A NEW APPROACH TO UNDERSTANDING TRAVEL BEHAVIOUR
AND ITS IMPLICATIONS FOR TRANSPORTATION PLANNING

Peter Malcolm Jones

Submitted for the Degree of PhD

University of London
Imperial College of Science and Technology
ABSTRACT

This research investigates some of the methodological aspects of urban transportation planning in the U.K. and other developed countries. It identifies a number of unresolved problems and examines the contribution that a new approach to studying travel behaviour can make to the assessment of recent policy issues and the resolution of some methodological difficulties.

The thesis is in three sections. Part One traces the evolution of urban transportation planning, examining changes in policy and methodological requirement as the perception of 'the transport problem' has broadened, and the emphasis has switched from increasing supply to restraining demand. Despite the variety of methods now available, a number of problems remain, and some formal requirements are established for an additional methodological approach.

Part Two sets out the conceptual framework of a new approach to studying travel behaviour, based on the analysis of daily household activity patterns. A number of factors affecting the structure of behaviour are identified (including roles, needs, time-space and interpersonal constraints), together with mechanisms by which households adapt to change and which may lead to secondary effects on travel. Empirical examples are provided from surveys in Oxfordshire, showing how travel relates to activity patterns.

Part Three briefly reviews related research by other writers and identifies six areas in which the activity-based work has or could contribute to urban transportation planning. Examples are given of its use in an exploratory and educational context, and its implications are examined at a more quantitative level with regard to data analysis, modelling and evaluation. Some additional material is provided in three appendices.

Conceptually, the activity-based approach appears to provide an appropriate basis for examining complex travel behaviour and for identifying the social aspects of transport policy. At a practical level the implications of the approach are very wide-ranging and the indications are that it will have an important role to play in transportation planning in the years ahead.
ACKNOWLEDGEMENTS

This document is the result of many years of research into household travel behaviour, and its contents have inevitably been influenced by a very large number of people, many of whom I know personally, and others whom I have become acquainted with through the literature. To them all, I would like to express my thanks for the stimulus they have provided, and for their advice, constructive criticism and healthy scepticism.

The basic line of argument and general conceptual approach was developed during my time at Imperial College and University College, London. Particular thanks and acknowledgement are due to my two supervisors. To David Briggs, my original supervisor, who allowed me to embark on what seemed a rather ill-defined task, and to Ian Cullen for taking over when David left for South America and for guiding me during what has been a much longer period of time than he could have anticipated. Many other colleagues at Imperial and University Colleges have also influenced this work, and I would like to record my thanks to Maurice Hansen for providing me with ready access to a wide range of published and unpublished material.

The final form of the thesis and most of the substantive material, however, result from my time spent at the Transport Studies Unit, working on an SSRC supported project on Understanding Travel Behaviour and subsequent studies of household travel behaviour. This provided an opportunity to develop, refine, test and apply the earlier ideas; in carrying out this process, I owe a very great deal to my colleagues, especially Martin Dix and Mike Clarke, and to Ian Heggie who appointed me to work on the SSRC project. I have tried to give explicit acknowledgement wherever possible to the work carried out by Martin and Mike through appropriate footnotes, but in a joint project it is inevitably very difficult to identify precisely the contribution of each person.

Exploratory research techniques play an important role in this thesis, and here I owe a particular debt to Martin Dix, who first introduced me to the ideas of in-depth interviewing. He and I were jointly responsible for most of the survey work on which the analysis in this thesis has been based, and he was largely instrumental in turning the notion of the HATS display into a piece of practical hardware. I also acknowledge the help of Gill Swann and Jane Hands with the Burford...
school hour study (reported in section 6.4).

Various people have helped in the typing of this thesis, through its various drafts. Particular thanks are due to Jan Tagg, Vi Gray and Deborah Alan who wrestled with my rough notes and to Beryl Perry and Pam Suffling who helped out when the going got tough — and who have still remained friends! This final version has been typed almost single-handedly by Audrey Roberts, to whom I am very grateful.

Finally, I would like to record my deep appreciation and thanks to my parents, who encouraged me to undertake the research originally and who have supported me steadfastly throughout.
TABLE OF CONTENTS

Title Page 1
Abstract 2
Acknowledgements 3
Table of Contents 5
List of Figures 12
List of Tables 15

Chapter 1: Introduction
  1.1 Transport and Urban Transportation Planning 17
  1.2 Objectives and Scope of the Thesis 20
    Objectives 20
    Scope 21
  1.3 Structure and Content of the Thesis 22

PART ONE: URBAN TRANSPORTATION PLANNING

Chapter 2: The Evolution of U.K. Urban Transportation Planning
  2.1 Events up to 1963 26
    American Developments 29
  2.2 1963 to 1970 30
    Legislative Developments 34
  2.3 The Early Seventies 36
    The Change in Public Mood 37
    The Political Response 39
    American Experience 43
  2.4 The Mid Seventies to the Present 43
    Disenchantment with the Transportation Study Process 45
    The Present Situation 46
    Problems and Issues 48

Chapter 3: Methodological Developments in Urban Transportation Planning
  3.1 The Process of Methodological Development 51
3.2 Methodological Developments up to the Early Seventies

The First Approach 54
The Second Approach 54
The Third Approach 55
The Fourth Approach 58
Other Developments 61

3.3 A Period of Re-Assessment

Unreliability in Data Inputs 64
Changing Model Requirements 65
The Use of Model Outputs 71

3.4 Methodological Developments Since the Early Seventies

Firmer Theoretical Foundation (1) 74
Development of Simultaneous Model Structures (2) 75
Development of Individual Choice Models (3) 75
Better Definition of Choice Sets (4) 77
The Modelling of Complex Travel Patterns (5) 78
Models Based on Travel Budgets (6) 79
Attitudinal Studies (7) 80
Simplified Models (8) 83
Cheaper Data Collection Procedures (9) 84
Incorporating Error and Uncertainty (10) 85

3.5 Summary and Assessment 86

Application of Individual Choice Models 88
Application of Attitudinal Methods 91

3.6 Conclusion 92

Chapter 4: The Case For a New Approach

4.1 Some Unresolved Problems and Issues 94

Unresolved Methodological Problems 94
Recent Policy Issues 97
Summary and Assessment 99

4.2 The Definition and Measurement of Travel 100

Representation of Travel Behaviour 102
Definitional Problems 107
Contextual Limitations 110
Conclusion 112
4.3 Some Requirements of a New Approach 112
   Examples of Aspects to be Incorporated 114
4.4 Conclusion 119

PART TWO : A NEW APPROACH TO UNDERSTANDING TRAVEL BEHAVIOUR

Chapter 5 : A Framework For Studying Travel Behaviour

5.1 Introduction 123
5.2 Basic Determinants of Behaviour 124
   Reasons for Activity Participation 124
   The Use of Activity as a Proxy for Need 129
   Summary and Conclusion 130
5.3 The Formation of an Activity-Travel Pattern 132
   Elements of Activity Pattern Formation 133
   The Temporal Structure of the Day 138
   The Spatio-Temporal Organisation of Behaviour 140
   The Effect of Inter-Personal Linkages 146
   Conclusion 152
5.4 Some Evidence From an Activity-Travel Survey 153
   Household Activity Patterns 155
   Resulting Patterns of Travel 161
   Some Evidence from Larger Studies 165

Chapter 6 : Household Adaptation

6.1 Factors Promoting Changes in Behaviour 167
6.2 Elements of Household Adaptation 170
   Dimensions of Impact 170
   Secondary Consequences 171
   Threshold Effects 175
   Subjective Factors 177
   Implications for Travel 182
6.3 Household Response Strategies 185
6.4 A Study of Household Response to School Hour Changes 187
   Aggregate Changes in Behaviour 189
   The Processes Involved 196
   Assessment 198
Chapter 7: A Comparison of Activity and Person Trip Approaches

7.1 Introduction 201

7.2 Some Essential Differences Between the Two Approaches 202
   - Contrasts in the Representation of Travel Behaviour 203
   - Ability to Deal with a Wider Range of Response 207
   - Resolution of Definitional Problems 211

7.3 An Assessment of the Activity Approach 212
   - Satisfaction of General Requirements 212
   - Relevance to Current Policy Issues 214

7.4 Summary and Conclusions 216

PART THREE: APPLICATIONS AND IMPLICATIONS

Chapter 8: An Overview of Developments

8.1 A Typology of Activity-Related Studies 221

8.2 Applications of Activity-Based Work in Transportation Planning 228
   - Problem Recognition and Policy Generation 229
   - Data Collection 232
   - Data Analysis 234
   - Modelling 235
   - Evaluation 237
   - Public Participation and Policy Coordination 239

8.3 Conclusion 240

Chapter 9: Exploratory and Educational Applications

9.1 Introduction 242

9.2 Gaming Simulation as an Exploratory Technique 244
   - Characteristics of the Method 244
   - The HATS Technique 246
   - Assessment of the HATS Technique 251

9.3 Policy Insights From Exploratory Studies 256
   - Changes in School Hours 258
   - Assessment of Alternative Petrol-Saving Policies 262

9.4 Methodological Insights From Exploratory Studies 264
### Chapter 10: Implications for Analysis, Modelling and Evaluation

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Data Analysis</td>
<td>289</td>
</tr>
<tr>
<td></td>
<td>Operationalisation of Concepts</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>Measurement of Activity-Travel Patterns</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>Identification of Variables Affecting Activity Patterns</td>
<td>302</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>307</td>
</tr>
<tr>
<td>10.2</td>
<td>A Strategy for Modelling Household Travel Behaviour</td>
<td>307</td>
</tr>
<tr>
<td></td>
<td>Response Patterns and Model Domains</td>
<td>309</td>
</tr>
<tr>
<td></td>
<td>Determining the Appropriate Domain</td>
<td>315</td>
</tr>
<tr>
<td>10.3</td>
<td>Models Incorporating Activity-Based Concepts</td>
<td>317</td>
</tr>
<tr>
<td></td>
<td>Improvements in Individual Choice Models</td>
<td>318</td>
</tr>
<tr>
<td></td>
<td>Event Models in a Simulation System</td>
<td>321</td>
</tr>
<tr>
<td></td>
<td>Pattern-Based Models</td>
<td>327</td>
</tr>
<tr>
<td></td>
<td>Assessment and Further Applications</td>
<td>332</td>
</tr>
<tr>
<td>10.4</td>
<td>Evaluation of Policy Measures</td>
<td>336</td>
</tr>
<tr>
<td></td>
<td>Improvements to Conventional Measures of User Benefit</td>
<td>338</td>
</tr>
<tr>
<td></td>
<td>New Measures of User and Non-User Benefit</td>
<td>342</td>
</tr>
</tbody>
</table>

### Chapter 11: Conclusions

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.1</td>
<td>Summary and Assessment</td>
<td>351</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>352</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>358</td>
</tr>
<tr>
<td>11.2</td>
<td>Potential Wider Applications</td>
<td>365</td>
</tr>
<tr>
<td></td>
<td>Labour Problems in the Transport Supply Industries</td>
<td>366</td>
</tr>
<tr>
<td></td>
<td>Energy Use Outside Transport</td>
<td>367</td>
</tr>
<tr>
<td></td>
<td>Land Use and Transport</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>A Framework for Inter-Sectoral Planning</td>
<td>371</td>
</tr>
</tbody>
</table>
11.3 Conclusions and Recommendations

Recommendations

APPENDICES

Appendix I: A Review of the Human Activity Literature

Introduction 380

(1) Analysis of Activity Events 382

Choice-Based Explanations 382
Constraint-Based Explanations 385
The Approaches Compared 385

(2) Activity Duration and Time Allocation 386

'Time Budget' Studies 387
Empirical Models of Time Use 388
Theories of Time Allocation 389
Measures of Activity 'Elasticity' 392

(3) Activity Timing and Sequencing 393

The Timing of Activities 393
Activity Sequencing 395
'Time Geography' 396
Conclusion 400

(4) Activity Structure and Patterning 401

Choice in the Context of Pattern Constraints 401
The Structure of Daily Behaviour 403
Longer Term Choice Options 405
Conclusion 407

Modelling Activity Patterns 409

Simulation of Individual Activity Choices 409
Representation of Aggregate Activity Patterns 411
Modelling Behaviour Options 412

Appendix II: The Household Activity-Travel Simulator: Display Equipment and Applications of the Technique 418

The Display Equipment 418
Uses of the Technique 422
Appendix III: A Hybrid Simulation/Choice Activity — Travel Model

Introduction 425
Model Operation 425
   I Control Program 425
   II Activity-Demand Model 425
   III Choice Set Definition Model 427
   IV Car Availability Model 428
   V Choice Model 428
Simple Example 429
Discussion 429

Bibliography 440
<table>
<thead>
<tr>
<th>FIGURES</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Structure of the Thesis</td>
<td>23</td>
</tr>
<tr>
<td>2.1 The Stages of an Urban Transportation Planning Process</td>
<td>32</td>
</tr>
<tr>
<td>3.1 The Development of Methodology in Urban Transportation Planning Over Time at Conceptual and Technical Levels</td>
<td>52</td>
</tr>
<tr>
<td>3.2 Elements of an Early Transportation Study</td>
<td>57</td>
</tr>
<tr>
<td>3.3 Example of a Four Stage Forecasting Procedure</td>
<td>60</td>
</tr>
<tr>
<td>3.4 Structure of a Disaggregate Travel Demand Model System</td>
<td>89</td>
</tr>
<tr>
<td>4.1 Translation from Behaviour to Model Input</td>
<td>103</td>
</tr>
<tr>
<td>4.2 Problems Associated with Complex Travel Patterns</td>
<td>106</td>
</tr>
<tr>
<td>4.3 Space-Time Constraints on Choice of Shopping Centre</td>
<td>117</td>
</tr>
<tr>
<td>5.1 Factors Influencing Activity Participation</td>
<td>126</td>
</tr>
<tr>
<td>5.2 One Day Activity Diary for a Hypothetical One Person Household</td>
<td>134</td>
</tr>
<tr>
<td>5.3 Factors Contributing to the Activity Pattern of Figure 5.2</td>
<td>136</td>
</tr>
<tr>
<td>5.4 Temporal Scheduling Constraints on the Activity Pattern of Figure 5.2</td>
<td>141</td>
</tr>
<tr>
<td>5.5 Space-Time Constraints on Behaviour: Fitting Shopping into the Activity Pattern of Figure 5.2</td>
<td>143</td>
</tr>
<tr>
<td>5.6a Choice in the Context of Constraints</td>
<td>145</td>
</tr>
<tr>
<td>5.6b Evaluation of Activity Options</td>
<td>145</td>
</tr>
<tr>
<td>5.7 Constraints Imposed by Joint Activity Participation</td>
<td>148</td>
</tr>
<tr>
<td>5.8 Constraints on Household Behaviour</td>
<td>151</td>
</tr>
<tr>
<td>5.9 Phototypical Activity Patterns for Two Life Cycle Groups</td>
<td>157</td>
</tr>
<tr>
<td>5.10 Aggregate Activity Patterns for Sampled Households in Life Cycle Stage C</td>
<td>160</td>
</tr>
<tr>
<td>5.11 Mean Household Trip Rates, by Purpose, for Two Life Cycle Groups</td>
<td>162</td>
</tr>
<tr>
<td>6.1 Dimensions of Behaviour Affected Directly by a Change</td>
<td>172</td>
</tr>
<tr>
<td>6.2 Mechanisms for Transmitting Secondary Effects</td>
<td>174</td>
</tr>
<tr>
<td>6.3 The Generation and Resolution of Threshold Effects</td>
<td>176</td>
</tr>
<tr>
<td>6.4 Impact of an Increasing Retarding of Work Hours on the Activity Pattern of Figures 5.2/3</td>
<td>178</td>
</tr>
</tbody>
</table>
6.5 Effect of Husband's Alternate Shifts on the Household's Activity Travel Pattern 181
6.6 Simulated Changes in Activity Patterns Due to School Hour Revisions, Using a Restricted Definition of Change 192
6.7 Simulated Impacts of School Hour Revisions Using a Broader Measure of Change 193
6.8 Simulated Impacts, Stratified by Change in Home Departure/Arrival Times, Using Both Measures of Change 195
6.9 Adjustments to Chauffeuring Arrangements in One Household Arising from the Proposed School Hour Revisions 197
6.10 Opportunities for Participation in New Activities as a Result of Proposals to Advance School Hours. 199

