 0 \) and \( F(\xi_t^-) > 0 \), and therefore

\[ \int_{\xi_t^{j+1}}^{\xi_t} F(y) \, dy > 0 \quad \Rightarrow \quad \xi_t - \xi_t^{j+2} > 0 \quad (4.3.38) \]

By induction, then, for \( \xi_t > \xi_t^1 > 0 \) and \( F(\xi_t^-) > 0 \), \( \xi_t > \xi_t^j > 0 \) for \( j \geq 1 \).

Q.E.D.

What the theorem states is that if we define a number, \( \xi_t \), and assume that the aspiration utility of a searcher in a finite sampling process with but one observation remaining falls within the bounds \( \xi_t > \xi_t^1 > 0 \), then the aspiration utility of the searcher at every opportunity in the sequence will fall within these same bounds. What must now be determined are the relationships between successive aspiration levels held by the individual over the sequence of observations. This is addressed in the following theorem (Leonardz, 1973, Ch. 2).

**THEOREM 4.7:** If \( \xi_t \) is defined as in (4.3.33) and \( \xi_t > \xi_t^1 > 0 \), and we define the number \( \xi_t^j = \xi_t^{j-1} + H(\xi_t^{j-1}) - \bar{u}_t(c) \), \( j \geq 1 \), then \( \xi_t^{j+1} > \xi_t^j \) for all \( j \geq 1 \).

**PROOF:** By the definition of \( \xi_t^{j+1} \) and (4.3.34),

\[ \xi_t^{j+1} = \xi_t^j + \int_{\xi_t^j}^{\beta} (1-F(y)) \, dy - \bar{u}_t(c) \]

---

\(^1\)Theorem 4.5 has defined the conditions over which this statement is true.
\[ \xi_t^j + \int_{\xi_t}^{\beta} (1-F(y))\,dy - \int_{\xi_t}^{\beta} (1-F(y))\,dy \]

\[ \xi_t^j + \int_{\xi_t}^{\xi_t^j} (1-F(y))\,dy \]

Therefore,

\[ \xi_t^{j+1} - \xi_t^j = (\xi_t - \xi_t^j) - \int_{\xi_t}^{\xi_t^j} F(y)\,dy \]

But since \( \xi_t > \xi_t^j > 0 \) then by Theorem 4.6, \( \xi_t - \xi_t^j > 0 \). Furthermore, \( F(\xi_t) > 0 \) which implies

\[ (\xi_t - \xi_t^j) > \int_{\xi_t}^{\xi_t^j} F(y)\,dy \]

and \( \xi_t^{j+1} - \xi_t^j > 0 \) for all \( j > 1 \).

Q.E.D.

The set of aspiration utilities \( \{\xi_t^j\} \) is therefore a strictly decreasing (in \( j \)) sequence of positive real numbers bounded from above by \( \xi_t \). This means that the individual's aspiration utility monotonically declines when sampling is limited to a finite number of observations on the population. Furthermore, the searcher's aspiration utility in a finite sampling process is never greater than \( \xi_t \). It now only remains to determine more precisely the relationship between \( \xi_t \) and the set of aspirations, \( \{\xi_t^j\} \).

**Theorem 4.8:** If \( \xi_t > \xi_t^j > 0 \), then \( \lim_{j \to \infty} \xi_t^j = \xi_t \).
PROOF: Since $\xi_t > \xi_t^1 > 0$, then by Theorem 4.7, $\xi_t^j$, for $j \geq 1$, is strictly increasing and bounded from above. Therefore, there exists a unique number, $\zeta$, such that $\lim_{j \to \infty} \xi_t^j = \zeta$. But since $H$ is continuous, then $\zeta$ must satisfy the equation

$$H(\zeta) = u_t(\zeta).$$

Therefore, $\zeta = \xi_t$, since $H$ uniquely determines the value of its argument.

Q.E.D.

The effects of imposing a limit to the number of observations that can be made upon the opportunity set can now be described. The aspiration utility of the searcher monotonically declines as fewer and fewer opportunities remain to be evaluated (Figure 4.8). Aspiration utilities associated with a finite sampling scheme over a given opportunity distribution are always less than aspirations associated with unlimited sampling allowed from the same distribution, the latter of which remain constant throughout the search process.

To the extent that constraints on the number of opportunities that can be sampled from the population of vacancies identify distinct classes of searchers in the urban housing market, the results derived above can be used to explain how search behavior might differ among households. We might hypothesize that households constrained to few observations are those that have been forced from their previous residences (or, for other reasons, have committed themselves to move within a short period of time), or are those with limited resources for conducting search. If such a characterization is accurate, we expect these households to hold lower aspirations and to gain less from search than house-
Figure 4.8  Relationship Between Aspiration Utility, $\xi_j$, and the Number of Opportunities Which Remain to be Sampled, $j$, from the Opportunity Set.
holds that enter the market under no such constraints. Whereas the latter group may maintain relatively constant aspiration utilities, households that constrain their sampling activities must re-evaluate their aspirations at each stage of the search process and adjust them downward to compensate for successive reductions in the number of alternatives left in their opportunity sets. Mobility precipitated by less than favorable circumstances (be they resource constraints or mobility stimulus) thereby results in lower gains from search than would otherwise be expected.

4.3.5 Adaptive Search Behavior

In the investigation of properties of the stopping rule model of residential search behavior, we have so far assumed that the individual possesses complete information about his/her opportunity distribution which comprises at least a subset of vacancies available in the housing market. Yet in Chapter 3, we argued that search is initiated on an a priori information base that is subject to revision during search as more vacancies and areas of the city are investigated. Search enables the individual both to evaluate candidate residential alternatives and to acquire more (or simply more accurate) information upon which to make the location decision. Information updating enables the searcher to adjust either the criteria used to evaluate vacancies, aspiration utilities, or both to accommodate any changes in housing market conditions perceived through search activity.

Adaptive search behavior, which refers to the adjustment of aspirations during search, is incorporated into the stopping rule model by considering each observation, in addition to its being a decision point,
as information which the individual uses to revise his/her current perception of the opportunity distribution (Lippman and McCall, 1976a, p.173). The adjustment is assumed to be undertaken in Bayesian fashion whereby a vacancy is first observed, the searcher's prior is then updated, and finally a decision is made whether the current opportunity should be accepted or rejected.¹ We assume that the searcher knows the form of the opportunity distribution, but knows only one or more of its parameters up to a prior probability distribution. In this analysis, we again do not allow rejected vacancies to be considered later in the search (no recall) and assume that the marginal disutility of search remains constant throughout the sampling process.

Under these assumptions, the decision rule associated with adaptive search behavior is identical to the one associated with non-adaptive behavior: continue sampling until a vacancy is located having utility at least as great as the individual's aspiration utility. The difference between adaptive and non-adaptive behavior, however, is how aspirations are defined.

Consider the searcher as he/she is about to evaluate the i\(^{th}\) vacancy in a countable and possibly infinite sequence of alternatives. The searcher has imperfect knowledge about a set of parameters which characterize an opportunity distribution, F, of known functional form, but has

¹Lippman and McCall (1976a, p.173) also suggest a second information updating regime, in which the opportunity is accepted or rejected by the searcher before the prior distribution is modified. Although plausible, this form of adaptive search behavior appears less consistent with the behavioral postulates of Chapter 3 than the adaptive search rules described here. Furthermore, the decision rule developed in (4.2.9), and sustained (in modified form) in this section, is not necessarily maintained under this alternative updating regime (Rothschild, 1974, p.701).
formulated a prior probability function, \( f(\theta) \), over the unknown parameters of the opportunity distribution, based upon his/her cognitive image of housing market conditions prior to the commencement of search, and from information gained over the first \((i-1)\) observations.\(^1\) After observing the \(i^{th}\) alternative with ascribed utility \(u^i_t\), \( f(\theta) \) is revised in Bayesian fashion to a posterior probability, \( f(\theta_i) \), from whence a new vector of parameters, \( \theta_i \), of the opportunity distribution is derived. Search may be discontinued at this point with the acceptance of the vacancy having utility, \( u^i_t \), or continued with expected utility, \( \xi_t \). Only now, \( \xi_t \), itself, is a random variable which is dependent upon the vector of parameters characterizing the opportunity distribution, and these parameters are successively updated during the search process. We distinguish the stochastic nature of aspirations under these conditions by the notation \( \xi_t(\theta) \).

The expected utility of the searcher after observing the \(i^{th}\) vacancy is therefore defined as:

\[
\xi_t(\theta) = E[\max(u_t, \xi_t(\theta_i))] - \bar{u}_t(\theta)
\]  

(4.3.39)

where the utility from continuing search for one more observation and proceeding optimally from there is calculated over a revised marginal

\(^1\)The term "prior" as it is used in this section is a relative term, as it is actually a posterior probability distribution over the previous \((i-1)\) observations, \(i.e.\) given a prior probability distribution over the parameters before sampling is undertaken, \(f(\theta^*)\), then (Zellner, 1971, p.17)

\[
f(\theta) = f(\theta|x_1, \ldots, x_{i-1})
= f(\theta^*)f(x_1|\theta^*) \cdots f(x_{i-1}|\theta^*)
\]
distribution on the observations, \( F_{\theta_i} \), which is dependent upon both prior information about \( \theta \) and the utility of the opportunity just observed in the sequence. Only now, because of its stochastic nature, \( \xi_t(\theta) \) can no longer be expressed in integral form as in (4.2.8); but its meaning remains the same. The decision rule of the searcher at the \( i^{th} \) opportunity is simply:

\[
\text{Reject the vacancy and continue searching if} \quad u_{t}^{i} < \xi_t(\theta) \\
\text{Accept the vacancy and stop searching if} \quad u_{t}^{i} \geq \xi_t(\theta) 
\]  

(4.3.40)

Although identical in form to non-adaptive search rules, aspirations are now adjusted during the search process on the bases of an established prior belief regarding the parameters which characterize the opportunity distribution and evidence provided by the utility of the currently observed vacancy. The nature and degree of change in aspiration utility depends upon how the marginal opportunity distribution, which represents the individual's prior perception of housing market conditions, is affected by new information from the most recent observation.

Although such a learning process during search is plausible, the resulting expression for deriving the individual's aspiration utility is analytically intractable. A more precise characterization of this change cannot be specified unless additional information about the form of the prior opportunity distribution and the characteristics of the sample from which housing opportunities are drawn are known.

Therefore, let us examine the behavior of aspirations in an adaptive search process through an example. Consider a sequential random sample of observations, \( \{U_{t}^{1}, U_{t}^{2}, \ldots \} \), drawn from an opportunity set having
varies that are normally distributed with unknown mean, \( \Omega \), and known variance, \( \sigma^2_o \). Associated with the observation of a vacancy is a disutility function, \( \tilde{u}_t(c) \). Before search is initiated, the individual believes the mean \( \Omega_p \) of the opportunity distribution is normally distributed with mean, \( \mu_p \), and variance, \( \sigma^2_p \). (To simplify notation in the following analysis, we shall omit the identifier, \( t \), from all variables and will assume the marginal disutility towards search to be equivalent to a scalar cost variable, \( c \).)

At any given stage of the sampling process, having observed a vacancy of utility, \( u_i \), the searcher can choose one of two alternatives: discontinue sampling and accept the vacancy having utility, \( u_i \), or, at cost \( c \), continue sampling and proceed from the next observation in an optimal manner. Before the decision is made, however, the searcher first incorporates information gained from observing \( u_i \) (via a likelihood function) into his/her prior beliefs in order to formulate a posterior probability density function for the mean of the opportunity distribution. This revised probability density function serves as the prior for calculating the expected utility of continuing search. Since the sample is being drawn from a normal population with known variance and the initial prior of the searcher is normal, the revised prior upon observing \( u_i \) will also be normally distributed, which we denote as \( \Omega_i \sim \mathcal{N}(\mu_i, \sigma^2_i) \). Obviously, the posterior distribution associated with the next observation, \( U \), will also be normal with mean \( \Omega(U) = \frac{\mu_i (\sigma_i^2)^{-1} + U(\sigma_o^2)^{-1}}{(\sigma_i^2)^{-1} + (\sigma_o^2)^{-1}} \), and variance \( (\sigma_i^2 + \sigma_o^2)^{-1} \).

Notation is simplified if we describe all distributions in terms of their means, \( \mu \), and precisions, \( \tau \), where \( \tau = \frac{1}{\sigma^2} \). Assume the precision of the opportunity distribution is \( \tau_o = 1 \). Then after observing the \( i^{th} \) vacan-
cy, the prior distribution of \( \Omega \) is \( \Omega \sim N[(\tau_i \mu_i + u)/(\tau_i + 1), 1/(\tau_i + 1)] \) and the marginal distribution of the variable \( U \) is \( U \sim N(\mu_i, (\tau_i + 1)/\tau_i) \) (DeGroot, 1968, p.337).

The expected utility from continuing search, based upon the updated prior, can now be calculated. From (4.3.39),

\[
\xi(\theta) = \xi(\mu_i, \tau_i) = E\{\max[U, \xi(\mu_i(U), (\tau_i + 1))]\} - c \tag{4.3.41}
\]

For analytical convenience, consider the function \( v \) which follows from \( \xi \) when the mean of the searcher's prior is translated to the value \( \mu_i = 0 \). That is (DeGroot, 1968, p.337),

\[
v(\tau_i) = \xi(0, \tau_i) = E\{\max[X, v(X/(\tau_i + 1), (\tau_i + 1))\}] - c \tag{4.3.42}
\]

In effect, this translation has reduced the utilities of all future observations by \( \mu_i \), the currently believed mean value of the mean of the opportunity distribution, and has transformed the marginal distribution associated with the next observation, \( U \), to a new variable, \( X \), where \( X \sim N[0, (\tau_i + 1)/\tau_i] \). \( v \) may thus be interpreted as the marginal gain from continuing sampling over an opportunity set having an expected mean utility of zero.

Equation (4.3.42) can now be decomposed as follows:

\[
v(\tau_i) = E\{\max[X, v(X/(\tau_i + 1), (\tau_i + 1))\}] - c
\]

\[= E\{\max[\tau_i X/(\tau_i + 1), v(0, (\tau_i + 1))] + X/(\tau_i + 1)\} - c
\]

\[= E\{\max[\tau_i X/(\tau_i + 1), v(0, (\tau_i + 1))]\} + \frac{1}{\tau_i + 1} E(X) - c
\]

But since \( X \sim N[0, (\tau_i + 1)/\tau_i] \), \( \frac{1}{\tau_i + 1} E(X) = 0 \). Now if we let \( Y = \tau_i X/(\tau_i + 1) \), then
\( v(\tau_i) = E\{\max[Y, \xi(0, \tau_i + 1)]\} - c \) \hspace{1cm} (4.3.43)

Note that the decomposition of (4.3.42) has transformed \( X \) into the new variable \( Y \) such that \( Y \sim N[0, \tau_i/(\tau_i + 1)] \).\(^1\)

When the opportunity distribution is normally distributed, we can exploit certain of its properties to arrive at a solution to (4.3.43). To do this, we first introduce a definition for the expected marginal gain from taking one more observation and proceeding optimally from there when \( X \) is a standard normal random variable. This enables us to state a fundamental relationship between negative and positive expected gains when \( X \) is standard normal. With these properties, we may then relate the marginal utility of search over any normally distributed random variable to that from search over a standard normal variable.

**DEFINITION 4.6:** The function \( \psi: \mathbb{R} \to \mathbb{R}_0 \) is called a **standard normal expected marginal utility** if and only if:

\[
\psi(s) = \int_s^\infty (x-s) \phi(x) dx = \phi(s) - s(1-\Phi(s))
\]

where \( \phi \) is a probability density function and \( \Phi \), the corresponding distribution function of a normally distributed variate, \( X \), having zero mean and unit precision. \( \psi \) is a special case of the expected marginal utility, \( \psi \), and exhibits identical properties.

\(^1\) \( E(Y) = E[\frac{\tau_i X}{\tau_i + 1}] = \frac{\tau_i}{\tau_i + 1} E(X) = 0 \)

\( \text{Var}(Y) = \text{Var}[\frac{\tau_i X}{\tau_i + 1}] = \left[\frac{\tau_i}{\tau_i + 1}\right]^2 \text{Var}(X) = \frac{\tau_i}{(\tau_i + 1)^2} \)

207
From this definition, the following identity is evident, and is stated without proof.

**Lemma 4.3:** If \( \psi(s) \) is a standard normal expected marginal utility function, then

\[
\psi(-s) = \psi(s) + s \tag{4.3.44}
\]

The relationship between the marginal utility of search over a normal distribution and that over a standard normal distribution can now be established (DeGroot, 1970, p.338).

**Lemma 4.4:** If \( X \sim N(\mu, \tau) \) and \( H(\xi) \) is the expected marginal utility of taking one more observation from \( X = X_1, X_2, \ldots \), and if \( \psi \) is a standard normal expected marginal utility function, then

\[
H(\xi) = \tau^{-\frac{1}{2}} \psi(\tau^{-\frac{1}{2}}(\xi - \mu)) \tag{4.3.45}
\]

**Proof:** From (4.2.7)

\[
H(\xi) = \mathbb{E}\{\max(X, \xi)\} - \xi
\]

\[
= \mathbb{E}\{\max(X-\mu, \xi-\mu)\} + \mu - \xi
\]

\[
= \tau^{-\frac{1}{2}} \mathbb{E}\{\max[\tau^\frac{1}{2}(X-\mu), \tau^\frac{1}{2}(\xi-\mu)]\} + \mu - \xi
\]

\[
= \tau^{-\frac{1}{2}} \mathbb{E}\{\max(Z, s)\} + \mu - \xi \tag{4.3.46}
\]

where \( s = \tau^\frac{1}{2}(\xi-\mu) \) and \( Z \sim N(0,1) \). (4.3.46) may be reduced in an identical manner to the development of (4.2.7) to yield:

\[
H(\xi) = \tau^{-\frac{1}{2}} \int_s^\infty (z-s) \phi(z) dz + \tau^{-\frac{1}{2}} [\tau^\frac{1}{2}(\xi-\mu)] + \mu - \xi
\]

208
\[ = \tau^{-\frac{b}{2}} \psi \left[ \tau^b (\xi - \mu) \right] \]

Q.E.D.

In the derivation of (4.3.43), the searcher's position has been reduced to one in which the expected utility of continuing search is calculated over a sequence of normally distributed variates having zero mean and known precision. Using the relationships stated in Lemmas 4.3 and 4.4, we can now derive a functional expression for \( v(\tau_i) \).

Let \( \tau' = \tau / (\tau + 1) \); then \( Y \sim N[0, \tau'_i^2] \). From (4.3.43),

\[ v(\tau_i) = E\{\max[Y, v(\tau_i + 1)]\} - c \]

which, by Lemma 4.4, expands to

\[ v(\tau_i) = v(\tau_i + 1) + \tau' \psi \left[ \frac{v(\tau_i + 1)}{(\tau'_i)^b} \right] - c \]

\[ = (\tau'_i)^b \left[ \frac{(\tau_i + 1)}{(\tau_i)^2} + \psi \left[ \frac{v(\tau_i + 1)}{(\tau'_i)^b} \right] \right] - c \]

By Lemma 4.3, this reduces to

\[ v(\tau_i) = (\tau'_i)^b \psi \left[ \frac{-v(\tau_i + 1)}{(\tau_i)^b} \right] - c \quad (4.3.47) \]

Rearranging terms in (4.3.47) and inverting this expression yields

\[ \text{Note that the transformation of } \xi \text{ effected in (4.3.42) has reduced the variable to one depending only upon the deterministic quantity, } \tau_i. \text{ The random component of } \xi \text{ has essentially been transferred to the other side of the inequality in the decision rule.} \]

\[ \text{The monotonicity of } \psi \text{ ensures that an inverse exists.} \]
\[ \nu(\tau_i+1) = -\left(\tau'_i\right)^{\frac{1}{2}} \nu\left(\frac{v(\tau'_i)+c}{(\tau'_i)^{\frac{1}{2}}} \right) \] (4.3.48)

At the point in the sampling process where the searcher has just observed a vacancy of utility, \( u \), and has incorporated information imparted by this observation to update his/her prior perception of the mean \( \Omega \) of the distribution of opportunities in the opportunity set such that \( \Omega_N(\mu_i, 1/\tau_i) \), the optimal procedure for the individual to follow is to:

**Reject the vacancy and continue searching if**
\[ u^* - \mu_i < \nu(\tau'_i) \] (4.3.49)

**Accept the vacancy and stop searching if**
\[ u^* - \mu_i \geq \nu(\tau'_i) \]

And the individual's aspiration utility associated with the continuation of search is simply
\[ \xi(\mu_i, \tau_i) = \nu(\tau'_i) + \mu_i \]

From these results, the entire sequence of expected utilities over the set of translated (such that \( E(X)=0 \)) marginal distributions may be calculated using the recursive relationship in (4.3.48), for, from an initially established prior about the mean upon the commencement of search, where \( \Omega_N(\mu_p, 1/\tau_p) \),

\[ \nu(\tau_p+1) = -\left[\tau'_p(i)\right]^{\frac{1}{2}} \nu\left(\frac{v(\tau_p'+i-1)+c}{[\tau'_p(i)]^{\frac{1}{2}}} \right) \] (4.3.50)

for \( \tau'_p(i) = \frac{\tau_p + i - 1}{\tau_p(i)} \) and \( i=1,2, \ldots \). Aspiration utility, relative to the actual (untransformed) sample, may then be established at each stage of the sampling process by combining the utility of the current observation with the appropriate translated expected gain to yield:

\[ \xi(\mu_i, \tau_i) = \nu(\tau_p+1) + \mu_i \] (4.3.51)
Optimal search behavior at the $i^{th}$ observation in the sequence thus requires the searcher to adopt the following decision rule:

\[
\begin{align*}
\text{Reject the vacancy and continue searching if } & u_i^* - u_i < v(\tau_p + i) \\
\text{Accept the vacancy and stop searching if } & u_i^* - u_i \ge v(\tau_p + i)
\end{align*}
\] (4.3.52)

for $i=1,2,...$

where $u_i$ is the searcher's estimate of the mean of the distribution of opportunities in the choice set revised *a posteriori* to observing the utility of the alternative at $i$.

A numerical example demonstrates how aspirations respond to changing perceptions of housing market conditions in an adaptive search process. Figures 4.9. and 4.10 show the results of a simulated search over a sequence of random drawings from a normal distribution with mean $\mu_o = 1$ and precision $\tau_o = 1$. (Values for the variables are given in Table 4.1.) Here, the prior distribution of the mean $\Omega$ is $\Omega \sim N(1.05, .9)$ and marginal sampling costs are constant ($c = .05$). \(^1\)

---

\(^1\) Note that although (4.3.48) enables us to calculate an entire sequence of expected utilities from a single term in the sequence, it does not propose how that initial value is to be determined. The estimation of an initiating aspiration value is, in fact, arbitrary.

Two methods may be suggested for developing an aspiration sequence. If, in an empirical context, we have data on the utilities of the sequence of observations evaluated (the search path) and the utility of the chosen alternative, we can assume the utility of the chosen alternative to exactly equal the aspiration utility of the searcher and then compute the sequence of aspirations backwards from there via (4.3.47). (That the expected utility of search may be equated to the utility of the chosen alternative is a property of the theoretical model. We are therefore implicitly assuming that the searcher has followed the decision rule of (4.3.49) throughout the search process if we invoke this procedure.)

A second procedure, which is used to develop the example, requires that we formulate an initial aspiration utility based upon the parameters of the searcher's prior, *i.e.*, initiate search under the assumption that the searcher believes the mean and precision of the population to be $\mu_p$ and $\tau_p$, respectively, with certainty. The sequence of aspirations can then be computed successively forwards from there via (4.3.48) after the
Population: $X \sim N(1,1)$
Prior: $\Omega \sim N(1.05, .9)$
Marginal Cost: $c = .05$
* Note: Search terminates at $n = 9$.

Figure 4.9 Aspiration Utility in an Adaptive Search Process
(see also Figure 4.10)
Figure 4.10 Significant Components of Behavior in Adaptive Search

(a) Observation Values $X \sim N(1,1)$

(b) Posterior Mean

(c) Aspirations

(d) Expected Utility for $X \sim N(0, \tau)$
<table>
<thead>
<tr>
<th>Observation Number $i$</th>
<th>Observation Value $X_i$</th>
<th>Posterior Mean $\mu_i$</th>
<th>Aspiration Utility $\xi_i$</th>
<th>Expected Utility for $X \sim N(0, \tau)$ $\nu_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>--</td>
<td>1.05</td>
<td>2.4</td>
<td>1.35</td>
</tr>
<tr>
<td>1</td>
<td>-1.878</td>
<td>-.491</td>
<td>.904</td>
<td>1.394</td>
</tr>
<tr>
<td>2</td>
<td>1.450</td>
<td>.178</td>
<td>1.610</td>
<td>1.432</td>
</tr>
<tr>
<td>3</td>
<td>.836</td>
<td>.347</td>
<td>1.813</td>
<td>1.466</td>
</tr>
<tr>
<td>4</td>
<td>.784</td>
<td>.436</td>
<td>1.935</td>
<td>1.499</td>
</tr>
<tr>
<td>5</td>
<td>.717</td>
<td>.484</td>
<td>2.015</td>
<td>1.532</td>
</tr>
<tr>
<td>6</td>
<td>-.611</td>
<td>.325</td>
<td>1.889</td>
<td>1.564</td>
</tr>
<tr>
<td>7</td>
<td>-.712</td>
<td>.194</td>
<td>1.791</td>
<td>1.598</td>
</tr>
<tr>
<td>8</td>
<td>1.804</td>
<td>.375</td>
<td>2.006</td>
<td>1.632</td>
</tr>
<tr>
<td>9</td>
<td>2.281</td>
<td>.567</td>
<td>2.234</td>
<td>1.667</td>
</tr>
</tbody>
</table>

Table 4.1 Simulation Values for Search Over $X \sim N(1,1)$ — See Figure 4.9
The changes in the values of the observations and posterior means are relatively straightforward.\(^1\)\(^2\) The searcher's prior is updated according to an initially established mean, and the utility of the observation, each weighted by its respective precision. Note that as more and more observations are taken into account, the weight given the prior mean (from the previous observation) becomes more significant relative to the importance given the value of the current observation; observations deviating significantly from the perceived mean have proportionately smaller impacts on the posterior mean further into the sampling process.

The behavior of aspirations, \(\xi\), (Figure 4.10 (c)) is more complex. Although sensitive to observation values, a decline in aspiration utility does not necessarily follow from a decline in the posterior mean,\(^3\) since aspiration levels depend upon both the posterior mean and the expected utility which would be anticipated from search over a translated distribution with mean 0. This latter term is dependent only upon the prior expected utility, \(v(\tau_1)\), search costs and the precision of the marginal distribution associated with the next (translated) distribution, and is a monotonically increasing function of the number of observations made upon the sample. Thus, a decline in the updated mean may not be sufficient to offset the increase in expected utility of continuing, which is

\(^1\)This particular example was chosen from several simulations actually performed because of its clarity and extended length of search before aspirations are exceeded.

\(^2\)Since the sample is drawn from a normal distribution, negative values for the observations are expected but do not detract from the analysis.

\(^3\)The converse is always true, however.

215
calculated independently. An example of this is shown in Figure 4.11.

Figure 4.9 has shown how aspirations adjust during search in response to the acquisition of additional information about housing opportunities. This property of adjustment defines the major difference between adaptive and non-adaptive search behavior: whereas in the former case, aspirations change at each observation, they remain constant in the latter unless a limit to the number of vacancies which can be sampled is imposed upon the searcher. More importantly, under the conditions postulated in the numerical example, where both the prior and population distributions are assumed normal, a general rule governing the difference between adaptive and non-adaptive utilities may be stated.\footnote{This rule, however, does not necessarily apply to all possible updating regimes and/or distribution functions under the no-recall assumption (Kohn and Shavell, 1974, p.106),} If both the prior and population distribution functions are normal, then, given priors of equal means and precisions at any arbitrary stage of search, the expected marginal utility anticipated from taking another observation and proceeding optimally from there in an adaptive search process is always greater than that expected from a non-adaptive process. Consequently, aspirations associated with the former are always greater than those associated with the latter.

That adaptive search behavior yields higher expected utilities is seen by comparing the precisions of the marginal opportunity distributions associated with the adaptive and non-adaptive processes, using a property of stopping rule models already explored in Section 4.2.2. Since, in a non-adaptive process, no further information is imparted by the observation, aspirations are calculated over a marginal opportunity distribution...
Figure 4.11 Adaptive Search: An Example of Increasing Aspiration Utilities in Response to Declining Updated Means (see \( i=13,14,15 \))
which is identical to the prior, i.e. one having precision, $\tau_p$. In adaptive search, however, information imparted by the observation transforms the precision of the prior to the value $(\tau_p + 1)/\tau_p$. In other words, the precision of the marginal opportunity distribution in an adaptive search process is reduced relative to that of the prior and is therefore less than the precision of the marginal distribution associated with non-adaptive search behavior. Since the precision of a distribution is simply the inverse of its variance, it can be seen that the variance of the marginal opportunity distribution in an adaptive search process increases relative to that in a non-adaptive one. But it was shown in Theorem 4.1 that increasing the variation of an opportunity distribution increases the expected marginal utility anticipated from search. Thus, aspirations at an arbitrary decision point are greater when information is imparted to the searcher by each observation than when it is not.

This characteristic difference between adaptive and non-adaptive search is shown in Figure 4.12, which is based upon the simulation using normally distributed prior and population distributions.

The relationship between aspirations in an adaptive search process and the marginal distribution of utilities, defined in (4,3.48) and used in the example which followed, was derived under rather restricted conditions. The searcher's prior was assumed normally distributed, and sampling was conducted over a normal population with known precision. In general, the derivation of expressions for the marginal utility of search for all but a small number of distribution functions is intractable (Telser, 1973, p.44), and must instead be numerically solved by other methods such as simulation.\footnote{For examples of this approach, see Telser (1973) and Axell (1974).} Even sampling over a normal opportunity distribution
Figure 4.12 Comparison of Adaptive to Non-Adaptive Aspiration Utilities
with unknown mean and variance, assuming a normal prior, results in an irreducible form, since the marginal distribution of utilities is Student t rather than normal (Zellner, 1971, p.22-23).

Analytical relationships have been derived by Rothschild (1974) under the assumption that the distribution of prices (in his context) in the searcher's prior is Dirichlet (DeGroot, 1970, p.49-51), which is defined by the parameters, \( \mu \), the average number of times each price has been observed, and \( \rho \), the total number of prices that have been observed. Although not strictly comparable to this study, since an alternative information updating scheme has been assumed, \(^1\) Rothschild suggests from his analysis that optimal search rules from unknown opportunity distributions possess the same qualitative properties as those from known distributions (Rothschild, 1974, p.694). \(^2\)

That adaptive search policies are suggested to be qualitatively similar to non-adaptive policies is important, for, if true, it allows us to apply many of the properties of non-adaptive models to this alternative context. Thus, we may relate changes in aspiration utilities to more than changing perceptions about the quality of housing in the opportunity set. Search costs, competition for housing opportunities, limits to the number of alternatives which may be sampled, and other factors found to be significant in non-adaptive search behavior are all expected to influence adaptive search behavior in the same qualitative manner.

\(^1\)Here, the decision of whether to accept or reject the alternative is made prior to the incorporation of the observation into the searcher's distribution. The differences between the two methods are discussed in more detail in Lippman and McCall (1976a, p.173-174).

\(^2\)The simulation experiments run for the example in this section offer further, though limited, support for this contention.
We may summarize the adaptive stopping rule model as one which recognizes the learning aspects of search. Each observation imparts information to the household, enabling it to expand and refine its perception of the opportunity distribution. Furthermore, adaptive stopping rule models, under certain conditions, retain the fundamental decision rule developed in Section 4.2, whereby an alternative is accepted if and only if its utility is at least as great as the searcher's aspiration utility. The conditions which generate this rule require only that the searcher update his/her prior expectations about the opportunity distribution before calculating the expected marginal utility associated with continuing search. For certain classes of opportunity distributions, other updating regimes produce the same decision rule (Rothschild, 1974). With the conjecture that adaptive search rules possess the same qualitative properties as non-adaptive rules, this suggests that the properties of search models established in previous sections remain valid, regardless of whether the search activity being investigated is adaptive or not. This, in turn, suggests that analysis of search behavior in urban housing markets should still reveal the characteristic properties of non-adaptive models even though locational choice decisions are likely to result from adaptive search behavior. Although the relationship between adaptive and non-adaptive search can be further strengthened upon the incorporation of recall, the results of this section provide a rationale for translating the properties of the simple model into the complex empirical contexts of the following chapters.

4.3.6 Search Activity With Recall

To this point in the chapter, the searcher has been allowed but a
single choice after the decision to discontinue search has been made: the chosen alternative must be that opportunity which is currently under observation. Those opportunities previously rejected have been discarded forever from the choice set. The assumption of recall allows the searcher to retain either all or part of the set of alternatives that have already been observed during search. With this option, the searcher is able to weigh the expected utility of continuing against the best (or some function of the best) of the alternatives retained in the choice set.

We may distinguish two types of recall which are important in stopping rule models. Total recall is defined when the searcher is allowed to choose from the entire set of vacancies which have been observed in the sequence. Partial recall refers to situations where only a subset of opportunities are retained in the choice set. The latter option is one which is operationally difficult to deal with and it is usually more convenient to consider uncertain recall, where each evaluated alternative remains in the choice set (as in total recall) but only with probability, p.

It is important to note that recall can be utilized effectively in only some of the stopping rule models presented in this chapter. Recall is important only in those situations where aspirations change over the course of search activity. To demonstrate this, consider the elementary stopping rule model introduced in Section 4.2.

The decision rule associated with this model states that search is discontinued when the utility of the currently observed vacancy is at least as great as the searcher's aspiration utility. But because the searcher possesses complete information about the opportunity distribution (F and its parameters are known with certainty) and may sample indefinite-
ly, his/her aspiration utility is constant throughout the sampling process. In other words, since everything is known about the opportunity set which could possibly be of significance to the searcher, there is no reason for adjusting aspirations during search. Thus, if the optimal decision rule is followed at each step of the activity, there is no conceivable situation where a previously declined opportunity could be considered more attractive (relative to aspirations) now than before. The elementary model of search behavior is therefore unaffected by the assumption of recall.

But in Sections 4.3.4 and 4.3.5, we have examined two cases where aspirations do change over the sequence of observations. In Section 4.3.4, we found aspirations to monotonically decline as a forced stopping point is approached, and in 4.3.5, aspirations were shown to adjust either up or down as additional information about the opportunity distribution is gained. In these situations, it is therefore possible for a previously rejected alternative to later become more desirable when aspirations, for some reason, decline during search.

An expression for the searcher's aspiration utility under the recall assumption can be developed by considering the alternative decision the searcher can make along the sequence of observations, \( U = \{ U_1^t, U_2^t, \ldots \} \). For generality, assume search to be adaptive: observations provide information about the housing market which the searcher uses to revise the marginal opportunity distribution, upon which the expected utilities of

---

1Note that we have not considered the incorporation of a "discount factor" (Weibull, 1978) into the searcher's utility function to account for risk aversion, which would affect significantly the behavior of aspirations over the search sequence.
continuing to sample are calculated.\(^1\)

As in the previous examples, after \(i\) alternatives have been sampled, the searcher chooses one of two strategies: he/she either stops and collects a payoff, or continues to sample in an optimal manner. The value of continuing is simply the expected utility of taking one more observation and proceeding optimally from there minus the associated costs of search, as before. But the payoff from terminating search is now the utility of the best alternative observed to date, which is defined by the maximum function, \(y^i_t\), where

\[
y^i_t = \max(u^1_t, u^2_t, \ldots, u^i_t)
\]

Denote by \(F^i_u\) the marginal distribution of the \((i+1)\)st alternative in the search sequence, as revised in view of the outcome of the \(i\)th observation. Then the maximum expected return the searcher can expect at \(i\) is:

\[
V_t(y^i_t, F) = \max(y^i_t, E[V(\max(y^i_t, U_t); F^i_u) - \tilde{u}_t(c)]])
\]

The second term in the maximum function may be evaluated by partitioning all possible realizations of the next observation, \(U_t\), into four domains (Kohn and Shavell, 1974, p.103). Upon taking one more observation (such that \(U_t = u_t\)), it will either be optimal to stop or it won't; regardless, \(u_t\) will either be greater than or equal to \(y^i_t\) or it won't. Define the possible domains of the expected utility of continuing beyond \(i\), \(\xi_t(F)\), to be as follows:

\(^1\)Bayesian updating, examined in Section 4.3.5, is but one example of adaptive search behavior which could be considered.
\[ R_1(\xi(F)) = \{ u_t | \xi_t(F^{u_t}) \leq \max(y, u_t); y \geq u_t \} \]
\[ R_2(\xi(F)) = \{ u_t | \xi_t(F^{u_t}) \leq \max(y, u_t); y < u_t \} \]
\[ R_3(\xi(F)) = \{ u_t | \xi_t(F^{u_t}) > \max(y, u_t); y \geq u_t \} \]
\[ R_4(\xi(F)) = \{ u_t | \xi_t(F^{u_t}) > \max(y, u_t); y < u_t \} \]  
\[(4.3.55)\]

Now, if the searcher is indifferent between stopping and continuing, then from (4.3.54)
\[ V_t^i(\xi(F), F) = E[V_t(\max(\xi(F), U_t); F^{u_t}) - \bar{u}_t(c)] = \xi(F) \]
\[(4.3.56)\]

Rearranging terms in this expression yields
\[ \xi(F) + \bar{u}_t(c) = E[V(\max(\xi(F), U_t); F^{u_t})] \]

which by (4.3.55) becomes
\[ \xi(F) + \bar{u}_t(c) = \int_{u_t \in R_1(\xi(F))} \xi(F) dF^{u_t} + \int_{u_t \in R_2(\xi(F))} u_t dF^{u_t} \]
\[ + \int_{u_t \in R_3(\xi(F))} V(\xi(F); F^{u_t}) dF^{u_t} \]

These domains are interpreted in the following matrix.

<table>
<thead>
<tr>
<th>Value of Maximum</th>
<th>Optimal to Stop Domain</th>
<th>Payoff</th>
<th>Optimal to Continue Domain</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y \geq u_t )</td>
<td>( R_1(\xi(F)) )</td>
<td>( y )</td>
<td>( R_3(\xi(F)) )</td>
<td>( V(y,F^{u_t}) )</td>
</tr>
<tr>
<td>( y &lt; u_t )</td>
<td>( R_2(\xi(F)) )</td>
<td>( u_t )</td>
<td>( R_4(\xi(F)) )</td>
<td>( V(u_t,F^{u_t}) )</td>
</tr>
</tbody>
</table>
\[ + \int v(y_t^i F^u_t^i) dF^u_t^i \quad \text{if} \quad y_t^i \in R_q^i(\xi(F)) \quad (4.3.57) \]

Solving for \(\xi(F)\) in (4.3.57) yields the aspiration utility of the individual after observing the \(i^{th}\) alternative in the sequence of opportunities from which may be established the optimal decision rule for the searcher to follow.

*Reject the vacancy and continue searching if* \(y_t^i < \xi_t(F)\) \quad (4.3.58)

*Accept the best of the observed vacancies and stop searching if* \(y_t^i \geq \xi_t(F)\)

Equation (4.3.57), although considerably more complex, essentially uses the same decision criterion as that of the elementary model in (4.2.8), *i.e.* aspirations are defined to equate the marginal disutility toward search with the expected marginal utility of observing one more alternative in the sequence. To show this, consider (4.3.57) when search is non-adaptive.\(^1\) Since in non-adaptive search, all observations are drawn from a known opportunity distribution, \(F^u_t^i = F\). Furthermore, \(R_3(\xi_t(F)) = R_4(\xi_t(F)) = \phi\), since \(u_t \in R_3(\xi_t(F))\) or \(u_t \in R_4(\xi_t(F))\) if and only if \(\xi_t(F^u_t^i) = \xi_t(F) > \max(\xi_t(F), u_t)\), which is obviously false.

Therefore, using previous notation, (4.3.57) reduces to

\[ \xi_t(F) + \Delta_t(c) = \xi_t + \Delta_t(c) \]

\(^1\)Remember that recall is irrelevant to the searcher in the elementary model.
\[= \int_{u_t \leq R_1(\xi_t)} \xi_t \, d\mathcal{F} + \int_{u_t \leq R_2(\xi_t)} u_t \, d\mathcal{F}\]
\[= \int_{\alpha}^{\beta} \xi_t \, d\mathcal{F} + \int_{\xi_t}^{\beta} u_t \, d\mathcal{F}\]

which, upon rearranging terms, yields

\[\bar{u}_t(\xi) = \int_{\alpha}^{\xi_t} \xi_t \, d\mathcal{F} - \int_{\alpha}^{\xi_t} \xi_t \, d\mathcal{F} + \int_{\xi_t}^{\beta} u_t \, d\mathcal{F}\]
\[= \int_{\xi_t}^{\beta} (u_t - \xi_t) \, d\mathcal{F}\]  

(4.3.59)

This is the expression for the marginal utility of continuing search in a non-adaptive search process (4.2.8), from which aspirations are determined.

The relationship between marginal utilities in non-adaptive and adaptive search contexts can be used to develop an important property of the latter which defines the fundamental difference between aspirations in an adaptive model with recall and those in the elementary model. The following theorem reveals that at any given observation in the sequence of alternatives, the aspiration utility associated with continuing search from a given point in an adaptive search process when recall is permitted will always be greater than or equal to non-adaptive aspirations formulated from the same point (Kohn and Shavell, 1974, p.103).
THEOREM 4.9: If $F^{x_i}$ is a marginal opportunity distribution updated after the $i$th vacancy has been observed from a countable and possibly infinite sequence of opportunities $x = \{x_1, x_2, \ldots \}$, and $\xi_t^{A_i}$ and $\xi_t^{N_i}$ are aspiration utilities (both formulated over $F^{x_i}$) associated with total recall and no recall search processes, respectively, then $\xi_t^{A_i} \geq \xi_t^{N_i}$ for all $i$.

PROOF: Adaptive search is characterized by the updating of the marginal distribution function, $F^{x_i}$, at each observation, $x_k$, $k \geq i$; non-adaptive search assumes that all remaining draws from $x$ are from a common distribution, $F^{x_i}$. By (4.3.57)

\[
\xi_t^{A_i} + u_t(c) = \int_{x \in R_1(\xi_t^{A_i})} \xi_t^{A_i}dF^{x_i} + \int_{x \in R_2(\xi_t^{A_i})} xdF^{x_i} \\
+ \int_{x \in R_3(\xi_t^{A_i})} v_t^{i}(\xi_t^{A_i}; F^{x_i})dF^{x_i} \\
+ \int_{x \in R_4(\xi_t^{A_i})} v(x; F^{x_i})dF^{x_i}
\]

Furthermore, by definition of $V_t$ in (4.3.54)

\[
V_t(\xi_t^{A_i}; F^{x_i}) \geq \xi_t^{A_i} \quad \text{and} \quad V_t(x; F^{x_i}) \geq x
\]

Then

\[
\xi_t^{A_i} + u_t(c) \geq \int_{x \in R_1(\xi_t^{A_i})} \xi_t^{A_i}dF^{x_i} + \int_{x \in R_2(\xi_t^{A_i})} xdF^{x_i}
\]
\[ + \int_{x \in R_3(\xi_t^{A_i})} \xi_t^{A_i}dx^i + \int_{x \in R_2(\xi_t^{A_i})} xdx^i \]

\[ = \int_{x \in R_1(\xi_t^{A_i}) \cup R_3(\xi_t^{A_i})} \xi_t^{A_i}dx^i + \int_{x \in R_2(\xi_t^{A_i}) \cup R_4(\xi_t^{A_i})} xdx^i \]

\[ = \int_{\alpha}^{\beta} \xi_t^{A_i}dx^i + \int_{\xi_t^{A_i}}^{\beta} xdx^i \]

Rearranging terms yields the inequality

\[ a_t(c) \geq \int_{\xi_t^{A_i}}^{\beta} (x - \xi_t^{A_i})dx^i \tag{4.3.60} \]

Now assume that \( \xi_t^{A_i} < \xi_t^{N_i} \). Then

\[ a_t(c) \geq \int_{\xi_t^{A_i}}^{\beta} (x - \xi_t^{A_i})dx^i \]

\[ > \int_{\xi_t^{N_i}}^{\beta} (x - \xi_t^{N_i})dx^i \tag{4.3.61} \]

But, by definition, \( \int_{\xi_t^{N_i}}^{\beta} (x - \xi_t^{N_i})dx^i = a_t(c) \), which contradicts (4.3.61).

Therefore, \( \xi_t^{A_i} \geq \xi_t^{N_i} \) and \( \xi_t^{N_i} \) is the lower bound to aspirations in an adapt-search process with recall. \( \text{Q.E.D.} \)
We can better understand the meaning of this theorem by using an interpretation offered by Kohn and Shavell (1974, p.105), who compare the search behavior of two individuals, A and N, both having the same utility function but differing in their beliefs about the sampling distribution. "A" is an adaptive searcher who revises a subjective probability distribution in succeeding observations. "N" believes that the marginal opportunity distribution associated with the next observation is $p^Xi$, as does "A", but also believes that all future observations will be identically distributed to this next one. Using this interpretation, the theorem states that A's aspirations toward continuing search from this point will at least be as great as N's.

A behavioral explanation for this result is seen if we examine the relative costs and benefits of adaptive (with recall) versus non-adaptive search strategies. In both cases, aspirations are formulated to equate the expected marginal utility of continuing search with the marginal cost of sampling. And, in both cases, if search is continued, it is predicated upon the anticipation of observing an alternative of greater utility than the currently defined aspiration level. But in adaptive search, there is another source of potential gain from continued sampling: information leading to a revised opportunity distribution, thereby warranting further sampling from the opportunity set (Kohn and Shavell, 1974, p.106). This leads Kohn and Shavell (p.106) to conjecture that "subjective uncertainty about the 'true' distribution may be preferable, in a limited sense, to certain knowledge". But since succeeding observations may also reveal less favorable distributions if search is continued, this potential gain (of information) from continued sampling can only be realized if
the searcher has the privilege of recall, to ensure that a favorable outcome is maintained. Hence, the fundamental distinction between recall and no-recall situations relates to the nature of aspiration utilities in adaptive and non-adaptive search contexts. From any given point in the search sequence, adaptive aspirations are always greater than or equal to non-adaptive aspirations only when the searcher has the privilege of recall.

Apart from this distinction, adaptive and non-adaptive models of search are remarkably similar. Kohn and Shavell (1974) have demonstrated relationships under quite general conditions, similar to those embodied in the elementary model, between aspirations and the characteristics of the opportunity distribution (with respect to variations in utilities and the mean utility of the opportunity set) and between aspirations and search costs, which adds further support to the conjecture of Rothschild regarding the qualitative similarity between elementary models and their more complex counterparts. Relationships between search behavior and environmental variables deduced from elementary models can still be expected to be observed in empirical contexts, even though the mechanics of search are likely to be much more complex in reality than assumed by the model.

While total recall provides a more general framework for studying search activity, search with uncertain recall is probably more reflective of the behavior and conditions actually encountered in the residential selection process, particularly in urban housing markets. Stopping rule models with uncertain recall recognize the two major uncertainties which confront the searcher during the evaluation of opportunities; the uncer-
tainty associated with what might be gained from continuing search, and the uncertainty associated with the continued availability of vacancies already inspected. That previously inspected vacancies are retrievable only in a probabilistic sense (which characterizes uncertain recall) is indicative of the dynamics of a housing market where opportunities are lost or withdrawn from the choice set by competitive elements, or more subtle supply-side shifts even as the household evaluates other units.\footnote{Note that since a previously observed vacancy can only become desirable in those situations where aspirations adjust during the search process, uncertain recall applies only to those models which account for this, i.e., adaptive search models and non-adaptive models having a forced stopping point.}

Uncertain recall in an adaptive search process may be incorporated into the stopping rule model by considering the availability of the most favorable alternative in the choice at any point in the process to be a Bernoulli trial. After having observed the $i^{\text{th}}$ alternative in the search sequence, we assume that the searcher has formulated a preference ordering over the vacancies still available, from which the most favorable alternative in the choice set has been identified. We again define the maximum of the function by $y_t^i$, where

$$y_t^i = \max(u_t^1, u_t^2, \ldots, u_t^i)$$

(4.3.62)

At this point, possibly through some verification procedure, the maximum is known by the searcher to be available with probability $1$. Uncertainty exists only when another sample from the opportunity set is contemplated by the searcher, for it is recognized that by delaying the decision and sampling again, the likelihood of the most favorable alternative being available after the next observation is made will be less than 1.
In mathematical terms, this means that the maximum function associated with the next observation can take on one of two possible values, 
\[ i.e., 1, 2 \]
\[ y_{i+1}^t = \begin{cases} 
\max(y_t^i, u_t^i) & \text{with probability } p \\
U_t^i & \text{with probability } (1-p) 
\end{cases} \] (4.3.63)

The searcher must therefore trade-off a payoff which may be received with certainty if search is discontinued against an expected utility which is predicated upon the potential gains to be made from continuing search, but also is tempered by the knowledge that continuation may cost him/her the best opportunity observed to date.

Denote \( F_t^i \) as the marginal opportunity distribution associated with the \((i+1)\)th alternative, revised in view of the outcome of the \(i\)th observation. The maximum return the searcher can expect at \(i\), knowing \(y\) is

---

1. In the context of residential search behavior, we may conjecture \(p\) to be a function of several variables, including time (the greater the elapsed time since its evaluation, the less likely the alternative is still available); the vacancy's utility (vacancies of higher utility are less likely still available); and the intensity of competition in the housing market (the more competitors in the market, the less likely the alternative's availability upon recall). However, the mathematical treatment of search behavior with uncertain recall becomes considerably more involved when \(p\) is explicitly related to these factors, and is not pursued here. Rather, \(p\) is assumed to remain constant throughout the search process. For a discussion of search behavior with time-dependent probabilities of recall, see Karni and Schwartz (1977).

2. Implicitly, we are structuring the choice situation as one in which, at each observation, the best observation inspected to date is available with probability, \(p\), while all other vacancies are lost to the searcher; that is, the searcher, in the evaluation of future gains, only cares about the best vacancy inspected to date. However, this is equivalent to saying that all rejected alternatives are available to the searcher with probability, \(p\) (Landsberger and Peled, 1977, p.19).
is available is:

\[
V^i_t(y; F, p) = \max \left\{ y, p \left[ E[V^{i+1}_t(y, U^{i+1}_t); F^{i}_t] \right] \right. \\
+ \left. (1-p) \left[ E[U^{i+1}_t(y, U^{i+1}_t); F^{i}_t] - \tilde{u}_t(c) \right] \right\} \quad (4.3.64)
\]

The first term in the maximum expression is simply the gain to be made from discontinuing search at \( i \) and is defined in (4.3.62). The second term, exclusive of the disutility variable, is composed of two major components. The first component is the expected utility of continuing search if the most favorable alternative inspected to date is still available after taking another observation. This event is assumed to occur with probability, \( p \). The second component is the expected utility of continuing search if the most favorable alternative is no longer available at the next decision point. If this event occurs (with probability \((1-p)\)), the searcher's choice set is reduced to the opportunity currently under consideration. Aspirations are therefore formulated over an overall expectation of what is potentially available to the searcher in the choice set if another observation is taken from the sequence of vacancies.

Equation (4.3.64) reduces to expressions for the maximum gain to be expected at \( i \) under total recall and no-recall situations. Setting \( p=1 \) results in the expression

\[
V^i_t(y; F, 1) = \max \left\{ y, E[V^{i+1}_t(y, U^{i+1}_t); F^{i}_t] - \tilde{u}_t(c) \right\}
\]

which is the maximum expected gain anticipated at \( i \) when total recall is assumed. Conversely, setting \( p=0 \) yields the maximum expected gain at \( i \) when recall is not allowed in an adaptive search process, i.e.
\[ v_t^i(y; F, 0) = \max \{ u_t^i, E[v_{t}^{i+1}(y_{t}^{i+1}); F^{u_{t}}] - \bar{u}_t(\bar{C}) \} \]

It can be shown (Karni and Schwartz, 1977, p.48) that aspiration utilities in total recall and no-recall adaptive search process form upper and lower bounds, respectively, to aspirations formulated in uncertain recall situations.

The impacts of total and uncertain recall on aspiration utilities during search are most clearly seen in the finite sampling model examined in Section 4.3.4, where aspirations in a search process with no recall monotonically decline as the forced stopping point is approached. Since search is non-adaptive, \( F^{u_{t}} = F \), by definition. To remain consistent with previous notation, let \( j \) denote the number of opportunities which remain in a finite sampling sequence of length, \( k \) (\( i = k - j \)). From (4.3.64), the maximum return the searcher can expect with \( j \) observations remaining is:\(^1\)

\[ v_t^j(y; p) = v_t^j(y) = \max \{ y, p \left[ E[v_t^{j-1}(\max(y, u_t^{j-1}))] \right] \]
\[ + (1-p) \left[ E[v_y^{j-1}(u_t^{j-1})] - \bar{u}_t(\bar{C}) \right] \}
\[ = \max \{ y, \int_0^\beta v_t^{j-1}(\max(y, u_t)) dF(u_t) \]
\[ + (1-p) \int_0^\beta v_y^{j-1}(u_t) dF(u_t) - \bar{u}_t(\bar{C}) \} \]

\(^1\)Recall that \( \alpha = 0 \) is an arbitrarily imposed lower bound to utilities in the finite sampling scheme.
\begin{align*}
&= \max \{ y, \, p \left[ \int_0^y v_{t}^{j-1}(y) dF(u_t) + \int_0^\beta v_{t}^{j-1}(u_t) dF(u_t) \right] \\
&\quad + (1-p) \int_0^\beta v_{t}^{j-1}(u_t) dF(u_t) - \bar{u}_t(\mathcal{C}) \} \\
&= \max \{ y, \, p \left[ v_{t}^{j-1}(y) F(y) + \int_0^\beta v_{t}^{j-1}(u_t) dF(u_t) \right] \\
&\quad + (1-p) \int_0^\beta v_{t}^{j-1}(u_t) dF(u_t) - \bar{u}_t(\mathcal{C}) \} \\
&= \max \{ y, \, \omega_t^j(y,p) \} \tag{4.3.65}
\end{align*}

Aspiration utilities, \( \xi_t^j \), can be defined, as usual, by assuming that the searcher is indifferent between stopping and continuing at \( j \), i.e., by solving the expression

\[ \omega_t^j(\xi_t^j, p) - \xi_t^j = 0 \] \tag{4.3.66}

It can be shown that \( \xi_t^j \) is uniquely defined by (4.3.66) (Landsberger and Peled, 1977, p.35). Furthermore, \( \omega_t^j(y;p) \) and \( v_t^j(y;p) \) are both strictly increasing functions of \( y \) for \( p > 0 \). \(^1\)

Now, sequences of aspiration utilities in no-recall, uncertain recall and total recall finite sampling models can be characterized by first dis-

\(^1\)These properties are utilized to develop the relationships between alternative recall assumptions in the section. However, the proof of this statement is involved and is deferred to Appendix 4.2,
tminating total from uncertain and no-recall aspirations and then de-
stermining how uncertainty (with respect to recall) affects the rate of
decline of aspirations as the forced stopping point is approached. These
properties are defined in the two theorems which follow (see also Leonardz, 1973).

**THEOREM 4.10:** Assume a search process with a finite number of observations,
k, and define the maximum return which can be expected with j observations
remaining as \( V_{t}^{j}(y;p) \), where \( p \in [0,1] \). Associated with each observation is
an aspiration utility, \( \xi_{t}^{j} \), which is the solution to (4.3.66). If total
recall is permitted in the search process, then \( \xi_{t}^{j} = \xi_{t}^{j-1} \) for all \( j=1, \ldots, k \);
if uncertain or no recall is assumed, \( \xi_{t}^{j} > \xi_{t}^{j-1} \) for all \( j=1, \ldots, k \).

**PROOF:** We prove this statement by induction. Note that total recall
corresponds to the case where \( p=1 \); uncertain and no-recall search is
defined for \( p \in [0,1] \). Let \( j=2 \) and assume \( V_{t}^{0}(x)=x \); then from (4.3.65),

\[
\begin{align*}
\omega_{t}^{2}(y;p) - \omega_{t}^{1}(y;p) &= p \left\{ \int_{y}^{\beta} V_{t}^{1}(y) F(y) + \int_{0}^{\beta} V_{t}^{1}(u_{t}) dF(u_{t}) \right\} \\
&\quad + (1-p) \int_{0}^{\beta} V_{t}^{1}(u_{t}) dF(u_{t}) \\
&\quad - p \left\{ y F(y) + \int_{y}^{\beta} u_{t} dF(u_{t}) \right\} - (1-p) \int_{0}^{\beta} u_{t} dF(u_{t}) \\
&= p \left\{ (V_{t}^{1}(y) - y) F(y) + \int_{y}^{\beta} (V_{t}^{1}(u_{t}) - u_{t}) dF(u_{t}) \right\} \\
&\quad + (1-p) \int_{0}^{\beta} (V_{t}^{1}(u_{t}) - u_{t}) dF(u_{t})
\end{align*}
\]
Let \( p \in [0,1] \). If \( y \geq \xi_1^t \), then by definition of \( \nu_1^t(y;p) \), \( \nu_1^t(y) = y \).

Therefore, \( \nu_1^t(y) - y = 0, \int_y^\beta (\nu_1^t(u_t) - u_t) dF(u_t) = 0 \), but

\[
\int_0^\beta (\nu_1^t(u_t) - u_t) dF(u_t) > 0. \quad y \geq \xi_1^t \Rightarrow \omega_1^2(y;p) - \omega_1^1(y;p) > 0.
\]

If \( y \leq \xi_1^t \), then \( \nu_1^t(y) - y > 0, \int_y^\beta (\nu_1^t(u_t) - u_t) dF(u_t) > 0 \), and

\[
\int_0^\beta (\nu_1^t(u_t) - u_t) dF(u_t) > 0. \quad y < \xi_1^t \Rightarrow \omega_1^2(y;p) - \omega_1^1(y;p) > 0.
\]

Therefore, for \( p \in [0,1] \), \( \omega_1^2(y;p) - \omega_1^1(y;p) > 0 \ \forall y \).

Let \( p=1 \). Then \( \omega_1^2(y;p) - \omega_1^1(y;p) = (\nu_1^1(y) - y)F(y) + \int_y^\beta (\nu_1^1(u_t) - u_t) dF(u_t) \)

\( y \geq \xi_1^t \Rightarrow \omega_1^2(y;p) - \omega_1^1(y;p) = 0. \) Similarly, \( y < \xi_1^t \Rightarrow \omega_1^2(y;p) - \omega_1^1(y;p) > 0. \)

Therefore, for \( p \in [0,1] \), \( \omega_1^2(\xi_1^t;p) - \omega_1^1(\xi_1^t;p) > 0 \Rightarrow \xi_2^t > \xi_1^t \)

and, for \( p = 1 \)

\( \omega_1^2(\xi_1^t;p) - \omega_1^1(\xi_1^t;p) = 0 \Rightarrow \xi_2^t = \xi_1^t. \)

Now assume these relationships are true for \( j=n-1 \). Then for \( j=n \),

\[
\omega_1^n(y;p) - \omega_1^{n-1}(y;p) = p \left\{ (\nu_1^{n-1}(y) - \nu_1^{n-2}(y))F(y) \right. \\
+ \int_y^\beta (\nu_1^{n-1}(u_t) - \nu_1^{n-2}(u_t)) dF(u_t) \right\}
\]

238
+ (1-p) \int_0^\beta (v_t^{n-1}(u_t) - v_t^{n-2}(u_t))dF(u_t)

But by induction, \(v_t^{n-1}(y) \geq v_t^{n-2}(y)\) with equality if and only if \(y > \xi_t^{n-1}\). Using arguments similar to those made earlier,

for \(p \in [0,1)\), \(\omega_t^n(\xi_t^{n-1};p) - \omega_t^{n-1}(\xi_t^{n-1};p) > 0 \Rightarrow \xi_t^n > \xi_t^{n-1}\), and

for \(p = 1\), \(\omega_t^n(\xi_t^{n-1};p) - \omega_t^{n-1}(\xi_t^{n-1};p) = 0 \Rightarrow \xi_t^n = \xi_t^{n-1}\).

Therefore, \(\xi_t^j > \xi_t^{j-1}\) for \(p \in [0,1)\) and \(\xi_t^j = \xi_t^{j-1}\) for \(p = 1\) for all \(j = 1, \ldots, k\).

Q.E.D.

The characteristic of total recall in a finite search process which distinguishes it from uncertain and no-recall simulations is now apparent. Whereas in uncertain and no-recall cases, aspiration utilities monotonically decline as the forced stopping point is approached, when the searcher is given the privilege of total recall, aspirations are maintained at a constant level. Furthermore, this constant aspiration level is equivalent to aspirations which would be formulated in an infinite sampling process over the same opportunity distribution, F. (Leonardz, 1973, p.53), and is therefore independent of both the utility of the best alternative inspected to date and the number of observations which remain before search is halted. Search in a finite sampling process when the privilege of total recall is given to the individual should therefore be carried out as if an infinite number of opportunities remain in the sample, i.e.
Reject the vacancy and continue searching if \( y < \xi_t \)  
Accept the vacancy and stop searching if \( y \geq \xi_t \)  

Even if all observations are lower in utility than \( \xi_t \), the rule is optimal, for if this event occurs, the searcher should sample all alternatives in the opportunity set until forced to stop and then choose the most favorable one in the sequence (Leonardz, 1973, p.53).

With uncertain recall assumed in a finite sampling process, however, the evaluation rules are changed. We have seen for \( p \in [0,1] \), \( \xi^{\xi_j}_{j-1} \) for all \( j=1, \ldots, k \), where \( j \) represents the number of observations which remain to be sampled. Furthermore, aspiration utilities formulated in a search sequence with no recall permitted (\( p=0 \)) define a lower bound to aspirations in an equivalent search process with uncertain recall. Since \( p \) measures the degree of uncertainty associated with retrieving previously rejected alternatives, intuitively, we expect greater uncertainty (lower values of \( p \)) to be associated with lower aspiration utilities. We formalize this statement in the following theorem,

**THEOREM 4.11:** If the maximum return the searcher can expect at a decision point with \( j \) observations remaining is \( V^j_t(y;p) \) and the associated aspiration utility is \( \xi^j_t \), then for any \( j=1, \ldots, k \), \( \xi^j_t \) is an increasing function of \( p \) for \( p \in [0,1] \).

**PROOF:** Assume, as usual, that \( V^0_t(x) = x \). Using (4.3.65) and setting \( j=1 \) reveals

\[
\frac{\partial V^1_t(y;p)}{\partial p} = 0 \quad \text{for } y \geq \xi^1_t
\]

240
\[
\frac{\partial V^1_t(y;p)}{\partial p} = \frac{\partial \omega^1_t(y;p)}{\partial p} \quad \text{for } y < \xi^1_t
\]

\[
\frac{\partial \omega^1_t(y;p)}{\partial p} = -\frac{3}{\partial p} \left( p \left[ y^F(y) + \int y^F(u^t) \right] \right.
\]

\[
+ \left( 1 - p \right) \int u^t_dF(u^t) - \bar{u}^t(c) \left) \right.
\]

\[
= y^F(y) + \int y^F(u^t) - \int u^t_dF(u^t)
\]

\[
= \int y^F(u^t) - \int u^t_dF(u^t)
\]

\[
= \int (y - u^t)dF(u^t) > 0
\]

Using the induction argument, assume the statement to be true for \( j = n - 1 \).

Therefore,

\[
\frac{\partial V^{n-1}_t(y;p)}{\partial p} = 0 \quad \text{for } y \geq \xi^{n-1}_t
\]

\[
\frac{\partial V^{n-1}_t(y;p)}{\partial p} = \frac{\partial \omega^{n-1}_t(y;p)}{\partial p} > 0 \quad \text{for } y < \xi^{n-1}_t
\]
Let $j = n$; then

$$\frac{\partial \nu_t^n(y; p)}{\partial p} = 0 \quad \text{for} \quad y \geq \xi_t^n$$

$$\frac{\partial \omega_t^n(y; p)}{\partial p} = \frac{\partial \omega_t^n(y; p)}{\partial p} \quad \text{for} \quad y < \xi_t^n$$

and

$$\frac{\partial \omega_t(y; p)}{\partial p} = \frac{\partial}{\partial p} \left( p \left[ \nu_t^{n-1}(y) F(y) + \int_y^\beta \nu_t^{n-1}(u_t) dF(u_t) \right] + (1-p) \int_0^\beta \nu_t^{n-1}(u_t) dF(u_t) - u_t(\xi) \right)$$

$$= \nu_t^{n-1}(y) F(y) + \int_y^\beta \nu_t^{n-1}(u_t) dF(u_t)$$

$$+ p \left( \frac{\partial \nu_t^{n-1}(y)}{\partial p} + \int_y^\beta \frac{\partial \nu_t^{n-1}(u_t)}{\partial p} dF(u_t) \right)$$

$$+ \int_0^\beta \frac{\partial \nu_t^{n-1}(u_t)}{\partial p} dF(u_t) - p \int_0^\beta \frac{\partial \nu_t^{n-1}(u_t)}{\partial p} dF(u_t)$$

$$- \int_0^\beta \nu_t^{n-1}(u_t) dF(u_t)$$
\[ \int_0^Y \left[ v_t^{n-1}(y) - v_t^{n-1}(u_t) \right] dF(u_t) + p F(y) \frac{\partial v_t^{n-1}(y)}{\partial p} \]

\[ + \int_y^B \frac{\partial v_t^{n-1}(u_t)}{\partial p} dF(u_t) + (1-p) \int_0^B \frac{\partial v_t^{n-1}(u_t)}{\partial p} dF(u_t) \]

But \( \frac{\partial v_t^{n-1}(x)}{\partial p} \geq 0 \) by assumption; furthermore, \( V_t(x) = \max(x, z) \) is an increasing function of \( x \) so that

\[ \int_0^Y \left[ v_t^{n-1}(y) - v_t^{n-1}(u_t) \right] dF(u_t) > 0 \]

Therefore, \( \frac{\partial \omega_t^n(y; p)}{\partial p} > 0 \) and \( \frac{\partial v_t^{n-1}(y; p)}{\partial p} > 0 \) for \( y < \xi_t^n \)

and \( \frac{\partial \omega_t^j(y; p)}{\partial p} > 0 \) for all \( j = 1, \ldots, k \) by induction.

However, note that \( \frac{\partial \omega_t^j(y=\xi_t^j; p)}{\partial \xi_t^j} > 0 \). Therefore, \( \frac{\partial \omega_t^j}{\partial p} > 0 \)

implies that \( \frac{\partial \xi_t^j}{\partial p} > 0 \) for all \( j = 1, \ldots, k. \)

Q.E.D.
Aspirations in a finite sampling process in total recall, uncertain recall and no-recall situations have now been characterized. Aspirations in a search process with no recall form a lower bound to aspiration utilities which can be attained in uncertain and total recall situations. An upper bound, equivalent to aspirations formulated in a corresponding infinite sampling process, is defined in a finite sampling process with total recall. Aspiration utilities monotonically decline in both uncertain and no-recall search activities as the number of observations remaining before sampling must cease approaches zero; aspirations remain constant throughout the search only when the individual has the privilege of total recall. Finally, for a given observation, $j$, aspirations in a search process with uncertain recall monotonically increase with the likelihood of retrieving the most favorable alternative evaluated to that point in the search sequence. These characteristics are illustrated in Figure 4.13. Note that similar relationships have been shown to exist in the more general context of adaptive search models as well (Karni and Schwartz, 1977).

The ability to retrieve previously observed vacancies is an important determinant of search behavior in urban housing markets. It is characterized in stopping rule models by the degree of recall afforded the searcher throughout the sampling process. That the degree of recall in stopping rule models affects aspiration levels in a predictable manner leads to a number of potential areas of investigation, since recall may be used to represent several supply-side responses to demand conditions in the housing market, such as competition, discrimination or other factors. Recall may also implicitly incorporate the amount of time that the household has
Figure 4.13 Comparison of Aspiration Utilities in a Finite Sampling Process When Different Types of Recall Are Allowed (continuous aspiration curves are displayed for comparative purposes only).
spent searching. Factors which increase the likelihood of retrieving previously inspected alternatives, such as lower levels of competition or discrimination may be expected to raise aspirations, prolong search and thus provide greater opportunity for choosing an alternative than otherwise would be anticipated. This is not only intuitively correct, but is consistent with the findings of more elementary models investigated earlier.

4.4 Summary

This chapter has developed a mathematical framework for characterizing search behavior in urban housing markets. It is a framework which departs from traditional approaches to the analysis of residential location behavior by its consideration of search as a sequential process of evaluation rather than a simultaneous one. In so doing, it recognizes the inherent uncertainties in the location decision faced by households engaged in search activity: housing opportunities, instead of being compared to other alternatives in a pre-defined choice set, are sequentially evaluated against an aspiration utility which embodies what the searcher believes is available for occupancy in the housing market. The framework thereby incorporates decision rules similar to the satisficing principles introduced by Simon (1957) and discussed in Chapter 3, yet maintains an underlying assumption of utility maximization.

To investigate search behavior, the chapter has developed a set of stopping rule models, ranging from the elementary to more complex formulations, which simulate the various conditions under which search may be undertaken by households. Analysis of the elementary model, which assumes an individual sampling sequentially and possibly indefinitely from a known
distribution of alternatives at fixed cost, and where the recall of past observations is not allowed, has revealed a set of theoretical relationships between search behavior and selected environmental variables which are relatively robust, in that these relationships continue to hold as assumptions are successively relaxed to better characterize the search process. These relationships form the bases for the hypotheses to be developed and tested in the following chapter.

The variable of particular interest for characterizing search behavior in this theoretical framework is the aspiration utility of the searcher, which is defined as the expected utility of taking one more observation from the sequence and proceeding optimally from there. Aspirations are the criterion upon which the housing/location decision is made in all models of search activity developed in this chapter. In general, search is discontinued at that point in the sequence where the utility of either the current or preferred previously observed alternative exceeds the currently defined aspiration utility. Otherwise, search is continued for at least one more observation.

Since a psychological variable, such as aspiration utility, is not susceptible to direct empirical measurement, it has been related to two other variables which may be inferred from empirical data on search behavior. Aspirations have been shown to be directly related to the number of observations evaluated during search and to the utility of the alternative eventually chosen by the searcher. (The latter is measurable only to the extent that choice is observed and, thus, a relative utility measure can be estimated.) Associated with higher aspiration utilities are more observations in the search sequence and residential choices of higher
utility than are associated with lower aspiration utilities.

Theoretical relationships which have been examined in this chapter are those between aspirations and search costs (or disutilities), perceived variations in housing quality, and competition for housing opportunities. The chapter has also examined the nature of aspirations when the number of observations is constrained in the search process, in a search process with learning (adaptive search), and in one with varying degrees of recall of past opportunities.

The individual's disutility towards search has been found to be a significant constraint to search activity since it is a "cost" associated with search that must be weighed against the marginal utility of continuing at each decision point in the search process. Higher disutility levels, whether in response to higher real costs (e.g. time, money, effort), or to changing (more pessimistic) attitudes towards search, depress aspiration utilities and reduce the number of observations likely to be made before search is discontinued. By definition, then, higher search costs reduce the expected gain which can be anticipated from search activity.

Greater variation in the distribution of utilities in the opportunity set has been shown to have the opposite impact on aspiration utilities during search. Aspirations associated with a given distribution increase with the variation in that distribution, reflecting an instrumental preference of the (risk-neutral) individual for searching for "bargains" or extreme values in the opportunity set. Households engaged in search in highly variable housing markets are therefore expected to search longer but to gain more through the activity than those sampling from more con-
centrated distributions.

Competition for vacancies in the housing market has been characterized in the model by a subjective success probability function which measures the chance the individual believes he/she has of being offered a vacancy of given utility when other households are known to be competing for similar opportunities in the market. Lower probabilities of success, indicative of higher competition levels, require the individual to revise his/her perception of the opportunity set to one which is skewed toward vacancies of lower utility levels, causing the searcher to revise his/her aspirations downward during search. The individual's aspiration utility is a non-increasing function of the number of competitors perceived in the market. As competition becomes more intense, aspirations are adjusted further downward, inducing a curtailment of search activity earlier and the acceptance of a vacancy of lower utility than would otherwise be expected under less competitive circumstances.

Finite sampling strategies represent the first modification to the elementary model undertaken in the chapter; their introduction profoundly impacts aspirations during the search process. Finite limits to sampling, which may approximate search conditions experienced by households forced from their current units, or households constrained by insufficient resources for conducting search, causes the individual to adjust aspirations downward as the forced stopping point is approached. This is contrasted with aspirations formulated with no limit to the number of vacancies which may be sampled, which remain constant throughout the entire search process. Aspirations in search, when sampling is constrained, approach those of the elementary model (unlimited observations) only when the number of vacancies
remaining to be sampled approaches infinity,

Further modification to the elementary model is accomplished through the incorporation of learning. Adaptive search behavior, which in Section 4.3,5 is characterized by the Bayesian updating of parameters of the opportunity distribution, allows aspirations to be adjusted up or down as further information about the true opportunity distribution is gained through observation. An upward revision in the individual's priors results in higher aspiration utilities; but if the individual's priors are revised downward, aspirations may rise or fall, depending upon the extent to which prior estimates are changed. In a Bayesian learning situation, where both the distributions of utilities in the opportunity set and the searcher's priors are normal, adaptive aspirations are always greater than non-adaptive aspirations formulated from the same decision point.

The introduction of recall into the model is a final generalization undertaken in this chapter, and, in combination with assumptions which allow aspirations to dynamically adjust over the search, produces a model which approaches the conditions of search likely to be encountered in urban housing markets. The degree of recall, which is the likelihood of the searcher still having the best alternative previously observed available in the choice set after making another observation, is directly related to aspiration utilities formulated during search. Aspirations in a search process with total recall form an upper bound, and those in an identical process with no recall form a lower bound to aspiration utilities which can be expected in a search process with uncertain recall. As the likelihood of retrieving a previously observed alternative declines (as recall becomes more uncertain), aspirations monotonically decline toward aspira-
tion utilities formulated in an equivalent no-recall search process. The likelihood of recall term has been conjectured to be related to several relevant factors in search, including competition, discrimination and the length of time since the most favorable alternative has been observed. Relationships developed between the likelihood of recall and aspiration utilities are intuitive when interpreted in these terms.

The most significant finding in the analyses of the more general models of search concerns the qualitative behavior of aspirations relative to the relationships embodied in the more elementary model. More general models, although they alter aspiration levels relative to those in the elementary model, appear to have embodied in them the same qualitative relationships between aspirations and environmental variables, such as search costs or disutilities, and variations in the opportunity distribution. This allows us to apply these basic relationships to empirical situations which are undoubtedly more complex than as represented in the elementary model. A basis for developing hypotheses for testing in the next chapter has therefore been established. For reference, the relationships examined in the chapter are shown in Table 4.2.

Although the models of search examined in this chapter offer more concise characterizations of individual behavior in the search process than traditional residential choice models, they are still relatively elementary in that environmental conditions governing search have not yet been fully relaxed nor has the sampling process been sufficiently defined in terms of time and space. It would be useful to briefly discuss how these models can be generalized further to establish directions for further research and development.

Recall the five basic assumptions proposed to characterize search
<table>
<thead>
<tr>
<th>ENVIRONMENTAL VARIABLE</th>
<th>ASPIRATION UTILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary Model¹</td>
<td>search cost/disutility: -</td>
</tr>
<tr>
<td></td>
<td>variation in the distribution of utilities in the choice set: +</td>
</tr>
<tr>
<td></td>
<td>intensity of competition: -</td>
</tr>
<tr>
<td>Finite Sampling Model¹</td>
<td>number of observations remaining before forced to stop: +</td>
</tr>
<tr>
<td>Adaptive Search (Bayesian)</td>
<td>prior adjusted upward: +</td>
</tr>
<tr>
<td></td>
<td>prior adjusted downward: +/-</td>
</tr>
<tr>
<td>Search With Recall¹</td>
<td>likelihood of retrieving best previously inspected alternative: +</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUMBER OF VACANCIES OBSERVED IN SEQUENCE</th>
<th>EXPECTED GAIN FROM SEARCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspiration Utility (+ve change)</td>
<td>+</td>
</tr>
</tbody>
</table>

¹For increasing values of the variables, their impacts on aspiration utility are shown.