7.1 Alternative Representations of the Travel Behaviour Recorded in Figure 5.2 204
7.2 Alternative Strategies for Satisfying Activity Needs 208

8.1 A Typology of Conceptual Levels used in the Analysis of Travel Behaviour 222

9.1 A Completed HATS Display Board 248
9.2 Typical HATS Interview Procedure 250
9.3 Major Elements of the HATS Procedure 252
9.4 The Role of HATS in Obtaining an Understanding of the Process and Outcome of Adaptation 255
9.5 Comparison of Diary Formats 269
9.6 Modified Travel Diary used in the 1981 Sydney Travel Survey 271
9.7 Example Page From the HATS Educational Manual, Showing O.H.P. Display Sheets 277
9.8 Activity-Travel Pattern of Example Household in the HATS Educational Simulation Exercise 282
9.9 Local Public Transport Timetable and Fares Used in the HATS Educational Exercise 284
9.10 One Possible Response to the Bus Service Cutbacks in the Educational Exercise 286

10.1 Range of Data Sources Used in Activity-Based Research 290
10.2 Deriving Patterns of Work Activity by Life Cycle Stage, Using Conventional Travel Data 296
10.3 A Classification of Path Types 298
10.4 Decomposition of an Activity-Travel Pattern 298
10.5 A Classification of Activity Patterns for the Morning Hours (06.00 - 09.30) 301
10.6 Relationships Between Response Strategies, Model Domains and Behavioural Rules 312
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.7</td>
<td>Structure of the Hybrid Activity-Travel Model</td>
<td>323</td>
</tr>
<tr>
<td>10.8</td>
<td>Modelled Impact of a Policy Change on the Urban System: Effects of a Reduction in Evening Bus Service</td>
<td>325</td>
</tr>
<tr>
<td>10.9</td>
<td>Schematic Representation of the Operation of CARLA</td>
<td>330</td>
</tr>
<tr>
<td>11.1</td>
<td>Display Boards Developed to Examine Driver Attitudes to Patterns of Shift Work</td>
<td>368</td>
</tr>
<tr>
<td>11.2</td>
<td>A Conceptualisation of the Urban Development Process</td>
<td>372</td>
</tr>
</tbody>
</table>

**Appendix I**

<table>
<thead>
<tr>
<th>Appendix I</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Different Activity Diary Formats</td>
<td>381</td>
</tr>
<tr>
<td>2</td>
<td>Some Basic Concepts in Time Geography</td>
<td>397</td>
</tr>
<tr>
<td>3</td>
<td>The Concept of the Space-Time 'Prism'</td>
<td>399</td>
</tr>
<tr>
<td>4</td>
<td>The Context and Components of Leisure Activity Decisions</td>
<td>402</td>
</tr>
<tr>
<td>5</td>
<td>The Structure of Daily Behaviour</td>
<td>406</td>
</tr>
<tr>
<td>6</td>
<td>Interrelationships Between Short and Long Term Behaviour</td>
<td>408</td>
</tr>
<tr>
<td>7</td>
<td>Flow Chart from an Early Version of the PESASP Model</td>
<td>414</td>
</tr>
<tr>
<td>8</td>
<td>Example of the Output from a PESASP Study</td>
<td>415</td>
</tr>
<tr>
<td>9</td>
<td>Main Stages of the Scenario Forecasting Model</td>
<td>417</td>
</tr>
</tbody>
</table>

**Appendix II**

<table>
<thead>
<tr>
<th>Appendix II</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HATS Display Equipment</td>
<td>419</td>
</tr>
<tr>
<td>2</td>
<td>Use of a Stacking Area to Help Plan In-Home Activities</td>
<td>421</td>
</tr>
</tbody>
</table>

**Appendix III**

<table>
<thead>
<tr>
<th>Appendix III</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Operation of the Activity-Travel Model</td>
<td>426</td>
</tr>
<tr>
<td>2</td>
<td>Model Assumptions and Data Requirements — Simple Example</td>
<td>430</td>
</tr>
<tr>
<td>3</td>
<td>Implied Decision-Making Sequence in the Activity-Travel Model</td>
<td>431</td>
</tr>
</tbody>
</table>
TABLES

3.1 Responsiveness of the Conventional Four-Stage Model to Various Peak Spreading Policies 69

4.1 Summary of Household Travel 115

5.1 International Time Budget Comparisons, by Social Role 131

5.2 Time Allocation to Activities (in minutes) for Lifecycle Groups A and C 156

5.3 Weekday Trip Circuits, by Life Cycle Group 163

6.1 Impact of Seasonal Changes on Activity Patterns 169

6.2 Summary of Major Changes in Behaviour Depicted in Figure 6.4, and the Factors Involved 179

6.3a Effects on Household Travel of the Response to Alternative Shifts Illustrated in Figure 6.5 184

6.3b Changes in Travel Associated with the Revisions to Work Hours in Figure 6.4 184

6.4 Some Household Response Strategies 186

6.5 Effects of Revised School Hours on the Time Budgets of Sampled Pupils 190

8.1 Areas of Recent or Potential Application of Activity Approaches in Transportation Planning 230

9.1 The Reliability of the Simulation Results, in a HATS Study of Bus Service Reductions 255

9.2 Comparison of Levels of Travel Information from Travel and Activity Surveys in Banbury 271

10.1 Daily Travel/Activity Pattern Types (12 Cluster Solution) 300

10.2 Summary of Empirical Findings of Activity-based Research, Based on a Comparative Study by Damm 303

10.3 Variables Associated with Each Representative Activity Pattern 304

10.4 Relationship Between Role Situational Type and A Pattern of Activity Scheduling 306

Appendix II

1 Potential Uses of HATS as a Policy Aid 424
## Appendix III

<table>
<thead>
<tr>
<th></th>
<th>Activity-Travel Model:</th>
<th>Sample Inputs and Outputs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>433</td>
</tr>
<tr>
<td>2</td>
<td>Activity-Travel Model:</td>
<td>Listing of Computer Program</td>
<td>435</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1 Transport and Urban Transportation Planning

Transport represents a major component of industrial and post-industrial economies. In the financial year 1978/9 Britain spent about one sixth of her gross domestic product (over £25,000 million) on the manufacture, planning and operation of transport systems and associated infrastructure of which about 55 per cent related to passenger transport (Baldwin, 1979). In the same year approximately 18 per cent of the country's civilian employment was either in the transport sector or in transport-related industries (the latter covering motor repairs, distribution, garages, filling stations and posts in local and central government — see Maltby and White, 1982). Transport is even more significant in energy terms; the Independent Commission on Transport (1974) reported that, directly or indirectly, freight and passenger transport account for about a quarter of end use fuel consumption in the U.K.

On the passenger side, the most significant development in the 'Western' world over the last 30 years has been the phenomenal growth in private vehicle ownership (especially cars), with consequent impacts on mobility, life styles, land use patterns and the environment. Between 1948 and 1978 the number of private cars and vans registered in the U.K. rose from 1.4 million to 14.4 million, and by 1978 over 80 per cent of motorised passenger movement (i.e. excluding walk and cycle) was by private vehicle. This increase in private vehicle ownership has resulted in people travelling both further and more often than hitherto. Over the 20 years up to 1975, travel by private transport increased by 243,000 m passenger kilometres in Great Britain, but this was matched by a decline of only 29,000 m passenger kilometres in travel by bus and rail (Maltby and White, 1982). Transport has thus come to play an
important role in most people's daily lives with, on average, householders spending nearly as much on transport as they do on housing (Department of Employment, 1979).

This gain in mobility has, however, brought with it many social and environmental problems. People without access to a car are becoming increasingly isolated as public transport services decline and land use patterns change (Hillman et al. 1973); much of the apparent drabness of modern urban design can be attributed to rigid adherence to road design standards (Crawford, 1973); and there are a number of well-known environmental problems associated with the internal combustion engine, such as noise, atmospheric pollution, vibration etc. One of the heaviest burdens modern societies face is the loss of life through road accidents. Between 1962 and 1971 over one million people were killed or seriously injured in this way in the U.K. (Independent Commission on Transport, 1974), and nearly half the deaths in the 15-19 age groups are due to road traffic accidents (Maltby and White, 1982).

Although less than one seventh of the annual expenditure on transport originates in central or local government, both play a key role in transport provision. Virtually the entire road network in the U.K. has been constructed or maintained through government funding — over £20,000 million has been spent on roads in Britain since the war (Starkie, 1982) — and much of the country's public transport system relies on government support. In general too, it is the government who tries to ameliorate the negative social and environmental effects of transport, through regulation and taxation policies. Even in areas of transport where government has no direct involvement '... it is the government that determines the rules and framework within which the principle decisions about transport are made.' (Department of Transport, 1977, paragraph 37).
Britain is a highly urbanised country, and it is in the urban areas that many of the pressures associated with the growth in road traffic have been felt most strongly. Successive U.K. governments have introduced administrative changes and various forms of regulation and penalty or inducement in an attempt to deal with these, and related problems. In the process, urban transport planning has developed as an important function of local government, involving both the engineer and town planner in the resolution of urban transport 'problems'.

This has led to the establishment of a formal urban transportation planning process, which is characterised by the use of analytical techniques to assist in the comprehensive planning of transportation and related facilities in urban areas, through the provision and maintenance of infrastructure and the adoption of suitable management policies. To assist in decisions concerning the priorities for public investment or the need for legislative control, governments rely on qualitative and quantitative data from a wide variety of sources. In order to extract 'relevant' information, identify important transport 'problems' and generate and assess possible 'solutions', decision makers and other professionals have developed a set of urban transportation planning procedures.

These procedures comprise a number of techniques that are used to collect and analyse data, forecast travel demand, and to evaluate the effectiveness and efficiency of different types of policy measure. Over time the methods have been extended or modified, and a number of different methodological approaches have been developed in response to new policy issues, or in the light of experience and technical or technological developments. As a result, the urban transportation planner now has a wide range of methods at his/her disposal, to examine a variety of issues and problems at varying levels of detail. Despite the many developments since the war, however, transportation planning continues
to change and there are still some more recent issues which cannot be handled adequately using existing methodologies, and instances where there are inadequacies in some of the methods used.

1.2 Objectives and Scope of the Thesis

This thesis focuses on the gap between methodological requirements and current capability. It examines the contribution that a new, additional approach to studying travel behaviour can make to the assessment of some recent policy issues and the resolution of a number of methodological problems associated with urban transportation planning.

Objectives

The research has three specific objectives:

(1) To review the historical development of urban transportation planning and methodology in the U.K., and to identify a number of remaining methodological problems.

(2) To set out the framework of a new approach to studying travel behaviour based on the analysis of daily household activity patterns which, *prima-facie* looks capable of resolving some of these problems.

(3) To demonstrate that this new approach is relevant to transport planning and can resolve some problems, and to discuss its further potential and implications for transportation planning.

The emphasis is not, however, on the development of one particular technique or model, but rather on the development of a new conceptual approach to travel which has implications for several aspects of urban transportation planning and methodology.
Scope

A number of restrictions have been placed on the scope of the thesis in order to define a research project that is manageable and objectives which are attainable. In brief, the research has been limited to an examination of the everyday travel behaviour of households and their members, primarily in urban areas* and with an emphasis on non-work travel. This specifically excludes any consideration of:

(a) Goods movements**
(b) Inter-urban or international travel
(c) Unusual or unexpected journeys
(d) Longer term decisions, relating to car ownership, or residential or workplace location.

The distinction between person and goods movement research is well established and clearly definable, provided we exclude from our investigation travel in the course of work. The next two restrictions are related and represent a decision to exclude longer journeys and/or unusual types of journey (e.g. to attend a wedding or go to hospital for emergency treatment) — those where, in effect, the day is being fitted around a journey rather than travel forming part of a daily pattern of behaviour. The final restriction limits the thesis to questions of short-term adaptation, during which it is assumed that factors such as car ownership and residential or workplace location remain unchanged. Other writers have made a similar distinction between short and long term change (see, for example, Ben-Akiva et al. 1976). Although the two are related, this represents a convenient

*Some attention is paid to local journeys in rural areas, but the prime concern is with urban travel.

**For a brief discussion of how an activity-related approach might be applied to the study of goods movement, see Jones (1975).
boundary when it is necessary to restrict the area of study in some way. Clarke, Dix and Goodwin (1982) have shown how some of the ideas discussed in this thesis can be applied in the context of longer-term change.

1.3 Structure and Content of the Thesis

The thesis is broadly divided into three parts, which relate to the three objectives set out in section 1.2. The first part examines the historical development of transport planning and methodology, highlights the way in which a succession of new approaches have been introduced, and identifies a number of methodological problems now requiring attention. Part two then sets out a framework in which concepts relating to human activity patterns can be applied to the study of household travel behaviour, and shows that there are both conceptual and empirical grounds for believing that this new approach can resolve some of these problems. The final part demonstrates the practicability of applying the approach to a number of urban transport planning problems and discusses several possible further applications and implications.