Table 4.2 Relationships Between Environmental Variables And Aspiration Utilities in Sequential Decision Models of Search
in the elementary model. Two of these assumptions have not been modified in any of the models developed in this chapter.

First, each model has assumed the marginal disutility toward search to remain constant throughout the activity, which is clearly a simplification of the structure of sampling costs actually perceived by households. That variable marginal disutilities should prevail during search is indicative of households' changing attitudes toward sampling as search is continued (eg. increasing pessimism) and alternative sampling strategies which might be attempted (eg. clustered sampling). Variable marginal disutilities or costs have been incorporated into several sequential decision models of search, including Leonardz (1973), Kohn and Shavell (1974) and Karni and Schwartz (1977).

A second unaltered assumption in the search models developed in this chapter concerns the linear utility function of the decision maker, implying the searcher to be risk-neutral, or indifferent towards risk when evaluating alternatives. The extent to which households are risk-loving or risk-averse in the search for housing has not been satisfactorily addressed in the literature. Furthermore, in light of the probable existence of both intrinsic and instrumental attitudes towards risk in the individual (David, 1974, p.27-28), such findings may be infeasible to determine. However, the models, as developed, do not recognize the potential existence of several types of individuals searching the market --some risk-averse, some risk-loving, etc.--and cannot, therefore, determine how one's explicit attitude towards risk affects aspirations, choice and the structure of optimal search. Although various proxies for risk have been incorporated into search models (eg. Weibull, 1978; Kohn and

253
Shavell, 1974), the analysis of Nachman (1972) and Hall (1975) (see Lippman and McCall, 1976a, p.171-173), where a non-decreasing, concave utility function is assumed for representing risk-aversion, suggest a more appropriate method for developing more general models of search which are sensitive to the household's attitudes toward risk.

Clearly, to relax assumptions concerning the structure of sampling disutilities and attitudes toward risk requires only minor respecification of the sequential decision framework. But more fundamental problems exist that cannot be as easily rectified; these relate to the way search models (as developed) consider both time and space.

Throughout the analysis, search has been characterized as a sequential sampling process with discrete periods of time, implicitly assumed to be equal, between observations (Lippman and McCall, 1976a, p.157). Although it simplifies the analysis, this characterization fails to recognize how searcher might alter their strategies given different circumstances or how transition times (between observations) might be affected by spatial elements of search.

Variable interarrival times between observations can affect the individual's search strategy in two ways. First, interarrival times can influence the likelihoods of retrieving previously observed alternatives in the choice set. We can expect the probability of recalling a given alternative to be inversely related to the time between observations: knowing a previously inspected alternative, \( x^* \), is available at time \( t \), but only with probability, \( p \), after the next observation, which occurs at time \( (t+\Delta) \), means that the likelihood of retrieving \( x^* \) gets smaller as \( \Delta \) becomes larger. This phenomenon has been investigated by Karni and
Schwartz (1977). Second, interarrival times can affect the searcher's assessment of his/her chances of finding a suitable alternative through further search activity. Long interarrival times between observations may be indicative of a shortage of acceptable vacancies in the searcher's opportunity set.\(^1\) In perceiving this, the searcher, because of impatience, pessimism, etc., may alter his/her decision criteria or quit searching altogether until more favorable conditions (characterized by shorter interarrival times) are restored. Search behavior in a sampling process with stochastic interarrival times has been investigated by Weibull (1978).

But searchers can also control the rate at which they sample, to some extent, provided that a sufficient number of vacancies exist in the opportunity set. Variable search intensity may depend upon household preferences, income, need, etc., but may also be related to the sampling strategy undertaken by households. Searchers who sample clusters of vacancies (in a given area of the city, for example) may experience lengthy interarrival times between clusters but then extremely short times when sampling within clusters. The searcher's position in the sampling process, eg. how many observations remain in the opportunity set in a finite sampling process, may also affect the intensity of search. Several issues related to variable search intensity have been investigated by Lippman and McCall (1976a, p.164-166; 1976c, p.376-382),

Spatial aspects of search are represented in the search models of this chapter only to the extent that alternatives are located in space

\(^1\)Supply-side shortages have also been characterized by the probability of recall (see Landsberger and Peled, 1977). Also, long interarrival times may indicate lack of commitment on the searcher's part.
and are therefore differentially valued by households according to their accessibility requirements. But the search process, itself, is essentially aspatial; there are no explicit directions embodied in the decision rules which suggest where the individual should search next. In fact, since sampled observations are assumed independent, though not necessarily identically distributed, the spatial sampling pattern of the individual must be considered to be quasi-random.\textsuperscript{1} Clearly, more rational spatial search patterns can be expected from searching households as they try to economize on the time, money and effort which must be expended upon search. Instead of randomly sampling the area, households are expected to systematically evaluate the market, initially evaluating those vacancies or sub-markets thought, a priori, through information agents, to be the most likely candidates for occupancy. Systematic search behavior in sequential decision models has been investigated by Salop (1973; see Lippman and McCall, 1976a, p.178; also Flowerdew, 1976, p.53).

Households can also be expected to sample hierarchically, choosing a general spatial area or sub-market in which to search, and then intensively sampling vacancies within the area or sub-market. Cluster sampling obviously affects interarrival times between observations (as mentioned above) and the structure of sampling costs or disutilities experienced by the searcher during this period. Search with hierarchical sampling has been analyzed by DeGroot (1970, p.423-429; see also Flowerdew, 1976, p.54). Hierarchical and systematic sampling strategies are, \textsuperscript{1}Spatial search patterns and sampling strategies may be implicitly incorporated into the opportunity distribution perceived by the searcher. However, appropriate functional forms that explicitly characterize these elements have not been considered.
of course, complementary, and may be employed concurrently by households.

What is evident from this evaluation is that the theoretical framework for analyzing search behavior investigated in this chapter, though more consistent with the intra-urban migration process than traditional residential location models, is still considerably removed from actual search and locational choice behavior observed in urban housing markets. Although some of the model's shortcomings can be rectified through appropriate reformulation of their assumptions, others, notably those related to the temporal and spatial aspects of search, present significant methodological issues which must be addressed before the framework can be extended to encompass these desirable characteristics. Clearly, there is need for future research in these areas.

That several elements of search are not addressed in the models developed in this chapter does not invalidate the stopping rule framework as a legitimate mathematical representation of search behavior. Though only partial, it embodies a series of relationships between search behavior and several environmental factors which we expect would be maintained in more sophisticated models and expect to observe in empirical contexts. It is this latter task we now wish to address.

4.5 Bibliographic Notes

The properties of stopping rule models related to search behavior, of which only a few have been illustrated in this chapter, have been studied extensively in the literature. Development of this theoretical approach to analyzing search is generally attributed to Stigler (1961; 1962), and the outline in Sections 4.2 and 4.3.1 of the basic model, including relationships embodied in it among aspirations, expected gain from
search, number of observations and search costs/disutilities is a standard one (see Lippman and McCall, 1976a, p.157-163).

The influence of variations in the opportunity distribution on search behavior has been studied by several authors including David (1974), Rothschild (1974) and Kohn and Shavell (1974). David's (1974) analysis is a more general one which attempts to develop a rationale for explaining individual preferences for more uncertain outcomes, while Rothschild (1974) investigates changes in the reservation price (in his context) to changes in the variation of a specific distribution. Kohn and Shavell (1974), which is the basis for the theoretical findings of this section, relating $\xi_t$ to the distribution function, $F$, presents a more general proof for Theorem 4.1 which holds for adaptive search with recall (p.114-115).

The characterization of competition by a success probability function which transforms the distribution of utilities in the opportunity set is attributable to Weibull (1978). However, Weibull's findings are limited since he considers only how search behavior is affected by the incidence of competition when the marginal distribution of alternatives is a gamma function. Lemmas 4.1 and 4.2 extend Weibull's proposition to account for any distribution function, $F$, and number of competitors in the market.

The section on finite sampling strategies uses a standard stopping rule model for characterizing search over a finite opportunity set. This model has been discussed by DeGroot (1970, p.331-333), Lippman and McCall (1976a, p.166-171), and most extensively by Leonardz (1973). Theorems 4.5 through 4.8 in this section are adapted from Leonardz (1973, Chapter 2).

Generalized models of search, such as those discussed in Sections 4.3.5 and 4.3.6, have been extensively investigated in the literature,
particularly in the context of employment search, Lippman and McCall (1976a) have analyzed an adaptive search model with no recall assuming a generalized marginal distribution function, and Bayesian updating of the marginal's parameters. Their model is used to introduce adaptive search in Section 4.3.5. This framework has been extended to Bayesian and non-Bayesian updating schemes and situations involving total recall by Kohn and Shavell (1974), and to those involving partial recall by Karni and Schwartz (1977). Partial recall in a search process with a finite number of observations has been investigated by Landsberger and Peled (1977). These models are the sources for the theoretical results derived in Section 4.3.6.

Adaptive search behavior over specific distributions has been analyzed by Rothschild (1974), Axell (1974) and DeGroot (1968). Rothschild (1974) assumes a Bayesian updating scheme over a Dirichlet prior. Unlike the models investigated in this chapter, the decision of whether to stop or continue is made prior to the revision of the distribution. Both DeGroot (1968) and Axell (1974) assume the distribution of utilities to be normal. DeGroot (1968) analyzes search behavior with and without recall over a normal distribution with known variance and unknown mean. Part of this analysis is used to develop the adaptive search rules defined in (4.3.52) in Section 4.3.5. Axell (1974) develops a series of simulations of search behavior with recall over a normal distribution when both the mean and variance are unknown to the searcher. In both DeGroot and Axell, the searcher's priors are assumed to be normal.

General discussions of optimal search models and their relationships to sequential decision theory, dynamic programming and Markov processes
can be found in Chow, Robbins and Siegmund (1971), Raiffa and Schlaifer (1961), Sakaguchi (1961), and MacQueen and Miller (1960).
APPENDIX 4.1

In this appendix we derive an alternative mathematical expression for \( H(\xi_t) \), the marginal utility associated with continued search activity on the part of the individual, \( t \). \( F \) is an opportunity distribution of utilities which is continuous along \( R_0 \). By (4.2.8)

\[
\begin{align*}
H(\xi_t) &= \int_{\xi_t}^{\beta} (u_t - \xi_t) dF(u_t) \\
&= \int_{\xi_t}^{\beta} u_t dF(u_t) - \xi_t \int_{\xi_t}^{\beta} dF(u_t) \\
&= \int_{\xi_t}^{\beta} \left[ \xi_t + \int_{\xi_t}^{u_t} dy \right] dF(u_t) - \xi_t \int_{\xi_t}^{\beta} dF(u_t) \\
&= \int_{\xi_t}^{\beta} \int_{\xi_t}^{u_t} dy \, dF(u_t) \\
&= \int_{\xi_t}^{\beta} \int_{y}^{\beta} dF(u_t) dy \\
&= \int_{\xi_t}^{\beta} (1 - F(y)) dy
\end{align*}
\]

\[ \text{Q.E.D} \]
Appendix 4.2

Assume a search process over a finite set of observations \( X = \{X_1, X_2, \ldots, X_k\} \) drawn from the distribution, \( F \), and define the variable \( z \) such that with \( j \) observations remaining (\( j \leq k \)), \( z = \max\{x_1, x_2, \ldots, x_j\} \). Let \( p \in (0, 1] \); then the maximum gain which can be expected at \( j \) is

\[
v^j_t(z;p) = \max(z, \omega^j_t(z;p))
\]

where

\[
\omega^j_t(z;p) = p \left( v^{j-1}_t(z)F(z) + \int_0^z v^{j-1}_t(x)dF(x) \right) + (1-p) \int_0^z v^{j-1}_t(x)dF(x) - \tilde{u}_t(\xi) \quad j = 1, \ldots, k
\]

\[
v^0_t(z;p) = z
\]

We wish to prove \( \frac{\partial \omega^j_t(z;p)}{\partial z} > 0 \) and \( \frac{\partial v^j_t(z;p)}{\partial z} > 0 \) for \( j = 1, \ldots, k \)

and \( p \in (0, 1] \).

Assume \( j = 1 \). Then

\[
\omega^1_t(z;p) = p \left( v^0_t(z)dF(z) + \int_0^z v^0_t(x)dF(x) \right) + (1-p) \int_0^z v^0_t(x)dF(x) - \tilde{u}_t(\xi)
\]

\[
= pz \int_0^z dF(x) + p \int_0^z xdF(x) + \int_0^z xdF(x) - p \int_0^z xdF(x) - \tilde{u}_t(\xi)
\]

262
\[ = pz \int_0^z dF(x) - p \int_0^z xdF(x) + \int_0^\beta xdF(x) - \tilde{u}_t(c) \]

Therefore

\[ \frac{\partial \omega_t^1(z; p)}{\partial z} = p \left( \int_0^z dF(x) + zf(z) - zf(z) \right) \]

\[ = pF(z) > 0 \quad \text{for } z > 0 \]

But \( v_t^1(z; p) = \max(z, \omega_t^1(z; p)) \Rightarrow \frac{\partial v_t^1}{\partial z} > 0. \)

Now assume the statements true for \( j = n-1. \) Then

\[ \frac{\partial \omega_t^{n-1}(z; p)}{\partial z} > 0 \quad \text{and} \quad \frac{\partial v_t^{n-1}(z; p)}{\partial z} > 0 \]

Let \( j = n; \) then

\[ \omega_t^n(z; p) = p \left( v_t^{n-1}(z)F(z) + \int_z^\beta v_t^{n-1}(x)dF(x) \right) \]

\[ + (1-p) \int_0^\beta v_t^{n-1}(x)dF(x) - \tilde{u}_t(c) \]

\[ = pv_t^{n-1}(z) \int_0^z dF(x) + p \int_z^\beta v_t^{n-1}(x)dF(x) + \int_0^\beta v_t^{n-1}(x)dF(x) \]

263
\[ -p \int_0^\beta v_t^{n-1}(x) dF(x) - \bar{u}_t(c) \]

\[ = pv_t^{n-1}(z) \int_0^z dF(x) - p \int_0^z v_t^{n-1}(x) dF(x) + \int_0^\beta v_t^{n-1}(x) dF(x) - \bar{u}_t(c) \]

\[ \frac{\partial \omega_t^n(z;p)}{\partial z} = p \left[ \frac{\partial v_t^{n-1}(z)}{\partial z} \int_0^z dF(x) + v_t^{n-1}(z)f(z) - v_t^{n-1}(z)f(z) \right] \]

\[ = p \left[ \frac{\partial v_t^{n-1}(z;p)}{\partial z} \right] F(z) \]

But \( \frac{\partial v_t^{n-1}(z;p)}{\partial z} > 0 \) by assumption, and therefore

\[ \frac{\partial \omega_t^n(z;p)}{\partial z} > 0 \] and \( \frac{\partial v_t^n(z;p)}{\partial z} > 0 \) for \( z > a \)

By induction then,

\[ \frac{\partial \omega_t^j(z;p)}{\partial z} > 0 \] and \( \frac{\partial v_t^j(z;p)}{\partial z} > 0 \) for \( j = 1, \ldots, k \).

Q.E.D.
Chapter 5
Empirical Tests on the Theoretical Framework

5.0 Introduction

The stopping rule models of search developed in Chapter 4 have been shown to exhibit relationships between search behavior and various stimuli which at least minimally satisfy our intuitive understanding of the residential search process. This chapter attempts to take the theoretical framework beyond intuition by empirically testing some of these relationships using data collected from a sample of households that, when interviewed, had recently moved to their current residences.

The analysis is an exploratory one as we recognize several limitations which preclude the direct testing of relationships identified in the model. The most serious limitations are two. The first relates to the correspondence between variables in the theoretical model and variables which are observed in empirical contexts. The second relates to the nature and quality of residential search data used in the analysis.

Variables in the theoretical framework are defined as they are to provide a plausible interpretation of a stopping rule characterization of search behavior. Here, a utility level at any given decision point is related to the marginal disutility of taking another observation, where the latter term is based upon the searcher's perceptions about the
distribution of utilities in his/her opportunity set. Thus utilities, probability distributions and factors which can alter these distributions are the generic elements of search behavior as characterized by the sequential decision framework. Elements of search activity which were defined in Chapter 4 include aspirations, disutility towards search, variation of utilities in the opportunity set, number of competitors in the sub-market being evaluated, degree of recall, number of opportunities remaining before the termination of search, etc.

In practice, however, variables such as these have only limited empirical meaning and surrogates are required. Relationships embodied in the theoretical framework can thus be only indirectly tested through empirically defined proxies.

We have shown in Chapter 4 that the aspiration utility of the searcher, which is not directly measurable, is related to two other variables that are susceptible to measurement and can be used as dependent variables for empirically examining relationships in the model. Both the number of alternatives evaluated in the search process and the quality of housing chosen by movers (using, for example, an hedonic index) are theoretically related to aspirations. Relating observations in the search sequence to specific intervals of time (Lippman and McCall, 1976a, p.157) defines a third observable measure of search: duration of search activity. As aspirations rise, both length of search (expressed both in terms of number of observations and time) and quality of chosen housing are expected to increase.

However, surrogate measures for the conditioning variables in the stopping rule framework have not been theoretically developed. And because they lack this theoretical foundation, their specification is
somewhat arbitrary and imprecisely defined from available measures on the data. Statistics inferred from the analysis of data must therefore be interpreted with caution, as considerable specification error is introduced in hypothesis development.

An example of how an hypothesis could be constructed to test relationships embodied in the theoretical model is instructive. We might (hypothetically) consider the search strategies of households owning automobiles compared to those who don't (controlling for socioeconomic and other factors). We can relate transportation to the model as follows: searchers lacking personal transportation are likely to incur higher search costs (in terms of time, money and effort) in their attempts to locate suitable housing. Furthermore, restricted access to more distant areas of the search field can be expected to reduce the variation in housing quality potentially available to the searcher. Now, high search costs (disutility) and reduced variation of utilities in the opportunity set both act (according to the theoretical framework) to depress aspirations. Therefore, ceteris paribus, we expect to find households owning no automobiles to:

- search for shorter durations of time
- evaluate fewer vacancies
- choose vacancies of poorer quality

than households owning one or more automobiles. Empirical measures required to indirectly test the theoretical relationship between aspirations and both search disutility and dispersion of utilities in the opportunity set are auto ownership, number of alternatives evaluated, duration of search, measures of housing quality and other variables
(for control purposes).

However, although these data requirements appear modest, few data bases are available which contain even the most rudimentary information about search behavior. Smith et al. (1979, p.3) have identified only two research efforts, those of Barrett (1973) and Hempel (1969a; 1969b), which are substantive empirical studies of search. In addition, MacLennan (1979a; 1979b) has studied search behavior using surveys of student and non-student populations in Glasgow, Scotland. Survey data of low income households in Pittsburgh and Phoenix from the Housing Allowance Demand Experiment, conducted for the U.S. Department of Housing and Urban Development (Weinberg et al., 1977), also contain some information about search activity as well. Empirical research on search behavior in the Los Angeles housing market is currently being supplemented by a data collection effort (Smith et al., 1979, p.19).

Data associated with each of these empirical studies have their weaknesses. Both Barrett and Hempel administered surveys to individual households after the search process had been completed. Although both data sets contain information about the spatial element of search and the way in which search was conducted, the retrospective nature of the surveys has likely introduced response bias into the data and eliminated considerable detail about the search process because of the amount of recall required of respondents. MacLennan had students maintain diaries of their search activities when they returned to their studies at the beginning of the school term and collected retrospective data from the non-student population for control purposes. But these data characterize search in a spatially and functionally restricted housing market, and

268
may not be applicable to other populations and contexts (see Hempel and Jain, 1978). The Housing Allowance Demand Experiment data, though longitudinal, do not characterize the spatial dimensions of search nor the order of vacancies evaluated by households; these latter data are therefore of limited value for the analysis of search behavior.

That little data concerning residential search behavior exist suggests that a modest approach to empirical analysis in this chapter is probably most appropriate. We expect few variables in the data to be acceptable surrogates for those in the theoretical model and this limits the number of hypotheses that are likely to be forthcoming from currently available data on search behavior. Given the quality of these data, only relatively unsophisticated statistical tests will be employed.

The data to be analyzed in this chapter are those derived from a home-interview survey undertaken in Metropolitan Toronto which was designed to assess the search and locational choice behavior of a sample of homeowners. This survey was administered and analyzed by Barrett (1973). Following a description of the data and their relevant characteristics in the next section, the chapter proceeds as follows. Section 5.2 develops a set of hypotheses for empirical examination, based upon the theoretical relationships derived and explored in Chapter 4. This section is followed by statistical tests on these hypotheses and their interpretation in the context of both the qualitative relationships embodied in the theoretical model and the quality of data used in the analysis. The findings of the empirical analysis and their implications for the theoretical framework are then summarized in a concluding
section.

5.1 Data

Data to be used in this analysis are based upon a retrospective survey of recent (at the time of the survey) movers from the six boroughs of Metropolitan Toronto: East York, Etobicoke, North York, Scarborough, York and the City of Toronto (Figure 5.1). The sample is a cross-section of households who were involved in residential property transactions between September and December of 1970. These households were identified in the Teela Digest, a bi-monthly listing of new property titles which indicated vendor, purchaser, date of closure, price paid for the property and mortgage arrangements. The sample was chosen by first excluding transactions involving commercial, industrial, non-developed residential property, transfer of ownership within a family, and double or triple selling of a property by speculators. Households were then drawn from each borough in proportion to the number of residential transactions recorded there.

Of 2,039 transactions recorded in the two issues of the Teela Digest used to define the population (January 15 and 30, 1971), 1,486 involved households moving to new residences. From the 1,486 households, 380 were administered the survey instrument. The number of households drawn from each borough is shown in Table 5.1. Additional details about the sample are given in Barrett (1973, p.12-18).

5.1.1 Characteristics of the Sample

Associated with each of the 380 observations in the sample are data which describe the household's socioeconomic characteristics,
<table>
<thead>
<tr>
<th>Borough</th>
<th>Number of Transactions in Borough(^1)</th>
<th>Borough Percentage of 1,486 Moves</th>
<th>Sample Size per Borough</th>
</tr>
</thead>
<tbody>
<tr>
<td>East York</td>
<td>47</td>
<td>3.2</td>
<td>12</td>
</tr>
<tr>
<td>Etobicoke</td>
<td>172</td>
<td>11.6</td>
<td>44</td>
</tr>
<tr>
<td>North York</td>
<td>344</td>
<td>23.2</td>
<td>88</td>
</tr>
<tr>
<td>Scarborough</td>
<td>289</td>
<td>19.5</td>
<td>74</td>
</tr>
<tr>
<td>City of Toronto</td>
<td>528</td>
<td>35.5</td>
<td>135</td>
</tr>
<tr>
<td>York</td>
<td>106</td>
<td>7.1</td>
<td>27</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>1,486</strong></td>
<td><strong>100.0(^2)</strong></td>
<td><strong>380</strong> (sample)</td>
</tr>
</tbody>
</table>

\(^1\) Residential property transactions, excluding non-developed residential property, transfer of ownership within a family and double or triple selling of a property by speculators, reported in the January 15 and 30, 1971 issues of the \emph{Teela Digest}.

\(^2\) Numbers do not add to total because of rounding.

Table 5.1 Spatial Distribution of Households in the Sample of Recent (1971) Movers in Metropolitan Toronto. (Source: Barrett, 1973, p.18).
conditions which precipitated the initial mobility decision, search activity which preceded choice of residence and environmental characteristics of the current (chosen) dwelling. These variables are discussed in detail below to reveal the type of information available for developing hypotheses for indirectly testing relationships embodied in the theoretical framework. Hypotheses are not specifically developed, however, until a later section of the chapter.

**Socioeconomic Variables**

The number of socioeconomic variables associated with each household in the data is few. Only total family income, number of children, ages of the youngest/oldest children, number of adults, age of the household head and the age of each reported adult are specifically related to the household's socioeconomic status. There are other variables in the data which may be indicative of socioeconomic status. These include duration of previous residence, former legal (tenure) status and workplace location. However, it may be argued that these latter variables are more related to mobility, search or location characteristics, discussed below.

Several important socioeconomic indicators are not present in the data. Sex of the household head, marital status, education and auto ownership are examples of missing data which could potentially be used as additional control variables in statistical tests, or for developing more hypotheses for testing the theoretical model. Auto ownership, as a variable for testing the combined relationship between aspiration utility and both search disutility and dispersion of utilities in the opportunity set (as described in Section .0) is an example of the
kind of hypotheses which cannot be tested for lack of appropriate or sufficient socioeconomic data in the sample.

Mobility Variables

Although this study is concerned with residential search behavior and the locational choices resulting from this search, several variables related to the decision to move are available in the data which could be used to develop hypotheses concerning search activity. These variables include previous type of dwelling, duration of previous residence and former legal (tenure) status. The latter two variables have already been cited above as quasi-socioeconomic indicators. A more important set of variables related to mobility, however, concerns the reasons given by households for choosing to move. From this set of reasons can be defined a dichotomy of forced and voluntary movers which may be used to attempt to validate the relationship between aspirations and the number of alternatives remaining in the searcher's opportunity set.

Search Variables

Most variables in the data relate to the search activities of households. These include methods by which alternatives were identified, duration of search activity, number of alternatives evaluated, familiarity with areas searched, locations of alternatives seriously considered and various statistics calculated from locational data.

Because only households who recently moved were surveyed, each observation in the sample defines a complete "search path". The entire sequence of locations considered from the time of the initial mobility
decision to the chosen alternative is identified for each household.\footnote{Generally, the number of alternatives claimed to have been evaluated and the number of evaluated alternatives the household could actually recall do not correspond in the data. This is discussed in greater detail in the following section.} That search has been completed allows us to define as dependent variables both the number of vacancies evaluated and the duration of search, which are (theoretically) directly related to aspirations. Since search is terminated only when the chosen alternative bears utility to the household at least as great as currently defined aspirations, more search activity, in terms of time or number of alternatives evaluated will, \textit{ceteris paribus}, be associated with higher aspirations. This relationship provides us with one part of the linkage between empirical and theoretical frameworks.

Several statistics were calculated from the survey data by Barrett (1973) which spatially quantify the search activity of households. These statistics include the average distance within the search cluster, distance from the former to current residence and an index of search concentration;\footnote{These statistics are defined in Table 5.2.} they have been evaluated by Barrett in considerable detail (1973, p.194-225). Since the intensity of search and index of search concentration are functions of one or both dependent variables related to search (number of alternatives and duration of search), they are not used as independent variables in the development and testing of hypotheses. However, certain distance statistics associated with each household could be assumed related to the variability of utilities in
the household's opportunity set in such a way as to suggest several hypotheses for testing. This is discussed further in Section 5.2.

**Location Variables**

There are five variables in the data associated with characteristics of the chosen alternative. For each household, data are available on present legal (tenure) status, reasons the household chose the current residence, the household's prior familiarity with the area (street) and how it became familiar with the area, and the price paid for the chosen dwelling.¹

Two problems exist with these data. First, they contain little information which can be related to environmental variables in the theoretical framework. For example, familiarity variables relate more to how spatial search areas are formed, and reasons for choice more to what constitute the most important elements of the searcher's utility function, than to theoretically-defined components of search identified in the stopping rule model. Price paid for housing, although indicative of housing quality chosen by the household, is too narrowly defined to be a proxy for quality or utility variables in the theoretical framework. (It is used as a surrogate for income in later sections, however.) Correspondence between the data and model is simply too obscure to allow the formulation of meaningful hypotheses.

A second problem is that there are no variables in the survey data, except location coordinates, which are common to both searched and chosen

¹This latter data item was extracted from the *Teela Digest*, not from the survey instrument (Barrett, 1973, p.45).
alternatives in the search sequence. This precludes the comparison of alternative housing opportunities in the household's search sequence unless survey data are supplemented from secondary sources. However, since this problem is one which is more critical in parametric model development and in the analysis of search paths chosen by households, its resolution is deferred to later chapters.

In summary, the survey data to be used in this chapter contain a number of variables which, by relating them to elements of the theoretical framework, may be employed to test relationships embodied in the stopping rule models of Chapter 4. A listing of these variables is given in Table 5.2. Although many hypotheses can be proposed which utilize these variables, the data appear to lack sufficient information for validating all relationships discussed in the previous chapter. Furthermore, many variables are defined such that very imprecise correspondence exists between theoretical and empirical frameworks. This means that the empirical analysis to be undertaken in this chapter is likely to be somewhat limited in scope and tentative in nature. More conclusive testing must await more informative data.

5.1.2 Limitations to the Analysis

Although Barrett's survey of recent movers in Metropolitan Toronto contains more information about search activity than perhaps any other available source, this information exhibits several sampling biases which could limit the application of empirical findings to more universal contexts.

One problem is that the sample consists almost entirely of homeowners. This is attributable to the method used to identify the
<table>
<thead>
<tr>
<th>Socioeconomic Variables</th>
<th>Mobility Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>total family income</td>
<td>previous type of dwelling</td>
</tr>
<tr>
<td>number of children</td>
<td>duration of previous residence</td>
</tr>
<tr>
<td>ages of oldest/youngest children</td>
<td>former tenure status</td>
</tr>
<tr>
<td>number of adults</td>
<td>mobility stimulus</td>
</tr>
<tr>
<td>age of household head</td>
<td>location of previous unit</td>
</tr>
<tr>
<td>ages of adults in household</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Search Variables</th>
<th>Location Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>duration of search</td>
<td>present tenure status</td>
</tr>
<tr>
<td>number of units searched</td>
<td>reasons for choosing current unit</td>
</tr>
<tr>
<td>initial search method</td>
<td>familiarity with chosen area</td>
</tr>
<tr>
<td>additional search methods</td>
<td>satisfaction with current unit</td>
</tr>
<tr>
<td>familiarity with searched areas</td>
<td>price paid for home</td>
</tr>
<tr>
<td>locations of units searched</td>
<td>location of chosen alternative</td>
</tr>
<tr>
<td>average distance of search cluster</td>
<td>workplace location(s)</td>
</tr>
<tr>
<td>intensity of search</td>
<td>distance from former to current residence</td>
</tr>
<tr>
<td>distance from origin to centroid of search cluster</td>
<td></td>
</tr>
<tr>
<td>index of search concentration</td>
<td></td>
</tr>
<tr>
<td>number of alternatives recalled</td>
<td></td>
</tr>
</tbody>
</table>

1 Locations of units which could be spatially recalled by searchers; number recalled usually differs from number claimed searched.

2 Statistics based upon only searched units whose locations could actually be recalled by households.

3 Average distance of the search cluster defined as the average distance from all points searched by the household to the centroid of the polygon connecting these points.

4 Intensity of Search = \[
\frac{\text{Number of Houses Searched}}{\text{Duration of Search}}
\]

5 Index of Search Concentration = \[
\frac{\text{Mean of Distances from all Vacancies Searched to Centroid of Vacancy Set}}{\text{Distance from Origin to Centroid of Search Cluster}}
\]

6 Data derived from Teela Digest; all others are from survey instrument.

Table 5.2 Variable Definitions in Survey Data on Recent Movers in Metropolitan Toronto
population of recent movers. The Teela Digest records only property transactions; no comparable information source exists for the rental market. A few households (less than 10 percent) were found to be renting housing units sampled in the survey, and are thus represented in the data, but this event occurred only in those situations where homes had been purchased and subsequently rented. Apartment renters are totally excluded from the sample. Differences (or similarities) in search behavior between owners and renters cannot, therefore, be imparted from the data.

The exclusion of renters also introduces an income bias into the sample. Barrett's investigation of housing prices in Metropolitan Toronto revealed lowest priced homes to sell for around $15,000 in 1971, requiring a household income of at least $6,000 annually to support this investment (Barrett, 1973, p.14). Lowest economic groups, which are generally confined to renter status, are therefore not represented in the sample.

Barrett also notes an age group bias in the sample, citing previous work on mobility by Rossi (1955), Simons (1968; 1971) and Boyce (1969) (see Barrett, 1973, p.15). These studies have suggested that movers tend to conform to distinct life-cycle classifications (see Chapter 2), with young married parents forming the largest group of movers; older households, on the other hand, have been found to move less frequently or move from houses to apartments. Households ranging in age from 25 to 40 years (household head) are probably disproportionately represented in the sample, while older households are likely under-represented (Barrett, 1973, p.15).
Two other biases relate to time. The sample is the product of a cross-sectional survey of households who moved between July 1970 and March 1971; most of these moves occurred in November and December of 1970. This suggests a possible bias from seasonal variations in housing market and household search activity.

Barrett (1973, p.16) reports that during 1970, there were 26,481 registered house sales in Metropolitan Toronto. The sample size of 380 was chosen to achieve a confidence level of 95 percent on the sample drawn from a population of 20,000 to 50,000 with sampling error for each attribute not to exceed 5 percent. However, the sample was actually drawn from a sub-population of 1,486 households representing real estate transactions which occurred over the September to December time period. Unless search behavior can be assumed to be uniform throughout the year, the survey may be incorporating an unspecified seasonal bias into the sample. That search behavior may vary seasonally can be attributed to climatic conditions, constraints related to childrens' schooling, variable supply-side activity resulting from climatic or other conditions (e.g. more new housing starts in the summer months) or other institutional factors (see Rosen, 1979).

A second, more fundamental problem concerns the retrospective nature of the survey. Retrospective responses to questions in surveys are often discounted (Smith et al., 1979, p.3) because of the tendency for respondents to consciously or unconsciously rationalize the motivations and actions which precipitated the event under study (Lyon and Wood, 1977, p.1171). Barrett attempted to minimize this bias by conducting interviews as close to the moving data as possible. As the survey instrument
was administered in February and March of 1971, the lag between move
and interview was typically two to four months (Barrett, 1973, p.16).

However, the sample remains biased from retrospection. This is
evidenced by the significant discrepancies between the number of alter-
 natives claimed to have been evaluated and the number of alternatives
whose addresses, or even approximate locations, could be recalled by
respondents. Despite claims by some households that they evaluated
many alternatives before choosing the current dwelling, the most that
could be recalled and spatially identified by any searcher was eight.
Whether attributable to human perceptual limitations (Miller, 1956) or
continual filtering of low potential alternatives (Gould, 1966), these
discrepancies illustrate the shortcomings associated with the present
data set.

5.1.3 A Profile of Sample Households

This section summarizes the salient characteristics of households
which comprise the sample to be analyzed in this chapter. The discus-
sion which follows is partially based upon analysis of data presented
(in considerably more detail) in Barrett (1973, p.45-144).

Socioeconomic characteristics of households are shown in Table 5.3.
Particularly evident in the table is the clustering of household heads
into the 25 to 44 year-old age category, revealing an age bias in the sample
referred to earlier. Barrett (1973, p.46) notes that heads of house-
holds in this sample are, on average, four to six years older than intra-
county migrants in general, revealing a fundamental age difference be-
tween homeowners and all movers (Simmons, 1968, p.635). The number of
children in households range from none to seven in the sample with 78
### Number of Households by Age of Household Head

<table>
<thead>
<tr>
<th>Age of Household Head (years)</th>
<th>&lt;20</th>
<th>20-24</th>
<th>25-29</th>
<th>30-34</th>
<th>35-39</th>
<th>40-44</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65-69</th>
<th>&gt;70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>1</td>
<td>14</td>
<td>69</td>
<td>86</td>
<td>78</td>
<td>46</td>
<td>29</td>
<td>28</td>
<td>14</td>
<td>9</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

### Number of Households by Number of Children

<table>
<thead>
<tr>
<th>Number of Children</th>
<th>None</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>108 (28.5)</td>
<td>86 (22.7)</td>
<td>102 (26.9)</td>
<td>58 (15.3)</td>
<td>13 (3.4)</td>
<td>6 (1.6)</td>
<td>14 (2.4)</td>
<td>0 (0.3)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

### Number of Households by Total Family Income

<table>
<thead>
<tr>
<th>Income (thousands of 1971 $)</th>
<th>&lt;5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>20-25</th>
<th>25-30</th>
<th>&gt;30</th>
<th>Refused</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>31 (8.2)</td>
<td>115 (30.3)</td>
<td>102 (26.9)</td>
<td>42 (11.1)</td>
<td>11 (2.9)</td>
<td>3 (0.8)</td>
<td>18 (4.7)</td>
<td>42 (11.1)</td>
<td>15 (4.0)</td>
</tr>
</tbody>
</table>

### Number of Households by Number of Other Adults

<table>
<thead>
<tr>
<th>Number of Other Adults in Household</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>15 (4.0)</td>
<td>276 (72.8)</td>
<td>40 (10.6)</td>
<td>35 (9.2)</td>
<td>10 (2.6)</td>
<td>2 (0.5)</td>
<td>0 (0.0)</td>
<td>1 (0.3)</td>
<td>0 (0.0)</td>
</tr>
</tbody>
</table>

Table 5.3 Profile of Socioeconomic Characteristics of Recent Movers in Metropolitan Toronto (n=379)
percent of households having two children or less. Barrett (1973, p.62) finds no distinct spatial patterning of households according to number of children. The majority of households in the sample fall within the $5,000 to $15,000 total family income range.

With respect to household mobility, the data show a significant shift from tenancy to ownership (Table 5.4). Formerly, 245 households rented their housing before moving to their current dwellings. Houses and apartments are usually identified as the previous type of unit. The desire for ownership shows up most clearly in households' responses to the question: "Why did you move from your previous residence?". Ownership was cited by 103 households, or 27 percent of the respondents in the survey; the only other notable response refers to space limitations in the previous dwelling, which was cited by 85 households (22 percent). The profile of households by duration of previous residence differs markedly from national estimates. Only seven percent of all households in the sample reported a previous move occurring within the past year, and only 69 percent reported one within the past 5 years, compared to Census estimates of 20 and 50 percent in the two categories, respectively (Statistics Canada, 1972; U.S. Bureau of the Census, 1966). However, these deviations are likely attributable to sampling bias in the Metropolitan Toronto survey, as renters, who are typically more mobile than homeowners (Pickvance, 1974), were excluded from the sample.