The chapter headings and logical structure of the thesis are shown in Figure 1.1. The three parts follow in order, from the identification of requirements (diagnosis), through the description of a new approach (prognosis), to an examination of its practical applications (trials) and implications. More specifically, the Need for a New Approach (Chapter 4) derives from an examination of changing policy issues in Chapter 2, and the methodological responses in Chapter 3. It then in turn acts as a yardstick for assessing the conceptual value of the proposed approach (Chapter 7), the range of applications presented in Chapters 8-10 and the overall assessment in Chapter 11. This final
Figure 1.1
Structure of the Thesis

1. Introduction

2. Evolution of Urban Transport Planning & Policies

3. Methodological Developments

4. The Case for a New Approach

5. Household Travel Patterns

6. Household Adaptation

7. Conceptual Assessment

8. Overview of Developments

9. Exploratory and Educational Studies

10. Analysis, Modelling and Evaluation

11. Conclusions
chapter also includes a more speculative discussion of the wider and longer-term implications of the approach described in Part Two. The thesis concludes with three appendices comprising: a review of the human activity literature (Appendix I), a description of the HATS technique (Appendix II), and a description of an activity-based trip model (Appendix III).
PART ONE

URBAN TRANSPORTATION PLANNING
2. THE EVOLUTION OF U.K. URBAN TRANSPORTATION PLANNING*

This chapter reviews the kinds of urban transport problem that have become apparent in the U.K. at different times since the war, and the policy measures and legislative changes which have been introduced to cope with them. Developments in the many areas of transport planning have occurred sporadically (sometimes concurrently but often with associated leads and lags), and it is difficult to identify a single, consistent pattern of change over the past 35 years. This review is, therefore, inevitably selective and draws in parts on the recent book by Starkie (1982). For convenience, I have divided it into four sections (although there is some overlap in treatment):

1. Pre-1963 (i.e. before publication of 'Traffic in Towns')
2. 1963 to 1970
3. The Early Seventies
4. Mid Seventies to the Present Time

2.1 Events Up To 1963

Although what is now termed urban transportation planning hardly existed in the U.K. before 1963, there were a number of developments in this early period which had an important influence on transport planning in later years.

The inter-war period saw considerable improvements and extensions to the transport infrastructure in the U.K., particularly associated with the rapid growth of urban areas. The total length of residential

---

*This chapter relates specifically to U.K. transportation planning with limited reference to related developments in the United States; detailed reviews of the historical development of transportation planning in the United States are provided in Holmes (1973) and Hassell (1980). For a brief review of parallel developments in Japan, see Niitani (1976) and for an Australian view, see Hensher (1979).
roads increased substantially and in London there were extensions to the Underground network. Existing roads were also improved, and in some cases major by-passes were constructed (e.g. the Kingston by-pass); there were also a number of schemes for railway electrification. In general, however, transport improvements were associated with new housing or industrial development, and the emphasis was on upgrading links or adding new ones, on the basis of simple operational requirements (e.g. to provide access) or financial criteria.

After the war, the procedure for adding or improving road links became more formalised and standardised through the 1947 Planning Act. This required local authorities to prepare Development Plans for their areas, on which were to be included proposals for road widening, junction improvements and new links.

Petrol rationing remained in force until 1950, and during the fifties the priority of national government was to re-build the fabric of the country. As money became available, emphasis was given to the development of a network of inter-urban motorways, linking the main industrial centres. The Preston by-pass (later to become part of the M6) was opened in December 1958, and the southern section of the M1 in the following year. Reconstruction also proceeded a pace on the railways, with the 1955 Modernisation Plan.

Although central government were concentrating investment into inter-urban travel, traffic problems began to emerge in urban areas — particularly in London (Hart, 1976). Between 1952 and 1960 the number of cars entering central London in the morning peak period nearly doubled, and by the end of the decade there was very serious concern that parts of London would literally grind to a halt unless something were done — indeed, this had happened for a while during the pre-Christmas shopping influx in December 1958. With a heavy commitment of available funds to inter-urban roads, and a lack of fully prepared urban road
schemes, the government's answer was to 'squeeze more capacity out of existing streets'. London was used as a test-bed, and a number of comprehensive traffic management measures were tried; these included one-way streets, 'tidal flow' across two bridges, urban clearways, box junctions, prohibited turns and the use of parking meters.*

The results exceeded all expectations, with increased traffic speeds and reduced accident rates, despite a continual increase in traffic. Between 1958 and 1962 the traffic flow in central London increased by 19 per cent, while journey speeds increased by 14 per cent and casualties (over a three year period) decreased by 6 per cent. This provided an important breathing space for London.

The other conurbations and large urban areas were less affected by traffic problems during this period, partly because of their smaller size, a lower growth rate for car ownership outside the South East, and useful increases in capacity gained through the removal of tram lines and better road maintenance. Nevertheless many engineers began to incorporate proposals for new networks of high-capacity roads in their Development Plans, often linked with proposals for slum clearance. These proposals were largely intuitive, however, based on roadside surveys and an operational assessment of requirements. Some schemes were quite extensive, and often involved several local authorities working together (e.g. the 1962 Highway Plan for South East Lancashire/North-East Cheshire).

Thus, by about 1962 several authorities were preparing their own plans for extensive road schemes, largely based on pre-war methodology. The government had attempted — successfully — to meet the short-term

*The 1956 Road Traffic Act had empowered Local Authorities to install parking meters, in order to increase traffic flow on main roads (rather than restrain traffic per se), but the measure was not effective until the 1960 Act created Traffic Wardens and a formal enforcement procedure.
problem of growing congestion, and a sizeable proportion of the inter-
urban motorway network was at an advanced stage of planning or con-
struction. Few planners had given serious thought at this stage to the
future role or requirements of local public transport — but this was
perhaps hardly surprising when most bus undertakings reached their peak
carryings in the mid fifties.

American Developments

Across the Atlantic, developments were taking place in the United
States which were to have an important influence on the form of modern
transportation planning in the U.K. during the sixties and seventies.
The Federal Government took an early interest in urban road building
after the war. It encouraged the comprehensive planning of highway
systems in large urban areas and provided substantial funds for con-
struction. Gakenheimer (1976) suggests that this interest was accen-
tuated by the inability of governments to effectively control other
facets of the rapid post-war growth in urban development.

Early metropolitan transportation studies included Detroit (begun
in 1953) and Chicago (in 1956);* such studies were characterised by a
large survey effort and the use of analytical techniques, assisted by
the availability of computers. The studies used a number of new tech-
niques based on the results of transport research during a period of
post-war 'conceptual development' (Gakenheimer and Wheaton, 1976),
lasting from 1946 to 1954, and culminating in the work of Mitchell and
Rapkin (1954) who argued strongly that urban traffic should be seen as
a function of the land use pattern. What resulted was a set of proced-
ures known as the 'transportation planning process', which came to form

---

*Developments in land use modelling were also associated with many of
these studies but are not considered here. For a review of U.K. and
U.S. work, see Batty (1976).
the basis of urban transportation planning in the U.K.

2.2 1963 to 1970

Aware that traffic management was only a short or medium-term palliative, the government commissioned a report in 1961 'to study the long term development of roads and traffic in urban areas, and their influence on the urban environment.' The Report, "Traffic in Towns" was compiled under the guidance of Colin Buchanan (HMSO, 1963), and included the following conclusions and recommendations:

- the growth in car ownership would be much more rapid and sustained than hitherto appreciated, to become almost universal;
- there is an inevitable conflict or trade-off between environment and accessibility, which can be ameliorated to some extent by better urban design, linked to comprehensive redevelopment;
- it showed that it would be very expensive to cater for unlimited car use in larger urban centres while maintaining acceptable environmental standards, and in the larger conurbations a physical impossibility to do so;
- it similarly showed that it would be necessary to restrain car traffic in large urban areas, especially at peak periods, and that although public transport would largely be relegated to a residual role, it would nevertheless remain a vital element for commuter travel;
- it recommended that local authorities prepare 'transportation plans' to supplement the statutory Development Plans, from the viewpoint of traffic as a function of land use.
These findings were a major influence on the birth and subsequent development of urban transportation planning over the next decade.

In 1964 the government announced that funding for large-scale road schemes would in future be based on the findings of land use/transportation studies, and offered a grant of 50 per cent towards their funding, as well as technical assistance. The major conurbations were first off the mark (e.g. the West Midlands Transportation Study was begun in 1964, and studies in Teesside and Greater Manchester in 1965) and other urban areas followed over the next ten years.*

A different conceptual approach and set of techniques was required to conduct a land use/transportation study (see section 3.2), and a heavy reliance was placed initially on American experience. A typical urban transportation planning process is shown in Figure 2.1. The study process was guided by a set of goals and objectives, which affected the types of problems examined, the alternatives considered, and the evaluation of options. Large efforts were devoted to obtaining a thorough inventory of transport facilities and travel problems, and mathematical models were used to analyse and forecast travel demand, with alternative schemes then being subject to a formal evaluation. Although some of the American-orientated procedures were to prove unsuited to British application, the land use/transportation study enabled urban transport planning to be undertaken on a more systematic, comprehensive and scientific basis than hitherto.

The transportation studies not only offered the promise of a rational basis for the allocation of very large sums of money among urban areas, but also provided a breathing space while the inter-urban roads programme was completed. In the interim period, local authorities

*See Atkins (1977) for a comprehensive list of nearly 100 U.K. urban transportation studies up to the mid-seventies.
The Stages of an Urban Transportation Planning Process

(Source: Bruton, 1975, Figure 1)
were advised to use parking controls as a means of restraint, and to implement appropriate traffic management measures. The emphasis was beginning to change from increasing road capacity in urban areas to the restraint of demand.

Roads Circular 1/68 went further, and requested all urban authorities in towns with over 50,000 people to prepare short-term Traffic and Transport Plans. These were to set out problems and objectives and the means by which authorities proposed to meet these difficulties, including provision for public transport and traffic regulation and parking controls. Outside the larger conurbations and historic towns, however, most authorities made very little attempt to restrain traffic, as they were finding that they could increase capacity through the introduction of comprehensive traffic management measures (following London's example) and by building stretches of relief and inner ring roads. They were also helped by a slowdown in the growth of car ownership, some decentralisation of jobs (especially industrial employment and associated traffic) and improved car performance.

In the meantime the early transportation studies were producing their findings which, on the whole, tended to endorse the earlier highway plans and proposed very high levels of expenditure. At the same time, however, it became clear that even these extensive networks would not be able to accommodate the forecast growth in traffic, and that public transport would have a vital role to play in any transportation plan for a large urban area.

These recommendations had a significant impact on the planning process (and the methodology — see section 3.2) within a relatively short period of time. Transport planners now needed to take much more serious account of public transport, seeing the transport problem as one of moving people by appropriate methods of travel — not simply accommodating road vehicles. At the same time, because of the high
cost of road (and rail) schemes, proposals had to be economically justified using some form of cost-benefit analysis, and alternative plans had to be prepared involving different levels of resources and with a different balance between private and public transport. London typified these changes in perspective. In 1961 the London Traffic Survey was started; by 1966 it had become the London Transportation Study, taking a much broader look at the travel requirements of Londoners by all modes (except walking).

Thus, by the late sixties, several of the larger urban areas were experiencing major transport changes. Parking controls were widely used as a means of restraining the amount of road traffic in an area, public transport use was being encouraged (especially at peak periods) through a series of improvements and priority measures,* and some of the early sections of urban motorway were coming into use.

Legislative Developments

The recognition of the need to deal with urban transport problems in a comprehensive manner was reflected in several important legislative developments in the late sixties and early seventies.

The 1968 Transport Act gave the Minister of Transport powers to provide grants for rail infrastructure projects on the same terms as for roads, and so removed an earlier financial bias. Grants could also be obtained for replacement of bus fleets (to encourage the switch to one man operation), and bus priority schemes were also encouraged. Passenger Transport Authorities were set up in the major conurbations outside London (i.e. Tyneside, Merseyside, West Midlands, SELNEC) to 'secure or promote the provision of a properly integrated and efficient

*A series of Bus Demonstration Projects were introduced in different parts of the country, to show the scope for improving urban public transport (e.g. see Heggie, 1977).
system of public transport to meet the needs of the area'. Under the 1968 Act and subsequent legislation a number of major rail projects were completed, including the Victoria Line extension, electrification schemes to the north of London, the Liverpool loop and link system and the Tyne and Wear Metro.

There were parallel administrative changes on the roads side, to simplify the planning and implementation of highway schemes. When the London Traffic Survey was set up in 1961 its study area encompassed the administrative area of the London County Council and covered substantial parts of several other counties. It soon became apparent that the demands of modern transportation planning required comprehensive co-ordinated planning over a wider area and the 1963 London Government Act created such a body: the Greater London Council. The GLC had responsibility for producing a development plan for the metropolis as a whole, and became the traffic authority for all roads within its area, except trunk roads (it had no specific public transport responsibilities at this time). Hart (1976) regards the transportation planning considerations as being largely instrumental in forcing this administrative change. Indeed, the GLC made major policy statements on highway planning within a few hours of becoming formally established in April 1965. The 1972 Local Government (England and Wales) Act established the Metropolitan (and the Shire) Counties as the bodies responsible for highway planning, and so enabled schemes for an entire conurbation to be prepared under the auspices of one authority.

Administrative procedures which enabled the co-ordination of public and private transport followed soon afterwards. The GLC became the first authority to have overall control of highway and public transport planning, with the passage of the Transport (London) Act of 1969, giving it general control over London Transport. It was with the implementation of the 1972 Local Government Act in April 1974 that
the new unified authorities were given responsibility for (most) highway and public transport planning — enabling them to implement the findings of land use/transportation studies which had been begun up to 10 years previously.

The Buchanan Report (Traffic in Towns) had recommended in 1963 that the new transportation plans should be included as part of the statutory development plans, and this was embodied as part of a basic revision of planning legislation in 1968.* The Town and Country Planning Act replaced the static development plan with a more flexible, two-tier planning process based on strategic level structure plans and more detailed local plans. The structure plan was intended to bring about a closer integration of land use and transport planning, by relating policies for housing, employment and daily movement.

Thus, within a few years the administrative framework within which urban transportation planning took place had altered fundamentally, greatly facilitating the co-ordination of transport planning along the lines envisaged by Buchanan.

2.3 The Early Seventies

The sixties had seen a broadening of view of the nature of transport, and the birth of comprehensive land use and transportation planning, generally on the lines recommended in Traffic in Towns.

Although most conurbations had developed plans for extensive urban motorway networks it was also appreciated that in the larger urban areas congestion could not be cured through new road building alone, and that at peak periods considerable reliance would have to be placed on improved public transport systems — offering a level of service that the

*For a detailed discussion of the role of local plans and structure plans in transport planning, see McMillen (1978).
motorist would find an acceptable alternative to his/her journey by car. It had been discovered that traffic capacity could be increased substantially through comprehensive traffic management measures, but in time these techniques were employed to increase personal as well as vehicular mobility, using parking control as a method of car restraint in city centres and traffic management measures as a means of giving buses priority. The approach was one of accommodating the car as far as practicable but relying in part on other modes in high density areas.

Yet, 'by the mid seventies the urban traffic policy that had applied for most of the previous decade had been stood on its head' (Starkie, 1982, p. 92). The early seventies were a period of significant political and economic change, and were associated with marked changes in public mood and transport policy.

The Change in Public Mood

One element of the Buchanan Report which most of the transportation study proposals failed to take adequate account of was the protection and enhancement of the urban environment. By the late sixties/early seventies a number of stretches of urban motorway had been completed, and the public gradually became disenchanted with the results; in the more extreme cases roads on stilts were sited within feet of people's living rooms, and the environmental problems of noise, pollution, visual intrusion, etc., became immediately apparent.

This was a period of growing public awareness of environmental and social issues, coupled with a growth of the conservation movement. Many of the remaining urban motorway proposals involved extensive demolition of housing (albeit often low quality stock); in Cardiff, for example, the construction of a spine motorway involved the demolition of around 1500 dwellings, and a serious deterioration in
environmental conditions for many more people. Public reaction built up against such proposals, and the associated break up of social communities. The tower blocks and 'concrete jungles' that were characteristic of many redevelopment schemes of the time were not seen to offer an attractive alternative living environment. A campaign built up in many parts of the country to put 'Homes Before Roads', and in the local government elections in 1972/3 a number of administrations were returned who supported this view (see below). Through the ballot box the public demonstrated that they were unwilling to accept basic changes in urban form to accommodate the motor car, in the way in which Traffic in Towns had envisaged.*

Over the same period there was an important intellectual response to the problems of accommodating cars in cities. 'Motorways in London' (Thompson, 1969) began this process by setting out the full economic, social and environmental costs of the GLC motorway proposals and by questioning the basic assumptions upon which urban transportation planning had been based during the sixties. This was followed by several books which considered more generally the future role of the private car in modern urban society (e.g. Bendixson, 1974; Plowden, 1972; Townroe, 1974).

The early seventies thus saw a growing academic, public and political concern with a much wider range of transport issues, relating to impacts affecting both users and non-users. These included:

(a) Environmental impacts: noise, pollution, visual intrusion, etc.

(b) Social impacts: severance, displacement and the general

*Although the early seventies marked the end of a political commitment to the philosophy behind Traffic in Towns, as it had been popularly interpreted, had the environmental principles in the report been more assiduously followed and high standards of urban design adopted, the outcome may have been very different.
isolation of non-car users in an increasingly car-orientated society (see Hillman et al. 1973).

(c) Distributional impacts, of investment and fiscal policies.
(The subsequent Labour government's transport consultative document examined the distributional effects of bus and rail subsidies in some detail; Department of the Environment, 1976.)

(d) Resource implications of a car-based society, particularly with regard to energy where in the U.K. about 20 per cent of end fuel consumption is used to provide passenger transport (both operation and manufacture, Chapman 1975). This aspect assumed a much greater practical and psychological importance after the 'oil crisis' of 1973/4.

By the time the government passed judgement on the Roskill Commission's recommendations for the siting of the Third London Airport (Commission on the Third London Airport, 1970), which had been based on a comprehensive economic cost-benefit analysis in which travel time savings to users predominated, the tide had turned and the majority recommendation was overruled on the popular grounds of environmental factors.

The Political Response

Inadequacies in urban transportation planning were examined by a House of Commons select committee on Urban Transport Planning (Expenditure Committee, 1972). The Committee described the growing mood of public discontent as taking several forms: 'In increasing complaints about inadequate train and bus services; in action groups and public demonstrations against the building of urban motorways, in dissatisfaction with traffic congestion and the swamping of city streets by private motor cars and intrusive heavy lorries.'
A comprehensive summary of the work of the Committee and its findings is provided in Starkie (1982, pp. 85-88). The inquiry focussed on the journey to work in the main urban areas, and concluded that:

Firstly, there should be a major and substantial effort to improve public transport. . . . Secondly, the use of private cars for the journey to work should be severely discouraged in areas where it impedes public transport.

The Committee acknowledged that 'the benefits enjoyed by motorists in peak hours are more than offset by the costs and penalties that they impose upon the community as a whole', and with regard to new road building concluded that '. . . we believe that the first step should be to make the best use of the present road system before adding substantially to it'. They envisaged that their recommendations would lead to a switch in travel from private back to public transport and that, as a result, 'the less mobile sections of the population would on the whole find travel easier, and the quality of life in our towns would be improved.' A number of measures were proposed to achieve these objectives, in particular:

(a) Tightening of parking controls as a means of restraint.
(b) Bus priority measures.
(c) Subsidies to cover losses on urban bus services.
(d) Giving rate rebates to firms who staggered work hours

The report of the Expenditure Committee well reflected the public mood of the time, and was associated with a switch in the May 1972 local government elections (and the 1973 GLC elections) to parties who advocated an end to urban motorway building and the promotion of public transport. Typical of the mood of this period was the proposal by the incoming labour administration in Nottingham to introduce a 'zone and collar' scheme (to restrain the amount of car traffic on
radial routes to ensure free-flow conditions), coupled with an improved public transport service, offering a more frequent and faster service. The significant point about schemes such as this is that they were seen as an *alternative* to extensive road schemes.* As Starkie (1982, p. 85) observes:

> Its proponents shared a belief that urban motorways were by no means an essential solution for urban traffic problems, and that it was possible for city transport to continue to operate well, without greatly expanded road capacity. Their emphasis, instead, was upon managing the demand for existing road space rather than trying, by building new roads, to accommodate as much traffic as possible and then leaving traffic restraint and better public transport to mop up the residue. It was this difference in emphasis that was crucial.

Central government responded to these growing political pressures with a series of legislative changes.

Recognition of the need to take account of broadening public concern over the environmental impacts of public works was given subsequent legal backing in the 1973 Land Compensation Act. This applied to land acquisition for new roads schemes, empowering local authorities to purchase land other than that required for construction purposes on environmental grounds,** to fully compensate nearby residents for hardship caused, and compelling them to insulate houses badly affected by noise. These changes increased considerably the cost of motorway

---

*The beginnings of this change of emphasis can be seen at the end of the sixties when Lichfield and Associates (1969) carried out a detailed cost-benefit study in Stevenage new town, to examine ways of increasing network capacity to cater for town expansion. They concluded that it would be more economic (as well as environmentally preferable) to provide an improved bus service rather than to build grade-separated junctions at key intersections on the road network.

**The Leitch Report (Report of the Advisory Committee on Trunk Road Assessment) published in 1978 showed how environmental factors could be taken more fully into account in road scheme evaluation, using a balance sheet rather than a strictly monetary cost-benefit approach.
building in urban areas. New arrangements for early public consulta-
tion in connection with the planning of motorway and trunk road schemes
in England and Wales were also set down in the same year.

In order to facilitate car restraint through better enforcement
of parking controls, legislation was introduced to make the registered
owner, rather than the driver, of a vehicle liable for fixed penalty
parking fines. The government also accepted the need for revenue
support for public transport and proposed a system of transport grants
which would 'eliminate the bias towards capital or current expenditure,
or towards particular forms of expenditure'.

This was subsequently implemented in 1974, with the introduction
of the Transport Policy and Programme (TPP) system.* It required each
Metropolitan (and Shire) County to produce for the Department of Trans-
port an annual, five year rolling programme for the improvement and
maintenance of roads, and for investment and operating subsidies for
road and rail services in their area. Some local transport expendi-
ture is covered by the Rate Support Grant, but expenditure above a
threshold level is paid for by means of a Transport Supplementary
Grant, on the basis of the TPP submission.

By the mid seventies the legislature framework for urban trans-
portation planning in the U.K. had thus been thoroughly overhauled,
enabling both strategic long term transportation planning to be under-
taken within a broader planning framework, and providing the flexibil-
ity and day-to-day control needed to cope with the political and econo-
mic changes of the seventies.

A general summary of the objectives and format of this adminis-
trative structure is provided by Gwilliam (1976, p. 39):

*The U.S. Transportation Improvement Programme (TIP) performs a broadly
similar function.
It was intended to provide a framework for efficient and comprehensive transport planning well integrated with land use policy, with proper scope for substantial local discretion, effective public participation, and free from inefficient institutional constraints. This framework consisted of the relocation of local transport planning responsibilities in the hands of the county authorities, the integration of long term transport and land use planning in a structure plan subject to public participation and inquiry, and the consolidation of the short term transport planning policy within the TPP in conjunction with a reformed local transport finance arrangement.

American Experience

Reaction against highway projects on environmental, social and resource grounds also grew rapidly in the United States, once again preceding British experience but this time by only two or three years. In 1970 the mayor of Boston declared a moratorium on all highway projects within an outer circumferential route, and similar action has subsequently followed in other cities. Hart (1976) and Gakenheimer (1976) provide detailed case studies of the rise and fall of major urban highway plans in London and Boston respectively, and it appears that the social and economic pressures were broadly similar.

For a more general discussion of parallel changes in emphasis in U.S. transportation planning, see Hassell (1980).

2.4 The Mid Seventies to the Present

By the mid seventies there had been a fundamental shift of resources in urban transport planning away from road building towards traffic management and public transport, with only a very limited implementation

*The equivalent symbolic act occurred in Britain in 1973, when an incoming GLC Labour administration scrapped the motorway proposals for London and released areas of land for development that had been safeguarded for many years.
of the land use/transportation study plans (Thomas and Puvanachandram, 1980). This change in emphasis was strengthened by the psychological impact of the 'oil crisis' in 1973/4, as a result of which future supplies of petroleum were now regarded as uncertain.

The impetus of these changes was maintained through the second half of the seventies by further transport planning legislation and directives. In 1975 the government announced that the normal deficits incurred on car park operations would no longer be eligible for Transport Supplementary Grant, and in the 1978 Transport Act local authorities were empowered to regulate the operation (charges, opening hours etc.) of privately owned public car parks. Authorities were also encouraged to proceed further with comprehensive traffic management measures and in the larger urban centres computer area control of traffic signals was used to increase road capacity still further.

On the public transport side, all operators in large urban areas were receiving substantial subsidy by the late seventies, to cover operating costs and investment and the concessionary fares usually provided for school children and old age pensioners. In 1978 these various grants provided around 15 per cent of revenue in West Yorkshire PTE, 40 per cent for Merseyside and Tyne and Wear, and over 60 per cent in South Yorkshire, where fare levels had been maintained at 1975/6 levels.

In the same year, under the 1978 Transport Act, the non-metropolitan counties were required to prepare annual Public Transport Plans, as part of the TPP submission, covering educational and social services transport, works contract, taxi, ferry, air, as well as conventional bus and rail services. Like the TPP, the PTP covers a five-year period; it is intended to review existing services, state objections and policy, indicate criteria used to identify need for service and subsidy, and record the concessionary fare schemes operated in the County. Extensive
consultation is provided for in the Act, which gives Shire Counties a much stronger coordinating (though not operating) role than hitherto.

Disenchantment with the Transportation Study Process

During this period of policy upheaval there was also a growing disenchantment with the 'classic' urban transportation planning process, as it had developed during the sixties and early seventies. Since the large urban motorways schemes had been produced — or, at least, endorsed — by these studies, it was felt that part of the fault must lie with the planning procedures used, which were seen as narrowly based and less appropriate to current needs. Similar sentiments in the United States led to attempts at a much broader-based planning approach. In Boston, for example, the classic transportation study was replaced by the 'Balanced Transportation Research Programme', which attempted to deal with:

... the entire series of elements of study: community liaison, design and evaluation criteria, system design, joint development, land use and travel forecasting, special mobility studies, technology, administration and legislative studies, environmental studies, the regional economy, residential relocation, business relocation, and neighbourhood cohesion.

(Gakenheimer, 1976, p. 28)

There was a conscious attempt to substitute breadth of treatment for depth of quantitative analysis, and very simple forecasting techniques were used.

In Britain, the response was varied and often uncertain. As experiments such as 'Superbus' in Stevenage, the zone-and-collar scheme in Nottingham, and bus priority schemes in Southampton, Reading and elsewhere came into operation, it became apparent that motorists were not generally willing to use a bus in place of their car (see section 3.3). It was true that bus patronage could be increased significantly
through better services and cheaper fares, but this was not as a result of substantial gains from motorists; rather it reflected higher trip rates among bus users and some switch from walking and cycling. It was thus becoming clear that the basic premise of the new policies (based on political hunch and some support from the conventional forecasting models) was not entirely valid: bus and rail services were not a complete substitute for road building.

This left conventional transportation planning in a confused state during the remainder of the seventies, with:

... local authority practice still very much wedded to the principles established in the 1960s; academia questioning the presumptions of traditional transportation planning, without being able to spell out the acceptable alternatives that flow from their criticisms; and a wide variety of pressure groups who are not backward in coming forward with alternative approaches, but have little conception of the implications of their propositions.

(Styles, 1974, p. 522)

The Present Situation

In the event, changing economic and political circumstances have taken the pressure off the search for greater transport capacity in urban areas — for the moment, at least — and there has been a gradual move away from large-scale, comprehensive transportation planning (with an emphasis on increasing supply), towards a short-term, management-oriented, ad hoc and incremental approach (which relies on the restraint of demand).

Between mid 1976 and mid 1977, for example, there was a complete moratorium on new road construction and by the end of the seventies expenditure on urban roads was about half the level it had been in 1973/4. With a few notable exceptions (e.g. road building in the Docklands area of East London), most of the urban roads budget is now
taken up with maintenance and minor road improvements. The economic recession has led to a reduction in the growth of car ownership and high unemployment is resulting in significantly fewer journeys to work. Urban traffic seems to be finding its own level, and the pressure for drastic solutions has receded.

For public transport operators, the last few years have been difficult ones, with increasing competition and changes in subsidy provision, against a background of a general decline in demand. The 1980 Transport Act introduced competition on longer-distance routes and removed fares control; this has particularly affected rail commuting (e.g. there are now over 60 coaches carrying commuters from North Kent to London in the morning peak), but it can cause local traffic problems and makes it more difficult for bus operators to cross-subsidise their services. Other government initiatives have encouraged car sharing schemes (through changes in insurance conditions, etc.) and this too has eroded the urban public transport market.