Statistics concerning household search activity are shown in Table 5.5. Note that the duration of search for most households was typically two months or less, although several families searched for a year or longer. Statistics on the number of houses searched reveals
### Number of Households by Past and Present Tenure Status

<table>
<thead>
<tr>
<th>Past Tenure Status</th>
<th>Present Tenure Status</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own</td>
<td>115</td>
<td>119 (31.4%)</td>
</tr>
<tr>
<td>Rent</td>
<td>219</td>
<td>245 (64.6%)</td>
</tr>
<tr>
<td>Parent</td>
<td>9</td>
<td>11 (2.9%)</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>4 (1.1%)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>345</td>
<td>379 (100%)</td>
</tr>
</tbody>
</table>

### Number of Households in Sample by Previous Type of Dwelling

<table>
<thead>
<tr>
<th>Type of Unit</th>
<th>House</th>
<th>Apartment</th>
<th>Flat</th>
<th>Duplex</th>
<th>Townhouse</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>226 (59.6%)</td>
<td>129 (34.0%)</td>
<td>4 (1.1%)</td>
<td>9 (2.4%)</td>
<td>3 (0.8%)</td>
<td>8 (2.1%)</td>
</tr>
</tbody>
</table>

### Number of Households by Primary Mobility Stimulus

<table>
<thead>
<tr>
<th>Mobility Stimulus</th>
<th>Number of Households (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced</td>
<td>32 (8.4%)</td>
</tr>
<tr>
<td>Dissatisfaction with Previous Unit/Location (&quot;push factors&quot;)</td>
<td>212 (55.9%)</td>
</tr>
<tr>
<td>- Space Limitations</td>
<td>85 (22.4%)</td>
</tr>
<tr>
<td>Attraction to Chosen Unit/Location (&quot;pull factors&quot;)</td>
<td>122 (32.2%)</td>
</tr>
<tr>
<td>- Desired Ownership</td>
<td>103 (27.2%)</td>
</tr>
<tr>
<td>Life-Cycle Changes</td>
<td>13 (3.4%)</td>
</tr>
</tbody>
</table>

### Number of Households by Duration of Previous Residence

<table>
<thead>
<tr>
<th>Duration of Previous Residence (years)</th>
<th>Number of Households (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (years)</td>
<td>28 (7.4%)</td>
</tr>
<tr>
<td>2</td>
<td>78 (20.6%)</td>
</tr>
<tr>
<td>3</td>
<td>78 (20.6%)</td>
</tr>
<tr>
<td>4</td>
<td>41 (10.8%)</td>
</tr>
<tr>
<td>5</td>
<td>38 (10.0%)</td>
</tr>
<tr>
<td>6</td>
<td>25 (6.6%)</td>
</tr>
<tr>
<td>7</td>
<td>16 (4.2%)</td>
</tr>
<tr>
<td>8</td>
<td>8 (2.1%)</td>
</tr>
<tr>
<td>&gt;8</td>
<td>67 (17.7%)</td>
</tr>
</tbody>
</table>

1 Rounded up to the nearest year.
2 First reason given for moving by surveyed households.
3 Aggregated from 30 initial categories (see Barrett, 1973, p.256).
4 Excluding death, divorce, and marriage which are considered as "forced".

**Table 5.4** Profile of Mobility Characteristics of Households in the Survey of Recent Movers in Metropolitan Toronto (n=379)
### Number of Households in Sample by Duration of Search

<table>
<thead>
<tr>
<th>Duration of Search (months)</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
</tr>
</tbody>
</table>

### Number of Households by Number of Units Searched

<table>
<thead>
<tr>
<th>Number of Units Searched</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>52</td>
<td>109</td>
<td>65</td>
<td>28</td>
<td>63</td>
<td>26</td>
<td>3</td>
<td>3</td>
<td>30</td>
</tr>
</tbody>
</table>

### Number of Households Using Information Channels as Initial Source

<table>
<thead>
<tr>
<th>Information Channel</th>
<th>Newspaper</th>
<th>Real Estate Agent</th>
<th>Localized Notices</th>
<th>Personal Contacts</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>104</td>
<td>116</td>
<td>95</td>
<td>39</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(27.4)</td>
<td>(30.6)</td>
<td>(25.1)</td>
<td>(10.3)</td>
<td>(8.6)</td>
</tr>
</tbody>
</table>

### Subsequent Use of Information Channels

<table>
<thead>
<tr>
<th>Information Channel</th>
<th>Newspaper</th>
<th>Real Estate Agent</th>
<th>Localized Notices</th>
<th>Personal Contacts</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Times Information Channel Used (percent)</td>
<td>59</td>
<td>145</td>
<td>310</td>
<td>104</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>(9.5)</td>
<td>(23.3)</td>
<td>(49.8)</td>
<td>(16.7)</td>
<td>(0.6)</td>
</tr>
</tbody>
</table>

Table 5.5 Profile of Search Characteristics of Households in the Survey of Recent Movers in Metropolitan Toronto (n=379)
a similar bias towards foreshortened search activity. Nearly 60 percent of surveyed households evaluated less than eight alternatives; less than 10 percent evaluated 30 alternatives or more.\(^1\) Combining duration of search with number of houses searched reveals a predominant search profile of households evaluating only a few selected alternatives over short periods of time before making the final decision.

The most important information channel used by households, both initially and subsequently in this predominantly owner-occupied submarket, is the real estate agent.\(^2\) Newspapers also appear to be important, but only during the initial stages of search, which lends support to the notion of hierarchical ordering of information channels by households to accommodate different information requirements during different stages of search, as discussed in Chapter 3.

Profiles of households with respect to locational choice variables are shown in Table 5.6. Households' responses to the question, "Why did you choose this house?", appear to center around two major concerns related to financing and design of the new residence. Neighborhood amenities and characteristics, and public services are also considered to be relatively important criteria in the location decision. This is consistent with most of the literature on residential location (see Chapter 2).

---

\(^1\) That such an important decision is tendered in such a short period of time leads Barrett (1973, p.139) to question the rationality of the search process undertaken by most households. Similar arguments have been made by Lyon and Wood (1977).

\(^2\) Localized notices are considered predominantly realtor-related in the Metropolitan Toronto housing market.
### Number of Households in Sample by Primary Reasons for Choosing Unit

<table>
<thead>
<tr>
<th>Reason for Choice</th>
<th>Number of Households (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Characteristics of Unit</td>
<td>195 (51.5)</td>
</tr>
<tr>
<td>Neighborhood Amenities</td>
<td>41 (10.8)</td>
</tr>
<tr>
<td>Accessibility Characteristics</td>
<td>10 (2.6)</td>
</tr>
<tr>
<td>Financial Considerations</td>
<td>93 (24.5)</td>
</tr>
<tr>
<td>Public Services</td>
<td>37 (9.8)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (0.8)</td>
</tr>
</tbody>
</table>

#### Number of Households Previously Familiar with Chosen Area/Street

<table>
<thead>
<tr>
<th>Area</th>
<th>Street</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td></td>
</tr>
<tr>
<td>265</td>
<td>159</td>
</tr>
<tr>
<td>(69.9)</td>
<td>(42.0)</td>
</tr>
</tbody>
</table>

#### Dissatisfaction with Current Residence

<table>
<thead>
<tr>
<th>With Home</th>
<th>With Neighborhood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>(5.5)</td>
<td>(5.3)</td>
</tr>
</tbody>
</table>

#### Number of Households by Price Paid for Chosen Unit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Households (percent)</td>
<td>37</td>
<td>165</td>
<td>114</td>
<td>52</td>
<td>16</td>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>(9.8)</td>
<td>(43.5)</td>
<td>(30.1)</td>
<td>(8.4)</td>
<td>(4.2)</td>
<td>(2.9)</td>
<td>(0.5)</td>
<td>(0.5)</td>
</tr>
</tbody>
</table>

*First reason given for choosing current residence.

Table 5.6 Profile of Households' Residential Choices in the Survey of Recent Movers in Metropolitan Toronto (n=379)

287
Prices paid for housing range from $12,000 to $83,000; the mean housing price in the sample is approximately $28,000, which compares favorably with the average price paid for housing in all of Metropolitan Toronto in 1971, $30,550 (see Barrett, 1973, p.72). Over 50 percent of houses bought by sample households lie within a $12,000 range, from $22,000 to $34,000.

Statistics shown in Tables 5.3 through 5.6 exhibit the basic socio-economic, mobility, search and locational choice parameters associated with sample households. They indicate the types of variables available for formulating hypotheses and reveal how these variables are distributed in the data. From these statistics we find the data to be reasonably consistent with other data on mobility and locational choice behavior, although characteristics specific to the owner-occupied housing market have been noted. Given this information, we can now turn to the development of testable hypotheses.

5.2 Hypotheses for Testing

The goal of this chapter is to empirically substantiate theoretically-derived relationships between aspirations and various environmental variables embodied in the stopping rule characterization of residential search behavior described in Chapter 4. To achieve it, this section develops a number of hypotheses which are contingent upon an assumed correspondence between variables defined in the data and those in the theoretical framework.

Ideally, several hypotheses should be constructed for each of the fundamental relationships found to exist in the stopping rule characterization of search to ensure that spurious relationships are not inferred.
from the data through misspecification of (theoretical) variables. However, data limitations have effectively eliminated three theoretical relationships from further empirical analysis. The impacts of competition, learning and recall upon search behavior cannot be meaningfully investigated with present data.

To ensure that the linkages between empirical and theoretical "models" are understood, each hypothesis is briefly discussed before being formally defined. Note that each hypothesis is actually two as both the "number of alternatives evaluated" and the "duration of search" variables are used as surrogates for the aspirations of searchers. This linkage has been discussed both in Chapter 4 and in the previous section. For convenience, hypotheses are developed in the contexts of the theoretical relationships to which they most closely correspond.

5.2.1 Disutility of Search

In Section 4.3.1 we showed that higher disutilities towards search, which were related to search costs, tend to depress the aspirations of individuals evaluating alternatives in a sequence. Furthermore, we conjectured that higher disutilities resulted from either actual changes in the costs of conducting search ("objectively" defined elements such as time, money or effort) or changing attitudes towards search. Ceteris paribus, an individual who experiences higher search costs and/or values his/her time or resources more should have lower aspirations, and therefore should be expected to evaluate fewer vacancies, and search for a shorter period of time, than one who does not.

Search costs and attitudinal variables which may be directly related to the individual's disutility towards search are not available
in the data. However, income may be suggested to be an approximate indicator of the household's ability to bear the monetary and temporal costs of search.

Income may be related to the disutility of search in two ways. First, higher incomes provide households with more financial resources for undertaking their search activities. Costs, which can relate to child care, access to vacancies, information acquisition, or other factors, are more easily borne by households in higher income categories, which should enable them to undertake more extensive searches of candidate opportunities. But counter to this, searchers in higher income categories are also likely to value their time more than lower income searchers. Since search requires a significant commitment of time from the searcher, those individuals who value their time highly can be expected to attempt to minimize their time spent searching for housing.

The interplay of these two competing factors may cause them to offset one another and produce ambiguous results if we attempt to isolate them in empirical tests. However, our data provide us with two measures of search activity which are so defined to possibly enable us to separate the two income effects. Since higher incomes provide greater resources for undertaking search, we might conjecture a positive relationship between income and the number of alternatives searched. But since individuals with higher incomes usually value their time more highly, we might conjecture a negative relationship between income and duration of search. We are suggesting that higher income families will search more intensively for housing by evaluating more vacancies in a shorter period of time. Clearly, their resources allow this type
of activity to take place.

These arguments lead us to our first set of hypotheses to be tested on the data. They attempt to represent the theoretical relationship between aspirations and the disutility towards search discussed in Chapter 4.

\( H_1: \text{There exists a positive relationship between household income and number of houses searched.} \)

\( H_2: \text{There exists a negative relationship between household income and duration of search.} \)

The null hypotheses for both \( H_1 \) and \( H_2 \) are that no relationships exist between these search variables and income.

5.2.2 Variation of Utilities in the Opportunity Set

The variation of utilities in the opportunity set has been suggested as an indicator of the uncertainty of opportunity facing the searcher. Opportunity sets containing widely variable housing alternatives allow for the possibility that the searcher may choose an inferior alternative through biased sampling. But on the other hand, variable opportunity sets allow for the possibility of locating a vastly superior alternative, or "bargain", through the sampling process. The nature of the decision rule for choosing a vacancy in the stopping rule model of search is such that more variable opportunity sets are "preferred" by searchers. Aspirations have been shown to increase with the variation of utilities in the individual's opportunity set.

The concept of an opportunity set is an abstract one. It has been characterized in the theoretical framework by a distribution function with some or all of its parameters known by the searcher. Variation of
utilities in the opportunity set has been defined by one or more of the distribution function's higher moments. Neither of these concepts can be empirically defined with the present data.

However, several variables may be suggested as surrogates for variability. For example, Chapter 3 described alternative information agents available to searchers and how many of these agents tend to specialize in different housing sub-markets in the search area. We might then conjecture the variation of utilities in the searcher's opportunity set to be related to the number of information channels used during search. Those households employing several information agents are likely to be aware of a wider variety of housing opportunities than are those households using few to aid their search. Households using more information agents might then be suggested to evaluate more alternatives and search for longer durations of time than households using less. This forms the basis for a first set of hypotheses relating to variability in the opportunity set.

\[ H_3: \] There exists a positive relationship between the number of information agents used by the household during search and the number of houses searched.

\[ H_4: \] There exists a positive relationship between the number of information agents used by the household during search and duration of search activity.

Null hypotheses for \( H_3 \) and \( H_4 \) admit no relationships between the number of information agents used in search and both number of houses searched and duration of search activity.

Although we expect these hypotheses to be supported by the data, statistical results must be tempered by the likelihood of poor corres-
pondence between the empirical variable and the theoretical one it is supposed to represent. Households could conceivably use several different information agents to define an extremely narrow housing sub-market. For example, the hierarchical use of different information agents could be used for this purpose. In an attempt to minimize search costs, one set of information channels could be used initially to locate the particular sub-market of interest before the household intensified the search effort using more costly information sources. Under this search strategy, number of information agents used during search would be totally unrelated (or possibly inversely related) to dispersion of utilities in the opportunity set.

However, other search-related phenomena can be related to variability as well. One indirect measure is the number of children of searching households. Although more of a constraint in the rental market, a large number of children in the family can constrain the types and locations of houses which may be considered suitable. For example, larger families must consider space requirements particularly, and probably accessibility and neighborhood characteristics more carefully, than families with fewer children. Simply put, families with large numbers of children must find larger units than households with none or few children. Given current supply characteristics of the housing market, we conjecture that families with large numbers of children generally face a less variable opportunity set than do households having fewer children. If this is so, we expect larger households to search for shorter periods of time and to evaluate fewer vacancies than smaller households. Therefore, the following hypotheses are proposed.
\( H_5 \): There exists a negative relationship between the number of children in a household and the number of houses searched.

\( H_6 \): There exists a negative relationship between the number of children in a household and the duration of search activity.

No relationships between number of children in a household and search variables are articulated in null hypotheses for \( H_5 \) and \( H_6 \).

Note that negative relationships between the number of children in the household and the two dependent search variables, if found to exist in the data, are likely reflecting several forces concurrently operating upon the household. For example, large families are likely to face higher search costs than small ones because of expenses related to child care, problems in organizing the search activity and, possibly, less disposable income for search because of other familial priorities. Constraints related to school terms may limit search activity both spatially and temporally. Thus, empirical support for these hypotheses cannot be attributed solely to the theoretically-defined relationship between aspirations and dispersion of utilities in the opportunity set. Support may only suggest the presence of this relationship.

A more precise correspondence between the data and the concept of variability in the theoretical model can be developed, however. Since the locations of each of the vacancies recalled by households are recorded in the data,\(^1\) a spatial measure of variability can be obtained.

\( ^1 \)Recall that the number of vacancies claimed evaluated and the number actually recalled by households are not always consistent in the data (see Barrett, 1973, p.205).
Barrett (1973, p.205-217) defines this variability statistic as the average distance of the household's search cluster and has used it to test whether distance and sectoral biases exist in households' search patterns (see Adams, 1969; Brown and Holmes, 1970; Brown and Moore, 1970). To use the statistic as a measure of variability of utilities in the individual's opportunity set requires two assumptions. First, the identified search area, defined by the set of vacancies recalled by households, must be assumed to approximate reasonably the area actually searched (defined by the area containing all opportunities claimed to have been evaluated by households). Second, we must assume that spatial variation is a reasonable proxy for quality variations in the housing stock and, thus, utility variations in the searcher's opportunity set. Since the average distance of the search cluster over the entire sample is only slightly more than a mile (Barrett, 1973, p.209), this latter assumption may not be true. However, sufficient variation in housing quality often exists at the block and neighborhood level, particularly in dense urban and suburban areas. We shall assume, therefore, that these two assumptions hold in proposing the following hypotheses.

\[ H_7: \text{There exists a positive relationship between the average distance of the household's search cluster and the number of houses searched.} \]

\[ H_8: \text{There exists a positive relationship between the average distance of the household's search cluster and duration of search activity.} \]

\[ ^1 \text{This is defined in Table 5.2.} \]
We again formulate null hypotheses that admit no relationships between average distance of the search cluster and the two measures of search activity.

These hypotheses, in conjunction with hypotheses $H_3$ through $H_6$ constitute the empirical tests on the relationship between aspirations and dispersion of utilities in the opportunity set to be performed in this chapter.

5.2.3. Forced Mobility

In the theoretical analysis, it was suggested that forced mobility is one of several constraints that potentially characterize a particular sampling process that can be imposed upon the stopping rule framework. It is a sampling process whereby only a finite number of vacancies may be observed; this constraint is known to the decision maker undertaking search. The model has shown that aspirations decline as this forced stopping point is approached. Furthermore, aspirations of searchers in a finite sampling scheme, ceteris paribus, are always less than those of searchers allowed to sample indefinitely.

This latter statement suggests an empirically testable hypothesis. If searchers employing (relatively) limited sampling strategies include households forced from their previous residences, then forced movers should be expected to evaluate fewer vacancies and search for a shorter duration of time than households who move on their own volition.

The survey of recent movers in Metropolitan Toronto specifically asked respondents for their reasons for moving, from which can be inferred whether the mobility decision was voluntary or not. More important, however, is whether the forced/non-forced dichotomy is sufficient
to distinguish the alternative sampling strategies considered by the theoretical framework. This is particularly critical given the rather eclectic definition of "forced" used to define the dichotomy in the following section, and suggests that a somewhat fuzzy correspondence between the empirical forced/voluntary dichotomy and the theoretically-defined finite/infinite dichotomy (in sample sizes) is likely to exist. Although this problem of correspondence can be expected to obfuscate empirical results considerably, we would like to explore whether there exists some degree of support in the data for the theoretical relationship between number of alternatives that can be sampled and aspirations. Against null hypotheses expecting no relationship to be exhibited, the following hypotheses are proposed.

\[ H_9: \text{Households forced}^1 \text{ from their previous residences evaluate fewer alternatives than voluntary movers.} \]

\[ H_{10}: \text{Households forced}^1 \text{ from their previous residences search for shorter durations of time than voluntary movers.} \]

5.2.4 Summary

We have suggested in this section a set of hypotheses which, within the limitations of available data, are to be used to attempt to validate the stopping rule characterization of the residential search process as developed in Chapter 4. These hypotheses are summarized in Table 5.7. They provide, however, only a partial test of the theoretical framework, as insufficient empirical information exists to examine the effects of

^1Forced movers are defined in Section 5.3.3.
<table>
<thead>
<tr>
<th>Theoretical Relationship Being Assessed</th>
<th>Hypothesis</th>
<th>Description of Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspiration Utility and Disutility Towards Search</td>
<td>$H_1$</td>
<td>There exists a positive relationship between household income and number of houses searched.</td>
</tr>
<tr>
<td></td>
<td>$H_2$</td>
<td>There exists a negative relationship between household income and duration of search activity.</td>
</tr>
<tr>
<td>Aspiration Utility and Variability in the Opportunity Set</td>
<td>$H_3$</td>
<td>There exists a positive relationship between the number of information channels used by the household and number of houses searched (duration of search activity).</td>
</tr>
<tr>
<td></td>
<td>$H_4$</td>
<td>There exists a negative relationship between the number of children in a household and number of houses searched (duration of search activity).</td>
</tr>
<tr>
<td></td>
<td>$H_5$</td>
<td>There exists a positive relationship between the average distance of the household's search cluster and number of houses searched (duration of search activity).</td>
</tr>
<tr>
<td></td>
<td>$H_6$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$H_7$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$H_8$</td>
<td></td>
</tr>
<tr>
<td>Aspiration Utility and the Number of Alternatives Remaining in the Opportunity Set</td>
<td>$H_9$</td>
<td>Households forced from their previous residences evaluate fewer alternatives (search for shorter durations of time) than voluntary movers.</td>
</tr>
</tbody>
</table>

1All tests are to be analyzed in relation to null hypotheses expecting no relationships between variables.

Table 5.7 Hypotheses to be Tested in the Empirical Analysis

298
competition, learning and recall upon the search behavior of households. Furthermore, for those elements of the stopping rule model subject to empirical scrutiny, the correspondence between variables in the theoretical framework and those in the data is often inexact and is expected to introduce considerable "noise" into statistics used to test the hypothesized relationships. Empirical results of this chapter should therefore be interpreted with caution and should be considered tentative until further data are available which more precisely characterize the elements of search behavior defined in the theory. With these _caveats_, the empirical analysis is presented in the next section.

5.3 **Empirical Tests on Hypotheses**

Before attempting to substantiate the relationships hypothesized in the previous section, we first define an appropriate set of statistics for interpreting the data. These statistics are non-parametric since, as it was argued above, problems of correspondence exist between empirical and theoretical variables, rendering the interpretation of parameters from more sophisticated tests meaningless.

The majority of variables in the data are measured in either nominal or ordinal scales. Even where more informative interval or ratio-scale measurement was made, data were usually categorized (by Barrett) into ranges from which only rank-order information can be extracted. Variables to be used in this section are primarily ordinal, including the forced/voluntary dichotomy of movers (Nie _et al._, 1975, p.5).

To remain consistent with data characteristics, then, non-parametric tests, which simply suggest the existence of relationships and/or measure rank-order correlations, are applied in this section. The data are first
cross-tabulated to reveal whether associations between variables can be
qualitatively identified. Chi-square tests are applied to cross-tabu-
lated variables to determine whether any of the identified associations
are statistically significant. Rank-order correlations using Kendall's
tau or gamma statistics are then applied to measure both the direction
and strength of relationships in the data. The utility of these sta-
tistics for interpreting relationships among ordinal data has been dis-
cussed in several references (see Blalock, 1972; Nie et al., 1975).

Although it would be preferable to control for factors suspected
of influencing relationships between primary variables in hypotheses,
this approach is generally not taken in the chapter. This is due to
the size of the sample which, given the number of categories in which
most variables are defined, is too small to support multidimensional
contingency tables and associated statistical tests. Where elaboration
of hypothesized relationships is deemed important, categories are first
aggregated before control variables are included.

Most hypotheses to be tested in this section are "paired"; that is,
if a relationship is proposed to exist between an independent variable
and one of dependent search variables, then a similar one is expected
between it and the other dependent variable.¹ The dependent variables,
number of houses evaluated and duration of search, are therefore assumed
to be correlated. Before testing the proposed hypotheses, we first ex-
amine this assumption.

¹The only exception concerns hypotheses $H_1$ and $H_2$ where the relation-
ship between income and duration of search is expected to be opposite to
that between income and number of houses evaluated (see p.290).
A cross-tabulation of dependent search activity variables is shown in Table 5.8. The table suggests a relationship between number of houses evaluated and duration of search, as expected. A raw chi-square value of 178.7 with 64 degrees of freedom indicates that this relationship is statistically significant at the .01 level. A statistically significant rank-order correlation (Kendall's tau b) of .33 supports the assumed positive association between the two variables: households that search over longer periods of time are therefore expected to evaluate more alternatives than those that search over shorter intervals, and vice versa. Note, however, that a perfect relationship between dependent variables does not exist, as a large number of off-diagonal elements appear in the table, and suggests that other factors are affecting the relationship between duration of search and number of houses evaluated. We have hypothesized in Section 5.2.1 that one of these intervening factors is income, which is examined in the following section. In general, however, we expect this "pairing" of hypotheses to hold in most empirical analyses discussed in this chapter.

5.3.1 Disutility of Search

We proposed in Section 5.2.1 that measures of household income may be appropriate surrogates for search disutilities, and that income may, in fact, show two fundamental relationships between disutility of search and search behavior: one involving how the searcher values his/her time, and the other reflecting objectively defined costs faced by the searcher.

---

1 All non-parametric tests performed in this chapter were run on SPSS software, Version M, Release 7.1, July 11, 1977 (see Nie et al., 1975), on an IBM 370/168.
<table>
<thead>
<tr>
<th>Duration of Search Activity (months)</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>19</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>1</td>
<td>24</td>
<td>56</td>
<td>31</td>
<td>9</td>
<td>18</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>153</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>20</td>
<td>6</td>
<td>7</td>
<td>11</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>54</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>6-12</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>13-24</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>&gt;24</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>34</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>52</td>
<td>109</td>
<td>65</td>
<td>28</td>
<td>63</td>
<td>26</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 178.7 with 64 degrees of freedom.\(^1\)
Kendall's tau b = 0.33\(^1\)

\(^1\)Statistically significant at the .01 level.

Table 5.8 Cross-tabulation of Duration of Search Activity with Number of Houses Searched
during the search and evaluation process.

Although the survey attempted to obtain total family income for each observation, 57 respondents either refused to divulge their incomes or, for other reasons, were unable to provide the necessary information. Furthermore, of those who reported income data, several incomes were found to be inconsistent with actual household circumstances (Barrett, 1973, p.72). These data are therefore useless in their present form for performing rank-order correlation tests with search activity variables. Rather than biasing statistical results by using only those respondents who revealed their income, ¹ another measure of income has been used, total price paid for the chosen alternative. This measure has been shown to be related to household income and has been used in that context by several authors (see de Leeuw, 1971). Price data are available for each observation and have been derived independently (by Barrett) from the Teela Digest, which was used to select the sample. These data therefore incorporate no biases from retrospection or other factors.

Cross-tabulations between price paid for the chosen alternative and search activity variables are given in Tables 5.9 and 5.10. The data reveal that, at best, only very weak relationships appear to exist between dependent and independent variables. In neither case are chi-

¹Barrett (1973, p.68) notes that households who refused to divulge income data were those generally residing in high income suburban areas of Metropolitan Toronto. Therefore, any statistical tests on only that portion of the sample with reported incomes would likely be biased, and hypothesized relationships could not be generalized to the population of home-owners. Insufficient data were available to statistically match households for estimating the incomes of non-reporting households.
<table>
<thead>
<tr>
<th>Price Paid for House (thousands of 1971 $)</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-19</td>
<td>9</td>
<td>12</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>20-29</td>
<td>25</td>
<td>57</td>
<td>32</td>
<td>9</td>
<td>20</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>11</td>
<td>165</td>
</tr>
<tr>
<td>30-39</td>
<td>10</td>
<td>27</td>
<td>18</td>
<td>11</td>
<td>24</td>
<td>10</td>
<td>0</td>
<td>2</td>
<td>12</td>
<td>114</td>
</tr>
<tr>
<td>40-49</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>50-59</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>60-69</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>70-79</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>80-89</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

| TOTAL                                     | 52 | 109 | 65  | 28   | 63    | 26    | 3     | 3     | 30  | 379   |

Raw Chi-square = 62.1 with 56 degrees of freedom.\(^1\)
Kendall's tau c = 0.14\(^2\)

\(^1\) Not statistically significant.
\(^2\) Statistically significant at the .01 level.

Table 5.9 Cross-tabulation of Income (Measured by Price Paid for Chosen Alternative) and Number of Houses Searched
## Duration of Search Activity (months)

<table>
<thead>
<tr>
<th>Price Paid for House (thousands of 1971 $)</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-19</td>
<td>3</td>
<td>16</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>37</td>
</tr>
<tr>
<td>20-29</td>
<td>14</td>
<td>69</td>
<td>26</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>15</td>
<td>165</td>
</tr>
<tr>
<td>30-39</td>
<td>9</td>
<td>47</td>
<td>19</td>
<td>8</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>114</td>
</tr>
<tr>
<td>40-49</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>50-59</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>60-69</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>70-79</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>80-89</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 38.0 with 56 degrees of freedom.\(^1\)

Kendall's tau c = 0.06\(^2\)

\(^1\) Not statistically significant.

\(^2\) Statistically significant at the .05 level.

---

Table 5.10 Cross-tabulation of Income (Measured by Price Paid for Chosen Alternative) and Duration of Search Activity
square values significant, meaning that null hypotheses cannot be re-
jected. The rank-order correlation coefficient (Kendall's tau c) be-
tween the income proxy and number of houses searched is significant and
of the expected sign. However, the income surrogate and duration of
search are positively rather than negatively correlated, although the
significance and strength of this relationship is less than that be-
tween income and number of houses searched.

More elaborate cross-tabulations between house price, duration of
search and number of alternatives evaluated tend to confirm these
findings. Cross-tabulating duration of search against number of houses
searched, but controlling for house price, reveals positive relation-
ships between variables in all categories (Table 5.11). If income
affected search behavior as hypothesized, we would expect negative
correlations between search activity variables in lowest and highest
housing price categories. Cross-tabulations of price paid for the home
with duration of search, controlling for number of houses searched, and
of price paid for the home with number of houses searched, controlling
for duration of search, generally do not reveal significant associations,
although the (weak) relationships usually have expected signs. That is,
when the number of houses searched is controlled, the relationship be-
tween the income proxy and duration of search is negative in the majority
of cases: households in higher income categories appear to search for
shorter durations of time. Conversely, when duration of search is con-
trolled, households who paid more for their housing search more inten-
sively and thus evaluate more alternatives in a given period of time.
However, relatively insignificant associations between variables,
### Table 5.11 Cross-tabulation of Duration of Search Activity with Number of Houses Searched Controlling for Income (Measured by Price Paid for the Chosen Alternative)

<table>
<thead>
<tr>
<th>Duration of Search Activity (months)</th>
<th>1-4</th>
<th>5-10</th>
<th>11-20</th>
<th>21-30</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>14</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>2-3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>4-5</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6-24</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>&gt;24</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>21</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>37</td>
</tr>
</tbody>
</table>

Raw chi-square = 20.8 with 12 degrees of freedom.\(^1\)
Kendall's tau c = 0.34\(^2\)
Conditional Gamma = 0.57
Income\(^6\) = $10-20K

<table>
<thead>
<tr>
<th>Duration of Search Activity (months)</th>
<th>1-4</th>
<th>5-10</th>
<th>11-20</th>
<th>21-30</th>
<th>&gt;30</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>26</td>
<td>14</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>56</td>
</tr>
<tr>
<td>2-3</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>2</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>4-5</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>6-24</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>&gt;24</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>37</td>
<td>29</td>
<td>24</td>
<td>10</td>
<td>14</td>
<td>114</td>
</tr>
</tbody>
</table>

Raw chi-square = 35.4 with 16 degrees of freedom.\(^2\)
Kendall's tau b = 0.25\(^2\)
Conditional Gamma = 0.33
Income\(^6\) = $30-60K

<table>
<thead>
<tr>
<th>Duration of Search Activity (months)</th>
<th>1-4</th>
<th>5-10</th>
<th>11-20</th>
<th>21-30</th>
<th>&gt;30</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td>11</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>2-3</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>4-5</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>6-24</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>&gt;24</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>21</td>
<td>15</td>
<td>13</td>
<td>4</td>
<td>10</td>
<td>63</td>
</tr>
</tbody>
</table>

Raw chi-square = 12.0 with 16 degrees of freedom.\(^3\)
Kendall's tau b = 0.15\(^5\)
Conditional Gamma = 0.19
Income\(^6\) > $40K

Zero Order Gamma = 0.41
First-Order Partial Gamma = 0.42

\(^1\)Statistically significant at the .05 level.
\(^2\)Statistically significant at the .01 level.
\(^3\)Not statistically significant.
\(^4\)Income measured by price paid for the chosen alternative.
\(^5\)Statistically significant at the .1 level.
measured by chi-square statistics, preclude any substantive interpretation of these relationships.

To summarize, the data do not unambiguously support hypotheses regarding the differential effects of income on the two search activity variables. Higher family incomes do not encourage households to curtail the duration of time they spend searching nor do lower incomes restrict the number of houses searched, ceteris paribus. Rather, relationships between income and both measures of search activity appear to be the same: households with greater incomes can be expected to search longer and evaluate more alternatives than households with lower incomes. Income does influence search behavior according to the data. This is revealed in zero-order and first-order gamma statistics in Table 5.11. But differential income effects upon the two measures of search activity do not appear to exist.

This finding leads to an interesting conjecture about utility functions of searchers. If we assume the theoretical relationship between aspirations and disutility to be correct, and the empirical one between income and search activity to approximate it within acceptable limits, then (objective) costs considerations in search appear to play a more important role in determining search behavior than how those components of cost are valued by households, ie. search costs may be valued about the same by households despite differences in income.

However, this should only be considered a conjecture at present, since the data are not informative enough to test it. Furthermore, it has been predicated upon a relationship involving an income variable, measured by the purchase price of the chosen alternative, which is, in
fact, thrice removed from its theoretical counterpart, disutility
towards search.

Empirical analysis has revealed, then, that the data do not
support the original hypotheses, $H_1$ and $H_2$, although they do not reject
a more general contention that search activity, both in terms of dura-
tion of search and number of houses searched, is positively related
to income.

5.3.2 Variation of Utilities in the Opportunity Set

The theoretical framework has shown that greater uncertainty in
the opportunity set tends to raise the aspirations of searchers. More
uncertain search situations are therefore expected to be associated with
households who search for longer periods of time and evaluate more alter-
natives than with those who undertake little search activity. Uncer-
tainty has been defined in the theoretical model in terms of a probabi-
licity distribution over the utilities of vacancies in the searcher's
opportunity set; more uncertain situations are those associated with
more variable distributions.

We have suggested three surrogate variables for variability of
utilities in the opportunity set: number of information agents used
during search, number of children in the household and the average
distance of the household's search cluster. For the first and third
variables, positive relationships with both measures of search activity
are hypothesized. Number of children in the household is conjectured
to be negatively associated with search activity variables.

Cross-tabulations for each measure of opportunity set variability
with both measures of search activity are shown in Tables 5.12 through
5.17. In all cases, relationships are in the expected direction, although the degrees of association between independent variables and duration of search are less significant than those with number of houses searched, particularly when variability is measured by number of children and average distance of the household's search cluster. For both of these variables, we cannot reject null hypotheses associated with the conjectured associations between these measures of variability and duration of search activity in chi-square tests. Rank-order correlations between search activity variables and both the number of information agents used and average distance of the household's search cluster are highly significant; the expected inverse relationships between number of children and search activity are less so, however. This latter finding may indicate a problem of specification rather than lack of support for the theoretical relationship, as numbers of children in the family may not be an important constraint in locating appropriate housing, particularly in the owner-occupied sub-market. Number of children may thus be an inappropriate surrogate for perceived housing quality variations in households' opportunity sets.

Overall, statistical tests on measures of variability in searchers' opportunity sets and search activity show some empirical support for the hypotheses developed in Section 5.2.2. The data reject null hypotheses associated with the number of information agents used during search, number of children in the household and average distance of the search cluster, to number of alternatives searched, as all relationships are of the expected sign and are significant. The data indicate, however, that measures of variability in the opportunity set are more significantly
### Number of Houses Searched

<table>
<thead>
<tr>
<th>Number of Information Agents</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>29</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>28</td>
<td>20</td>
<td>9</td>
<td>20</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>7</td>
<td>107</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>24</td>
<td>24</td>
<td>7</td>
<td>23</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>104</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>15</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>12</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>52</td>
<td>109</td>
<td>65</td>
<td>28</td>
<td>63</td>
<td>26</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 113.6 with 56 degrees of freedom.\(^1\)

Kendall's \( \tau_c \) = 0.18\(^1\)

\(^1\) Statistically significant at the .01 level.

Table 5.12 Cross-tabulation of Number of Information Channels Used During Search and Number of Households Searched
### Duration of Search Activity (months)

<table>
<thead>
<tr>
<th>Number of Information Agents</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>36</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>38</td>
<td>11</td>
<td>12</td>
<td>9</td>
<td>3</td>
<td>12</td>
<td>4</td>
<td>12</td>
<td>107</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>46</td>
<td>17</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>10</td>
<td>6</td>
<td>7</td>
<td>104</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>15</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>15</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 78.1 with 56 degrees of freedom.\(^1\)

Kendall's tau c = 0.11\(^2\)

\(^1\)Statistically significant at the .05 level.

\(^2\)Statistically significant at the .01 level.

Table 5.13 Cross-tabulation of Number of Information Channels Used During Search and Duration of Search Activity
<table>
<thead>
<tr>
<th>Number of Children in Household</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>23</td>
<td>18</td>
<td>9</td>
<td>21</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>10</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>32</td>
<td>16</td>
<td>2</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>26</td>
<td>12</td>
<td>10</td>
<td>21</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>102</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>19</td>
<td>15</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>52</td>
<td>109</td>
<td>65</td>
<td>28</td>
<td>63</td>
<td>26</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 82.4 with 56 degrees of freedom.¹
Kendall's tau c = -0.05²

¹Statistically significant at the .01 level.

²Statistically significant at the .1 level.

Table 5.14 Cross-tabulation of Number of Children in Household and Number of Houses Searched
<table>
<thead>
<tr>
<th>Number of Children in Household</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>39</td>
<td>20</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>11</td>
<td>7</td>
<td>9</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>40</td>
<td>9</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>86</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>45</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>11</td>
<td>102</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>19</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 63.2 with 56 degrees of freedom.¹

Kendall's tau c = -0.04¹

¹Not statistically significant.