The effects of the recession and increased competition have been to make it more difficult for operators to cover costs and so require an increase in subsidy (re-inforced in some instances by the introduction of local government low fare policies). A successful legal action by Bromley Borough Ratepayers against the Greater London Council, however, has called into question the legality of a cheap fares policy, and Central Government are now acting to limit the amount of subsidy paid to operators (see "Public Transport Subsidy in Cities", Cmd 8735). This is likely to lead to a substantial reduction in service provision in some metropolitan areas.

The emphasis in urban transport is on value-for-money, both in the provision and maintenance of road infrastructure and the operation of bus and rail services. This is tending to reduce the attention given to the co-ordination of transport planning as each department attempts
to resolve its own problems and increase its internal efficiency.

Several writers have warned of the dangers of adopting a more incremental, *ad hoc* and less coordinated approach. In a review of the success of transport policies in O.E.C.D. countries, for example, Horn (1981) concludes that 'consistent, coordinated combinations of measures have a better chance of success than individual measures taken in isolation'. Wachs (1977) has argued in the U.S. context that various conflicts and inconsistencies in the present piecemeal approach are likely to become apparent in the eighties, and that this will lead to a return to larger-scale, comprehensive transportation planning in the United States. Such plans, he suggests, will need 'boldness and vision' and will require a rather different approach to urban transportation planning than that which was born in the fifties.

**Problems and Issues**

The types of transport problems and working pressures faced by the transportation planner and engineer have thus continued to change during the seventies, since the basic reorientation during the early part of the decade. In particular, financial considerations now have a greater weight than for many years. As Hassell (1980, p. 5) has observed:

> Today's transportation planner has to emphasize the management of demand by spreading peaks through variable work hours, increasing spatial occupancy through car pooling and more efficient transit service, while minimizing, or at least attempting to hold constant, operating subsidies.

Issues which now assume a much greater importance than in the early seventies include:

- the definition of travel need and the identification of the requirements of disadvantaged groups;
• the definition of level of public transport service and the minimisation of hardship caused through cut backs in services;
• the level and allocation of subsidy to public transport services (e.g. Van Harreveld and Vogelaar, 1982), linked with questions of effectiveness and efficiency;
• labour problems in the transport supply industries;
• the role of timing policies (e.g. work or school hour staggering or revised shopping hours) as a means of spreading transport demand;
• the impact and effectiveness of selective car restraint policies.

At the same time, there has been a general broadening of interest in the impacts of transport policy, on both travellers and non-travellers. This has been made explicit in the U.S. by the Department of Transportation, who have recently adopted five urban transportation policy objectives (Hassell, 1980), covering:

(1) Urban impact (including development, tax revenues, public expenditures, employment, accessibility and the environment).
(2) Energy conservation (including both operating/maintenance costs and fuel consumed in construction).
(3) Minority and neighbourhood effects (covering travel, life styles, housing, etc.).
(4) Investigating improvements to existing systems as an alternative to major construction programmes.
(5) Consideration of alternative investment programmes, with an analysis of their cost effectiveness.

There are also important changes in the medium and long term issues which relate to transport in the context of structure plans, or
their equivalents in other countries. In a European context, Horn (1981) has listed the following major problem areas:

- 'the long-term response in the transportation sector to increasing economic constraints, uncertain oil supply and price developments, as well as decreasing material resources';
- 'the effects of these developments and of actions taken on the use of the automobile and motorisation levels, highway investments and maintenance, public transportation, urban structures';
- 'the long-term effects of changes in urbanisation trends and patterns on transportation, and of evolutionary policies of environmental protection, quality of life and increasing leisure time and aspirations';
- 'the long-term impacts of public participation and equity schemes in transportation planning and operation and of various forms and degrees of governmental interventions';
- 'the long-term potential of the application of new or innovative technologies in transportation systems'.

In addition, there are external but related changes such as the likely long-term impact of telecommunications on patterns of work, shopping and leisure and in some areas the recognition that it may be necessary to plan for long-term decline.

The objectives and processes of urban transportation planning have thus changed and broadened considerably since the preoccupation with traffic growth in the fifties. New issues often require new methodologies and in the next chapter we examine methodological developments in urban transportation planning since the fifties, noting how these have both responded to and influenced the changes in U.K. transport policy since the war.
3. METHODOLOGICAL DEVELOPMENTS IN URBAN TRANSPORTATION PLANNING

3.1 The Process of Methodological Development

Paralleling, and closely relating to, the changing issues and policies in urban transportation planning outlined in Chapter 2, there have been a number of major developments in methodology. These have affected the methods used for data collection, analysis, forecasting and evaluation. As a consequence of the various advances since the fifties, the transport engineer and planner now have available a wide range of techniques with which to tackle different issues at varying levels of detail.

This chapter examines the main developments in the type of concepts and techniques employed in urban transportation planning since the war. Its concern is not with the technical detail of the methods used (e.g. whether to use a regression or category analysis technique for trip generation, or a probit or logit function in an individual choice model), but rather with their scope, overall structure and the role they have come to play in transportation planning.

As with the evolution of urban transportation planning, developments in methodology do not conform to a simple pattern of change. Nevertheless, it is possible to discern a general direction of movement, which is shown in a stylised way in a three-dimensional form in Figure 3.1. As new methodologies have been developed over time, they have tended to differ from the existing methods in one of two respects:*

(a) In the type or range of concepts used, by developing approaches that embody a deeper understanding of the nature of the nature

*This is inevitably an oversimplification, in that some developments relate to both dimensions simultaneously (e.g. certain aspects of individual choice models).
Growing range of conceptual/technical packages at different levels of sophistication, for different purposes.

KEY
(1) New policy requirements, leading to conceptual and technical responses
(2) Conceptual developments
(3) Technical developments

Figure 3.1:
The Development of Methodology in Urban Transportation Planning Over Time, at Conceptual & Technical Levels
of travel and the decision processes of travellers.  

(b) Technically, by representing some 'advance', in the broadest sense; this might involve an approach that is mathematically or statistically more sophisticated, or one which is computationally more efficient (and hence faster, cheaper or easier to use).

The process of development represented in Figure 3.1 is primarily one of accretion rather than replacement. That is, new methodologies have in most cases been developed to deal with new situations and issues, and hence represent additions to the armoury of methods available to the traffic engineer or transport planner, to be used alongside more established procedures where appropriate.

This thesis is concerned primarily with developments in methodology along dimension (a). These tend to have been closely related to changes in the perception of the nature of traffic and transportation, and the types of issue that have arisen in public debate. However, although developments have usually been responsive to the requirements of the planner and politician, in some instances the methods used have themselves helped to shape a political belief of the time (e.g. that motorists could be easily encouraged to switch to rail or bus for their work journey).

The role and development of methodology in urban transportation planning is examined in the remaining sections of this chapter. Following the line of argument in Chapter 2, a general distinction is made between developments up to the early seventies and advances since that date — with a period of re-assessment in between. In the course of this discussion some attention will also be paid to changes along the technical (b) dimension, particularly where these relate to planning issues or changes affecting dimension (a).
3.2 Methodological Developments up to the Early Seventies

Conceptually, at least four distinct approaches can be identified in the development of methodology to forecast the demand for urban transport facilities, up to the early seventies. Each approach was designed for a different purpose, and tended to be more comprehensive than its predecessors, following the pattern shown in Figure 3.1. There were also a number of important and related technical developments.

The First Approach

The initial focus in urban transport planning was on minor improvements to the road network (e.g. as part of the 1947 Development Plan procedure), involving the upgrading of a link, a junction improvement or the by-passing of a small bottleneck (see section 2.1). In terms of the concepts employed to forecast demand, engineers were dealing with VEHICLE FLOWS on LINKS or specific stretches of road. Simple methods were developed to achieve three main requirements:

(1) Counts of vehicles on (the) appropriate link(s).

(2) Growth factors applied to the link volumes to obtain the level of usage at a pre-determined date in the future.

(3) An operational assessment of proposed upgrading schemes to ensure that capacity would be adequate to cater for the flows in (2) using the volume/capacity (v/c) ratio.

The Second Approach

By the late fifties this piecemeal approach was proving inadequate in the face of a rapid growth in traffic in the larger urban areas, where local authorities were beginning to produce comprehensive highway plans. Although the emphasis was still on vehicles it was
now necessary to deal with transport supply on an aggregate NETWORK, rather than just at a link level, and to trace vehicle TRIPS across the network, rather than deal simply with flows at strategic points. This change in perspective from the link to the network, involved five important methodological developments:

1. The notion of dividing the study area into a set of traffic zones, for purposes of analysis.

2. The extensive use of roadside interviews with drivers, to obtain information on trip origins and destinations.

3. Introduction of a rudimentary trip distribution phase into the analysis, through an examination of the main desire line movements.

4. Development of procedures to factor traffic growth for a complete matrix of O-D movements (e.g. Fratar, 1954).

5. Development of simple traffic assignment procedures, based in most cases on the use of diversion curve techniques.

For details of the methods used, see Martin, Memmott and Bone (1961).

The Third Approach

The early to mid sixties saw the arrival of a third methodological approach, associated with the development of formal urban transportation planning procedures (see section 2.2). This was based on methods imported from the United States, where they had been developed during the previous decade, and which relied heavily on the use of computerised procedures; these had the advantage of enabling more detailed methods to be used than would otherwise have been possible.

Conceptually, the urban transportation study procedures dealt with many of the same elements as had the earlier U.K. highway studies (i.e. vehicles, trips, networks) but were based on a different,
broader perspective: that of TRAFFIC AS A FUNCTION OF LAND USE. This had a number of important consequences:

(1) It was now necessary to take more detailed account of land use, and to forecast changes in this pattern.

(2) A new TRIP GENERATION stage was added to the analysis and forecasting procedures, in order to model the relationships between traffic and land use at a zonal level. This identified separately households with and without a car, and concentrated on the former.

(3) The home interview survey became an important instrument of data collection, with roadside O-D surveys and traffic counts being relegated to a secondary role.

(4) The use of computers enabled more sophisticated methods of analysis to be employed. For example, the development of network assignment procedures and the gradual replacement of growth factor methods with gravity models in trip distribution.

An example of the methodological components of an early land use/transportation study are shown in Figure 3.2. The methods are described, for example in Lane, Powell and Smith (1971). Detailed inventories of land use, transport facilities and travel were required at a zonal (or link) level, in order to identify problem areas and to derive relationships between travel, land use and population characteristics. Forecasts were first made of changes in zonal population, economic activity and land use for the design year; future levels of traffic movements over the study area were then predicted, showing where there would be serious over-loading and helping to guide the development of a land use and transport plan. This plan was then
Figure 3.2

Elements of an Early Transportation Study

(Source: Oi and Schuldiner, 1962, Figure 2)
tested (to see whether it was able to accommodate the projected traffic) and evaluated, usually in operational terms. If there were any deficiencies (i.e. areas of under- or over-provision of network capacity), the plan was modified and re-tested.

The Fourth Approach

The results of the early transportation studies showed the impracticability of catering for full car use in larger urban areas (see section 2.2). In many cases it was not physically possible to provide sufficient road capacity to meet the forecast traffic demands without destroying the fabric of city centres and, even where it was, it would have been prohibitively expensive to do so. This had two important and related consequences:

(i) Public transport would be needed to cater for much of the city centre travel demand, particularly at peak periods.

(ii) Trade-offs would have to be made between environment, accessibility and cost. This required that alternative transport plans be prepared and evaluated, in order to look at the benefits of different investment allocation between public and private transport, as well as different levels of overall investment.

The first realisation was an important one for urban transportation planning and had very important consequences for methodology. Apart from incorporating public transport at the inventory, assignment and other stages in Figure 3.2, it necessitated a fundamental change in the way in which travel demand was analysed; instead of primarily accommodating vehicles in cities, the emphasis switched to one of catering for the daily movement needs of TRAVELLERS, by whichever method of travel was most appropriate. Conceptually, this involved
four important advances:

(1) A switch in emphasis from the vehicle to the PERSON TRIP as the basic unit of analysis (although the analysis was still at a zonal level).

(2) The addition of a separate MODAL SPLIT stage to the three-step forecasting process (previously it had been subsumed under trip generation) based initially on some form of diversion curve.

(3) A gradual switch from travel time to a composite measure of GENERALISED COST as the basis for assessing the attractiveness of different modes. (This was necessary in order to take account of walk, wait and fares for public transport, and fuel costs and parking charges for car travel, and to enable a full economic evaluation to be undertaken).

(4) Associated with (3), it became essential to use some form of gravity or related model rather than growth factor or intervening opportunity models, since the latter do not incorporate measures of travel impedance.

An example of the type of analysis framework associated with this fourth methodological approach is shown in Figure 3.3. (For descriptions of the methodology see Black, 1981; Bruton, 1975; Hutchinson, 1974; Wells, 1975). Here the trip generation and trip distribution submodels are expressed in terms of person rather than vehicle trips, and modal split is introduced at one or more stages in the process.*

Households 'captive' to public transport (by virtue of not having a car) — or, conceivably, households captive to car because of a lack of

*The merits of different arrangements of the trip distribution and modal split submodels are discussed in Senior and Williams (1977).
Figure 3.3
Example of a Four Stage Forecasting Procedure
(Source: Adapted from Hutchinson, 1974, Figure 1.13)
public transport services — are separated at the trip generation stage, as before. For those who do have a choice between public and private transport, an estimate is next made of the pattern of destinations they wish to visit, and they are then allocated to one mode or another, on the basis of the time and cost characteristics of each. Network assignment is then carried out for each mode separately.

Other Developments

As a consequence of the rejection of the idea of developing motorway cities, there was a broadening of the process of evaluation from a concern purely with operational criteria, to one which took account of economic and (later) environmental factors.* Economic evaluation was becoming well established as a basis for resource allocation in the late sixties, encouraged by the Treasury. The use of a benefit/cost framework enabled resources to be allocated efficiently among projects and between different forms of transport investment, and helped to determine the appropriate scale of investment in an area. Benefits were assessed to both travellers (travel time savings) and vehicles (savings in operating costs), and instead of evaluating a single design year plan, economic evaluation now demanded choices to be made between several phased programmes of investment in an urban area. Environmental evaluation subsequently increased demands on the forecast output of transportation studies still further, by requiring reliable traffic forecasts on a link basis, so that noise levels etc. in individual streets could be assessed.

Over a relatively short period of time, therefore, the urban travel forecasting methodology had become considerably more

*For a description of the operational, economic and environmental assessment procedures used in urban transportation planning in the early seventies, see Wells (1975, Chapter 9).
sophisticated, both conceptually and technically, and its outputs were being used in a number of different ways. Environmental evaluation often demanded reliable forecasts at a highly disaggregate level; economic evaluation required forecasts to be made of several plans, with different elements and over different time periods; and the assessment procedures in general assumed that the models could be used to forecast the way in which travel behaviour would change in the future (under conditions of car restraint or a better public transport system) — whereas they were originally designed to extrapolate existing patterns of behaviour into the future.

Too much was being asked of any one modelling system and by the mid seventies, at a time when transport policy was undergoing a major re-orientation, there was a growing dissatisfaction with the 'conventional' four-stage model. There was a period of re-appraisal, followed by further conceptual and technical developments.

3.3 A Period of Re-Assessment

By the mid seventies urban transport policy has changed fundamentally in the U.K. (see sections 2.2 and 2.3), and the whole transportation planning process was showing signs of strain. This was a significant gestation period for developments in methodology since, on the one hand, it was becoming apparent that the technical procedures had not been as accurate or reliable as they might have been, and on the other, the changing transportation planning environment was itself making new demands on methodology. Before looking at developments since the early seventies, it is appropriate therefore, to examine the problems that emerged and the reasons for them.

In an award-winning paper presented to the Institute of Civil Engineers in 1976, the author made the following very damning comments
about the four-step forecasting methodology (e.g. Figure 3.3) used in most urban transportation studies (Atkins 1977, p. 62):

... we have a series of excessively complicated and expensive models using unsubstantiated and biased techniques to provide information of dubious accuracy for answering the wrong questions.

Although this was one of the more outspoken statements of the time, it did reflect an underlying concern felt by many about the performance of the models then in general use.

Why this reaction against what a few years previously had been seen as a great technical achievement? Apart from the public disquiet about many of the plans produced by these studies (discussed in Chapter 2), there were four main methodological problems:

(1) Unreliability in the input data (particularly forecasts of population and employment).

(2) The inability of procedures originally developed to project the status quo, to instead predict traveller response to a wide range of policies that involved explicit changes in levels of service and behaviour.

(3) Problems with the way in which study forecasts were presented, and the context in which they were interpreted and used.

(4) Related technical problems, associated with the difficulty of manipulating very large matrices, or the sheer time and expense involved in calibrating and running a complete model system.

The final point is not considered further in this section, although it was of considerable practical importance.
Unreliability in Data Inputs

The first contributory factor lay largely outside the control of the transportation planner. Most transportation studies were commissioned in the sixties, at a time when it was believed that the growth of traffic would be one of the major urban problems of the seventies and eighties. The studies largely confirmed this viewpoint and duly recommended large investments in new infrastructure. Nearly twenty years later most of the investment has not been made, and yet the larger cities and conurbations (particularly London) have managed without grinding to a halt.

The reason that the forecast chaos has not occurred is mainly because of substantial errors in the inputs to the process provided by land use planners and economic forecasters. Population, income and car ownership have not risen at anything like the rate anticipated, and there have been substantial shifts of population and employment away from the larger urban areas. During the sixties planners in London were assuming a further growth in the conurbation's population and employment, whereas both in fact were declining.

In a study of the predictive accuracy of 31 British transportation studies, Evans and Mackinder (1980) examined the disparities between the forecasts of planning variables and the actual values subsequently observed, over a comparable ten-year period. They found that average forecast errors for population and employment were 12 per cent and 13 per cent respectively; for cars per head and household income the average over-estimation was in excess of 20 per cent, and highway and public transport trips were over-estimated by 41 per cent and 32 per cent, respectively. Indeed, the authors conclude that the studies would have predicted traffic levels more accurately if they had assumed no change in the base year situation, rather than using the values on which plan design and evaluation were based. Although it appeared that
the over-estimates in road traffic could not be completely explained by the inflated planning inputs, they were certainly a major cause.

Changing Model Requirements

A second contributory factor was the way in which, in British applications, the travel demand forecasting procedures came to be used to examine how behaviour would be modified in the light of restrictions in transport supply, rather than for their original purpose which was to show by how much supply should be increased to enable current behaviour patterns to be maintained. This distinction between projecting behaviour patterns into the future and modelling behavioural responses proved to be an important one.

It was evident at an early stage that the basic four-stage model could not describe adequately what would happen if the road network had restricted capacity. In the London Transportation Study, for example, the amount of traffic assigned to the motorway box was in places more than could have been parked on the road surface, and so an additional traffic restraint procedure had to be used, based on a linear programming technique (e.g. see May, 1975). What was not appreciated at that time, however, was that there were also problems with the trip generation and modal split submodels which would seriously affect the forecasts of public transport patronage associated with different types of service improvements. This was seriously to mislead policy formulation in the early seventies.

Forecasts produced using the aggregate, four-stage models encouraged the belief that a substantial number of trips could be transferred from private car to public transport at peak periods, through fairly modest improvements in relative travel times or reductions in fares. On the basis of such forecasts the U.K. and U.S.
governments funded a number of demonstration projects to show how car commuters could be attracted to public transport, and local authorities introduced their own schemes (e.g. the Nottingham zone-and-collar scheme described in Chapter 2). In most cases the monitoring studies found that the model forecasts were wrong, and were able to reveal a number of features of travel decision making which were not incorporated in the current models.

Detailed summaries of the main studies are provided in Heggie (1977) and Hovel et al. (1975). The major findings included:

(a) Travellers do not respond to small improvements in service, and are often unaware that they have taken place. The introduction of bus lanes in Reading and the Southampton area had no apparent effect on patronage, although small improvements in objective journey times resulted. Studies in London have shown that bus passengers are often unaware of the existence of the bus lanes along which they travel.

(b) Reduced or free fares schemes attract very few car drivers, but can generate a large number of extra trips by non car users, especially during off-peak periods; a free fares experiment in Rome failed to reduce peak period car traffic, but did lead to a nearly 50 per cent increase in evening traffic. Peak and off-peak fare differentials can also result in traffic switching from one time period to the other.

(c) Car drivers may be attracted to public transport by improvements other than cost or travel time; comfort, convenience and quality are also important factors (e.g. luxury commuter coaches in Hale Barns and Peoria). In a review of studies of inter-urban travel, Earp et al. (1976) found a wide range of service attributes to be of importance, including comfort, convenience of access, safety, reliability, service frequency and the extent to which the travel time could usefully be employed.

(d) Travellers do not have a complete knowledge of service characteristics and advertising can have an important effect on patronage. Traffic on the Norwich-London railway line increased
by 10-15 per cent above trend after a promotion campaign, although there was no service improvement and some cheap fare facilities were withdrawn (Hollings, 1970). A similar campaign on the Tyneside local rail services led to a 45 per cent increase in passenger journeys.

(e) There is evidence of asymmetry in response to service changes; in particular, service deteriorations have more consistent effects than service improvements. Fare increases, for example, lead to more predictable effects than fare reductions, and a prolonged bus strike can lead to a permanent loss of patronage as passengers readjust and make alternative arrangements (Harmatuck, 1975). The existence of habitual behaviour patterns and selective information receptiveness is apparent from the effect of introducing a rail feeder bus service in Formby, where new residents were much more likely to use the bus than people who had lived in the area for some time.

(f) Limited evidence suggests that apparently competing modes of transport are not fully interchangeable. Studies into the likely effect of petrol rationing in London indicate that about 30 per cent of trips made by car would be suppressed rather than be transferred to public transport (Collins and Flower, 1975). And in a study of water travel across the Solent (where ships, hovercraft and hydrofoil provide competing alternatives), Earp et al. (1976) reported that about 40 per cent of people interviewed said that they would cancel or postpone their trip if the chosen mode were not available.

(g) There was also some evidence to suggest that policy measures might have important secondary effects, at other times of day and affecting other members of the household. Heggie (1977) discusses the secondary effects of peak period car restraint. To the extent that such policies are successful in persuading commuters to leave their cars at home, they become available to housewives and other non-workers for use during off-peak periods. This leads to greater environmental deterioration during the day and imposes a financial strain on public transport as the disparity between peak (gains) and off-peak (losses) in patronage widens.

Findings such as these played a considerable role in guiding
methodological developments in the latter part of the seventies.

During this later period there was also a much greater preponderance of short-term, management-oriented policies, designed to deal with traffic congestion problems. Remak and Rosenbloom (1976), for example, proposed a number of policies for reducing peak period traffic congestion in American cities, which they grouped under 11 categories (see Table 3.1); many of these could not be handled adequately using the forecasting procedures available at that time.

One of the key issues which this raised concerned the 'behavioural' validity of the forecasting model and, in particular, the relationship between the structure of the four-stage model and the type of travel decision process which this implied. Since the model was used to predict changes in behaviour then, it was argued, the model structure had — or should have — a behavioural significance. Wilson (1974, p. 129) summarises this implied representation as follows:

These various submodels of the transport model correspond to a conceptualization of the trip-making process as follows: shall I make a trip? (generation); where shall I go? (distribution); by what mode? (modal split); by what route? (assignment).

Since the submodels were run in sequence, with in most cases only very limited recursive linkages, this further implied that the decision process was a sequential one.

A number of writers were unhappy with this as a representation of behaviour. Horton (1972, p. 417) for example, saw it as 'obviously an operational concern rather than one based on the realities of the traveller's decision making process', and Kraft and Wohl (1967, p. 212) suggested that 'trip making decisions are made simultaneously rather than sequentially' — although few arguments were based on firm research findings. In retrospect, it is apparent that the models were developed primarily to analyse peak-period work journeys and were most suited to
Table 3.1

Responsiveness of the Conventional Four-Stage Model to Various
Peak Spreading Policies.*

<table>
<thead>
<tr>
<th>METHOD</th>
<th>MODEL RESPONSIVENESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staggered and flexible work hours</td>
<td>Low</td>
</tr>
<tr>
<td>Shortened work weeks</td>
<td>Low</td>
</tr>
<tr>
<td>Pricing and regulatory mechanisms</td>
<td>High</td>
</tr>
<tr>
<td>Restriction of auto access</td>
<td>Medium</td>
</tr>
<tr>
<td>Land use planning</td>
<td>Medium</td>
</tr>
<tr>
<td>Marketing</td>
<td>Low</td>
</tr>
<tr>
<td>Car pooling and ride sharing</td>
<td>Medium</td>
</tr>
<tr>
<td>Communications in lieu of travel</td>
<td>Low</td>
</tr>
<tr>
<td>Practical traffic engineering</td>
<td>High</td>
</tr>
<tr>
<td>Transit operations</td>
<td>Medium</td>
</tr>
<tr>
<td>Vehicle design features</td>
<td>Low</td>
</tr>
</tbody>
</table>

Methods of peak spreading proposed by Remak and Rosenbloom (1976)

*Assessment of model responsiveness made by the writer, based on a review of the literature and personal experience. Note that responsiveness does not necessarily correlate with accuracy or reliability.
this type of travel. Here trip frequency and destination are long-term decisions and in the short-term the major elements of choice are the mode or route.

In the case of non work/education trips, however, the model's structure and components are less tenable. For more discretionary travel it seems likely that the decision to travel is taken after considering destination and transport options, and frequency is not independent of local accessibility. Indeed, in the case of pleasure driving, Duffield (1973) has argued that it is not meaningful to use the sequencing or components of the conventional model at all, since route characteristics form a part of the attraction of the trip and there may be no specific destination other than the origin!

Another methodological problem which a number of the monitoring and policy studies revealed was the difficulties caused by the very limited ability of the models to handle issues related to time of day of travel (see also Horton, 1972). Where attempts had been made to incorporate real-time effects, they had almost exclusively been confined to making adjustments to the time duration measures in the modal split submodel. Examples included the use of different mode performance characteristics for peak and off-peak periods, allowing for wasted time at either end of a journey by adding it to travel waiting time (Heraty, 1976), or by introducing a factor to account for the unpredictability of travel times (Starkie, 1971). It was comparatively rare for trip distribution to be run for different times of day (often only peak requirements were considered) and no account was taken of trip scheduling problems in trip generation or any of the submodels.

In some instances the lack of a timing mechanism in a model was identified subsequently as the cause of its poor predictive ability. Heraty (1976), for example, describes the failure of a mode split model to correctly predict patronage of a new public transport facility in
West London; this was subsequently found to be due to high customer sensitivity to the timing of the schedules.

The Use of Model Outputs

A third contributory factor in the methodological reassessment which took place at this time was the way in which information from the modelling process had been presented to and interpreted by professionals and others not directly involved. The processes were generally viewed as scientific and value-free, with political objectives only entering the process at the plan generation and evaluation stages. As Manheim (1981) has observed, there was a highly technocratic overtone to the nature of transportation planning at this time.

Traffic forecasts — in the form of vehicle flows or passenger volumes — were usually presented as single numbers, which carried with it the implication of a high degree of accuracy in the forecasts. While those technically involved in the modelling procedures had some idea of the errors and uncertainties involved, many of those who came to use the results did not. Robbins (1978, p. 37) makes this point:

> Although modelling is very inaccurate and embodies numerous subjective judgements, to the uninitiated — both the layman and the professional on the fringe of modelling — it presents a convincing illusion of accuracy and objectivity. An inevitable consequence of this is that proposals 'substantiated' by sophisticated modelling exercises carry more weight than those without such backing.

Harrison (1974) suggests that if uncertainty were recognised, then the projects presented for evaluation might themselves be modified — possibly resulting in different policy recommendations.

Other writers have explored the implicit value judgements which were embedded in the modelling and evaluation procedures. Headicar (1974, p. 4) for example, argued that:
there is an automatic tendency to view trips in terms of their significance for transport, rather than the wider social purpose they are serving. A ten mile work trip by car is accorded vastly more importance than a child's half mile walk to school simply because of the transport resources it claims, but there is no indication that society values the importance of the trips so differently.

More generally, the forecasting procedures used in the urban transportation studies at that time limited significantly the types of policy option which could be tested, the dimensions along which the evaluation could be made, and the accuracy with which certain effects could be estimated. To a degree, therefore, the modelling procedures were influencing the findings of the evaluation process. This influence could be seen in other ways too. For example, the monitoring study carried out by TRRL on the Nottingham zone-and-collar scheme (Vincent and Layfield, 1977) only examined the scheme's impact on peak period travel; there did not appear to be any consideration of possible secondary effects on off-peak travel, had the scheme succeeded.

We now go on, in the next section, to examine how practitioners and researchers sought to overcome many of these problems in the latter part of the seventies.

3.4 Methodological Developments Since the Early Seventies

The re-appraisal of transportation planning in the early to mid seventies (see section 2.3) led to a fundamental shift in transport policy, from large-scale, long-term investment-oriented planning with an emphasis on catering for demand, to a more local, ad hoc, management-oriented approach concerned with the modification and restraint

*At this time, short walk trips were often excluded from the transportation study — because they had no significance for vehicle flows or public transport patronage.*
of demand. From a methodological point of view, this brought to light several problems relating to the behavioural basis and performance of the conventional four-stage travel demand model. These were discussed in the previous section and led to a recognition of the need for a number of changes, including the following:

- trip generation rates should be sensitive to accessibility levels;
- modal split procedures should be improved, to reflect more accurately the choice process involved;
- greater account should be taken of subjective factors (both attitudes and perception of information);
- additional variables should be incorporated into the analysis, including time of day;
- there should be a better representation of interactions between people and trips;
- there should be an explicit recognition of uncertainty in forecasts.