Table 5.15 Cross-tabulation of Number of Children in the Household and Duration of Search Activity
### Table 5.16  Cross-tabulation of Average Distance of Household's Search Cluster and Number of Houses Searched

<table>
<thead>
<tr>
<th>Average Distance of Search Cluster (miles)</th>
<th>Number of Houses Searched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>.01-1.00</td>
<td>44</td>
</tr>
<tr>
<td>1.01-2.00</td>
<td>1</td>
</tr>
<tr>
<td>2.01-3.00</td>
<td>0</td>
</tr>
<tr>
<td>3.01-4.00</td>
<td>0</td>
</tr>
<tr>
<td>4.01-5.00</td>
<td>0</td>
</tr>
<tr>
<td>5.01-6.00</td>
<td>0</td>
</tr>
<tr>
<td>6.01-7.00</td>
<td>0</td>
</tr>
<tr>
<td>7.01-8.00</td>
<td>0</td>
</tr>
<tr>
<td>8.01-9.00</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>52</td>
</tr>
</tbody>
</table>

Raw Chi-square = 130.9 with 72 degrees of freedom.\(^1\)

Kendall’s tau c = 0.23\(^1\)

\(^1\)Statistically significant at the .01 level.
<table>
<thead>
<tr>
<th>Average Distance of Search Cluster (miles)</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>0.01-1.00</td>
<td>20</td>
<td>94</td>
<td>30</td>
<td>15</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>209</td>
</tr>
<tr>
<td>1.01-2.00</td>
<td>5</td>
<td>25</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>2.01-3.00</td>
<td>1</td>
<td>14</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>43</td>
</tr>
<tr>
<td>3.01-4.00</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>4.01-5.00</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>5.01-6.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>6.01-7.00</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7.01-8.00</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8.01-9.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-Square = 75.5 with 72 degrees of freedom.\(^1\)
Kendall's tau c = 0.14\(^2\)

\(^1\) Not statistically significant.

\(^2\) Statistically significant at the .01 level.

Table 5.17  Cross-tabulation of Average Distance of Household's Search Cluster and Duration of Search Activity
related to number of alternatives searched than to duration of search, as associations between the latter variable and both number of children in the household and average distance of the search cluster are not statistically significant in chi-square tests.

5.3.3 Forced Mobility

A final set of hypotheses considered in this chapter concerns how constraints on the number of alternatives the searcher is allowed to sample influence search activity. To represent this, we have related these constraints to the concept of forced mobility in this and in the previous chapter. In defining forced mobility for empirical analysis, we have partitioned the data on reasons for moving into two categories from 30 previous ones. Households whose first response to the survey question regarding their reasons for moving was one of the following: demolition of the previous residence; selling of the previous residence (forcing renters to vacate); death, divorce or marriage in the family; eviction because of children; or, unspecified forced mobility (landlord forced), have been defined as involuntary movers for the analysis.\textsuperscript{1} All other reported moves were assumed voluntary. The sample therefore includes 32 forced and 347 voluntary movers when this classification scheme is used.

Cross-tabulations between mobility (forced/voluntary) and search activity variables are shown in Tables 5.18 and 5.19. In neither case are statistically significant chi-square values found. Even when the tables are collapsed to 10 cells, by aggregating the number of alterna-

\textsuperscript{1}This is the same classification scheme used by Barrett (1973, p.97).
<table>
<thead>
<tr>
<th>Mobility Stimulus</th>
<th>1</th>
<th>2-4</th>
<th>5-7</th>
<th>8-10</th>
<th>11-20</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>&gt;50</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary</td>
<td>49</td>
<td>100</td>
<td>57</td>
<td>25</td>
<td>56</td>
<td>24</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>347</td>
</tr>
<tr>
<td>Forced</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>TOTAL</td>
<td>52</td>
<td>109</td>
<td>65</td>
<td>28</td>
<td>63</td>
<td>26</td>
<td>3</td>
<td>3</td>
<td>30</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 5.8 with 8 degrees of freedom.¹
Kendall's tau c = -0.006¹

¹Not statistically significant.

Table 5.18 Cross-tabulation of Mobility Stimulus with Number of Houses Searched
<table>
<thead>
<tr>
<th>Mobility Stimulus</th>
<th>&lt;1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6-12</th>
<th>13-24</th>
<th>&gt;24</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary</td>
<td>26</td>
<td>140</td>
<td>48</td>
<td>25</td>
<td>17</td>
<td>17</td>
<td>23</td>
<td>18</td>
<td>33</td>
<td>347</td>
</tr>
<tr>
<td>Forced</td>
<td>3</td>
<td>13</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>TOTAL</td>
<td>29</td>
<td>153</td>
<td>54</td>
<td>27</td>
<td>17</td>
<td>18</td>
<td>28</td>
<td>19</td>
<td>34</td>
<td>379</td>
</tr>
</tbody>
</table>

Raw Chi-square = 7.2 with 8 degrees of freedom.\(^1\)
Kendall's tau c = -0.02\(^1\)

\(^1\)Not statistically significant.

Table 5.19 Cross-tabulation of Mobility Stimulus with Duration of Search Activity
tives searched and duration of search to five categories to compensate for the number of observations on forced mobility, no discernible associations can be found between mobility stimulus and search activity. Rank-order correlation coefficients, though of the expected sign, are statistically insignificant and essentially reveal the variables to be completely independent. Null hypotheses associated with hypothesized relationships cannot, therefore, be rejected.

Rather than negating the fundamental relationship between finite sampling strategies and aspirations, which is embodied in the theoretical model, these empirical results instead exhibit the weaknesses associated with the data, particularly the classification scheme used to define the forced/voluntary dichotomy, and the logic used to relate forced mobility to the theoretical concept of a finite sampling strategy. That few observations on "forced" movers are available tends to reduce the variability of the data along this dimension, which can be expected to affect significance levels. Similar problems of significance can be attributed to the vague definition of "forced mobility" used to classify households, which has likely introduced considerable noise into the data. Households who moved because of life-cycle changes (marriage, divorce, death) may not have been any more forced to move than those who moved because of dissatisfaction with the previous housing/location package or because of various "pull" factors which influenced their decision. Differences in search and choice behavior among these households may thus be minimal (Moore, 1972, p.4). Finally, the association of forced mobility with constrained opportunity, even at an abstract level, is not necessarily correct. If this is the case, empirical
tests on mobility stimulus/search activity relationships are not validating any corresponding relationships embodied in the theoretical model and a priori specification of hypotheses $H_9$ and $H_{10}$ is largely unjustified.

Clearly, these problems cannot be solved without better data. Eliminating all but truly forced movers from the "forced" category renders the sample too small to undertake any meaningful tests. Even if an unambiguous dichotomy between forced and voluntary movers was available, problems of correspondence between it and the concept of constrained opportunity would not be resolved. Obviously, a better measure of constrained opportunity is needed to validate that aspect of the theoretical framework, a measure not available in the current data set.

5.3.4 Summary of Hypothesis Tests

The results of empirical tests on proposed hypotheses concerning a subset of relationships embodied in the theoretical framework are somewhat ambiguous (Table 5.20). Although supporting the hypothesized relationship between search activity and quality variations in the opportunity set, the data do not support associations between income and search activity. An alternative hypothesis relating income directly with both measures of search activity -- duration of search and number of alternatives searched -- has been suggested as more appropriate than hypotheses $H_1$ and $H_2$, which attempted to isolate attitudinal and objective influences on search behavior.

The rejection of hypotheses relating mobility stimulus (a forced/voluntary dichotomy) to search activity cannot be reconciled with the
<table>
<thead>
<tr>
<th>Theoretical Relationship Being Assessed</th>
<th>Hypothesis</th>
<th>Variables</th>
<th>Observed Empirical Relationship</th>
<th>Outcome of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspiration Utility and Disutility Towards Search</td>
<td>$H_1$</td>
<td>Number of Houses Searched; Income$^2$</td>
<td>positive$^3$</td>
<td>$^5$</td>
</tr>
<tr>
<td></td>
<td>$H_2$</td>
<td>Duration of Search Activity; Income$^2$</td>
<td>positive$^3$</td>
<td>$^5$</td>
</tr>
<tr>
<td>Aspiration Utility and Variability of Utilities in the Opportunity Set</td>
<td>$H_3$</td>
<td>Number of Houses Searched; Number of Information Channels</td>
<td>positive</td>
<td>$H_0$ rejected</td>
</tr>
<tr>
<td></td>
<td>$H_4$</td>
<td>Duration of Search Activity; Number of Information Channels</td>
<td>positive</td>
<td>$H_0$ rejected</td>
</tr>
<tr>
<td></td>
<td>$H_5$</td>
<td>Number of Houses Searched; Number of Children in Household</td>
<td>negative</td>
<td>$H_0$ rejected</td>
</tr>
<tr>
<td></td>
<td>$H_6$</td>
<td>Duration of Search Activity; Number of Children in Household</td>
<td>negative$^3,4$</td>
<td>$H_0$ not rejected</td>
</tr>
<tr>
<td></td>
<td>$H_7$</td>
<td>Number of Houses Searched; Average Distance or Search Cluster</td>
<td>positive</td>
<td>$H_0$ rejected</td>
</tr>
<tr>
<td></td>
<td>$H_8$</td>
<td>Duration of Search Activity; Average Distance of Search Cluster</td>
<td>positive$^3$</td>
<td>$^5$</td>
</tr>
<tr>
<td>Aspiration Utility and the Number of Alternatives Remaining to be Sampled</td>
<td>$H_9$</td>
<td>Number of Houses Searched; Mobility Stimulus$^6$</td>
<td>negative$^{3,4,7}$</td>
<td>$H_0$ not rejected</td>
</tr>
<tr>
<td></td>
<td>$H_{10}$</td>
<td>Duration of Search Activity; Mobility Stimulus$^6$</td>
<td>negative$^{4,7}$</td>
<td>$H_0$ not rejected</td>
</tr>
</tbody>
</table>

$^1$Directionality of relationship measured by rank-order correlation coefficients.

$^2$Income as measured by price paid for the chosen alternative.

$^3$Raw chi-square test not statistically significant.

$^4$Rank-order correlation coefficient not statistically significant.

$^5$Outcome of test is inconclusive.

$^6$Mobility stimulus as a voluntary/forced mobility dichotomy.

$^7$Positive relationship - forced movers evaluate fewer houses and search for shorter durations of time than voluntary movers.

Table 5.20  Summary of Empirical Tests of Hypotheses
theory, however. But this has been attributed to inadequate data rather than model structure, since problems related to the number of observations in the "forced" category, the arbitrary classification of movers in the dichotomy, and correspondence between the theoretical concept of constrained opportunity and mobility stimulus are likely preventing any meaningful analyses from being made.

5.4 Summary

This chapter has attempted to provide empirical support for the stopping rule models of residential search behavior developed in Chapter 4. Because of the structure of the theoretical framework, however, this validation exercise has required the specification of surrogate variables from a limited data set. Many variables in the theoretical model simply have no measurable counterparts in the real world. Thus, only some of the relationships examined in the theoretical model have been translated into testable hypotheses and subjected to empirical analysis. In several tests, the data have failed to support hypotheses, although some of these findings have been attributed to problems of correspondence between theory and data, rather than inherent inconsistencies in the theoretical framework itself. Failure to substantiate the models can also be attributed to the rather unsophisticated statistical tests performed on the data.

Clearly, more meaningful empirical results could be obtained if the theoretical model conformed closer to the realities of data than does the current framework. Although the data are extremely limited, an appropriately specified model might provide empirical verification for the sequential decision framework that is more substantive than the
evidence uncovered in this chapter.

This is the intent of Chapter 6. It is to develop an empirical counterpart to the theoretical model, which retains the essential characteristics of the sequential decision framework but can also be calibrated to data. The development of this model and the estimation of its parameters follow in the next two chapters.
Chapter 6
An Empirical Model of Residential Search Behavior

6.0 Introduction

Although data quality contributes to the ambiguous empirical results obtained in the previous chapter, it is also true that the variables in the theoretical stopping rule framework and the empirically observable phenomena (represented by data), which relate to actual residential search activity, are fundamentally incompatible. These incompatibilities have precluded the testing of several interesting relationships embodied in the theoretical model and have helped to obfuscate the findings of those empirical tests which have been conducted. Thus, although the sequential decision-theoretic approach to modeling residential search behavior may provide a more plausible conception of the residential search and selection process than the traditional paradigm, we have not been able to validate it in empirical tests.

This chapter attempts to overcome some of these problems of compatibility by developing an empirical model of residential search behavior which more closely conforms to available search data. By taking this approach, we expect to use the data more efficiently to gain greater insight about the validity of relationships in the theoretical model. By specifying the model parametrically, we hope, furthermore,
to go beyond the theoretical framework and to begin to assess the relative importance of each of those environmental and behavioral factors found in Chapter 4 to qualitatively influence search activity.

The criteria for developing this empirical model are three. One is that it should retain the essential structural characteristics of search activity as conceived in the stopping rule framework so that the theoretical formalism can be validated. Decision rules in the theoretical model were founded upon the assumption that the searcher sampled sequentially from either a finite or infinite opportunity set. This sampling rule was chosen because, in Chapter 3, it was argued to be a more realistic characterization of residential search than alternative paradigms, which usually assumed choice to evolve from the simultaneous evaluation of a well defined and collectively exhaustive set of alternatives. Clearly, the sequential nature of search must be retained in the empirical model for it to plausibly represent the search process as conceived in the theoretical model and as it is likely to exist in reality. The empirical model must furthermore incorporate search costs and the individual's attendant disutility towards these costs, since this disutility term has been shown in theory to define, in part, the utility level (aspirations) upon which the location decision is made, and is a factor not recognized in traditional modeling approaches.

A second criterion concerns the behavioral assumptions of the theoretical framework. Stopping rule models assume an implicit rationality on the part of the searcher whereby the individual's net utility (the utility of the chosen alternative minus the disutility of accumulated search costs) is maximized over a sequence of random drawings from a known distribution of vacancies. What is important about this
objective function is the decision rule which results; it is essentially a satisficing principle, which was suggested in Chapter 3 to more appropriately characterize decision making behavior under the uncertain conditions suspected to exist in urban housing markets. To accommodate the theory, the empirical model should therefore be structured to reflect decision rules which embody some form of satisficing behavior on the part of the searcher.

A final criterion which must be satisfied is that the empirical model must conform more closely to the observable characteristics of search behavior than does the theoretical one. This, in essence, implies that the specification of the model must be such that it can be calibrated to data.

It is the purpose of this chapter to construct an empirical model which satisfies these criteria and thus, which characterizes search behavior in urban housing markets in such a way that relationships among the factors considered important in search can be quantified and tested.

The model is conceptually similar to the theoretical framework in that locational choice evolves from a sequence of choices, each of which is predicated upon the utilities ascribed by the individual to alternatives. Choice at each decision point in the sequence is also an optimal one, i.e. the searcher chooses the alternative having greatest utility, and therefore the expected net payoff (utility) from search is maximized over the entire sequence. However, the utilities associated with alternatives, and thus the evaluation criteria considered by the searcher, are specifically identified and parameterized by estimating choice probabilities derived from choice-theoretic principles. This allows us to
apply the model directly to data in order to identify significant empirical relationships which exist in the sample.

The development of the model proceeds as follows. Since the theoretical basis for the empirical model is fundamentally different from the sequential decision framework developed in Chapter 4, the chapter first reviews choice theory and its application to problems involving discrete alternatives. Following this, a conceptual framework for empirically characterizing the search process is formulated. This framework and the choice-theoretic principles developed in the previous section are then brought together to specify the empirical model to be estimated in the following chapter. After reviewing this model's properties and limitations in the context of the criteria set out in this introduction, a concluding section summarizes the chapter.

6.1 A Theory of Individual Choice Behavior

To understand the behavioral basis of the empirical model, let us abstract from the sequential decision process and consider a situation where the individual is required to choose one of n mutually exclusive and collectively exhaustive alternatives from a well defined choice set, \( A = \{a_1, a_2, \ldots, a_n\} \). We assume in each case that the individual's utility can be expressed as a function of socioeconomic characteristics, \( s \), and a vector, \( x \), of the attributes of alternatives being considered. At any decision point, a complete ordering of alternatives based upon these utilities is assumed to exist, which constitutes "rational behavior" on the part of the individual. This ordering has the usual reflexive, symmetric and transitive properties required for mathematical treatment of the problem. The individual is assumed to choose that alternative
impacting greatest utility at any decision point.

Although, theoretically, optimal decisions can be expected from rational decision making, observational deficiencies and unobserved variations in behavior add an element of randomness to observed choice behavior, making rational choices appear otherwise (McFadden, 1974, p.308). This precludes the formulation of deterministic statements about choice behavior and allows only the estimation of probabilities of choosing alternatives.

Situations which can lead to observational difficulties have been summarized by Manski (1973, p.13-14) into the following four classes of problems:

- **Omitted Structure**: a subset of variables known to influence the individual's utility functions are not observed (or are not available in data).

- **Cross-Sectional Preference Variation**: parameters associated with each variable in the individual's utility function are fixed, but vary across the population in an unknown manner.

- **Instrumental Variables**: instrumental or surrogate variables are used to specify the individual's utility function because some elements of utility are not directly measurable in available data.

- **Imperfect Information**: the utility function of the individual is estimated upon the observed attributes of alternatives and the individual's socioeconomic characteristics which, themselves, are subject to measurement error when, in fact, choice is predicated upon perceived measures of these attributes and characteristics.

Manski argues that choice behavior in these situations is most appropriately modeled probabilistically, i.e. by assuming that the individual's utility function is stochastic. Furthermore, although each situation leads to a different type of randomness, under appropriate
assumptions about the nature of the error introduced, utility functions in all four observational circumstances can be specified by a linear in the parameters, additive in the disturbances (LPAD) stochastic structure.

Thus, we may express the individual's utility function as $U(x,s)$, where:

$$U(x,s) = V(x,s) + \varepsilon(x,s) \quad (6.1.1)$$

In this relation, $V$ is the non-stochastic component of utility and comprises the observed, representative characteristics of the population. This function is of the form:

$$V(x,s) = \beta_1 v^1(x,s) + \ldots + \beta_k v^k(x,s) \quad (6.1.2)$$

where $v^i(x,s)$, $i = 1, \ldots, k$ are specified numerical functions or transformations, and the $\beta_i$ are unknown parameters (McFadden, 1974, p.113). The function $\varepsilon(x,s)$ in (6.1.1) is stochastic with mean independent of $x$ and represents the uncertainties brought about by the observational difficulties referred to above.

Now, consider a multiple choice situation involving the choice set $A = \{a_1, \ldots, a_n\}$, where each alternative, $i$, is characterized by an attribute vector, $x^i$. We assume that the individual chooses, say, the $i^{th}$ alternative if:

$$U(x^i,s) > U(x^j,s) \quad \text{for } j = 1, \ldots, n; j \neq i \quad (6.1.3)$$

The probability of this event occurring, assuming the probability of $U_i = U_j = 0$, is simply:

$$P_i = \text{Prob} \left[ U(x^i,s) > U(x^j,s); j = 1, \ldots, n; j \neq i \right] \quad (6.1.4)$$

330
which, by (6.1.1) is equivalent to:

\[ P_i = \text{Prob} \left[ V(\mathbf{x}_i, s) + \varepsilon(\mathbf{x}_i, s) > V(\mathbf{x}_j, s) + \varepsilon(\mathbf{x}_j, s); \ j = 1, \ldots, n; \ j \neq i \right] \]

\[ = \text{Prob} \left[ \varepsilon(\mathbf{x}_j, s) - \varepsilon(\mathbf{x}_i, s) < V(\mathbf{x}_i, s) - V(\mathbf{x}_j, s); \ j = 1, \ldots, n; \ j \neq i \right] \]

(6.1.5)

Let \( F(t_1, \ldots, t_n) \) denote the joint cumulative distribution function of \((\varepsilon(\mathbf{x}_1, s), \ldots, \varepsilon(\mathbf{x}_n, s))\) and define its derivative with respect to the \( i \)th argument to be \( F_i \). Given this, (6.1.5) becomes (Domencich and McFadden, 1975, p.52):

\[ P_i = \int_{-\infty}^{\infty} F_i(t + V_i - V_1, \ldots, t + V_i - V_n) dt \]

(6.1.6)

The specific functional form of \( P \) depends upon the specification of a joint distribution function, \( F \). For example, if \((\varepsilon(\mathbf{x}_1, s), \ldots, \varepsilon(\mathbf{x}_n, s))\) are distributed multivariate normal with mean zero and covariance matrix, \( \Sigma \), then \( P_i \) is a probit function of the form:

\[
P_i = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \psi(r; \mathbf{0}, \Sigma) dr_1 dr_{i-l} dr_{i+l} dr_n
\]

(6.1.7)

where \( \psi \) is a multivariate normal density function evaluated at \( r \) with mean vector, \( \mathbf{0} \), and covariance matrix \( \Sigma \).

On the other hand, if \((\varepsilon(\mathbf{x}_1, s), \ldots, \varepsilon(\mathbf{x}_n, s))\) are independent random variables having identical Gumbel distributions, then \( P_i \) is a logistic function, \textit{i.e.}
\[
\frac{\exp(V(x^i, s))}{\sum_{j=1}^{n} \exp(V(x^j, s))}
\]  (6.1.8)

Other choice probability functions can be derived from different assumptions about the distribution of the stochastic components of the individual's utility function (see Domencich and McFadden, 1975, p.68).

Clearly, the functional form of any probabilistic choice model is highly dependent upon assumptions concerning the distribution of the stochastic component of the individual's utility function. However, specification of the "correct" distribution for the situation at hand is problematic. Although, as Manski (1973, p.18) has shown, appropriate distribution functions can theoretically be associated with particular observational circumstances or processes generating the randomness, those processes which actually occur in empirical contexts generally cannot be identified. For example, if we consider the observational deficiencies in the Metropolitan Toronto survey with which the parameters of the empirical model in this chapter are to be estimated, we can expect all four classes of problems described earlier to be contributing to the randomness in the data. Since the resulting composite stochastic term has unknown (and likely complex) properties, assumptions concerning its distribution which produce a tractable analytical expression for choice probabilities must generally be made. Usually, the stochastic components of utility are assumed to have joint normal or independent Gumbel distributions, resulting in the probit and logit models of (6.1.7) and (6.1.8), respectively.

The probit model is considered theoretically more attractive because assumptions concerning the stochastic components of utility are
more robust. In multiple choice situations, the joint distribution 
\( \varepsilon(x_1, s), \ldots, \varepsilon(x_n, s) \) can be parameterized by a covariance matrix, allowing for dependencies among alternatives. Furthermore, the normal distribution provides reasonable approximations to many other multivariate distributions, particularly in large samples (Hausman and Wise, 1976, p.10). However, the probit model cannot be expressed in closed functional form and this characteristic considerably increases the computational burden and costs of statistical estimation procedures (Domencich and McFadden, 1975, p.58; Sheffi, 1979, p.193).

The logit model, on the other hand, is considered attractive for computational reasons. Because each choice probability function is a closed form expression, and the likelihood function used to estimate the model is strictly concave (McFadden, 1974, p.118), parameters of the model may be easily estimated using any algorithm that converges. Furthermore, logit and probit functions are virtually equivalent when the error terms are independent, except at the tails of their cumulative distribution functions, and produce virtually identical probability estimates in many empirical applications (Domencich and McFadden, 1975, p.58).

However, the logit model embodies an assumption which is implausibly strong in many situations. The independence from irrelevant alternatives (IIA) assumption (Luce, 1959), which derives from the proposition that the stochastic components of the individual's utility associated with each alternative are independent random variables, states that the relative odds of two alternatives being chosen are independent of the presence or absence of any other non-chosen alternatives in the choice set. Several authors (Mayberry, 1970; Florian and Fox, 1976; Daganzo and Sheffi,
1977) have shown that, because of this assumption, logit models applied
to choice situations involving alternatives with positively correlated
utilities tend to overestimate choice probabilities, although these esti-
mates may sometimes be corrected by appropriate respecification of the
choice set (Hausman and Wise, 1976, p.2).

These arguments suggest that the acceptability of the more computa-
tionally convenient logit specification is largely dependent upon the
context in which it is applied. For example, choice probabilities asso-
ciated with the simultaneous evaluation of alternatives with correlated
random components can be expected to be biased if these probabilities
are assumed to be logistically distributed. Similarly, choice probabili-
ties representing sequential choice activities, where alternatives are
nested or ranked\(^1\), and are thus implicitly dependent, can be shown to be
more appropriately modeled assuming the stochastic elements of utility
to be joint normal rather than independently Gumbel distributed (Sheffi,
1979).\(^2\) The degree to which disturbance terms are likely to be correlated
and the suitability of alternative choice models for characterizing the
sequential decision problem are issues discussed in the empirical model's
development, which is undertaken in the next section.

---

\(^1\) Choice among nested alternatives refers to situations where choosing
the \(i^{th}\) opportunity implies that opportunities 1,2,..., (i-1) have also
been chosen.

\(^2\) McFadden (1977) has shown that dependence among alternatives can also
be represented in a family of generalized extreme value (GEV) choice
models, of which the multinominal logit model is a special case. The
advantage of the GEV specification is that it can be structured to
explicitly recognize dependence among the unobserved attributes of alter-
natives in the choice set, yet yields a closed form for the choice prob-
babilities. Furthermore, the GEV specification (as do logit and probit)
defines a choice model which is consistent with utility maximization,
a property not shared by other choice models proposed in the literature
(see McFadden, 1977, p.5-6).
6.2 Specification of the Empirical Model

We develop the empirical model by first outlining a conceptual framework which considers the individual, \( t \), sequentially evaluating a set of alternative vacancies drawn from an opportunity set (Figure 6.1). To simplify the structure of the model and make it conform to available data\(^1\), we assume that the searcher cannot recall previously observed alternatives. At each observation, \( i \), then, the searcher chooses either to discontinue search and accept the current housing opportunity or to continue searching for at least another observation. Each decision in the sequence is based upon utility measures on the alternatives; if the utility of continuing beyond \( i \), defined as \( U_{ct}^i \), is greater than the utility of stopping and choosing the current opportunity, \( U_{dt}^i \), then search is continued for at least another observation.

We assume, because of observational deficiencies and preference variations, that the utility functions associated with alternatives at each stage, \( i \), are stochastic. As in the previous section, each function, \( U_t^i \), can therefore be considered to be composed of a deterministic component, \( V_t^i \), of measurable attributes, and a stochastic error term, \( \epsilon_t^i \). Maintaining consistency with Manski (1973), we assume the utility functions to possess an LPAD (linear in the parameters, additive in the disturbances) stochastic structure. Therefore, the stochastic utility term can be functionally represented as:

\(^1\)Repeated observations of vacancies are not recorded in the Metropolitan Toronto data set and cannot, thus, be accounted for in the empirical model. Also, all searchers in the data are movers. This precludes the opportunity for investigating the behavior of households who searched but decided to remain at their current residences.
Figure 6.1 Conceptual Framework for Developing the Empirical Model
\[ U_t^i (v_t, \varepsilon_t^i) = V (x_t^i, s_t^i) + \varepsilon (x_t^i, s_t^i) \]  

(6.2.1)

where \( x_t^i \) and \( s_t^i \) are as defined previously, and \( V \) is defined in (6.1.2).

With these assumptions and the choice-theoretic framework discussed in Section 6.1, we can now characterize the decision rule used by the searcher in terms of probabilities. Since choice is strictly binary and without the privilege of recall, then at the \( i \)th observation, the individual \( t \) will discontinue search and choose the current housing unit, given that he/she has rejected all opportunities up to that point, if and only if:

\[ u_{dt}^i > u_{ct}^i \]  

(6.2.2)

which occurs with probability:

\[ p_{dt}^i = \text{Prob} \left[ u_{dt}^i > u_{ct}^i \right] \]

\[ = \text{Prob} \left[ V_d (x_t^i, s_t^i) + \varepsilon_d (x_t^i, s_t^i) \geq V_c (x_t^i, s_t^i) + \varepsilon_c (x_t^i, s_t^i) \right] \]

\[ = \text{Prob} \left[ \varepsilon_c (x_t^i, s_t^i) - \varepsilon_d (x_t^i, s_t^i) < V_d (x_t^i, s_t^i) - V_c (x_t^i, s_t^i) \right] \]  

(6.2.3)

Conditional choice probabilities associated with each decision in the sequence and the determinants of search behavior can therefore be derived by specifying the distribution of error terms, \( \varepsilon_{dt}^i \) and \( \varepsilon_{ct}^i \) (or the distribution of their differences), and defining the attribute vectors associated with the alternatives.

We recognize the elements of search behavior from the theoretical framework in the empirical model by using the relationships examined in
Chapter 4 to suggest appropriate variables to be included in the searcher's utility function. From this framework, we note that the utility of stopping at \( i, U^i_{dt} \), is simply the "payoff" or, in this case, the utility of the \( i^{th} \) vacancy, and is therefore solely a function of the attributes of the housing/location package perceived by the searcher to be important and his/her socioeconomic characteristics. Clearly, the results of previous empirical research into residential location behavior can be used to develop a candidate set of relevant variables.

The utility of continuing beyond \( i, U^i_{ct} \), is exactly the aspiration utility, \( a^i_t \), in the theoretical framework, which was shown in Chapter 4 to be affected by factors such as search costs, variations in housing quality, competition, constraints on search behavior and the amount of information gained and then utilized in subsequent search activity. But rather than treating them as stimuli that are external to the individual's utility function, as was done in the stopping rule model through the cost vector \( c \) and the distribution function \( F \), the empirical model treats these factors as "attributes" of the continuation alternative, thereby considering them as a weighted linear combination with parameters to be estimated against the data.

The model, as specified, is not yet complete, however, for we have only defined the decision rule associated with any single observation, \( i \), and the binary choice model which results from this rule when appropriate assumptions are made about the structure of the searcher's utility function. As emphasize above, these decision rules, and thus choice probabilities, are conditional ones, as they each characterize a choice situation which assumes that the individual arrives at that particular decision node and is confronted with the opportunity of either accepting or rejecting
the alternative. Since search is a sequence of such decisions, we must formulate a mechanism for combining these individual rules into a coherent framework which recognizes the entire evaluation process undertaken by the searcher.

Choices made at any point in a sequential decision process are not mutually independent. Rather, they exhibit an interdependence which is manifested in the condition that no alternative can be considered without irrevocable decisions having already been made for all prior alternatives in the sequence. In a sequential search process without recall, this condition is further defined: no alternative can be considered without all prior alternatives in the sequence having been rejected.

We can symbolically represent a search process which exhibits this form of interdependence by considering the combination of events which leads to the final choice. Define the set of potential actions that the searcher can take at any decision stage, i, by the domain $A_i = \{a_i^*, a_i'\}$, where $a_i^*$ represents the acceptance of the opportunity at i and $a_i'$ (the complement of $a_i^*$), its rejection. Clearly, $a_i^* \cap a_i' = \emptyset$, $a_i^* \cup a_i' = A_i$, and $A_i' = \emptyset$. Then the search sequence which terminates at, say, $k$ is simply the joint event:

$$S_k = a_1' \cup a_2' \cup \ldots \cup a_k' \cup \ldots \cup a_{k-1}' \cup a_k$$  \hspace{1cm} (6.2.4)

That is, a search process which ends with the individual choosing the $k^{th}$ opportunity can be characterized as a joint event involving the selection of alternative $k$ and the rejection of the preceding $k-1$ observations in the sequence. A stochastic utility model of the entire search process can therefore be developed by determining the choice probabilities associated with each possible joint event $S_k$ for $k = 1, \ldots, n$.\(^1\)

\(^1\)Note that $k$ is the observation in the sequence where search is terminated and varies in the data between 1 and $n (\neq 8)$.  

339
To show this, denote the probability that individual $t$ chooses the $k^{th}$ alternative in the sequence of opportunities as $p^k_t$, i.e.,

$$p^k_t = \text{Pr}(S_k)$$

$$= \text{Pr}(a'_1 \cup a'_2 \cup \ldots \cup a'_{k-1} \cup a'_k) \quad (6.2.5)$$

Now, consider how these joint probabilities are related to the set of conditional decisions which are made along the sequence. If only one observation is made by the searcher, the choice model is trivial, since:

$$p^1_t = \text{Pr}(S_1)$$

$$= \text{Pr}(a'_1)$$

$$= \text{Pr}(U^1_{dt} > U^1_{ct}) \quad (6.2.6)$$

If two observations are taken before choice is made, however, the choice probability is dependent upon the rejection of the first observation and the acceptance of the second, which can be expressed as a product of conditional and marginal probabilities as follows:

$$p^2_t = \text{Pr}(S_2)$$

$$= \text{Pr}(a'_1 \cup a'_2)$$

$$= \text{Pr}(a'_2|a'_1) \cdot \text{Pr}(a'_1) \quad (6.2.7)$$

But the conditional probability term, $\text{Pr}(a'_2|a'_1)$, is equivalent to that derived in (6.2.3) and the marginal is calculated directly from (6.2.6), yielding:
\[ P_t^2 = \Pr(U_{dt}^2 \geq U_{ct}^2) \cdot \left[ 1 - \Pr(U_{dt}^1 \geq U_{ct}^1) \right] \]  

(6.2.8)

Following the same arguments, the probability of choosing the \( k \)th alternative can be derived as follows:

\[
P_t^k = \Pr(a'_2 \cup a'_3 \cup \ldots \cup a'_{k-1} \cup a_k) \\
= \Pr(a'_k \mid a'_1 \cup a'_2 \cup \ldots \cup a'_{k-1}) \cdot \Pr(a'_{k-1} \mid a'_1 \cup \ldots \cup a'_{k-2}) \\
\ldots \Pr(a'_2 \mid a'_1) \cdot \Pr(a'_1)
\]

\[
= \Pr(U_{dt}^k \geq U_{ct}^k) \cdot \left[ 1 - \Pr(U_{dt}^{k-1} \geq U_{ct}^{k-1}) \right] \cdot \ldots \\
\ldots \cdot \left[ 1 - \Pr(U_{ct}^{2} \geq U_{ct}^{2}) \right] \cdot \left[ 1 - \Pr(U_{dt}^{1} \geq U_{ct}^{1}) \right]
\]

\[
= \Pr(U_{dt}^k \geq U_{ct}^k) \cdot \prod_{i=1}^{k-1} \left[ 1 - \Pr(U_{dt}^i \geq U_{ct}^i) \right]
\]

(6.2.9)

Empirically, then, search behavior is expressed as a probability of discontinuing search at a particular observation in the sequence, and is specified as the product of conditional probabilities associated with the set of binary choices made by the searcher at each decision point in the search sequence. Relating this expression to the assumed form of the individual's utility function in (6.2.1) yields the probability of individual \( t \) stopping at the \( k \)th observation as:

\[
P_t^k = \Pr(\epsilon_c(x_{ct}^k, s_t^k) - \epsilon_d(x_{ct}^k, s_t^k) < V_d(x_{ct}^k, s_t^k) - V_c(x_{ct}^k, s_t^k)) \\
\cdot \prod_{i=1}^{k-1} \left[ 1 - \Pr(\epsilon_c(x_{ct}^i, s_t^i) - \epsilon_d(x_{ct}^i, s_t^i) > V_d(x_{ct}^i, s_t^i) - V_c(x_{ct}^i, s_t^i)) \right]
\]

(6.2.10)

\[ ^1 \text{Implicitly, we are assuming } U^i \text{ to be independent of } U^j \text{ for all } j \neq i. \]
which may be expressed in functional form by specifying the distribution of error terms, $\varepsilon$.

For example, if we assume the error terms associated with each conditional choice set in the sequence to be independent random variables with extreme value (Gumbel) distributions, then from (6.1.8), the conditional probability of choosing the $i^{th}$ alternative is a binary logistic function, and the joint probability of stopping at $k$ is:

$$p_k^t = \frac{1}{1 + \exp\left(\frac{V_c(x^i_t, s^i_t) - V_d(x^k_t, s^k_t)}{\lambda}\right)} \cdot \prod_{i=1}^{k-1} \frac{\exp\left(\frac{V_c(x^i_t, s^i_t) - V_d(x^i_t, s^i_t)}{\lambda}\right)}{1 + \exp\left(\frac{V_c(x^i_t, s^i_t) - V_d(x^i_t, s^i_t)}{\lambda}\right)}$$

(6.2.11)

Similarly, we can express the choice probability, $p_k^t$, as the product of binary probit probability functions by assuming the stochastic elements associated with each conditional choice set to be bivariate normal with covariance matrix,

$$\Sigma^i = \begin{bmatrix} (\sigma_d^i)^2 & \sigma_d^i \sigma_c^i \\ \sigma_d^i \sigma_c^i & (\sigma_c^i)^2 \end{bmatrix}.$$ 

$p_k^t$ is thereby functionally defined as:

$$p_k^t = \phi \left( \frac{V_c(x^k_t, s^k_t) - V_d(x^k_t, s^k_t)}{\sqrt{\left[\left((\sigma_d^i)^2 - 2\sigma_d^i \sigma_c^i \sigma_c^i + (\sigma_c^i)^2\right)\right]^k}} \right) \prod_{i=1}^{k-1} \left[ 1 - \phi \left( \frac{V_c(x^i_t, s^i_t) - V_d(x^i_t, s^i_t)}{\sqrt{\left[\left((\sigma_d^i)^2 - 2\sigma_d^i \sigma_c^i \sigma_c^i + (\sigma_c^i)^2\right)\right]^k}} \right) \right]$$

(6.2.12)

where $\phi$ is the standard cumulative normal distribution function.
In binary choice situations, the probit model offers no statistical advantages to the logit model, since only the differences in utilities (and thus error terms) associated with alternatives are relevant to model estimation. (This precludes the meaningful specification of a covariance matrix to capture dependencies among alternatives.) However, neither specification recognizes contemporaneous correlations that exist across trials in this sequential decision problem, i.e. the specifications assume that the searcher's utility function associated with any conditional choice is independent of utility functions associated with all other conditional choices made in the search sequence. Although we may legitimately assume that the searcher's utility function is independent of those of all other searchers, we expect a given individual's utility to exhibit dependence from trial to trial (i.e. observation to observation), and failure to account for these dependencies is likely to lead to biased coefficient estimates (Heckman, 1978, p.233). However, reformulation of the choice model to one which accounts for contemporaneous correlations across trials results in specifications that are analytically and computationally cumbersome, at best (see Heckman, 1978; Chamberlain, 1979). While recognizing the biases likely to be introduced through the independence of utilities assumption of the logit and probit models in (6.2.11) and (6.2.12), respectively, the exploratory nature of this study dissuades us from experimenting with more complex specifications. We shall, instead, adopt the logit specification in this research effort for its computational advantages.