In short, there was a need for models which were more responsive to the new problems and issues, based on an improved representation of travel behaviour and enabling a better understanding and prediction of traveller response. At the same time the growing use of models highlighted the need for greater technical efficiency and reliability.

These problems were perceived both by academic researchers and practitioners, and the seventies saw a major expansion in the funding available for travel demand research. As a consequence there were a wide range of methodological developments during the decade.* At

---

*In some instances work had begun in the sixties, but the main development work and applications took place in this period.
least ten distinct avenues of work can be identified:

1. A firmer theoretical foundation for the conventional model.
2. Development of simultaneous model structures.
3. Development of individual choice models.
4. Better definition of choice sets (especially car availability).
5. Modelling of complex travel patterns.
6. Models based on travel budgets.
7. Attitudinal studies.
8. Simplified models.
10. Incorporation of error and uncertainty.

Each is briefly considered below.

Firmer Theoretical Foundation (1)

A number of writers have examined the theoretical validity of the structure and components of the conventional trip model. Early work sought a theoretical basis for the gravity distribution model, or its derivatives (e.g. Wilson, 1967; Neidercorn and Bechdolt, 1969; Cesario, 1973); and this interest rapidly extended to the mode choice submodel and its relationship to trip distribution (Wilson, 1973). Williams (1977) has examined the theoretical implications of using different forms of composite cost function, and Williams and Senior (1977) have emphasised the need to base aggregate models on an explicit micro-level decision structure that is behaviourally valid. They go on to demonstrate that the appropriate model structure (in particular, the order in which trip distribution and mode choice are handled) will

*The research into activity-based methods also began at this time, but is described in later chapters.*
vary according to the anticipated responses of the population.

Development of Simultaneous Model Structures (2)

Developed as an early alternative to the conventional model, the economic or direct demand model is an aggregate, simultaneous model with a theoretical basis in economic consumer theory. The rationale behind the basic model is described in Kraft and Wohl (1967). The volume of travel between an origin-destination pair by a particular mode is assumed to be inversely proportional to the 'price' of that mode (i.e. travel times, costs and other levels of service variables) and directly proportional to the price of competing modes. Income and other socio-economic and land use variables are included in the model, and the component travel decisions (i.e. generation, distribution and mode split) are handled simultaneously.

A general review of economic demand models is provided in Stopher and Meyburg (1975, Chapter 15). In comparison with the aggregate, sequential model, its proponents argue that the economic demand model is internally consistent, that the total volume of travel is sensitive to transport system and land use characteristics, and that it is explicitly based on consumer theory. The original direct demand models were developed for the North East Corridor Study in the United States, and a number of variants on the basic model structure have since been proposed. The approach was first used to model intra-urban travel by Talvitie (1973).

Development of Individual Choice Models (3)

The origins of this area of disaggregate or individual choice modelling can be traced back to Warner (1962), who developed a set of three mode choice models for work and non-work trips, using household data. Further mode choice studies were carried out in the late sixties (e.g. Lisco, 1967; Quarmby, 1967; Stopher, 1969) and during the
seventies the approach was extended to include other travel choices (particularly trip frequency and destination choice). For recent reviews of various research issues in disaggregate demand research, see Hensher and Stopher (1979) and Stopher, Meyburg and Brög (1981).

Much has been written about this approach, and a number of alternative model forms and structures have been proposed (see, for example, Domencich and McFadden, 1975; Richards and Ben-Akiva, 1975; Stopher and Meyburg, 1975, Chapter 16; Talvitie, 1976; Williams, 1977). Its key features are that it models individual travel choices on a probabilistic basis, and uses individual-specific data on the attributes of travellers and the choice options which they face. It can thus take account of the personal characteristics of travellers, and incorporate the specific travel characteristics (times, costs, etc.) of the alternatives available to each person — using either 'objective' or 'perceived' data.

Several writers have shown that the commonly used logit form of the model can be derived from both psychological and economic theories of traveller behaviour — though the two theories account for the probabilistic element of choice in a different way* — and on this basis it is claimed that the model is a 'behavioural' representation of the travel decision process.

Individual choice models have been used in a growing number of transport planning studies since the early seventies, notably in the United States. A comprehensive, general review of the American applications may be found in Spear (1977), and more partial reviews are

---

*The psychological derivation assumes that the utilities of the alternative options are fixed (i.e. Strict Utility assumption), but that people vary their choice of preferred alternative. Conversely, the economic derivation assumes that decision makers always optimise (i.e. choose the option with the highest utility), but that there is a degree of variation in perceived utilities between individuals (i.e. Random Utility assumption).
provided by Ben-Akiva et al. (1976) and Reid (1979). Spear distinguishes three broad contexts in which these models have been used in the United States:

(i) As sub-models in the traditional travel demand forecasting process.

(ii) As a basis for assessing Transport System Management (TSM) policies.

(iii) As a device for forecasting the demand for new transportation systems, or major service improvements.

Practical applications are discussed further in section 3.5.

Better Definition of Choice Sets (4)

One of the reasons why the commonly used aggregate mode split models had proved to be so unreliable was that they failed to distinguish adequately between travellers who did or did not have a real choice of mode. All adult members of a car-owning household were assumed to have access to that car—even though in practice that would mean it was being used for different journeys at the same time. There was no mechanism for taking account of competition for the car between different people or types of journey in a household. This resulted in a mis-specified mode split model (because people who were captive to public transport were included in the choice model and inferred to have preferred public to private transport) and explains why the planners had thought that people were very sensitive to changes in relative times and costs.

It is now recognised that travellers with a real choice between car driver and public transport modes for urban journeys invariably choose the former (Lucarotti, 1977) unless they are restrained or discouraged from doing so in some way. It is therefore important to correctly define the traveller's mode choice set. A mechanism for
doing this is now incorporated in both aggregate and disaggregate models, and means that the different trips made by household members have to be linked in some way. In the Bristol Land Use/Transportation Study, for example, mode choice for the work journey was forecast first and the number of cars used were subtracted from the total stock of household cars before the off-peak model was run (Lamb et al., 1976). The detailed development of a mode choice model based on car availability is described in Banister (1977).

The Modelling of Complex Travel Patterns (5)

The urban transportation studies concentrated primarily on the bulk of trips which began or ended at home and paid relatively little attention to non-home based trips (which were usually assumed to remain a fixed proportion of the forecast home-based trips). Data from these studies demonstrated, however, that between one quarter and one third of journeys from home included non-home based trips (Jones, 1978a), and there were indications that this proportion was likely to rise over time. Daws and McCullock (1974) found that household travel patterns became more complex in form as car ownership and usage increased, and one response to petrol shortages has been to increase the proportion of non-home based trips (e.g. Peskin, Schofer and Stopher, 1975).

Some attempt has therefore been made to allow for variations in journey structure over time in the aggregate models. Havers (1977) describes how this has been achieved in the Greater London Transportation Study Model. Here non-home based trip productions are directly derived from home based trip attractions using sets of empirically derived transition probabilities (stratified by mode and purpose). Although the probabilities are fixed in the present model, it is possible to allow for the effects of a changing mix of modes or trip purposes on the overall structure of journeys.
A number of other approaches have also been developed to model complex travel patterns, and are reviewed in Jones (1978a) and Hanson (1979). They include the use of Markov and semi-Markov models (e.g. Horton and Schuldiner, 1967, Gilbert et al., 1972); the harmonic series model of Vidakovic (1974); the use of a serial queue model (Kobayashi, 1976); and models based on a multinomial logit model formulation, by Adler and Ben Akiva (1979) and Horowitz (1978). None has been yet able to predict the timing, sequence, route, purpose and mode of a complete trip chain, although recent work by Kitamura (1983) is showing useful advances in this direction.

Models Based on Travel Budgets (6)

A number of writers have reported an apparent constancy and stability in average daily travel time budgets between areas and over time. Zahavi (1974) compared travel patterns in Washington D.C. over a 13 year period and found this constancy, despite a considerable increase in trip lengths and average speed brought about by extensive motorway building. At a more micro level, Tomlinson et al., (1971) found that students at two English universities seemed to spend the same amount of time travelling each day, regardless of location: those living far from college would make fewer trips than those living closer by, which compensated for the longer duration per trip for the former. There also seems to be some evidence that there are constant travel cost budgets, which are similar between countries and remain unaffected by sharp changes in operating costs (e.g. Mogridge, 1977).

Recent studies have thrown some doubt on the notion of a strict budget constraint (e.g. Landrock, 1981), although most writers accept that there is some form of restraint operating on the allocation of time and money to travel. It may be that the relationship is more complex than previously was thought. Zahavi, (1982), for example, compared
results from Baltimore, Washington, London and Reading and found that the daily travel time per traveller is a function of door-to-door speed and other related factors, for a given socio-economic group.

If there is some constancy in behaviour, then it seems reasonable to suppose that model forecasts would be improved by building in this factor as a constraint. Goodwin (1981), for example, discusses how a travel budget could be incorporated into the generation, distribution and mode choice components of the conventional trip model, and Poeck and Zumkeller (1978) describe a travel simulation model which predicts how travel patterns would be modified if petrol were increased sharply in price – assuming aggregate travel time and cost expenditure levels were maintained. Models of this form automatically deal with complete daily travel patterns, and so take account of interdependencies between trip purposes. Zahavi (1979) has gone further, and used the apparent regularities of travel budget expenditures to develop a Unified Model of Travel (UMOT), which interrelates travel demand, transportation supply and urban form. The basis in economic utility theory of such an approach is discussed by Golob et al., (1981).

Attitudinal Studies (7)

The seventies also saw a rapid growth in interest in the subjective aspects of travel decision making, as it became apparent that time and cost differences alone could not fully explain mode choice decisions. In addition, a desire to market public transport services gave rise to an interest in the impact of advertising and the potential importance of factors such as improved comfort, reliability and safety (Hovell et al., 1975). The tradition of marketing has also become well established in retailing and has had a strong influence on recent attempts to model destination choice (see, for example, the review in Jones, 1978b).
A very wide range of so-called attitude research has been carried out, from broad surveys to elicit general opinions about transport problems, to detailed studies of travellers' perceptions and evaluations of attributes of modes. Comprehensive reviews of the application of attitudinal techniques in transport research may be found in McFadgen (1975), Spear (1976), Thomas (1976), Levin (1979), Louviere et al. (1979) and Dix (1981). Only a few general aspects are mentioned here.

One major interest has been in trying to predict travel behaviour from a knowledge of 'attitudes'. As in other areas of application of this type of work (McFadgen, 1974) results have not been very encouraging; Hartgen and Keck (1974), for example, found that respondents' estimates of likely usage of a new dial-a-ride system were approximately double actual ridership levels. Attempts have been made to improve on this in two ways: by incorporating situational variables, and by measuring attitudes and objects more precisely.

Hartgen (1974) calibrated a number of logit mode choice models which included attitudinal and situational variables, and found that the former contributed only 10-20 per cent of the explanation in his models. Brög and Schwerdtfeger (1977) reached a similar conclusion in a German study of mode choice for the work journey, in which they found that only 14 per cent of bus users and 8 per cent of car users had a real choice of mode. It is not surprising, therefore, that attitudinal studies which ignore situational factors exhibit only a loose association between elicited attitudes and behaviour. Uncertainties also arise in the measurement of attitudes (which can be elicited at a number of levels, in several different contexts, and combined in a number of different ways), and in establishing a relationship between 'objective' and 'perceived' attribute levels (e.g. Ewing, 1973, Hensher, 1977).
Despite these difficulties, there have been several attempts to develop attitudinal models, using linear preference scales, weighted by the reported importance of each attribute. Golob and Recker (1977) propose a general methodology using factor analytic and logit modelling techniques, which involves: the identification of situational factors, the collection of attitudinal data and its reduction to identify the 'latent psychological dimensions of the attribute space', the selection of proxim physical attributes, and the modelling of the choice process. Other attitudinally-based analysis and modelling procedures have also been applied. Thomas (1976) has used Fishbein's Expectancy-Value model to look at mode choice decisions, and Sheldon and Steer (1982) discuss the application of conjoint analysis to transport problems.

Attitudinal research has also identified other processes which affect travel decision-making. Golob et al. (1979) were able to substantiate aspects of 'Cognitive Dissonance' theory in a study of the attitudes of bus and car users to their own and the competing mode; they found, for example, that an individual with a choice of mode will upgrade his evaluation of the chosen mode and downgrade his evaluation of the choice alternative more than a person who is captive to the mode he is using, in order to justify his actions.

Other writers have examined the effects of habit on behaviour; once behaviour becomes routinised it is unlikely to be modified until changing conditions reach a threshold point (Hensher, 1975; Banister, 1978). As a consequence of habit and threshold effects, decisions such as mode choice become asymmetrical (Goodwin, 1977). New types of model based on Catastrophe Theory are being developed to handle this type of response (e.g. Blase, 1979).
Simplified Models (8)

One response to the rather cumbersome form of the conventional trip model has been to develop simplified models for less detailed applications — either for use in the smaller urban areas that do not warrant a full scale model system, or to give quick forecasts of the broad effects of alternative policies in larger urban areas. General reviews of simplified models are available in O.E.C.D. (1974) and Grecco et al., (1976).

Simplification may be achieved in a number of ways; in particular, through:

(a) Partial modelling: either restricting attention to a particular travel decision, or concentrating on a limited area of a city and using sector or corridor models (e.g. Landau and Fedorowicz, 1980).

(b) Coarser modelling: reducing the detail with which travel behaviour is modelled (e.g. fewer variables, coarser zones, simplified relationships). The CRISTAL suite provides an example of a simplified urban transport planning model (Tanner et al., 1973), which uses a geometric representation of a transport network.

(c) Alternative modelling techniques: models may be developed using simpler techniques, such as regression analysis (e.g. Lewis, 1977), usually to deal with specific problems. Models based on the use of elasticities have also grown in importance in passenger demand research (Mullen, 1975) and have been used to test a wide range of transport policies (Wallis, 1977).

Such models have the advantage of being quick and cheap to operate, both because of their computational speed and their more limited data
requirements. However, they are largely pragmatic tools and are not usually capable of dealing with more complex forms of adaption to change.