1Domenich and McFadden (1975, p.58) have shown that, for empirical purposes, binary probit and logit models are virtually indistinguishable, differing only at the tails of their (choice) probability distributions.
Parameters of utility functions associated with discontinuing or continuing search at each decision point in the search sequence may be estimated using maximum likelihood methods. One way to accomplish this is to separately estimate the coefficients of utilities for each conditional choice made along the sequence, meaning that n independent likelihood functions must be specified and numerically solved. Therefore, each decision maker choosing the \( k^{th} \) (\( k \leq n \)) alternative in the sequence is a source for \( k \) data points in the estimation procedure, that individual being an observation relating to the continuation of search in the first \( k-1 \) likelihood functions (decision points) and discontinuation at the \( k^{th} \) decision.

We can examine the properties of the estimator in this application by considering the conditional choice probabilities at any arbitrary point, \( k \), in the search sequence. Since utilities are assumed linear in the parameters, using (6.1.2) we let

\[
V_c(x_t, s_t) = \sum_{i=1}^{m} \beta_i^k v_i(x_t, s_t) = V_{c}(x_t^k, s_t) \beta^k
\]

and

\[
V_d(x_t, s_t) = \sum_{i=1}^{m} \beta_i^d v_i(x_t, s_t) = V_{d}(x_t^k, s_t) \beta^k
\]

where \( \beta^k \) is a vector of unknown parameters, \( v(\cdot, \cdot) \) is a vector of transformations upon the attributes of the alternatives and the socioeconomic characteristics of the searcher. For purposes of exposition, let

\[
z_t^k = v_d(x_t^k, s_t) - v_c(x_t^k, s_t)
\]

Then, if choice probabilities are logistic, the conditional probability of the individual \( t \) stopping at \( k \) is:
\[ p^k_{dt} = \frac{1}{1 + \exp(-z^k_{dt} \beta^k)} \quad (6.2.14) \]

Denote the observed choice of the individual by the variable:

\[ y^k_{dt} = \begin{cases} 
1 & \text{if the individual } t \text{ stops after } k \text{ observations} \\
0 & \text{otherwise}
\end{cases} \quad (6.2.15) \]

Since choice at \( k \) is binary, \( y^k_{dt} \) is binomially distributed and the likelihood function for estimating the vector of parameters, \( \beta^k \) (only those associated with the \( k^{th} \) decision) is simply:

\[ L_K = \prod_{t=1}^{N_K} (y^k_{dt})(1-y^k_{dt})^{1-y^k_{dt}} \quad (6.2.16) \]

where \( N_K \) is the number of households in the sample that either chose the \( k^{th} \) alternative or evaluated it and decided to continue searching. Logarithmic transformation of (6.2.16) yields the log-likelihood function from which first and second order conditions for the maximum likelihood estimate of \( \beta^k \) can be derived (McFadden, 1974, p.115). Properties of the maximum likelihood estimator for this problem have been studied extensively by McFadden (1974). Under very general conditions, provided the data are not collinear, the maximum likelihood estimator of the conditional logit model is strictly concave, and parameter estimates are unique, unbiased, asymptotically efficient and normally distributed (McFadden, 1974, p.113-130).
Note that the maximum likelihood estimator in (6.2.16) is applied to each binary choice made along the decision sequence observed in the sample. The variables of interest, the choice probabilities of stopping and selecting the $k^{th}$ alternative, as in (6.2.11), are then calculated as the products of independently estimated conditional choice probabilities.

However, the procedure of independently estimating likelihood functions for each conditional choice in the sequence is statistically inefficient. By estimating the coefficients of utility for each conditional choice independently, we are implicitly assuming that each choice made along the sequence is governed by a different set of parameters, i.e., the individual's valuations of all attributes associated with both the termination of search and continuation of search alternatives are permitted to change at every observation. Although this procedure, then, allows for attitudinal changes attributable to risk and uncertainty, as suggested by Weibull (1978), it is inefficient if only a subset of attributes are differentially valued along the search sequence, since single coefficient estimates for attributes not differentially valued are derived only if all conditional choices are jointly estimated.  

That we should expect several coefficients to remain invariant throughout search should be apparent from both our analysis of the theoretical framework and the suggested specification of the searcher's

---

1 In a model with recall, independent estimation of the conditional choices would have obvious implications for vacancies previously observed but rejected, since re-evaluation would likely yield suitable opportunities upon the adjustment of attribute preferences.
utility function. The theoretical framework has shown that value changes brought on by uncertainty and risk are manifested only in the aspiration utility of the searcher, since that is the standard over which evaluation is made. Since, in the empirical model, the attributes of utility comprise both search variables (associated with the continuation alternative) and perceived characteristics of the vacancy under evaluation (associated with the termination alternative), theoretical hindsight suggests that, at most, we should expect only a subset of the former to change if, indeed, uncertainty and risk are incorporated into the searcher's utility function in this way.\footnote{Alternatively, utility could be estimated by the searcher using an identical preference structure at each observation and then could be discounted or appreciated if the searcher was influenced by uncertainty or risk.} What is required, then, is an estimator that considers all conditional choices jointly to efficiently estimate invariant parameters, but which also is capable of recognizing potential preference changes toward selected attributes.

An estimator with these required properties has been suggested by Sheffi (1979). As multiplication is an associative operator, the product of maxima of likelihood functions is equivalent to the maximum of the product of likelihood functions. Therefore, we can define a new likelihood function, $\ell_n$, which will estimate the coefficients of utility functions associated with all estimable branches of the sequential decision process. This composite function is defined as:

$$\ell_n = \prod_{k=1}^{n} \ell_k$$
\[
\log l_n = \sum_{k=1}^{N_k} \sum_{t=1}^{n} \left[ \log p_k^{x_t} + (1-y_k^{x_t}) \log (1-p_k^{x_t}) \right]
\] (6.2.18)

which can be logarithmically transformed into a linear function, i.e.

\[
\log l_n = \sum_{k=1}^{N_k} \sum_{t=1}^{n} \left[ y_k^{x_t} \log p_k^{x_t} + (1-y_k^{x_t}) \log (1-p_k^{x_t}) \right]
\] (6.2.19)

which, when maximized, yields estimates for a parameter vector, \( \beta \), corresponding to an invariant preference structure over all observations made in the search sequence, i.e.

\[
\log l_n = \sum_{k=1}^{N_k} \sum_{t=1}^{n} (1-y_k^{x_t} z_c^{k \beta} + \log (1+\exp(-z_c^{k \beta})))
\] (6.2.19)

Since the estimator constrains all coefficients to single values over the search sequence, changing valuations of attributes must be incorporated into the searcher's utility function in another way. This is accomplished by indexing those variables hypothesized to be differentially valued during search with respect to the number of vacancies sampled. Specifically, consider the variable \( x_{jt} \), which is the \( j \)th attribute in the searcher's utility function associated with the \( i \)th sample taken by individual \( t \) during his/her search activities. Let \( \beta_j \) be the parameter to be estimated, which is invariant over the search process. Indexing simply requires the specification of a function, \( f^i \), which, when combined with the attribute \( x_{jt}^i \) and parameter \( \beta_j \), reflects our \textit{a priori} notions.
concerning how the attribute will be differentially perceived\textsuperscript{1} by the
searcher as sampling is continued. That is, we specify a transformation
of $x_{jt}^i$, $f_i(x_{jt}^i)$, which relates the attribute to the index number $i$, which,
in this case, represents the number of vacancies sampled by the searcher.

Note that although variable transformation is widely practiced in
econometrics, when applied to a sequential (or nested; see Sheffi, 1979)
choice problem, it requires a different interpretation. As an example,
consider a "marginally impatient" (Weibull, 1978) searcher who pays a
fixed sampling cost, $c$, to observe another vacancy. Associated with
the attribute is the coefficient, $\beta_c$, which is presumably negative. We
might then hypothesize marginal impatience to be a linear specification
of the cost variable with respect to the index set. That is, $f_i^i(c) = i \cdot c$,
where $i$ represents the number of vacancies sampled by the searcher. Here,
the perceived cost of searching increases linearly with the number of
vacancies sampled, although the actual cost remains constant over the
search process. Thus, we are hypothesizing the searcher to have constant
impatience with respect to search costs; increasing marginal impatience
could be represented by, say, an exponential or similar function.

\textsuperscript{1}Note the change in emphasis from values (preferences) to perceptions
implicit in this technique, two determinants of choice not thoroughly
distinguished in this research (see Bem, 1970; Sonnenfeld, 1976). This
shift is more an artificial than substantive one though, since, when in-
ferring preferences (from coefficient estimates) in an imprecisely
measured world, the distinction is usually lost.
Clearly, it is beneficial to possess an *a priori* hypothesis concerning how perceptions toward an attribute can be expected to change with respect to the index set to effectively exploit the technique. (Several could be conjectured from the theoretical framework in Chapter 4.) Alternatively, one could estimate several functional forms and, from estimation results, infer an appropriate relationship. Regardless, when the specifications of variables with respect to an index set is combined with the product likelihood estimator in (6.2.19), it provides a convenient framework for estimating the searcher's utility function,\(^1\) a framework that is exploited in the next chapter.

6.3 **Summary**

The empirical model to be used for analyzing the search behavior of Metropolitan Toronto households has now been functionally defined, and procedures for estimating its parameters have been developed and reviewed. By assuming that households cannot recall previous opportunities, the search process has been characterized as a sequence of conditional binary choice models.\(^2\) Factors which have been found to qualitatively affect search behavior in the theoretical framework are to be incorporated into the empirical model as attributes of the individual's utility function. Theoretical findings are therefore anticipated to be validated by comparing parameter estimates in the empirical model (particularly

---

\(^1\)Applications of choice models using indexed variables can be found in Burns *et al.* (1976) and Sheffi (1979).

\(^2\)That recall is precluded from the model is not because of limitations imposed by the choice-theoretic framework. If data permitted, the process could be characterized as a sequential decision process with several branches at each node rather than just two.
their signs and statistical significance) to relationships inferred from the stopping rule framework. For empirical and computational reasons, conditional choice probabilities have been assumed to be logistically distributed, and maximum likelihood estimation procedures have been suggested for estimating the coefficients of the searcher's utility functions associated with the sets of binary choices along the search sequence.

The model, as specified, clearly satisfies the criteria laid out in Section 6.0. It retains the structural characteristics of search activity by explicitly accounting for the sequential nature of the search and selection process, and by recognizing search costs through an appropriate specification of the individual's utility function. The model's behavioral assumptions are consistent with those of the theoretical model, as the specified random utility formulation is consistent with the principle of utility maximization, yet coincidentally exhibits satisficing behavior on the part of the individual over the sequence of observations, i.e. the model's behavioral assumptions embrace the concept of bounded rationality on the part of the individual, which is expected in this particular decision situation. Finally, the model, through an appropriately defined estimator, can be applied to data to derive parameter estimates for theoretically defined factors considered to be important determinants of residential search and choice behavior.

But although it is expected to capture many important aspects of search behavior, the model still retains several simplifying assumptions about the motivations of searchers and the conditions they experience during the course of search, which should be recognized in order to realize the model's limitations and potential biases.
Some of these limitations are empirical ones brought on by data inadequacies, and have been briefly discussed previously. For example, the absence of data on recall and multiple observations upon a single dwelling has made the simplification of the empirical framework necessary. The data are furthermore not sufficiently informative to detail the nature of search undertaken by the household and require many potentially interesting characteristics of search to be implicitly (through surrogate variables in the utility function) rather than explicitly considered in the analysis. The data do not allow us to characterize the locational selection process and likely hierarchical search patterns established during search as a result of information gain. We, instead, must assume search to be composed of a set of \( n \) independent random drawings from an unspecified distribution of vacancies, where a sequence of home-vacancy-home trips is made by the searcher over the course of the activity. Thus, although the empirical model can be made to replicate the data sufficiently well, it may not be in direct agreement with reality.

A more fundamental problem with the empirical model we have developed lies in its assumptions concerning independence of the searcher's utility function from trial to trial. By adopting the logit model to characterize choice probabilities, we have neglected the dependence among utilities formulated by the searcher along the sequence of vacancy observations, thereby introducing unknown biases into coefficient estimates. Although such dependencies could be recognized in alternative model specifications, their complex structures and properties, which have not been extensively investigated, encourages us to use the logit formulation.

Aware of these limitations, then, we now turn to the specification
and estimation of the empirical model in an attempt to validate the theoretical framework.
Chapter 7
Estimation of the Empirical Model

7.0 Introduction

The empirical framework developed in the previous chapter has characterized the search process as a sequence of binary decisions which the individual must make in order to locate a new residence. Each decision has been cast as an independent, discrete choice event, where choice is based upon the individual's evaluation of the utility of continuing search versus the utility of stopping and accepting the alternative under consideration. The framework has evolved in this direction both because of its similarity to the theoretical structure developed in Chapter 4 and its suitability for model estimation. That a parametric specification of the model has resulted will enable more rigorous tests of the theoretical model's properties to be conducted than those performed in Chapter 5.

This chapter seeks to provide empirical support for the theoretical and empirical frameworks developed in this study. It intends to identify the set of variables associated with the termination and continuation alternatives relevant to the searcher's decision problem, to estimate their relative importance and to compare the model's predictions to
observed search behavior in the data. It aims both to empirically qualify the set of fundamental hypotheses about search behavior abstracted from the theory and to suggest additional factors which, though not apparent in the theoretical framework, appear to intervene in the decision making process, and thus substantially influence residential choice.

To achieve these aims, the chapter is structured as follows. First, the data base upon which the model is estimated is described in Section 7.1. Recall that non-parametric tests on search behavior conducted in Chapter 5 found the survey data on recent movers in Metropolitan Toronto to be inadequate in a number of respects. To compensate for their shortcomings, survey data are supplemented by data collected in the 1971 Census of Canada. Procedures used to merge the data and an outline of their contents are briefly sketched. Section 7.2 then specifies the utility functions of searching households in the empirical model and relates them to the theoretical considerations examined in Chapter 4. Preliminary hypotheses concerning the relationships of these variables to observed search behavior are discussed and documented. Section 7.3 presents coefficient estimates of models proposed to represent the decision process. It interprets these findings in terms of prior expectations, and discusses their implications for understanding the behavioral motivations of searchers which appear to underly their actions. Section 7.4 then reconstructs the empirical model from the conditional binary choice models estimated in the previous section. This enables comparisons of model predictions to choice behavior observed in the data, and facilitates the evaluation of the model both as a predictor of actual
search behavior and as an instrument for validating the theoretical model. Section 7.5 then summarizes the major findings of the chapter and discusses their implications in terms of the paradigm advanced in this research effort.

7.1 Data Development

As detailed in Chapter 5, data developed from Barrett's survey of recent movers in Metropolitan Toronto contain little information about the socioeconomic and physical attributes of alternative housing units sampled by searching households. Since Barrett (1973) was interested primarily in spatial rather than behavioral patterns of search, only the locational coordinates of seriously considered alternatives were recorded for each sampled unit. Such information is clearly insufficient for characterizing the utilities of households engaged in search, and to provide the necessary information, they have been supplemented with data derived from the 1971 Census of Canada.

The 1971 Census file comprises a series of cross-tabulations on the Canadian population according to various demographic, household, family, housing and economic characteristics. These cross-tabulations relate either to the short form or long form questionnaires, and are available at several levels of geographic detail. For this study, data developed from the long form questionnaire, an instrument containing forty basic demographic, socioeconomic and housing questions, and administered to one-third of the Canadian population, have been utilized because of their greater information content. These data, defined at the
census tract\textsuperscript{1} level of detail, have been extracted and merged with Barrett's survey data. Census data were collected on June 1, 1971; this provides a reasonable match to the time frame over which Barrett's sample searched for housing (from September to December, 1970) and likely characterizes the neighborhood conditions encountered by households during their search activities fairly accurately.

The two data sets were merged by matching the digitized location coordinates recorded by Barrett to census tracts through a manual mapping procedure. (Each digitized unit is equivalent to approximately .006 mile.) Some problems of scaling were encountered during this operation, but, at worst, this has resulted in the mapping of a location coordinate onto the census tract adjacent to the actual tract searched. The search paths of households in Barrett's sample, through this procedure, were thus expressed in terms of census tracts searched, which could then be related to the tracts' socioeconomic and housing characteristics available in Census data. Since measure of distance would be required in variable specification, however, digitized location coordinates were also retained in the data.

In all, eleven cross-tabulations were drawn from the Census file to develop tract characteristics upon which locational decisions were

\footnotesize\textsuperscript{1}Statistics Canada defines census tracts to be permanent small census geostatistical areas established in large urban communities which conform to criteria pertaining to the identifiability and permanence of their boundaries, their shape, and the homogeneity of economic status and social living conditions within them. Their populations range between 2,500 and 8,000 persons except for census tracts in central business districts, industrial areas and peripheral rural areas (Statistics Canada, 1978). The City of Toronto and the five boroughs considered in this study contained 346 tracts in the 1971 Census of Canada (Figure 7.1).
Figure 7.1  Census Geographical Units over which Independent Variables Defined
assumed to be based (Table 7.1). Although lacking in several respects, particularly those relating to housing quality, these data, in conjunction with household characteristics in Barrett's sample, provide a consistent and relatively complete set of measures relevant to search behavior and permits specification of the empirical model.

7.2 **Specification of the Utility Function**

Recall that the empirical model developed in Chapter 6 allows us to specify a utility function for the searcher which is linear in the parameters and additive in the disturbance terms. The function is of the form:

\[
U(x,s) = \beta_1 V_1(x_1,s) + \beta_2 V_2(x_2,s) + \ldots + \beta_k V_k(x_k,s) + \epsilon(x,s)
\]

(7.2.1)

where \(V^i(x_1,s)\), \(i=1, \ldots, k\), are transformations upon the attributes, \(x\), and socioeconomic characteristics of the household, \(s\), and \(\beta\) is a vector of unknown parameters. With the data base described in Section 7.1, these attributes and transformations can now be given empirical meaning. Before doing so, however, it is important to note how these alternatives in the choice set are to be defined.

Compared to most applications of discrete choice models published to date, the alternatives which constitute the searcher's choice set are somewhat abstract. The search process is one in which the household is comparing something "real" or attainable (i.e., the vacancy) to an expectation or belief of what might be attainable if search is continued. The result is a specification for the utility function which is not immediately intuitive.
Census Tract Area

Population by Ethnic Group by Age and Sex

Persons Aged 5+ by School Attendance by Age and Sex

Persons Aged 5+ by Migration Status

Persons Aged 5+ by Number of Intermunicipal Moves by Age and Sex

Dwellings by Tenure by Construction Period

Dwellings by Tenure by Number of Bedrooms

Tenant-Occupied Non-farm Dwellings by Monthly Gross Rent

Owner-Occupied Single House Non-farm Dwellings by Value

Total Primary Family Households by Income Recipients by Family Income

Total Labor Force by Educational Attainment by Age and Sex

Table 7.1 Cross-tabulations Drawn from 1971 Census of Canada for Variable Specification
Recall that in the theoretical framework, determinants of the continuation decision were described as conditioning factors on the searcher's opportunity set, which were defined by a distribution function, F. Thus, aspiration utility, which was simply an expected utility, consisting of the same attributes as the opportunity under observation, was only indirectly influenced by these determinants through the searcher's estimation of what alternatives might still be available if search was continued (primarily through the cost vector, $c$, and distribution function, F).

In the empirical model, determinants of the continuation decision\(^1\), such as perceived competition for vacancies from other searching households and quality variations in the housing stock, are treated as attributes in the searcher's utility function, since it presents the only opportunity for incorporating such variables.

Because the two alternatives being compared at any decision point are so fundamentally different, all variables which define the searcher's utility in the empirical model are alternative-specific. The selection of variables from the data and their transformations into relevant attributes associated with the choice process are therefore discussed in the contexts of the alternative they are intended to represent.

\(^1\)It is recognized here that in choice-theoretic models, the individual is assumed, as a matter of convenience, to possess a single utility function which applies to the evaluation of all alternatives, i.e. the determinants of the continuation decision are identical to those of the stopping decision, regardless of which alternative the attribute is actually intended to represent. However, since the attributes to be used to specify the utility function for the empirical model are alternative-specific (taking on non-zero values when applied to one alternative and zero value when applied to the other), the relating of attributes to individual alternatives will be adopted throughout the chapter, where necessary, to clarify arguments regarding their theoretical meaning.
7.2.1 Continuation of Search

When evaluating whether he/she should continue search or abandon it for the current opportunity, the searcher is assumed, in the empirical model, to be weighing the attributes of the opportunity against attributes relating to what has happened thus far in search, what conditions governing search are currently believed to be in effect, and what can be expected from search if it is continued. From our study of the theoretical framework in Chapter 4, we intend to define these attributes in terms of the generic determinants of search behavior investigated there.

The data allow us to define measures associated with five of these generic determinants for specifying the searcher's utility function. These measures relate to search costs, competition for housing opportunities, forced mobility, the mean quality and the variance in quality of housing perceived by the searcher to exist in his/her opportunity set.

Search Costs

Four measures of search costs have been drawn from the data. As discussed above, the coordinate locations of all alternatives seriously considered or chosen by sample households are recorded in the data, from which distances travelled during their search activities may be calculated. Although the use of distance as a surrogate for search costs ignores other considerations, such as the time required to observe opportunities and informant costs, it is expected to at least be indicative of the effort required of households to conduct their search activities. However, the ways in which search was actually conducted
by households is not recorded in the data, i.e. whether a subset of observations constituted a trip chain or separate events; alternative assumptions regarding sampling strategies have been articulated to arrive at different specifications for distance.

One set of distance measures is based upon the assumption that each observation taken by the household constituted an independent event, thus requiring the household to conduct a series of home-based trips to all alternatives sampled. Another set of measures assumes that search activities were conducted as a single event (i.e. a trip chain) where travel costs to the household are incremental from the last observation. Alternative sampling strategies essentially define upper and lower bounds to distances actually travelled during search, unless repeated observations were made upon selected alternatives in the opportunity set. Alternative specifications of the model could potentially suggest whether one assumption or the other is a more reasonable approximation to the searcher’s perception of distance as search is conducted.

However, even if we accept both of these conceptions of sampling behavior to be representative of actual search patterns, the specification of appropriate distance measures remains problematic, because many alternative measures which characterize how search costs are progressively perceived by the searcher have been suggested in the literature.

Recall that search rules developed in Chapter 4 equated the marginal gain with the marginal cost of search in calculating the expected utility of continuing. Alternatives were rejected only if the expected marginal utility of continuing for one more observation exceeded the expected
marginal cost of taking the observation. This suggests that an estimated marginal distance to the next alternative in the searcher's opportunity set could be a significant determinant of search behavior.

On the other hand, it is possible that the household retains a perspective on the total costs expended thus far in search, since its expected gain must at least offset cumulative search costs for the household to realize a payoff from its search activities (see equation 4.2.5). We may define this measure as the cumulative distance travelled by the household (using either sampling scheme) to observe all sampled opportunities up to and including the current observation. Both marginal and cumulative measures have been calculated from the data.

Exponential transforms of cumulative distance measures have also been derived. These are intended to characterize the searcher's increasing concern, or as suggested by Weibull (1978), increasing marginal impatience towards continued unsuccessful search efforts. Regardless of functional form, all specified distance measures are expected to have negative coefficients.

Three other variables have been defined to measure search costs. A simple indicator of search effort is the number of alternatives that have been observed up to and including the current opportunity. Since, in general, fewer observations require less total expenditures of time, money and effort by the searching household, we expect to observed a negative coefficient associated with this variable.

An indirect indicator of search costs is measured by the number of workers in the household. Here, it is anticipated that search activities of multi-worker households are inhibited relative to single worker and
non-working households because the coordination of time-budgets and resources necessary for engaging in the search process is probably more difficult.

Finally, income has been specified as a measure of search costs, though primarily to control for its effects on other cost variables. As suggested in the theoretical framework, income can exert a dual influence upon search behavior. One the one hand, higher incomes provide more resources for conducting search activities and, therefore, for prolonging search. On the other, if we accept the hypothesized relationship between income and value of time, we expect higher income to induce abbreviated search activities. Furthermore, higher incomes remove many of the financial constraints to choice, allowing these households the opportunity to quickly resolve their locational dilemmas. Because of these considerations, the sign of this measure's coefficient cannot be anticipated a priori.

**Competition for Housing Opportunities**

Competition for housing opportunities has been characterized in the searcher's utility function by a measure of the turnover of population in the census tract. Formally, it is a ratio of the number of migrants that moved into the tract between 1966 and 1971 to the total number of owned and rented dwellings in the tract. The variable actually can be given a dual interpretation, both of which suggest its coefficient will have a negative sign when estimated. The first interpretation relates directly to competition effects. Tracts experiencing high turnover of the population are anticipated to be those where competition is perceived to be most intense by searchers. *Ceteris paribus*, if the household
perceives these tracts as desirable alternatives, and furthermore, perceives other households to similarly consider them attractive, then the theoretical framework suggests that searching households will curtail search activities sooner than would otherwise be expected for fear that the opportunity available to them would be lost to another household. However, this interpretation, though plausible, is not complete because it fails to take more macroeconomic housing market factors into account. Tracts experiencing high rates of population turnover, in addition to receiving high proportions of in-migrants, are those experiencing high rates of out-migration, since the variable is conditioned on total housing stock in the census tract. If the household perceives this history of out-migration, it may anticipate greater supply potentials (in a relative sense) in these tracts and may tend to concentrate search there as a result (provided the tracts are perceived to be suitable in other respects). If high out-migration rates still characterize these areas at the time of search, search is likely to be more successful than in tracts experiencing low population rates, since there is a greater effective supply of housing there. In other words, choice may be facilitated and search abbreviated not only because of perceived competition, but because tracts experiencing the greatest population turnover rates are those containing the greatest supplies of housing. As stated above, this supply-related phenomenon would tend to reinforce competition effects to produce a negative coefficient on the variable.

**Forced Mobility**

The measure of forced mobility to be included in the searcher's utility function is identical to that defined for the empirical analysis
in Chapter 5. It is a dummy variable which is operative only for those households that were forced to move because of eviction, death, divorce or marriage in the family. The non-significance of its associations with selected search indicators, as shown in Chapter 5, plus its overall ambiguity of definition, suggests that this forced mobility measure is unlikely to have a significant impact on the searcher's utility function in the parametric model. But, given that it is the only indicator of forced mobility in the data, its specification provides the sole opportunity for testing its effects on search behavior. Because of the way it is defined, we expect a negative coefficient to be associated with it.

Perceived Housing Quality

Two other measures to be used to specify the searcher's utility function relate to the quality of housing perceived by the searching household to exist in its spatial search field. These measures are important because they articulate what the household perceives it can expect from further search.

The theoretical framework expressed perceived housing quality in terms of a distribution function (of utilities) from which changes in its mean and variation were derived to gauge their effects on the searcher's aspiration utility. More sophisticated variants of the framework then cast the search process as a Bayesian decision process where the distribution function was sequentially revised to incorporate new information from the most recent observation. These characteristics of the theory are retained in the construction of empirical surrogates of perceived housing quality.
The specification of quality measures, however, is problematic because there is no direct counterpart to the theoretical framework's "utility" in the data. Any attempts to construct an a priori utility measure, say, through econometric estimation would, in fact, be inappropriate, since such a measure would have to include the empirical model's specification (as the choice model, itself estimates a utility function); this would make estimation intractable. In recognition of such specification problems, three measures on the single family housing stock in Metropolitan Toronto census tracts have been drawn from the data to proxy for housing quality: age, value and number of bedrooms. In deference to the theory, these measures are expressed in terms of their means and standard deviations.¹

To account for information acquisition and subsequent learning during search, a simple updating scheme for the means and standard deviations of these measures has been adopted. The household has been assumed to formulate its prior expectations on the basis of the quality of the housing stock in its immediate environment. Prior means and standard deviations of the three quality measures have therefore been

¹Categorical definitions used by Statistics Canada to describe age and value characteristics of the housing stock in census tracts precluded the calculation of unconditional means and standard deviations for these two variables. For age, census data reported the number of owned dwellings built prior to 1946, and in closed intervals after that date. Similarly, the number of owner-occupied single house non-farm dwellings in a tract was reported in closed intervals up to and including houses valued at $62,500; all houses valued greater than this were aggregated to a single count. Thus, the age and value statistics associated with single family houses in a census tract have been conditioned upon their being built after 1945 and their valuation being $62,500 or less, respectively. Re-examination of the data showed that, in most tracts where sample households searched, the proportions of the housing stock outside these limits were small, and thus conditioning was likely admitting only small biases into age and value statistics.
calculated over an area which includes the census tract containing the household's previous residence and all tracts adjacent to it. The priors are updated at each observation by incorporating the means and standard deviations of the measures associated with the observed tract to form posterior measures of housing quality. If another observation is taken, the posterior becomes the new prior to be updated. Note that the operation assumes a pre-decision updating scheme as was analyzed in Chapter 4, whereby the searcher incorporates information acquired from the observation before he/she evaluates the utilities associated with the two alternatives.

Prior and marginal statistics are weighted by the number of single family dwellings associated with each. Since prior measures of housing quality are formulated from an aggregation of census tracts, we are implicitly assigning greater importance to the searcher's priors, particularly the prior formulated before search is commenced, than to housing quality measures associated with the current observation.

Both the housing quality measures and weighting scheme to update them are admittedly primitive. With regard to the former, we are limited by data, as more appropriate measures of housing quality are simply not available. The updating procedure is simplistic because of both data and methodological problems. Although an individual's awareness space and spatial search fields have been conceptually (Wolpert, 1965; Hägerstrand, 1957) and theoretically defined (see, for example, Smith, 1980), they have been given only limited empirical meaning and definition to date (see Smith, 1978; Burnett, 1973; 1978; Louviere, 1975); there are no empirical concepts which are compatible with the data used in this study.
In the theoretical framework, we showed that an increase in either the mean or variation in the distribution of utilities raises the aspirations of the searcher and thus encourages further search. We expect similar effects from our empirical measures of housing quality on the search behavior of households in the sample. We therefore anticipate positive coefficients to be associated with these variables when estimated in the model. Measures of updated means and standard deviations of the three housing quality indicators have been expressed both in terms of their absolute values at each stage of the search process and as differences from the values extant at the previous observation.

**Empirically-Defined Search Variables**

Two other alternative-specific variables have been defined for the empirical analysis which do not relate directly to concepts in the theoretical model. Both are derived from Barrett's survey of households and are expressed as dummy variables. Former tenure status of the household has been included to investigate whether previous tenure influences search behavior. Michelson (1977) observed that former renters who eventually chose to buy homes generally searched for longer periods of time and inspected more vacancies than former owners, and attributed this to the latters' more precisely defined selection criteria during the search period. The extended search activities of former renters might also be due to their greater uncertainty regarding opportunities in a housing sub-market they have had little or no experience in. We have argued that greater uncertainty tends to prolong search and thus expect former renters in the survey to sample more alternatives before
making their choices than former owners. Since the dummy variable is assigned zero-value when associated with former renters, we expect its coefficient to be negative.

When asking respondents to recall and locate seriously considered alternatives evaluated during their search activities, Barrett also asked whether they were previously familiar with the areas in which they searched. These responses form the basis for another alternative-specific dummy variable in the searcher's utility function. However, the exact meaning of this variable is not clear. The household could have become familiar with the area through one of many potential information channels, all of which transmit qualitatively different messages (see Chapter 3). Except for the chosen alternative, however, this distinction is not made in the data, and thus, the degree of familiarity the household possesses of each area is not known. Regardless of qualitative differences in familiarity, households that search familiar areas are likely adding little information to their priors. We expect non-informative observations to induce further search to enable the household to increase the variance of housing opportunities in its sample. On these grounds, a positive coefficient associated with familiarity measure is anticipated.

Variables conjectured to influence the search behavior of households in the residential evaluation process have now been empirically defined in relation to the generic elements of search embodied in the theoretical framework, and have been specified in terms of attributes of search considered in the searcher's utility function. Search costs
have been specified in terms of a set of distance measures characterizing distance travelled during the household's search activities. Costs associated with search activities have also been related to the number of alternatives sampled up to the current observation in the search sequence, the number of workers in the household, and an income proxy, defined as the price paid for the chosen alternative. Competition effects have been defined through a pseudo-housing supply measure which relates total in-migrants to the tract over the preceding six years to total housing stock in the tract. Forced mobility has been specified as an indicator variable using the same dichotomy between forced and non-forced movers as was used in Chapter 5. Perceived housing quality measures have been defined in terms of the means and standard deviations of three tract-level housing quality indicators, age, value and number of bedrooms, which are updated from initial prior estimates at every observation. Finally, previous tenure status of the household and the household's prior familiarity with areas searched, though not suggested in the theoretical framework, have been specified as dummy variables to test their anticipated importance in the decision making process. Variable names, their definitions and precise specifications are shown in Table 7.2. When these variables are estimated, these variables will define the searcher's utility of continuing search against which the utility of terminating and choosing the vacancy, whose components are discussed below, is weighed.

7.2.2 Termination of Search

Since the searcher is assumed to discontinue search only when a suitable housing opportunity is located (there is no information on
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
<th>Specification</th>
<th>Source</th>
<th>Expected Sign of Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAR CST</td>
<td>Distance travelled by household from previous residence to sampled alternative.</td>
<td>( MAR CST = \begin{cases} 0 &amp; \text{if termination alternative} \ MAR CST &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>CUM CST</td>
<td>Cumulative distance travelled by household to all vacancies up to and including the current observation.</td>
<td>( CUM CST = \begin{cases} 0 &amp; \text{if termination alternative} \ CUM CST &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>NSEARCH</td>
<td>Cumulative number of vacancies sampled by household up to and including the current observation.</td>
<td>( NSEARCH = \begin{cases} 0 &amp; \text{if termination alternative} \ NSEARCH &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>NWORK</td>
<td>Number of workers in household.</td>
<td>( NWORK = \begin{cases} 0 &amp; \text{if termination alternative} \ NWORK &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>INCOME</td>
<td>Price paid for chosen alternative.</td>
<td>( INCOME = \begin{cases} 0 &amp; \text{if termination alternative} \ INCOME &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Barrett</td>
<td>?</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>Ratio of number of in-migrants that moved to tract between 1966 and 1971 to total number of owned and rented dwellings in tract.</td>
<td>( SUPPLY = \begin{cases} 0 &amp; \text{if termination alternative} \ SUPPLY &amp; \text{if continuation alternative} \end{cases} )</td>
<td>Census</td>
<td>-</td>
</tr>
<tr>
<td>FORCED</td>
<td>Forced mobility indicator.</td>
<td>( FORCED = \begin{cases} 0 &amp; \text{otherwise} \ 1 &amp; \text{if continuation alternative and household was forced to move from previous residence} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>MQAL Y (VQLAV1), DELVAL (DELVAL)</td>
<td>Conditional mean (standard deviation of) value of single family housing in sampled census tracts updated⁴ from prior observation.</td>
<td>( MQAL Y = \begin{cases} 0 &amp; \text{if termination alternative} \end{cases} )</td>
<td>Census/Barrett</td>
<td>+</td>
</tr>
<tr>
<td>MQAL A (VQLAV1), DELVAGE (DELVAGE)</td>
<td>Conditional mean (standard deviation of) age of single family housing in sampled census tracts updated⁴ from prior observation.</td>
<td>( MQAL A = \begin{cases} 0 &amp; \text{if termination alternative} \end{cases} )</td>
<td>Census/Barrett</td>
<td>+</td>
</tr>
<tr>
<td>MQAL B (VQLAB), DELMBED (DELMBED)</td>
<td>Mean (standard deviation of) number of bedrooms in single family housing in sampled census tracts updated⁴ from prior observation.</td>
<td>( MQAL B = \begin{cases} 0 &amp; \text{if termination alternative} \end{cases} )</td>
<td>Census/Barrett</td>
<td>+</td>
</tr>
<tr>
<td>LEGALS</td>
<td>Previous tenure status of household.</td>
<td>( LEGALS = \begin{cases} 1 &amp; \text{if continuation alternative and household owned previous residence} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
<tr>
<td>FAMAREA</td>
<td>Indicator of household's prior familiarity with sampled opportunity's surrounding area.</td>
<td>( FAMAREA = \begin{cases} 0 &amp; \text{if termination alternative} \ 1 &amp; \text{if continuation alternative and household was familiar with area prior to sampling the vacancy} \end{cases} )</td>
<td>Barrett</td>
<td>-</td>
</tr>
</tbody>
</table>

(over)

373
Table 7.2  Independent Variables Associated with the Searcher's Continuation Alternative
searchers who discontinued search and remained at their current residences), attributes which directly relate to this alternative are the characteristics of searched and chosen vacancies. As such, the literature on residential choice behavior has been used to suggest the following variables for defining these elements of the searcher's utility function. Generally, these variables fall into one of three generic categories of attributes, which relate to the alternative's locational, housing quality and neighborhood quality characteristics.

**Locational Attributes**

Although several measures of accessibility are potentially relevant, data constraints have restricted the characterization of the alternative's locational attributes to distance to work. It has been included to measure the accessibility of the vacancy to the workplace, a determinant which has been consistently, though not always unambiguously, related to locational decisions in the literature. To account for the locational decisions of multi-worker households, average distances to the workplace have been computed, where appropriate; non-working households have been assigned zero workplace distances.

Theoretically, distance has been shown not to be a good indicator of accessibility over non-isotropic surfaces (Angel and Hyman, 1976), since it correlates poorly with travel time and cost, and accessibility to other locations of importance in household activity patterns. More sophisticated measures which include travel time, modal transfers and other considerations have been proposed in the literature (see Ben-Akiva and Lerman, 1977), but the present data are not sufficiently informative to permit their construction. Despite its weaknesses, however, we still
expect a negative coefficient to be associated with this variable in the estimated utility function.

**Housing Attributes**

Housing quality attributes of sampled vacancies have been characterized by two measures. Space requirements of the moving household are measured by number of bedrooms, expressed as the percentage of single family dwellings in the tract having a specified number of bedrooms or more. The number of bedrooms criterion is dependent upon the number of adults and children in the searching household. Therefore, this attribute is uniquely defined for each household in the sample. Given the observed importance of space requirements in the residential choice literature, we expect this term to have a positive coefficient associated with it.

Another measure of housing quality in sampled census tracts relates to the age of the single family housing stock. Butler et al.'s (1969) evidence suggested households to have a slight preference for newer housing and, given the pronounced trend toward new suburban housing in Metropolitan Toronto (Spurr, 1976), we expect these preferences

---

1Note that variables defined from census data to specify the utility function are tract averages rather than the actual characteristics of vacancies observed by searching household, and thus the potential exists for extracting inferential fallacies from coefficient estimates (see Alter, 1969), particularly when they are used to define housing attributes. We must assume, therefore, that homogeneity criteria specified by Statistics Canada for census tract definition (p.357) have reduced this potential to within acceptable limits, making forthcoming behavioral inferences valid.
to be revealed in the present data. However, it is important to differ-
entiate age-related preferences among households from those, though
correlated with age, are attributable to other quality variations,
particularly those pertaining to the general condition of the vacancy
(eg. whether it is in need of significant repair, etc.). To compensate
for this, the average age of owned dwellings has been conditioned upon
the mean value of owner-occupied single family dwellings in the tract.¹
Thus, an indifference relationship is recognized between older and
newer housing, which is contingent upon its value, the latter of which
is a surrogate for general structural quality. It is recognized that
potential ambiguities in this measure might arise because housing values
are contingent upon other factors, particularly those related to local
housing demand and supply conditions, neither of which could be readily
inferred from that data. Regardless, we expect this variable to be
well enough defined to have a negative coefficient associated with it,
reflecting household preferences for newer housing stock.

**Neighborhood Attributes**

The remaining variables in the utility function, relating to the
attributes of attainable alternatives, define the physical and socio-

¹Average age of owned housing stock has been divided by the average
value of owner-occupied single family houses in the tract. (Note the
terminological distinction between owned dwellings and owner-occupied
single family dwellings, the number of the latter always being equal to
or less than that of the former. Definitions for both housing types are
given in Statistics Canada, 1978, p.vii. These differences are not dis-
tinguished further in the text.)

Recall that data limitations preclude the calculation of unconditional
means and standard deviations for age and value measures. They are again
conditioned on single family housing built after 1945 and valued less
than $62,500.
economic characteristics of the neighborhood in which they are situated. The percentage of single family dwellings has been calculated to capture household preferences for neighborhoods composed of the same type of housing stock that searching households in the survey chose to live in. Indirectly, the attribute measures the household's affinity towards neighbors likely to be adopting similar lifestyles. Since the sample used for this analysis comprises only households that purchased single family residences\(^1\), we expect them to prefer to locate in areas containing high proportions of single family units, and thus anticipate a positive coefficient on this variable.

A measure of the number of young families in the area has been specified as the percentage of the tract population that is 16 years of age or younger and attending school full time. Here, we expect families in the sample with school-age children will be attracted to areas containing higher proportions of similar families, revealing preferences to remain associated with others at the same stage of the life-cycle. Since families without school-age children are not expected to consider this attribute important in their locational decisions, however, this variable is assigned a non-zero value only for households that reported in the survey that they had children living at home. A positive coefficient is expected for this attribute.

\(^1\)In Chapter 5, we reported that a small percentage of the sample (8 percent, or 34 households) were renting the current single family unit when surveyed. Barrett (1973, p.87) found the majority of these households residing in houses purchased as revenue-making properties by absent landlords. Because the decision making process in these cases was actually a dual process, involving ownership choice by the landlord and tenancy choice by the occupiers, these households were rejected from the sample. (In these cases, Barrett located the property transaction of the owner, but collected search data from the renter.)
The percentage of new immigrants in the census tract, defined as the percentage of the population that moved to the tract from outside Canada between 1966 and 1971, has been included to capture household preferences for settling in neighborhoods containing families of similar socioeconomic status and ethnicity. That census tracts containing high proportions of new immigrants are anticipated to be avoided in search and, ultimately, in choice is attributable to two factors. First, tracts containing high proportions of immigrants can be expected to offer fewer housing opportunities of the kind desired by searchers in the sample than other areas. New immigrants to the country are typically less established financially than homebuyers, which results in their demanding rental or other units that require lower initial financial outlays. Second, most immigrants, except those of British or U.S. origin, bring with them distinct cultural characteristics which are often considered alien to the cultural "mainstream" of Canada, of which the current sample of homebuyers is suspected of representing. As Murdie (1969) has shown pronounced spatial biases in the settlement patterns of different ethnic populations in Metropolitan Toronto, this tendency is likely to be maintained by households in the sample. For these reasons, a negative coefficient is expected to be associated with this variable.

A final attribute associated with neighborhood characteristics is a function of population density and household income. As most studies have found, households appear to prefer lower to higher density areas. But in accordance with Alonso (1964), we also assume the intensity of these preferences will increase with income. This measure is therefore expressed as the product of population density in the census tract and
the income of the searching household.\footnote{Recall from Chapter 5 that 57 respondents to Barrett's survey either were unable to estimate or refused to divulge their incomes. Further, several reported incomes were found to be implausible given current family financial commitments (Barrett, 1973, p.72). As was employed in Chapter 5, we have used the purchase price of the chosen alternative as a surrogate for income to eliminate these biases. For a justification of this measure, see page 303.} It is uniquely defined for each household in the sample. Because it is defined in this manner, we expect the variable to have a negative coefficient.

In summary, attributes of the termination alternative associated with each conditional binary choice problem in the search sequence have been defined in terms of the locational, housing and neighborhood characteristics of considered vacancies using tract averages as proxies for their specific attributes, where necessary. Locational attributes have been characterized by average distance from the vacancy to the workplace, the only measure of accessibility available in the data. Housing attributes have been defined in terms of living space, by the proportion of single family dwellings in the census tract having a specified number (related to family needs) of bedrooms or more, and in terms of the vacancy's age, conditioned on its value, again using tract averages. Attributes of the neighborhood have been characterized by proportional measures related to the numbers of single family dwellings, school-age children and new immigrants in the tract, and by a product specification of population density and income. These variables are formally defined and specified in Table 7.3.

7.2.3 Summary

The preceding two sections have defined the set of variables which
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
<th>Specification</th>
<th>Source</th>
<th>Expected Sign of Coefficient</th>
</tr>
</thead>
</table>
| WRKDIS  | Average distance from the vacancy to the household's workplace(s). | \[
|        | WRKDIS = \begin{cases} \text{WRKDIS if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Barrett | - |
| PSFBD  | Proportion of single family dwellings with (no. of adults plus no. of children in household) bedrooms or more. | \[
|        | PSFBD = \begin{cases} \text{PSFBD if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Census/Barrett | + |
| AGE    | Ratio of conditional mean age of owned dwellings to conditional mean value of owner-occupied single house non-farm dwellings in tract. | \[
|        | AGE = \begin{cases} \text{AGE if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Census | - |
| PSFD   | Proportion of single family dwellings in tract. | \[
|        | PSFD = \begin{cases} \text{PSFD if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Census | + |
| PSCH16 | Proportion of tract population 16 years of age or younger attending school full time. | \[
|        | PSCH16 = \begin{cases} \text{PSCH16 if termination alternative} \\ \text{and household reported children living at home} \\ 0 & \text{otherwise} \end{cases} | Census/Barrett | + |
| PNEWIM | Proportion of population in tract that moved to the tract from outside Canada between 1966 and 1971. | \[
|        | PNEWIM = \begin{cases} \text{PNEWIM if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Census | - |
| PDENINC| Product of population density in tract and price paid for new home.\(^1\) | \[
|        | PDENINC = \begin{cases} \text{PDENINC if termination alternative} \\ 0 & \text{if continuation alternative} \end{cases} | Census/Barrett | - |

\(^1\)Price paid for home used as surrogate for household income.

**Table 7.3 Independent Variables Associated with the Searcher’s Termination Alternative**
will be used to specify the utility functions of searchers in the sample of Metropolitan Toronto households. In developing them, we have attempted both to remain consistent with the theoretical principles embodied in the stopping rule framework in Chapter 4 and to provide substantive empirical meaning to these variables to facilitate their interpretation in estimation results. As was demonstrated in discussions concerning variable specification, the data are still not sufficiently informative to permit the unambiguous characterization of all determinants of search and choice behavior. That a parametric specification of the empirical model can be constructed and estimated,\(^1\) however, provides the opportunity for undertaking preliminary empirical tests on the theoretical framework and for suggesting appropriate areas for future research.

7.3 Estimation Results

The estimation results in this section are based upon the search and choice behavior of 292 households drawn from Barrett's survey of movers in Metropolitan Toronto.\(^2\) However, because the empirical model

\(^1\)We note that the partitioning of variables into categories relating to the termination and continuation alternatives is arbitrary and has no statistical effect on estimation results. That is, variables such as those relating to search costs could have been alternatively associated with the termination alternative, yielding the same coefficient estimates, though of opposite sign. Furthermore, specification of these measures as alternative-specific variables could have been avoided by transforming the set of conditional discrete choice problems into an equivalent "log of the odds" specification (Domencich and McFadden, 1975, p.108). However, the current specification was retained because of its more direct relationship to the theoretical framework.

\(^2\)In addition to households who were found to be renting their current residences (see footnote on p.370), households that were unable to estimate or refused to divulge their incomes were rejected from the sample.
relates unconditional choice probabilities to the product of conditional
choice probabilities associated with the search sequence and because it
permits the simultaneous estimation of utility functions associated with
all decisions made by households along their search sequence (see Chapter
6), maximum likelihood estimates of model coefficients are actually based
upon 893 conditional binary choices made by the 292 households in the
sample.

Recall what this estimation procedure implies in terms of model
assumptions. Note, first, that we have (reasonably) specified a utility
function which remains structurally invariant throughout the household's
search activities, i.e. the evaluation of alternatives involves the same
vector of attributes regardless of how many observations have been taken
in the search sequence. By estimating all binary choices simultaneously,
however, we have also assumed that the household values these attributes
invariantly throughout the search. Changing attitudes towards search
are only reflected in those attributes which increase or decrease in
proportion to the number of opportunities sampled. In the models to be
estimated, only NSEARCH, the number of opportunities sampled to date, and
the cumulative measures of search distance are indexed in this way. That
households could be adjusting their valuations of other specified attri-
butes as search progresses is not investigated in this study.

Several specifications of the empirical model have been tested to
evaluate alternative specifications and to refine the model for further
analysis.¹ From these tests have been derived four specifications which

¹All models were estimated on TROLL's (Time-shared Reactive On-Line
Laboratory) Multinomial Logit Analysis Package, Version 2.4, on an IBM
370/168.
are discussed on the following pages.

7.3.1 Preliminary Estimation Results

In the initial stages of testing, several variables were eliminated because either their signs were incorrect and could not be accounted for, or they were highly correlated with other measures in the model. The most surprising finding at this stage of analysis was that all measures of distance travelled during search, i.e. marginal distance, both measures of cumulative distance, and their exponential transforms, possessed coefficients which were consistently significant but had incorrect signs. That distance travelled during search activities had a positive impact on utility implied that as cumulative (or marginal) distance travelled during search increased, households preferred to continue searching rather than choose sampled opportunities.

The inadequacy of distance travelled as a measure of generalized search cost has already been discussed, and these arguments would suggest its inappropriateness as a cost surrogate, particularly if sample households have access to automobiles (a characteristic not recorded in the data) to conduct search. However, significance levels were consistently high (asymptotic t-values were usually significant at the 99 percent confidence level), which suggested distance to be measuring another determinant of choice behavior not apparent in the data. Unfortunately, all attempts to identify this alternative effect failed.

Other variables initially estimated but subsequently rejected from the model relate to forced mobility and two measures of perceived housing quality in the searcher's opportunity set. The coefficient for forced mobility was generally insignificant and consistently of the
wrong sign. That the coefficient was positive implied that forced
movers in the sample had higher utilities for continuing search than
did non-forced households. Given the rather inexact definition of
forced mobility used by Barrett (1973), and subsequently adopted in
this study, and given the lack of information concerning the amount
of time forced movers were allowed to locate other premises before
being required to vacate their previous residences, the ambiguity of
this measure is perhaps not surprising.

Relative to measures of perceived value of housing in the searchers'
opportunity sets, measures relating to the age of the housing stock and
number of bedrooms were found to add little to the model's explanatory
power, though generally they were of the correct sign. However, to
investigate the behavior of these variables further, additional models
were estimated, each of which contained only the mean and standard de-
viation of one of the quality measures. Again, coefficients associated
with housing value were of greater significance than those of age or
number of bedrooms, and were consistently of the correct sign. Further-
more, greatest significance levels for models which considered value
measures only were achieved when the standard deviation was expressed
in absolute form and the mean was expressed as the difference between
its updated value and that associated with the previous observation.
This implied that while searching households in Metropolitan Toronto ap-
peared to be sensitive to absolute variations in the value of housing
perceived to exist in their opportunity sets, they also appeared to
be more concerned with how their perceptions of the mean value changed
from observation to observation than what its average value was at any
time. This phenomenon is discussed more thoroughly later in the chapter.

That measures of age and number of bedrooms performed poorly in estimations of the model probably indicates their failure to define housing quality to the precision required for this analysis. Given the comprehensive indicator they attempt to represent, this is perhaps not surprising and suggests that single variable surrogates for housing quality are introducing considerable specification error into the model. Within current data constraints, it was not possible to overcome this problem; final specifications considered the changes in mean housing value from the previous observation and the updated standard deviation in housing values only.

7.3.2 Estimation Results from Final Model Specifications

After recalcitrant variables were eliminated, four model specifications were estimated and analyzed in further detail. Two of these models were of an extended, or full form, embracing most of the measures of utility described in Section 7.2. The other two models were of an abbreviated form which considered only those variables found to be significant in the former. Variants of the full and abbreviated forms examined the behavior of NSEARCH, the most significant variable in the model, and how it impacted the household's probabilities of continuing its search activities.

Estimated coefficients and associated asymptotic t-values for the first form of the full model (Model I) are shown in Table 7.4. Their signs reveal general agreement with a priori expectations, particularly for those coefficients associated with the utility of continuing search, although some anomalies are apparent. Also, the statistical significance
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORK</td>
<td>-0.110297</td>
</tr>
<tr>
<td>NSEARCH</td>
<td>-0.805591*</td>
</tr>
<tr>
<td>INCOME</td>
<td>0.006497</td>
</tr>
<tr>
<td>DELVAL</td>
<td>0.204146***</td>
</tr>
<tr>
<td>VQUALV</td>
<td>0.042792</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>-0.758931 (-1.36121)</td>
</tr>
<tr>
<td>LEGALE</td>
<td>0.197131 (1.03798)</td>
</tr>
<tr>
<td>PSFD</td>
<td>1.24658** (2.27748)</td>
</tr>
<tr>
<td>PNEWIM</td>
<td>3.54197 (-1.61524)</td>
</tr>
<tr>
<td>PSFDSB</td>
<td>0.224462 (0.305048)</td>
</tr>
<tr>
<td>PSCH16</td>
<td>-0.910394 (-0.947719)</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.713324 (-0.9823894)</td>
</tr>
<tr>
<td>PDEINNC</td>
<td>-0.025935 (-0.667029)</td>
</tr>
<tr>
<td>WRKDIS</td>
<td>0.01009 (0.414086)</td>
</tr>
<tr>
<td>CONSTANT ²</td>
<td>-2.81783** (2.2794)</td>
</tr>
</tbody>
</table>

\[-L(\hat{\theta}) = 474.16\]

\[-2(L(\hat{\theta}) - L(0)) = 289.64\] with 14 d.f. ³

*Significant at the .99 confidence level.
**Significant at the .95 confidence level.
***Significant at the .90 confidence level.

¹Asymptotic t-values are shown in parenthesis.
²Associated with the termination alternative.
³Implies rejection of the null hypothesis at the .995 confidence level.

Table 7.4 Estimated Coefficients of Model I
of many variables in the model is less than satisfactory. The model's likelihood value, however, is such that we reject the null hypothesis that all coefficients in the model are identically equal to zero.

The two variables relating to search costs, for which we articulated expectations with respect to sign, both perform as anticipated. Number of workers in the household and the number of observations taken to date both depress searchers' utilities for continued search, although only the latter is highly significant. Household income, however, a variable that has been hypothesized to play a multiple role in the search process, exhibits a positive relationship and thus can be interpreted as a variable which tends to encourage more extensive search activities on the part of households, a finding that is in agreement with non-parametric tests performed in Chapter 5. This would imply that income acts more as a resource for conducting search than either as a resource for facilitating choice or as a constraint related to how people value their time. That its coefficient's significance is so low, however, suggests its multiple influences are operating simultaneously, thereby masking each of the variable's effects.

The most interesting characteristic among these search cost variables is the significance of the indexed variable, NSEARCH. Its obvious importance in influencing the household's disutility towards search suggests further tests should be performed on this variable, which are carried out later in this section.

Both measures of perceived housing quality relate to the searcher's utility as expected, although, because quality is only characterized by value in the model, a cautious interpretation of their behavior implica-
tions is required. We have reasoned that searchers who discern the housing market to be more favorable than previously expected can be anticipated to continue searching because they perceive their chances for drawing a windfall opportunity to be improving. Thus, search is continued in the hope of drawing that windfall from the sample of vacancies. In this respect, the estimated model is in agreement. But by specifying average quality in value terms essentially violates the meaning of "windfall" (although characterizing the variance in quality levels in terms of values is perhaps not unrealistic). Households with relatively constrained financial resources could not possibly be encouraged by a succession of rising house prices in the way this variable has thus far been interpreted, unless the values of the opportunities remained within their budget ceilings. That searchers are so judicious in their initial screenings before undertaking active search could, then, plausibly vindicate the variable's employment as a surrogate for housing quality.

What is possibly occurring, however, is that increasing housing values observed during search are actually discouraging households from choosing the vacancy because it is out of financial reach. A positive change in the perceived mean value of housing stock in the opportunity set may thus be encouraging further search not for its positive connotations, but for its negative ones. It must be admitted, then, that instead of supporting the precepts of the theoretical framework, the positive coefficient on this variable is possibly revealing alternative behavioral or, perhaps, spurious relationships.

Regardless of their precise behavioral meanings, it is interesting
to note that while utility exhibits a relationship to the updated standard deviation of housing values (though that association is weak), its relationship to the mean value of housing is most significant when the latter is expressed as a change from the mean value perceived at the previous observation.¹ Thus, households appear more sensitive to marginal changes in housing values when attempting to formulate expectations concerning the average unit potentially available to them than they are to average housing values. Conversely, though low significance levels advise caution, households find variations in housing values more informative when expressed as an absolute measure rather than as a change from the previous observation.

The competition measure, SUPPLY, also relates to search behavior as expected, although the significance of its coefficient is low. Census tracts which have experienced higher turnovers of their populations thus tend to lower the household's utility for continuing search, and make the alternative currently under consideration relatively more attractive. The degree to which this effect is induced by competitive factors rather than supply factors cited earlier, however, is neither apparent in the estimate nor extractable from the data.

Finally, previous tenure status of the household does appear to influence the household's utility of continuing search, though not in the direction expected a priori, nor observed in other studies of urban housing markets. That the household previously owned its former residence appears to increase its utility for undertaking further search.

¹ Alternative combinations of the two variables were estimated to arrive at this finding.
We note that this finding is in contradiction to Michelson's observations of searching households in Metropolitan Toronto. But this may be partly attributable to controls placed on this variable in the econometric specification, through the introduction of other variables related to search, which were not considered in Michelson's study.

The more extensive search activities of former renters has been attributed essentially to the different priors about opportunities in the housing market possessed by former renters and owners. Michelson (1977, p.101), for example, has cited the more precisely defined choice criteria likely to be articulated by former owners, while we have suggested that their relative unfamiliarity with attainable opportunities in the owner-occupied sub-market forces former renters to gather more information through search activities than former owners. But the information content of the searcher's opportunity set has at least been partially controlled for by the perceived variation in housing values, which the searcher updates at every observation. This suggests that former tenure status may be more reflecting the establishment of criteria for choice than the possession of knowledge about attainable opportunities in the housing market. And when examined as an independent factor in the choice process, the establishment of a rigid set of criteria upon which to evaluate alternatives does not necessarily portend abbreviated search.

Former renters, with less well-defined criteria for choice, brought on by their inexperience with home-ownership, may be far more willing to settle for a vacancy lacking certain desirable structural or other characteristics than former owners, who are relocating to improve their
previous locational circumstances. If we recall from Chapter 5 that nearly one-half of former renters in the sample cited home-ownership as the major reason for moving, we might conclude that this over-riding criterion for choice could be dominating their other standards, enabling choice to be made sooner than would otherwise be expected.

Clearly, the differences in search behavior between former owners and renters are not totally explained by these factors alone, which suggests further analysis is required to better understand the distinct motivations of these sub-populations in their residential search strategies. Although the sample could have been segmented to permit separate specifications and estimations of the parameters, the exploratory nature of the empirical analysis and its intent to focus the research toward behavior relationships embodied in the theoretical framework precluded this option for the present study.

The remaining variables in the full specification of the model are characterized in terms of the attributes of the opportunities currently under observation. Although the theoretical and empirical literature has been used to suggest expected relationships between these variables and choice behavior in estimation results, several coefficients, though they have correct signs, are statistically insignificant.

The most significant determinants of choice associated with the attributes under investigation relate to the density characteristics of the neighborhood and its composition with respect to immigrants from outside Canada. Households in the sample reveal strong preferences for neighborhoods consisting of high proportions of owner-occupied single
family dwellings and low proportions of new immigrants in their residential choices.

That the former relationship is expected was earlier attributed to homeowners' desires to be associated with others experiencing similar lifestyles and values. These preferences are likely being reinforced, though, both by residential zoning practices prevalent in the metropolitan region and the geographical units used to define these variables. Mixed density zoning has not been widely practiced in the suburban areas of Metropolitan Toronto and, given the suburban bias in relocation patterns of homeowners in the sample (Barrett, 1973, p.89), attributable both to housing supply and spatial preferences, choice has necessarily been encouraged in areas containing high proportions of single family units. Furthermore, to the extent that socio-economic characteristics comprise one set of factors which distinguish household tenure status, as contended by several authors (see Chapter 2), census tract homogeneity with respect to these characteristics are conceivably correlating tract composition with residential preferences.

With regard to the proportion of new immigrants in the neighborhood, we are, in fact, assuming the latter correlations to exist to provide a partial explanation for observed residential preferences. That recent immigrants have not likely accumulated sufficient wealth to support the financial requirements of home-ownership (see Barrett, 1973, p.89; Michelson, 1977, p.34) encourages them to seek rental units or owned

---

1 Personal communication with Roger Hubbard, Development Control Supervisor, Metropolitan Toronto Planning Board, Development Control Division, 5 May, 1980.
dwellings of lower value in mixed density areas, i.e. areas avoided by more financially stable relocators in the data. However, the tendency for households to reside in tracts containing lower proportions of new immigrants also likely reflects genuine locational preferences for neighbors who possess similar cultural characteristics and values.

Estimated coefficients also reveal that larger households prefer areas containing higher proportions of larger homes (in terms of number of bedrooms) and that all households prefer newer to older homes. Space limitations has long been recognized as a major stimulus to residential mobility in the empirical literature and has been shown to be a major concern of households in the sample (see Table 5.4). That households have articulated these concerns into a definitive criterion for choice, then, is not an unexpected finding. The lack of significance associated with its coefficient, however, may indicate that this criterion for choice is de-emphasized during search as other factors are taken into account, or may simply be due to data deficiencies.

Note that the preferences of larger households for locating in tracts containing higher proportions of larger houses do not appear to be motivated by desires to be associated with families at similar stages of the life-cycle. The percentage of tract population 16 years of age or younger attending school full-time, specified to independently account for this effect, is negatively related to utility, suggesting that socio-economic attributes of the neighborhood associated with this variable are generally regarded with antipathy by searching households rather than with respect.\footnote{Recall that this variable is only operative for families in the}
ferences, larger households with children appear to be faced with a paradoxical decision problem during their search activities, since the two attributes often covary.

Revealed preferences for newer housing by searchers supports a similar finding by Butler *et al.* (1969), although newer units tend to characterize the available supply of vacant housing in this rapidly expanding metropolitan region. There is also some contention regarding what this variable is actually measuring, since it is conditioned upon the average value of housing in the tract, rather than more meaningful housing quality indicators. That lower values of this variable are preferred to higher ones may, as well, be indicative of the price structure of single family housing in a residential market that experienced severely inflated demand and disproportionately higher prices for newer units over the period of analysis (Spurr, 1976; Lorimer, 1975). Given the likelihood of specification error in its construction, then, relating the sign of the coefficient to housing age-related preferences should perhaps be regarded with some scepticism.

Only a weak preference is shown in choice decisions for low density residential areas by households in the sample, although the variable was consistently of the correct sign in estimated experimental specifications of the searcher's utility function. The lack of significance is probably due to multicollinearity with the percentage of single family dwellings in the observed census tract. However, its coefficient indicates some support for the contention that low density preferences are

---

sample with school-age children. Therefore, a rudimentary control on the life-cycle stage of the searching household is in effect.
intensified by household income.

The estimated coefficient associated with distance to the workplace, on the other hand, does not support classical hypotheses concerning the effects of this variable on location behavior. However, issues related to variable misspecification and the inadequacies of distance as a surrogate for accessibility, addressed in Section 7.2, are likely of fundamental importance in both the sign and non-significance of the coefficient. Further, preferences for home-ownership and the location of most of the supply of single family residences at the suburban fringe of the metropolitan area are probably diminishing the impacts of this variable in the locational considerations of households. For these reasons, the ambiguous relation of distance to utility is not totally unexpected.

Despite the levels of significance associated with estimated coefficients, we have interpreted (somewhat liberally) the relationships between specified variables and the searcher's utility, the latter of which probabilistically determines subsequent search and choice behavior in the empirical framework. From these relationships, we have shown that the signs of these coefficients generally agree with a priori expectations, although several anomalies have been found to persist. These anomalies have usually been attributed to misspecification arising from weaknesses in the data from which estimates were derived.

To reduce measurement error and develop a specification with more statistically significant coefficients, several abbreviated forms of the model were estimated which selectively considered subsets of variables from the original specification, primarily those whose coefficients had statistical or marginal statistical significance associated with them.
and for which *a priori* theory was supportive. From these tests, a final abbreviated form of the model (Model II) was specified and estimated. Coefficient estimates and their asymptotic t-values are shown in Table 7.5.

In this specification, all coefficients except the change in the mean value of housing in the opportunity set and previous tenure status are significant at the 95 percent confidence level. Furthermore, all previously defined relationships have been retained in this specification. Note that the pseudo-competition measure associated with the continuation alternative, \textsc{supply}, is now highly significant, suggesting possible multicollinearity problems in the previous specification. From the data describing household search patterns through the owner-occupied housing market in Metropolitan Toronto, variables incorporated into the utility function in the abbreviated specification appear to be the most significant identifiable determinants of those defined to explain the residential search and choice behavior of sample households.

Two observations should be noted from this specification. First, we have introduced a dummy variable associated with the continuation alternative which indicated whether the searcher was previously familiar with the area being searched. The coefficient is highly significant and its positive sign may be interpreted to mean that households that sample in areas in which they are familiar possess higher utilities for continuing search than households that are not, as expected.

We have argued that if the household is familiar with the area, *i.e.* aware of the neighborhood's socioeconomic and housing characteristics,
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSEARCH</td>
<td>-0.808459* (-11.5513)</td>
</tr>
<tr>
<td>DELMVAL</td>
<td>0.170183*** (1.7789)</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>-0.974865* (-2.79071)</td>
</tr>
<tr>
<td>LEGALB</td>
<td>0.275609 (1.57574)</td>
</tr>
<tr>
<td>FAMAREA</td>
<td>0.396447** (2.17443)</td>
</tr>
<tr>
<td>PSFD</td>
<td>1.08372** (2.12159)</td>
</tr>
<tr>
<td>PNEWIM</td>
<td>-3.16245** (-2.2093)</td>
</tr>
<tr>
<td>CONSTANT&lt;sup&gt;2&lt;/sup&gt;</td>
<td>-3.13381* (-5.90629)</td>
</tr>
</tbody>
</table>

-L(\(\hat{\beta}_{II}\)) = 474.51
-2(L(\(\hat{\beta}_{II}\)) - L(0)) = 289.058 with 7 d.f.<sup>3</sup>

*Significant at the .99 confidence level.
**Significant at the .95 confidence level.
***Significant at the .90 confidence level.

<sup>1</sup>Asymptotic t-values are shown in parenthesis.

<sup>2</sup>Constant associated with the termination alternative.

<sup>3</sup>Implies rejection of the null hypothesis at the .995 confidence level.

Table 7.5 Estimated Coefficients of Model II
search there is relatively uninformative. In other words, there is little in the way of information which can inform the household about the distribution of housing opportunities which are potentially available to it. Since the amount of time and resources for sampling vacancies constrains the number of alternatives which can be evaluated, search is more effectively conducted in unfamiliar areas, from which a better, though still incomplete characterization of the distribution can be inferred. Once this distribution is comprehended, residential choice is facilitated, since the relative "value" of the current opportunity is known with more precision than would otherwise be the case; the decision process essentially tends toward a rational one in this way.

That familiarity with neighborhoods in the opportunity set encourages longer search is supported in Barrett's (1973) study. Using the same survey data analyzed in this research, he found that greater percentages of households that undertook longer searches (in terms of number of vacancies sampled) were more often familiar with the areas in which they searched than those that sampled fewer vacancies (Barrett, 1973, p.171). The current study suggests that this is due to the information embodied in those observations. Note, however, that unfamiliarity does not necessarily precipitate choice. Although not apparent in coefficient estimates, Barrett (1973, p.131) found that nearly 70 percent of all households sampled claimed to be previously familiar with the area in which they now resided.

A second observation noted from coefficient estimates associated with the second specification of utility concerns the significance of NSEARCH, the number of alternatives thus far sampled during search.
As in the first model, the coefficient is highly significant and of the correct sign; as the number of observations taken increases, the searcher's utility toward further search declines and the relative probability of continuing is correspondingly reduced. Because of its relative stability and continuing importance in influencing search behavior, these results encouraged further tests to more precisely guage the variable's impact on the searcher's utility as search progressed.

Additional tests involved respecifying the variable from one which was indexed, to a set of dummy variables, each of which was associated with the number of observations the household had sampled to the current point in the search process.\(^1\) This procedure effectively removed the

\(^1\) A household that made \(k\) observations was assigned \(k\) alternative-specific dummy variables, \(N_1, \ldots, N_k\). Each dummy variable was defined as follows:

\[
N_i = \begin{cases} 
0 & \text{if the alternative was to terminate search and choose the currently observed vacancy} \\
1 & \text{if the alternative was to continue search and the household was currently observing alternative } i \\
0 & \text{otherwise}
\end{cases}
\] (7.3.1)

The utility function of the searcher, when considering the continuation alternative at observation \(i\) therefore contained a sub-vector of dummy variables, \((N_i, \ldots, N_k)\), with the \(i\)th element equal to one and the other \(k-1\) elements equal to zero. The sub-vector associated with the termination alternative was a zero-vector for all households and observations.

The maximum number of dummy variables plus constants that could be specified in this form for this problem without producing a singular matrix was six (see McFadden, 1974, p.116). To maintain consistency with previous specifications, the constant term was retained, and five dummy variables, \(N_1, \ldots, N_5\), were defined as in (7.3.1) to replace the NSEARCH term in the searcher's utility function.
linearity constraint on the variable's relationship to the searcher's utility, thereby allowing us to investigate whether successive observations upon the housing market impacted utilities otherwise.

Estimation results for both the full and abbreviated specifications of utility, using the dummy vector rather than the indexed variable, are shown in Tables 7.6 and 7.7 (Models III and IV). What is readily apparent from these tables is the distinctly non-linear form of the relationship between number of opportunities searched and the utility of continuing.\(^1\) Furthermore, in each case, the significance of the estimation equation has increased substantially from its counterpart containing the indexed variable. Chi-square tests on likelihood ratios, which use model specifications containing the variable NSEARCH as null hypotheses, reject the null hypothesis in both cases.

If we consider only the constant estimated in both specifications, the impacts of this variable upon relative choice probabilities are readily illustrated (Figure 7.2). Except for the probability associated with \(N_3\), the relative effects of the number of vacancies sampled resembles an exponential decay function. This suggests that successive observations, though they reduce the probability of continuing search, reduce it a marginally decreasing rate. And although the lack of sufficient data points render it tentative, the result is significant

\(^1\) That coefficients associated with these variables are not negative is attributable to variable definition. For the indexed variable, NSEARCH, the estimated coefficient measures the slope of the relationship between the number of observations sampled and utility. As such, it was rightly found to be negative. For the dummy variables, measurement of the slopes of their relationships is no longer meaningful. What is important are the relative effects of these variables on utility and subsequent probabilities of continuing.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWORK</td>
<td>-0.120279 (-0.847842)</td>
</tr>
<tr>
<td>$N_1$</td>
<td>4.34097* (7.00921)</td>
</tr>
<tr>
<td>$N_2$</td>
<td>1.4681* (2.65223)</td>
</tr>
<tr>
<td>$N_3$</td>
<td>1.39934** (2.48042)</td>
</tr>
<tr>
<td>$N_4$</td>
<td>0.65102 (1.12702)</td>
</tr>
<tr>
<td>$N_5$</td>
<td>0.114155 (0.179492)</td>
</tr>
<tr>
<td>INCOME</td>
<td>0.007443 (0.710386)</td>
</tr>
<tr>
<td>DELIVAL</td>
<td>0.247863** (2.0036)</td>
</tr>
<tr>
<td>VQUALV</td>
<td>0.023403 (0.272205)</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>-0.914845 (-1.57356)</td>
</tr>
<tr>
<td>LEGALB</td>
<td>0.186314 (0.960532)</td>
</tr>
<tr>
<td>PSFD</td>
<td>1.26233** (2.22011)</td>
</tr>
<tr>
<td>PNEWIM</td>
<td>-3.57034 (-1.62052)</td>
</tr>
<tr>
<td>PSFDBD</td>
<td>0.11064 (0.384902)</td>
</tr>
<tr>
<td>PSCH16</td>
<td>-1.07365 (-1.05373)</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.708822 (-0.805519)</td>
</tr>
<tr>
<td>PDENINC</td>
<td>-0.029152 (-0.74857)</td>
</tr>
<tr>
<td>WRKDIS</td>
<td>0.008519 (0.336136)</td>
</tr>
<tr>
<td>CONSTANT$^2$</td>
<td>0.803136 (0.578626)</td>
</tr>
</tbody>
</table>

\[-L(\hat{\beta}_{III}) = 441.14\]
\[-2(L(\hat{\beta}_{III}) - L(0)) = 355.68\text{ with } 18\text{ d.f.}^3\]
\[-2(L(\hat{\beta}_{III}) - L(\hat{\beta}_I)) = 66.04\text{ with } 4\text{ d.f.}^3\]

*Significant at the .99 confidence level.
**Significant at the .95 confidence level.

$^1$Asymptotic t-values shown in parenthesis.
$^2$Constant Associated with the termination alternative.
$^3$Implies rejection of the null hypothesis at the .995 confidence level.

Table 7.6  **Estimated Coefficients of Model III**

402
| Variable | Coefficient
table:1 |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_1$</td>
<td>4.40036*</td>
</tr>
<tr>
<td></td>
<td>(7.17813)</td>
</tr>
<tr>
<td>$N_2$</td>
<td>1.42617*</td>
</tr>
<tr>
<td></td>
<td>(2.50303)</td>
</tr>
<tr>
<td>$N_3$</td>
<td>1.39608**</td>
</tr>
<tr>
<td></td>
<td>(2.48256)</td>
</tr>
<tr>
<td>$N_4$</td>
<td>0.69875</td>
</tr>
<tr>
<td></td>
<td>(1.21303)</td>
</tr>
<tr>
<td>$N_5$</td>
<td>0.062642</td>
</tr>
<tr>
<td></td>
<td>(0.098638)</td>
</tr>
<tr>
<td>DELMAVL</td>
<td>0.228757**</td>
</tr>
<tr>
<td></td>
<td>(2.09598)</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>-1.04696*</td>
</tr>
<tr>
<td></td>
<td>(-2.00045)</td>
</tr>
<tr>
<td>LEGALB</td>
<td>0.252761</td>
</tr>
<tr>
<td></td>
<td>(1.4136)</td>
</tr>
<tr>
<td>FAMAREA</td>
<td>0.611429*</td>
</tr>
<tr>
<td></td>
<td>(3.09842)</td>
</tr>
<tr>
<td>PSFD</td>
<td>1.00601***</td>
</tr>
<tr>
<td></td>
<td>(1.89449)</td>
</tr>
<tr>
<td>PNEWIM</td>
<td>-2.75367***</td>
</tr>
<tr>
<td></td>
<td>(-1.90453)</td>
</tr>
<tr>
<td>CONSTANT2</td>
<td>0.750242</td>
</tr>
<tr>
<td></td>
<td>(1.00984)</td>
</tr>
</tbody>
</table>

\[-L(\hat{\beta}_{IV}) = 438.57\]
\[-2(L(\hat{\beta}_{IV}) - L(\hat{\beta}_{II})) = 360.82 \text{ with 11 d.f.}^3\]
\[-2(L(\hat{\beta}_{IV}) - L(\hat{\beta}_{II})) = 71.77 \text{ with 4 d.f.}^3\]

*Significant at the .99 confidence level.
**Significant at the .95 confidence level.
***Significant at the .90 confidence level.

1 Asymptotic t-values shown in parenthesis.
2 Constant associated with termination alternative.
3 Implies rejection of the null hypothesis at the .995 confidence level.

Table 7.7 Estimated Coefficients of Model IV
Relative probability of continuing search

Relative probabilities calculated from models III and IV are, for illustrative purposes, identical.

Figure 7.2 Impact of Number of Vacancies Sampled (Expressed as the Dummy Vector, N) on the Probability of Continuing Search
because it contradicts theoretical expectations which have been articulated in the literature. Rather than considering successive failures with increasing marginal impatience, as suggested by Weibull (1978), the data reveal that households, in the same terminology, appear to regard them with decreasing marginal impatience. In other words, the household's commitment toward search declines with each observation (at least up to five observations), but its concern toward the marginal effort required to repeatedly sample housing opportunities diminishes with each successive draw.

Clearly, indicator measures on the number of vacancies sampled to the current decision point do not capture all dimensions of search costs likely to be considered by households in their search for housing. And several of the dimensions, particularly those related to time, could potentially exhibit behavioral relationships to utility which reflect increasing marginal impatience or similar attitudinal changes, as suggested in the literature. That other factors in search activity patterns, which are unobservable in the data, might be obfuscating a more conventional relationship between number of vacancies sampled and the utility of continuing search could also be hypothesized.  

1As mentioned previously, some degree of trip chaining, i.e. multiple observations during a single search event, was likely employed by some households in the sample. Alternative cumulative distance measures, however, were unable to bear this out and it remains unobservable in the current data set. Also, re-examination of the data revealed some households to be employing what appeared to be hierarchical search strategies whereby, after one or two observations, the opportunity set was reduced to a single census tract and sampling was subsequently confined to that tract. Since the empirical model assumes each observation to be an independent event, observations undertaken in an hierarchical manner are likely biasing parameter estimates. The extent to which this hierarchical pattern of search could be responsible for the observed "marginal decreasing impatience" with respect to number of vacancies sampled is not known.
significance of its coefficient, when stated as an indexed variable and the significance of the model when number of vacancies sampled is stated as a dummy vector, suggests otherwise. Whether similar economies of continuing search are perceived by households along other dimensions of utility deserves further investigation.

Estimation results presented in this section have tended to support most a priori expectations concerning the impacts of selected variables, pertaining to search and choice behavior, upon the searcher's utility function and subsequent choice probabilities, although the statistical significance of several have been found to be low. Those variables which did exhibit anomalous relationships in the estimated models have generally been found to be data limited or misspecified with respect to the phenomena they were intended to represent. Only measures of distance travelled to sampled vacancies in the opportunity set, an intended surrogate for search cost, were consistently of the wrong sign and statistically significant in all initial specifications of the model. Its counter-intuitive relationship to utility remains unexplained.

What appear to be the most significant factors in the search and choice behavior of households in the Metropolitan Toronto survey have been identified in an abbreviated specification of the model. Its results have shown that, of the variables which can be related to search behavior, the number of vacancies sampled by the household (a measure of cost), the change from the previous observation in the mean value of housing, historical population turnover in the tract under observation (a pseudo-competition measure), previous tenure status,
and the household's familiarity with the area prior to observation, appear to be the most significant determinants of the household's utility of continuing search. In conjunction with these variables, residential choice, which is dependent upon the utility of terminating search, appears to be predicated upon the proportion of single family dwellings in the tract and the proportion of new immigrants who reside there.

Additional analysis has examined the relationship of the number of vacancies sampled by the household to the utility of continuing search. Through a respecification of the variable to remove linearity constraints, estimation results have shown that its relationship to utility is distinctly non-linear, and resembles a negative exponential function. This relationship has been noted because its behavioral implications oppose conventional hypotheses regarding the effects of repeated failures in search upon the individual's attitudes toward continuing the process. Rather than exhibiting increasing marginal impatience with respect to the number of vacancies sampled, households, although they view the process with increasing disutility, appear to sense certain economies in the marginal cost of continuing search. We suggest this implication with caution, however, since the number of data points upon which the relationship is based is few, and certain aspects of search behavior not observable in the data, but which could motivate such a relationship, have not been thoroughly investigated in this research.

That the searcher's utility function has been specified and estimated in a choice-theoretic framework, and the behavioral relation-
ships of the attributes of search and choice alternatives have been identified, only partially addresses the relationship of the empirical model to the theoretical framework, however. Since search has been characterized in the former as a product of the binary choice probabilities calculated at each decision point in the process, it remains to reconstruct the search model from the results derived in this section. By doing so, we provide a more comprehensive overview of the empirical model as a predictor of actual search behavior and as an instrument for evaluating the theoretical framework.

7.4 Reconstruction of the Empirical Model of Residential Search

In the empirical model developed in Chapter 6, residential search behavior is characterized by a probability function which measures the unconditional probability that the searcher chooses a given alternative. This probability is expressed as a function, or more specifically, the product of a series of conditional probabilities over the set of binary choices which confront the searcher at each observation, i.e. those of whether to terminate search and accept the vacancy or to sample again from the opportunity set. It is the latter set of probabilities which have been estimated in the previous section. To empirically construct the search model, then, we must now recombine the conditional probabilities associated with the binary choice set back to their product form.

Tests on the reconstructed search model proceeds along two fronts. We first relate model predictions to search behavior in the data by comparing the frequency which the model replicated the choices made by households in the survey. The estimation package used in this analysis, in addition to estimating coefficients of the utility function, calcu-
lated the choices that would have been made by the household if it had evaluated the stop and continuation alternatives with a utility function identical to that specified in the model. (The predicted alternative is taken as that which has the highest probability associated with it.) Frequency counts can thereby be used to compare what the model predicts the search sequence to be with the search sequence actually followed by households in the data. We classify this procedure as a comparison of model predictions.

Although informative, this approach is limited because it mis-represents the true meaning of the estimated choice probabilities calculated from searcher's utilities. By assigning, say, the probability \( p \) to one alternative and \( 1-p \) to the other, the model is actually asserting that, given the two alternatives defined by characteristic attribute vectors, \( X_1 \) and \( X_2 \), the household will choose the one alternative with probability \( p \) and the other with probability \( 1-p \). Under these circumstances, search behavior predicted by the model is more meaningfully evaluated by directly calculating the unconditional probabilities associated with each household's search path, and then aggregating these probabilities to compare the expected choice behavior of households to those observed in the data. This comparison of model expectations is undertaken following the evaluation of frequency counts described above.

The evaluation of the empirical framework utilizes two of the model specifications described in the previous sections. One is the full specification of utility (Model I) which imposes a linear constraint upon search costs through the estimation of the indexed variable, NSEARCH. The second model to be used is an abbreviated form which specifies the
number of vacancies sampled by the dummy vector, N (Model IV). These models are summarized in Table 7.8 for future reference. We note at this point the statistical differences of fit of the models to the data (via likelihood ratio tests) and expect the latter to compare more favorably to observation than the former.

7.4.1 Comparison of Model Predictions

As described above, the estimation procedure calculated the expected choices of households at each binary decision point by assigning choices to the alternatives possessing greater conditional probability values. These choices were then aggregated by simple enumeration to arrive at frequency counts which were associated with each of the redefined alternatives available to the searcher. (At this point, the term "alternative" loses its spatial meaning, and is simply the vacancy (observation number) at which search is terminated.)

This procedure, however, leads to a problem of interpretation. Aggregation of individual binary choice decisions was necessarily accompanied by a comparison to the actual observational process undertaken by the household in the data. If the household sampled, say, two vacancies unsuccessfully before choosing the third, then model predictions were evaluated to determine the choices assigned to the first, second and third observations. If the model predicted choice by the third observation, then comparisons to observed behavior could be directly accounted for. If, however, the model predicted the continuation of search beyond the third observation, the point at which it predicted search terminated was indeterminant, since the opportunity set of the household beyond the actual chosen alternative, i.e. the set of vacancies.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Model I</th>
<th>Model VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWORK</td>
<td>-0.110297</td>
<td>-</td>
</tr>
<tr>
<td>NSSEARCH</td>
<td>-0.805591*</td>
<td>-</td>
</tr>
<tr>
<td>(N_1)</td>
<td>-</td>
<td>4.40036*</td>
</tr>
<tr>
<td>(N_2)</td>
<td>-</td>
<td>1.42617*</td>
</tr>
<tr>
<td>(N_3)</td>
<td>-</td>
<td>1.39608**</td>
</tr>
<tr>
<td>(N_4)</td>
<td>-</td>
<td>0.69875</td>
</tr>
<tr>
<td>(N_5)</td>
<td>-</td>
<td>0.062642</td>
</tr>
<tr>
<td>INCOME</td>
<td>0.006497</td>
<td>-</td>
</tr>
<tr>
<td>DELMVAL</td>
<td>0.204146***</td>
<td>0.228757**</td>
</tr>
<tr>
<td>VQUALV</td>
<td>0.042792</td>
<td>-</td>
</tr>
<tr>
<td>SUPPLY</td>
<td>-0.758931</td>
<td>-1.04696*</td>
</tr>
<tr>
<td>LEGALB</td>
<td>0.197131</td>
<td>0.252761</td>
</tr>
<tr>
<td>FAMAREA</td>
<td>-</td>
<td>0.611429*</td>
</tr>
<tr>
<td>PSFD</td>
<td>1.24658**</td>
<td>1.00601***</td>
</tr>
<tr>
<td>PNEWIM</td>
<td>-3.54197</td>
<td>-2.75367***</td>
</tr>
<tr>
<td>PSFDBD</td>
<td>0.224462</td>
<td>-</td>
</tr>
<tr>
<td>PSCH16</td>
<td>-0.910394</td>
<td>-</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.713324</td>
<td>-</td>
</tr>
<tr>
<td>PDENINC</td>
<td>-0.025935</td>
<td>-</td>
</tr>
<tr>
<td>WRKDIS</td>
<td>0.01008</td>
<td>-</td>
</tr>
<tr>
<td>CONSTANT (termination alternative)</td>
<td>-2.81783**</td>
<td>0.750242</td>
</tr>
</tbody>
</table>

*Significant at the .99 confidence level.
**Significant at the .95 confidence level.
***Significant at the .90 confidence level.

Table 7.8 Estimated Coefficients of Models I and IV
it would have sampled had the third vacancy been rejected, was unknown. To compensate for this, the frequency statistic defined to compare model predictions with the data is expressed in the awkward form, "number of households making not less than i observations". Given the absence of suitable alternatives, this statistic, although awkwardly defined, should at least provide initial indications about the performance of the model.

Comparisons of frequency counts on the number of households making not less than the specified number of observations are shown in Table 7.9. The table reveals two features which immediately distinguish model predictions from observed search behavior. One relates to an apparent undercounting of vacancies sampled by searchers. While households in the data sampled up to seven vacancies before choosing a residence, the models fail to reveal directly any choices made after the fifth observation, although some households in both models continue their searches beyond that point for an indeterminate number of observations. The second feature concerns the minimum number of observations taken before search is terminated. By definition, all households had to sample one vacancy before choosing to relocate. And of those surveyed, ten households reported that they seriously considered only their current residence before deciding to move there. Surprisingly, however, both models predict no households choosing the first vacancy observed in the sampling process. And even after two observations, the termination decision is made by few households, particularly in the choices generated in Model I. In general, then, the table reveals a systematic bias in model predictions, tending toward an overcounting of households continuing search near the initial stages of the process and an undercounting of households.
<table>
<thead>
<tr>
<th>Number of Observations&lt;sup&gt;1&lt;/sup&gt;</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>292</td>
<td>289</td>
<td>165</td>
<td>95</td>
<td>41</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(0.97)</td>
<td>(0.57)</td>
<td>(0.33)</td>
<td>(0.14)</td>
<td>(0.04)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Model I</td>
<td>292</td>
<td>292</td>
<td>276</td>
<td>115</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(0.95)</td>
<td>(0.39)</td>
<td>(0.04)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Model IV</td>
<td>292</td>
<td>292</td>
<td>217</td>
<td>104</td>
<td>22</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(0.74)</td>
<td>(0.36)</td>
<td>(0.08)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

<sup>1</sup> Proportions of sample making not less than i observations indicated in parenthesis.

Table 7.9 Comparison of Observed Search Behavior with Choices Predicted by Models I and IV (expressed as the number of households making not less than i observations)
in later stages.

These characteristics of model predictions are more clearly shown in Table 7.10 and 7.11. Here, the matrices would indicate exact replication of search behavior in the data if only their diagonal elements were non-zero. Particularly evident in both cases, however, is a pattern of non-zero elements above the diagonal of the sub-block consisting of the first three observations and below the diagonal of the sub-block consisting of the fourth to the seventh observations. Note especially the over-counting associated with those households that actually chose the second opportunity observed.

Comparison of the two models reveals the significantly (though not necessarily in a statistical sense) improved performance of the abbreviated specification of the model (Model IV), particularly with respect to its not extending search beyond households' observed activities. This is probably attributable to the exponential decline in the relative conditional probabilities of continuing search beyond initial observations, associated with the dummy cost variable, N. The variable's influence also likely accounts for the significant number of households whose search activities are underestimated. Examination of the diagonal elements of the matrices reveals, overall, that the models, when considered in this way, replicate the search behavior of households in the data reasonably well, though they tend to concentrate choice in the middle observations of the process.

That model predictions are characterized by the determinate selection of alternatives based upon conditional probability measures and the comparison of frequency counts with actual residential selections, how-
<table>
<thead>
<tr>
<th>Observed Number of Households</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>292</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>282</td>
<td>112</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>164</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>18</td>
<td>77</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>7</td>
<td>27</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>3</td>
<td>10</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Table 7.10 Matrix of Observed Search Behavior versus Search Behavior of Households Predicted by Model I (expressed as the number of households making not less than i observations)
### Table 7.11
Matrix of Observed Search Behavior versus Search Behavior of Households Predicted by Model IV
(expressed as the number of households making not less than i observations)
ever, tends to distort the models' estimates. We have argued earlier that since the model is probabilistic, its estimates are more meaningful when considered in a statistical sense. By calculating the expected, rather than deterministic behavior of the model, we can gain greater insight into its predictive, rather than replicative capabilities.

7.4.2 Comparison of Model Expectations

Expected numbers of households terminating search at successive observations were estimated by first calculating each household's choice probabilities (of stopping at a given observation) associated with its search activities. Using the relation defined in (6.2.9) between the probability of stopping at i and the conditional probabilities associated with the residential choice and search continuation alternatives, a set of measures was derived which could be aggregated to estimate expected choice behavior, and could then be compared to that of the sample population.

Individual choice probabilities were aggregated by sample enumeration (see Koppleman, 1975, p.72). Thus, the expected number of households terminating search at the i\textsuperscript{th} observation was simply a summation of each household's unconditional probability of stopping search at i. However, since conditional choice probabilities beyond searchers' chosen alternatives were unknown, a smoothing procedure was used to account for missing observations.\textsuperscript{1}

\textsuperscript{1}Rather than simply scaling expected choice behavior from enumerated probabilities, a procedure was devised which attempted to account for the residual unconditional probabilities of continuing search, which could be calculated from choice probabilities. To effect this, the set of average probabilities associated with stopping at each observation
Estimated probabilities and the number of households expected to discontinue search after each observation are shown in Table 7.12. These results are compared to choice frequencies and numbers of households that actually chose the alternatives in the residential survey. The overall fit of both models is good, although the abbreviated specification (Model IV) is clearly a better predictor of observed choice behavior. Both models estimate the probability of discontinuing search after just one observation to be small. Thereafter, the choice probabilities peak at the second or third observations and then asymptotically decline toward zero after that.

In terms of number of households expected to discontinue search at each observation, the estimates of Model IV are remarkably similar to the choice behavior of sample households (Figure 7.3). Again, as in the

\[ P_{t}^{k+} = 1 - \sum_{i=1}^{k} P_{t}^{k} \]  

(7.4.1)

This residual probability measure was then distributed among the remaining observations in proportion to the expected choice behavior of households that stopped search beyond the kth observation.

Although we acknowledge the introduction of bias from this procedure into expected search behavior embodied in the model's probability estimates, its severity cannot be readily determined; it is undoubtedly inversely related to the number of households that sampled the observation. Clearly, since most households sampled at least two or three vacancies before choosing a unit, enumerated expectations associated with these early observations are based upon an almost complete set of choice probabilities, and the biases introduced via smoothing are therefore relatively small. Beyond the third observation, however, the procedure is likely introducing errors of larger magnitude into expectation estimates.
<table>
<thead>
<tr>
<th>Number of Households Terminating Search at $i^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td><strong>Observed</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Model I</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Model IV</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

$^1$Proportions of households stopping at observations shown in parenthesis.

Table 7.12 Comparison of Observed Search Behavior to that Expected from Probability Estimates Aggregated from Models I and VI
Figure 7.3 Comparison of Observed Number of Households Terminating Search at Each Observation with Expected Number of Households Estimated by Models I and IV
analysis of frequency counts, the models are distinguished by their estimates associated with the second and third observations. Whereas the expected number of households terminating search peaks sharply at the second observation in the abbreviated specification of the model, a relatively even distribution of terminations amongst the second through the fourth observations is estimated by Model I. That the former better replicates the data suggests, again, that the searcher's attitude toward search costs, when expressed in terms of the number of opportunities sampled, exhibits a distinctly non-linear relationship to utility over the course of search, imposing relatively greater increments of disutility upon earlier vacancy rejections than upon rejections encountered later in the sampling process.

Since it could be argued that comparisons of model expectations to the data on which they are based only partially substantiates its behavioral structure, an additional test was carried out to validate the choice-theoretic framework. Recall that earlier in the chapter, we rejected 57 households from the sample because they were unable to estimate or refused to divulge their incomes. Since stated incomes were subsequently replaced or removed from later specifications, these households now provide an alternative sample population upon which to gauge the model's predicted capabilities. For this additional analysis, only Model IV has been used.

To compare model expectations with search activities undertaken by the sub-population of households, relevant household characteristics and attributes of the stopping and continuation decision were associated with
each of the opportunities that the households sampled. Conditional choice probabilities for each binary decision were then calculated by transferring estimated coefficients of the variables specified in Model IV to the alternatives evaluated by this sub-population of households. Unconditional choice probabilities and their associated expectations were developed from these estimates through the same procedure described previously.

The results of this exercise are shown in Figure 7.4. Given the small sample size upon which the comparison is based, the fit of model expectations to observed search behavior is again reasonably close, as it characterizes households terminating search most frequently after the second observation, with fewer and fewer continuing to search as more opportunities are sampled. Again, we note the small proportion of households terminating search after just one observation, although the expected number of households choosing the first opportunity is significantly less than the actual number of households claiming that only one vacancy was seriously considered. (First opportunities are chosen by a relatively higher proportion of households in this sample than in the sample upon which the model was estimated.) Note also that the actual distribution has been estimated, as is borne out in summary statistics. The mean number of opportunities actually sampled by households in this sub-population is 2.8; the model estimated an average of 3.0 observations per household.

\footnote{Six of the 57 households in this sub-population were found to be renting their current residences and were rejected from the sample. This left 51 households who made a total of 145 observations upon the single family housing market.}
Number of Households Terminating Search at Observation

![Bar chart showing the number of households terminating search at each observation, with observed and model IV predictions.]

<table>
<thead>
<tr>
<th>Number of Observations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>5</td>
<td>25</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>(0.10)</td>
<td>(0.49)</td>
<td>(0.12)</td>
<td>(0.12)</td>
<td>(0.14)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Model IV</td>
<td>2</td>
<td>21</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.40)</td>
<td>(0.20)</td>
<td>(0.20)</td>
<td>(0.09)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td></td>
</tr>
</tbody>
</table>

Proportions indicated in parenthesis.

Figure 7.4 Comparison of Number of Households in Sub-population Excluded from Estimation Sample that Terminated Search at Each Observation with Expected Number of Households Estimated by Model IV.
The results of this test, then, tend to support the findings of the comparative analysis of model expectations with residential choice behavior observed in the data. As a predictor of household search activities, in terms of the number of opportunities likely to be sampled during search, Model IV replicates search behavior to a considerable degree of precision. When applied to a semi-independent set of observations not used to estimate the searcher's utility function, its precision is reduced, but only marginally. This suggests the behavioral relationships upon which choice in the model is premised may be capturing many of the fundamental criteria upon which the residential choice decision is made. Although it is acknowledged that smoothing procedures introduced to compensate for incomplete observations in the data are likely distorting these results somewhat, model predictions concerning choice in the early stages of search, which suffer little bias, suggest the explanatory power of the model to be reasonable.

7.4.3 Synthesis

Empirical tests upon the predictive capabilities of the reconstructed model of residential search behavior have lent support for its underlying structure and behavioral hypotheses. Comparison of frequency counts derived from the deterministic assignment of choices at each conditional decision point has revealed some systematic deviation from actual search behavior, characterized by the over-concentration of termination decisions toward the median observation in the search sequence. However, most households are correctly classified by the models using the admittedly crude statistic defined to compare search behavior. Comparison of classifications generated by the two models used in this analysis has
also revealed that the abbreviated specification, which relaxes the linearity constraint on the relationship between the number of observations made by the household and the utility of continuing search, is a better predictor of search activity than than the fully specified model. This supports statistical tests performed earlier on the likelihood functions associated with estimated coefficients.

Further tests have been performed which more precisely account for the statistical meaning of estimated choice probabilities. These tests have shown that, when conditional choice probabilities are recombined to their product specification and then aggregated to derive the expected choice behavior of searching households, the expected frequencies associated with the termination of search compare favorably with frequencies observed in the data. Analysis of frequency distributions has also more precisely identified where expectations calculated from the two specifications of utility differ, and has offered a behavioral explanation for these differences.

The performance of the abbreviated specification (Model IV), one which replicated the choice behavior of households in the sample well, has been further evaluated by testing it against search activities undertaken by a sub-population of households not used to estimate the model's coefficients. Comparison of expected to actual frequencies has offered support for the model's explanatory power and in this way has suggested the behavioral relationships which it embodies to be salient.

While results of both comparative analyses have been somewhat obfuscated by missing information and procedures used to compensate for its absence, it has been argued that where introduced bias is small, model
estimates have compared favorably to actual search behavior, which suggests their frameworks to be behaviorally valid. That different model specifications estimate notably qualitative differences in search behavior, though, also suggests further research is needed to more precisely quantify the relationships of attributes associated with conditional choice behavior to utility, and expected search activities which result.

7.5 Summary

This chapter has attempted to empirically substantiate the theoretical framework of residential search behavior, constructed in Chapter 4, through an analysis of the behavioral relationships embodied in an empirical model based upon choice-theoretic principles. It has done so by specifying a utility function for the searching household which considers the attributes of the alternatives evaluated by the household in a sequential search process: those related to the attainable alternative currently under observation and those which condition the searcher's expectations of continuing search in the hope of locating a more suitable opportunity. Attributes have been empirically defined in the context of survey data describing the search activities of a sample of households in Metropolitan Toronto and census data describing the characteristics of the alternatives that sample households investigated.

From the set of variables potentially available, several models were estimated to infer relationships between attributes of the termination and continuation alternatives and the searcher's utility function, from which conditional choice probabilities at each decision point could be calculated. Estimated coefficients revealed that relationships were
generally in accordance with theoretical expectations and those articulated in the residential choice literature, although many of these relationships were found to be statistically insignificant. However, an anomaly in the relationship between distance travelled in search and the searcher's utility of continuing was found that could not be explained or contradicted through further analysis of the data. After further refinement, four specifications of utility were estimated and analyzed in the context of their relationships to the theory.

Two of these specifications considered an alternative definition of a highly significant variable related to the conditional continuation decision, the number of vacancies sampled to the current observation. Respecification of the variable, by relaxing the linearity constraint implicit in its former indexed form, revealed a non-linear relationship between it and the probability of continuing search, which somewhat resembled a negative exponential function. This finding is significant because it implies that, although households appear to regard repeated failures in search with increasing disutility, the marginal increment in disutility decreases as the number of failures increases, which is contrary to earlier theoretical expectations.

Choice models associated with the conditional decisions made at each observation were then combined to reconstruct the model of search behavior developed in Chapter 6. Predicted choices along each household's search path and expected choice behavior embedded in the conditional probability estimates were aggregated and compared with the search behavior of households in the sample. The comparison revealed the models to replicate the data reasonably well, particularly when statistical expecta-
tions of the models were considered. An abbreviated specification of the model, which recognized the non-linear relationship between number of vacancies sampled and the probability of continuing search, was found to be a considerably superior estimator of search behavior in the data. Application of the model to data not used to estimate its coefficients again compared favorably with actual search activities undertaken by households in this sub-population, and suggested that we could not reject the model's structural validity nor the behavioral relationships embedded in the conditional choice framework.

That the product specification of residential search performs well against observed search activities undertaken by households in both samples is significant because it lends empirical support to the behavioral hypotheses underlying the model's structure. By specifying the residential choice process as a series of binary choices, each involving a trade-off between an attainable residential opportunity and the continuation of search, we have retained the fundamental paradigm about residential choice behavior which underlies this research effort. Furthermore, by specifying the searcher's utility function with measures of search activity which relate to the framework over which search and choice behavior has been theoretically investigated, we have found support, though some of it tenuous, for the basic relationships which this framework embodies. Through an empirical investigation of a critical variable which characterizes, to some extent, the effort required to locate suitable residential opportunities, we have identified a relationship between the number of vacancies sampled and the probability of continuing search which is contrary to theoretical conjectures. Finally,
by developing a specification for a model of search behavior which explicitly takes into account the (behaviorally based) conditional decisions made by the searcher during the evaluation process, we have demonstrated a workable empirical framework capable of investigating residential decision making behavior within a paradigm more consistent with reality.
Chapter 8
Summary and Conclusions

This dissertation has been concerned with the study of residential choice and the ways in which uncertainty and constraints on human behavior impact residential mobility, both as a process and as a decision problem. In being so concerned, it has articulated a paradigm for residential choice behavior which is contended to be more in accordance with the relocation process as it occurs in reality. To investigate its underlying behavioral precepts, it has formalized this paradigm in a mathematical framework which is amenable to theoretical analysis, and has subjected it to empirical scrutiny to engender support for the behavioral relationships it embodies.

Considering intra-urban mobility as an outcome of the independent choices of the metropolitan area's residents, the dissertation surveyed the literature to identify the capabilities and weaknesses of current theoretical conceptions of the locational choice process, and the support these conceptions have received in empirical studies. In doing so, it compared conceptual theories to formalized models of the mobility process to demonstrate the latter's neglect of residential search as an important aspect of residential choice behavior. The dissertation reviewed the search process and the roles that information, uncertainty
and human perceptual limitations play in residential decision making from which a conceptual model of residential choice, as the outcome of search activities, was developed.

The conceptual outline of the process was then translated into a formal mathematical framework which recognized residential choice as an outcome of a sequential search process. By casting residential choice within a sequential decision framework, the dissertation found the overriding criterion for choice to be the searcher's aspiration utility, which served as the standard upon which the decision was made. Whether to terminate search and accept the residential alternative or to continue in the hope of finding something better. Aspirations were shown to summarize the information the searcher possessed for facilitating decision making as alternative housing opportunities were evaluated, and to embody the uncertainties inherent in the evaluation process and the perceived costs involved in the relocation decision.

Various relationships associated with these concepts were analytically investigated to qualitatively gauge their impacts on aspiration utilities. Using the literature on search theory as a basis for analysis, the investigation found that:

- increases in real or perceived search costs lower the searcher's aspiration utility,

- increases in the mean or variation of the searcher's opportunity distribution, which characterizes the searcher's perceptions about attainable housing opportunities in the urban area, raise his/her aspiration utility,

- competition for vacancies in the searcher's opportunity set, if perceived, lowers his/her aspiration utility; furthermore, the decline in aspirations is a function of the number of competitors perceived to be vying for vacancies in the searcher's opportunity set,
• limitations to the number of vacancies that can be sampled during search depress the searcher's aspiration utility; aspirations monotonically decline as the number of observations left to be sampled approaches zero,

• information gained during search enables the searcher to adjust his/her aspirations to accommodate changing perceptions of housing market conditions; if the searcher's prior perception of the distribution of attainable opportunities is adjusted upward, aspirations follow; but since aspirations are contingent upon both the mean and variability of the opportunity distribution, they do not necessarily decline when the searcher's priors are adjusted downward in response to information received during search,

• if opportunities previously rejected during search are still considered by the searcher to be viable alternatives, aspirations for continuing search decline as the likelihood of losing these alternatives to other searcher's increases.

The implications that changing aspirations had upon choice behavior were shown in two fundamental relations: an increase in the searcher's aspiration utility promotes longer search (in terms of the number of vacancies sampled) and leads to a greater expected payoff (in terms of the utility of the chosen alternative) than would otherwise occur.

Analysis of the relationships between aspiration utility and conditioning variables on search behavior led to the development of empirically testable hypotheses which were applied to data drawn from a survey of household search and residential choice behavior conducted in Metropolitan Toronto. Data limitations precluded to formulation of hypotheses concerning all relationships investigated in the theoretical framework, but hypotheses associated with search costs, variability of the opportunity distribution and finite sampling constraints, and their relation-
ships to the number of vacancies sampled and duration of search activity were subjected to empirical scrutiny. The analysis found only limited support for theoretically derived relationships (only the null hypotheses associated with hypothesized relationships between the variability in the opportunity distribution and aspiration utility were rejected in statistical tests), although the ambiguous results were partly attributed to data quality and the limited number of parameters the data offered for testing.

But a more fundamental problem with the theoretical framework, conjectured earlier in the paper, was confirmed in the analysis. The sequential decision framework, as theoretically developed, does not lend itself well to empirical scrutiny. By relating residential choice to factors such as aspiration utility, subjectively defined opportunity distributions, information acquisition and synthesis, and other behavioral concepts, the theoretical framework is essentially defined in terms of variables that have little empirical meaning.

This led to a reformulation of the theoretical framework to one which, although it retained the fundamental concepts embodied in the sequential decision model, was more amenable to empirical analysis. The dissertation developed a model, based upon behaviorally-based choice-theoretic principles, that characterized residential choice as the outcome of a series of conditional binary choice problems which, when combined as a product of probabilities, yielded unconditional choice probability measures on each of the alternatives sampled by the searcher. It furthermore utilized a property of the model's maximum likelihood estimator, originally proposed by Sheffi (1979), to suggest a computationally and statistically efficient technique for simultaneously estimating the coefficients of utility
associated with all conditional binary choices made in the search sequence. Variables considered to be important in residential search behavior, rather than acting as conditioning agents on search costs or the searcher's opportunity distribution, were specified as attributes of the searcher's utility function.

Alternative specifications of utility were estimated on survey data cited earlier, supplemented by Census data extracted from the 1971 Census of Canada. Analysis of coefficient estimates revealed more substantive support for relationships inferred from the sequential decision framework than could be obtained in non-parametric tests attempted earlier, although the significance of many estimated coefficients was low. The empirical model suggested that the search activities of the Metropolitan Toronto sample were reinforced (i.e. extended) by a positive change from the previous observation in the mean value of housing, prior familiarity with the area searched and previous home-ownership, but were negatively influenced by the cumulative number of vacancies sampled during search and higher rates of population turnover in the area (a pseudo-competition measure). Furthermore, a non-linear relationship between the searcher's utility of continuing search and number of vacancies sampled was inferred from coefficient estimates, which contradicted theoretical conjectures. Rather than perceiving continued search with increasing marginal impatience as more vacancies are rejected, coefficient estimates indicated that, while the utility of continuing declines under these circumstances, it declines at a decreasing rate, suggesting that searchers regard successive rejections with less aversion as search continues. Coefficient estimates also revealed that the residential choices made by households in the sample
were positively influenced by the proportion of single family dwellings in the area, but negatively influenced by the proportion of new immigrants who reside there.

The predictive performance of the empirical model was evaluated by comparing model-generated choices, extracted from estimated choice probabilities, to the observed choice behavior of households in the sample. Additionally, one specification of the model was compared to the observed choice behavior of a sub-population of households that was not used to estimate the model's coefficients. The predictive performance of the empirical model was found to be satisfactory in most cases, particularly when the estimated choice probabilities were statistically interpreted. These results suggested empirical support for both the behavioral relationships between search variables and search behavior embodied in the sequential decision framework, and to the structural validity of the empirical model which incorporated its concepts.

Though tentative, the results of this research effort have engendered support for the central theme of this dissertation. Residential choice is an outcome of an evaluation process that, to the individual, is significantly affected by information and its associated uncertainties and costs. It is an outcome that results from a decision making process which characterizes the individual as a satisficer, whereby constraints on behavior and human perceptual limitations bound his/her rationality to one which considers the utilities of few alternatives in comparison to a subjectively defined expectation which may or may not be reflective of actual housing opportunities available in the
urban housing market. Within these constraints, optimizing (i.e. utility maximizing) behavior leads to residential choices which, in more traditional modeling contexts, appear distinctly sub-optimal.

That sub-optimal choice has been observed empirically has led several researchers to conclude that, for the importance of the decision, households appear to act irrationally in the residential selection process (Barrett, 1973; Lyon and Wood, 1977). This dissertation has suggested that seemingly irrational behavior results from the paradigm used as the basis of comparison, and that irrational behavior is not necessarily so when information and its uncertainties and costs are considered. It has argued that search models, based upon principles developed in sequential decision theory, provide a means for taking these considerations into account.

In expounding this viewpoint, two methodological issues have been identified which make the modeling of residential search behavior problematic. First, characterizing residential choice as an outcome of an explicitly defined search process requires considerably more information about the individual as a decision maker than other characterizations of the residential location decision. However, most data bases concerning residential choice are incapable of fulfilling these requirements, and their inadequacies lead to a problem of model validation. Though suggested to be a more realistic conception of the residential choice process, there is still insufficient evidence to render such opinion definitive.

The second issue concerns the non-correspondence between the behavioral concepts embodied in search models and empirical reality.
We have argued that the lack of correspondence between the two is both a measurement problem (data; discussed above) and a structural one. It is a structural problem because many critical variables in the theoretical framework have limited empirical meaning. Although the empirical model developed in Chapter 6 demonstrated that the transfer of theory to empirically measurable phenomena is possible, many concepts remain vague and undefined. For example, the individual's spatial search field, that subjectively defined area which identifies the searcher's opportunity set, has so far eluded empirical definition. Yet such a definition is necessary if search models are to be used in other than an experimental sense. (We note that opportunity (choice) set definition has also not been satisfactorily addressed in traditional models of residential choice.) Research is required to better understand the psyche of the relocator, what he/she thinks and perceives, and how he/she responds to changing psychological and environmental conditions, to better characterize the alternative residential opportunities that define the population of vacancies from which sample vacancies are drawn. More macroeconomic concepts, such as competition in the housing market and housing supply, need also to be refined to provide more substantive links than present between theory and reality.

The analysis of residential search behavior, and the locational outcomes which result from it, is far from complete. We have theoretically characterized search in a mathematical framework that is partial, in that it captures only one of many possible strategies that can be employed by the searcher to locate a suitable residence, and one that is disjointed, in that several models, rather than a single model, have been
used to examine the impacts of various environmental and psychological elements on search behavior; furthermore, as more realistic assumptions have been introduced, we have seen the model increase in complexity to the point where the inferences that can be made concerning their impacts are largely indirect. Clearly, a synthesis of these models into a coherent structure that is flexible enough to address a wide range of contingencies on search behavior is desirable.

In the empirical model, several enhancements are possible, and their incorporation could provide stronger empirical support for the model's theoretical foundations. The model's restrictive assumptions concerning the independence of utilities along the search sequence, and empirical definitions of variables used to characterize the attributes of the continuation alternative are two features of the empirical framework which could be relaxed immediately in further tests. More precise specification of the searcher's utility function and the incorporation of full or partial recall at each decision point are other features which, though conceptually feasible, must await more informative data before their consideration can become meaningful. Though data remains the most important problem in empirical verification, continuing interest in this area of research could eventually provide sufficient resources for their collection and analysis.

Finally, it remains to synthesize the residential search and selection process into a coherent representation of the residential mobility process, a framework which recognizes the interdependencies between the decision to move, the perception of the residential environment, search strategies and residential decision making. The literature
has too often considered mobility and locational choice decisions independently (a mode of investigation adopted in this research). Synthesis would provide a more definitive understanding of intra-urban migration than our current conception of the process, an advancement that is of obvious significance in the evaluation of social policies. The direction suggested by Smith et al. (1979) appears to be most appropriate in the context of this argument.

The framework developed and tested in this dissertation is an exploratory one in that the implications of restructuring the residential choice problem into one which explicitly recognizes the imperfect conditions that constrain choice behavior have been analyzed and subjected to empirical scrutiny. From the analysis we have shown how factors not considered in traditional models of residential location can influence residential decision making, and have suggested that these factors are important determinants of search, and, subsequently, of choice. To claim immediate policy relevance of this approach would be premature, given the exploratory stage at which this research has concluded. But the potential exists for developing an instrument capable of assessing anticipated mobility responses to policy as traditional models of residential choice are used now.

Search activities, and the perceptions and motivations which influence them, have been shown to be important elements of the mobility process (Chapters 2 and 3). To the extent that search activities determine choice, traditional models that fail to recognize this relationship are of limited policy relevance, even when they are successfully applied. That an alternative paradigm exists suggests
that it should be nurtured to realize its properties and limitations, and its potential application to an important social phenomenon.
REFERENCES


Chow, Y.S. S. Moriguti, H. Robbins and S.M. Samuels (1964) "Optimal selection based on relative rank (the 'Secretary Problem')". *Israel Journal of Mathematics*, 2, 81-90.


Hägerstrand, T. (1957) "Migration and area. Survey of a sample of Swedish migration fields and hypothetical considerations on their genesis", in D. Hannerberg, T. Hägerstrand and B. Odeving (eds.).


Hall, J.R. (1975) "Expected utility maximizing job search in a dynamic economic system". Unpublished paper, Department of Economics, University of California at Los Angeles, Los Angeles, California.


Heckmann, J.J. (1978) "Simple statistical models for discrete panel data developed and applied to test the hypothesis of true state dependence against the hypothesis of spurious state dependence", Annales de l'Insee, 30-31, 227-269.


Miller, G.A. (1956) "The magical number seven, plus or minus two: some limits on our capacity for processing information", Psychological Review, 63, 81-97.


451


Stigler, G.J. (1962) "Information in the labor market", Journal of Political Economy, 70, 94-104.