Cheaper Data Collection Procedures

The large-scale household surveys which formed an integral element of the urban transportation studies of the sixties were both very expensive and time consuming (when account was also taken of coding and processing), and efforts were soon made to reduce the level of resources needed. The development of the category analysis method of trip generation (Wootton and Pick, 1967), for example, enabled the consultants to transfer trip rates between study areas and so use much smaller sample sizes; one firm claimed that a sample of 1,000 households would be sufficient to enable the standard trip rates to be applied.

Resource cutbacks have made it much more difficult to obtain substantial funds for household surveys and, in addition to cutting sample sizes, other forms of saving and efficiency have been sought. Examples include the more general pre-coding of responses (thereby avoiding the coding stage, and in some cases enabling responses to be machine read), the use of postcode information to speed up destination coding (Neffendorf et al., 1981) and the more extensive use of mailback rather than interviewer-administered household questionnaires. There have also been recent experiments involving the use of micro computers as a data collection technique (e.g. Bartram and Eastaugh, 1981).

Despite these recent cost savings, it is not possible to carry out frequent household surveys, and so other methods of updating information on passenger and vehicle flows are being developed. Tyson et al., (1981) describe a system based on the continuous sampling of passenger
journeys, using on-board surveys, developed for the Greater Manchester P.T.E.; and several writers have developed methods to update O-D traffic matrices using selected traffic flow or licence plate data (e.g. Willumsen, 1982; Geva and Hauer, 1982).

Incorporating Error and Uncertainty (10)

One of the criticisms of the urban transportation studies was that they made no attempt to assess the error and uncertainty attached to the predictions that were made; this criticism has been repeated in the inter-urban context more recently by the Leitch Committee, in connection with car ownership and traffic forecasts (Committee on Trunk Road Assessment, 1978).*

Most stages of the transportation study process have been closely scrutinised in recent years, in order to assess the errors and uncertainties inherent in the procedures used; this has extended from data collection (e.g. Wermuth, 1981), through to project evaluation (Gilbert and Jessop, 1978). Talvitie and Dehghani (1979) for example, show the catastrophic effects which poor network coding can have on model forecasts. The individual choice model used in the Bay Area Rapid Transit (BART) study predicted a 13 per cent mode share for BART, against a subsequent observed share of only 6 per cent; the authors found that if actual level of service values were substituted in the model for the network derived ones, then the forecast mode share fell from 13 per cent to 5 per cent.

Several studies have also been undertaken into the error and uncertainties within the forecasting models themselves. Horowitz (1981), for example, investigated individual choice random utility models and concluded (p. 543) that:

*In this context, see the work of Ashley (1981).
The numerical results indicate that zonal averaging of explanatory variables, omission of relevant explanatory variables, and random parameter variations in models that have fixed-parameter specifications can cause forecasting errors that are capable of destroying the usefulness of a model.

In a more wide-ranging study, Williams and Ortuzar (1979) examined the problems of forecasting traveller response using aggregate and disaggregate models calibrated on cross-sectional data. They simulated the responses of a synthetic population under different behavioural assumptions, using Monte Carlo procedures and compared the results with the predictions of models calibrated on the base data. They found that competing models of behaviour could be derived which produced an acceptable statistical fit on cross-sectional data, and yet which differed significantly in their decision structures. The authors concluded that (p. 256): 'From the point of view of predicting response, it is not sufficient simply to know that a good fit to base data has been obtained'. Problems arising from biases in the selection of choice sets were seen as particularly troublesome.

3.5 Summary and Assessment

Transportation planning methodology has developed very considerably since the early fifties, both in terms of the scope of its coverage and the variety of methods available. Developments in the sixties were largely associated with the establishment of a formal urban transportation planning process; many of the methods now widely used were first introduced in this period, when a number of basic decisions were also made about the breadth and context of the planning process, and the way in which travel behaviour is measured and analysed (see Chapter 4). The early seventies saw major changes in transport policy, requiring a more detailed understanding of traveller response to policy
measures. As a consequence there was a rapid growth in methodological innovation and development, designed to address these new issues and resolve a number of problems identified with the methods used in the sixties. The transport planner of the eighties thus has a very wide range of methods at his disposal, to deal with a number of issues at varying levels of detail.

The areas of recent work briefly outlined in section 3.4 have helped to improve the theoretical and behavioural basis of transport planning methodology in a number of related ways. The research into both car availability and travel time budgets, for example, has helped to identify a number of interdependencies between trips and among household members; and the theoretical underpinnings now associated with travel demand models, coupled with work on error and uncertainty and the better definition of choice sets, has resulted in forecasting models that are more reliable, and whose performance characteristics are much better understood than hitherto.

Not all of the new areas of development in the seventies have proved successful, however, or have yet been widely adopted in practice. The simultaneous, economic demand models, for example, encountered considerable calibration problems (associated with multicollinearity among variables and high residual errors), and some versions produced implausible forecasts; although this form of model is still widely used in econometric studies it has not become well established in transportation planning practice. Similarly, the work on travel budgets has strong theoretical appeal and can lead to a number of useful predictive tools; however, there is considerable debate as to whether time and cost allocation to travel is more stable than trip rates, and so this area of work is still at an experimental stage of development. The areas which saw most practical application in the seventies were the individual choice models and the attitudinal studies; these are
briefly considered further below.

Application of Individual Choice Models

Individual choice modelling represented the most significant development in the seventies, in terms of the resources devoted to research and applications. The proponents of these models regarded them — at least initially — as a 'second generation' approach (Manheim, 1976) which offered an alternative to the 'first generation' aggregate models of the sixties that was 'behaviourally' based and able to resolve a number of the problems associated with the aggregate models at that time. Apart from the specific applications listed by Spear (see section 3.4), there were also attempts to develop complete disaggregate model systems, in California, Holland and elsewhere.

Figure 3.4 shows the structure of the model system developed for the San Francisco Metropolitan Transportation Commission. Here a basic distinction is made between work and non-work travel, and separate forecasting models are developed for car ownership, trip frequency, destination and mode choice, route choice and time of day (i.e. peak/off-peak); there is also a separate sub-model for non-home based trips. In addition to taking account of car availability, the system incorporates recursive linkages between destination choice, mode choice and car ownership, in order to allow for the influence of the level of public transport service on car ownership decisions. Aggregation* is achieved in this type of study through population grouping (by type and area), or sample enumeration procedures, in which model predictions are made for a random sample of individuals and the results grossed up to the total population (see description in Daly, 1982).

*A general discussion of the merits of different aggregation techniques may be found in Koppelman (1976).
Figure 3.4
Structure of a Disaggregate Travel Demand Model System

(Source: Ruiter and Ben-Akive, 1977; developed from the San Francisco Metropolitan Transportation Commission)
The early view expressed by proponents of disaggregate models that they would replace the aggregate versions is no longer widely held. There have been substantial calibration and interfacing problems in studies such as the one illustrated in Figure 3.4 that have attempted to use disaggregate models in a large-scale, traditionally aggregate context. At the same time aggregate models have been improved considerably through the developments described in section 3.4 (such as better choice set definition), and Wilson (1977) has argued that if these improvements were fully incorporated into operational planning models most of the problems associated with the models of the sixties would be overcome.

In many respects the distinctions between the 'first' and 'second' generation models are becoming blurred. At a practical level, for example, Ben Akiva et al. (1978) have argued that 'disaggregate models can be integrated into a working aggregate model system that resembles the conventional systems with which planners are familiar.' And theoretically, too, Williams (1977) has shown that it is possible — and essential — to develop macro models which derive from a realistic representation of decision making at the micro level; hence there is now little reason to regard disaggregate models as being more behaviourally valid than their aggregate counterparts.

The clearest remaining distinction between the two types of model is in the level of data analysis. The proponents of individual choice models point to the need for smaller data sets for estimation because it is possible to make more efficient use of the variation in the data, and the fact that public transport access times can be incorporated more readily at the individual level. In other respects the differences are now much less substantive.

The individual choice models are not, therefore, a direct substitute for the aggregate models — rather, each has a distinct role to play.
They are, however, more suited to handling some of the detailed policy issues which arose in the seventies, such as the Transport System Management (TSM) schemes that are usually short-term, low capital options, affecting only small areas of a city, or specific groups of people (e.g. car parking incentives, see Ben Akiva and Atherton, 1977). Conversely, the aggregate models are suited to longer term, area-wide strategic modelling — especially when it is important to take explicit account of the equilibrium between demand and supply (Wilson 1979).

Application of Attitudinal Methods

The attitudinal studies introduced a new dimension into transportation research and planning in the seventies, drawing heavily on studies in psychology, marketing and sociology. This area of work has led to a greater understanding of the travel decision making process, and the complexities that can arise through the operation of cognitive dissonance and habit and threshold effects. Much of this work has been linked with and incorporated into individual choice models, where it is much easier to take account of, for example, differences in perceived travel times, than in aggregate models.

Several writers have incorporated attitudinal variables in the utility functions of individual choice models, especially mode choice; early examples include Spear (1974), who included a measure of convenience and Nicolaidis (1975) who incorporated a comfort variable.* And Hansen and Rogers (1979) have suggested that attitudinal research could provide a means of calibrating models outside the range of current experience, by using information on potential rather than actual decisions.

A number of problems are becoming apparent, however, as attempts

*For other examples see Spear (1976).
are made to link together objective and subjective structures. Kostyniuk (1975), for example, found differences between reported and implied ratings in her logit models of shopping destination choice, and Levin (1979) and Louviere (1978) found that attitude components appear to be related to one another in non-linear ways.

In general, there is a growing awareness that attitudes are very complex phenomena, and difficult to analyse quantitatively. As a consequence there has been a growing interest in more qualitative research techniques (see Dix 1981), using group interviews and other loosely structured techniques which allow respondents to use their own frames of reference. Examples of the findings from this type of work are cited in later chapters.

3.6 Conclusion

These new developments in the seventies, coupled with a number of improvements to well-established procedures that have not been reviewed here, such as the sophisticated assignment capabilities of the SATURN model (Hall et al., 1980), have provided the transportation planner and traffic engineer with a whole armoury of different methods to deal with a very wide range of problems. The transport 'problem' of the sixties has been replaced by the problems of the seventies. As Hutchinson (1974, pp. 28-9) observed: 'Urban transport planners now recognise that there is not a unique urban transport problem, but a set of sub problems of different scales and scopes'. Each places different requirements on the travel demand forecasting and other processes.

There is thus no longer a single transportation planning methodology for all purposes (as the literature of the sixties often implied), but rather it is a case of 'horses for courses', with new developments leading in the main to complimentary rather than substitute approaches,
and some of the older procedures finding new applications. The three-stage travel demand model used in the early transportation studies (Figure 3.2), for example, has been superceded as a comprehensive planning tool in large urban areas by a four-stage process incorporating mode choice (Figure 3.4), but it has recently formed the basis of a U.K. National Traffic Model designed as a tool for evaluating large road building schemes (see for example, Outram 1982).

Despite these various methodological developments, however, there are a number of areas where further work is needed. Transport planning issues have continued to evolve since the early seventies (see Chapter 2) and not all the methodological problems identified at that time have been resolved satisfactorily, while others have since come to light. In the next chapter we identify a number of these outstanding issues and unresolved methodological problems and propose a new approach to deal with them.
4. THE CASE FOR A NEW APPROACH

4.1 Some Unresolved Problems and Issues

Although the developments in urban transportation study techniques since the war have been impressive, with regard to improvements in both the capability and range of the methods available, there are inevitably a number of gaps and shortfalls. Several were identified in Chapters 2 and 3, caused both by shifts in policy (e.g. sudden interest in issues relating to public transport) and weaknesses in methods that have become apparent in use (e.g. problems in forecasting aspects of behavioural response). The major change in policy perspective in the early seventies (described in section 2.3), coupled with growing evidence of limitations in the transportation planning procedures then used, led to a flurry of methodological developments during the seventies. In this section we examine some problems that have not been resolved by this work, and consider some of the policy issues that have arisen in the last few years (reviewed in section 2.4) and have placed new demands on methodology which have not as yet been met.

Unresolved Methodological Problems

A number of methodological problems were identified with the transportation planning procedures of the early seventies, and at least ten avenues of work were begun in an attempt to overcome them (see section 3.4). Some of these developments, such as the incorporation of error and uncertainty into planning procedures or the use of simplified models, have largely been successful. In other areas only partial success has been achieved: notably with choice set definition, where the work on car availability has greatly improved the definition of mode choice sets but there are still basic problems in defining
destination choice sets. And, in a few cases, very little progress has been made (particularly in the modelling of complex travel patterns), or else the area of work has proved to be largely unfruitful (e.g. economic demand models).

In addition, there are some issues that were raised in the early seventies which have hardly received any attention at all. In relation to peak spreading policies, for example, Table 3.1 identified five types of policy to which the models of the early seventies were rated as having a low level of responsiveness:

(i) staggered and flexible work hours  
(ii) shortened work week  
(iii) communications in lieu of travel  
(iv) marketing  
(v) vehicle design features.

Significant progress has been made in the last two areas (iv and v) through the use of attitudinal techniques, and communications in lieu of travel (iii) has been the subject of several studies by the telecommunications and data processing industries. But very little attention has been paid to the first two areas which relate to the duration and timing of work, and which cannot be examined fully using existing methodologies.

Many of the developments during the seventies, such as individual choice modelling, improved (mode) choice set definition and the various attitudinal studies, were part of a more general concern to better understand the decision processes of travellers. This was related to the growing policy emphasis on restraining and managing travel demand rather than simply planning to maintain existing service levels. It soon became apparent, from a number of monitoring studies, that household response to policy measures could be extremely complex, and would
not necessarily lead to the anticipated effects.

Heggie (1978), for example, demonstrates the extreme adaptability of households when faced with some restriction on their behaviour. In a study of the impacts of car restraint in Oxford he identified at least twelve different forms of adaptation, ranging from changes in mode and destination, to the restructuring of travel patterns, the consolidation of journeys, the re-assignment of tasks within or between households, and the substitution of non-travel generating for travel-inducing activities. This work shows clearly some of the relationships between travel and other aspects of daily life and the important inter-dependencies in household behaviour, both between individuals (inter-personal linkages) and among elements of the travel pattern (space-time linkages).

The work on car availability and the development of models based on travel time budgets have enabled some account to be taken of inter-dependencies between people and events, respectively, but there is still much that cannot be handled adequately using existing methodology. If the time taken to travel to work is increased, for example, the travel time budget approach provides guidance as to which other types of travel might be reduced in duration to compensate. But if the timing of the work journey is altered, or work hours reduced, it is not possible to anticipate how travel behaviour will be modified (except by looking at people already in this position). More extreme problems remain in areas such as shopping travel, where the methods developed during the seventies are unable to deal with the impacts on travel of changes in shopping hours, or with technological developments which affect the shopping activity itself, such as freezer ownership or shopping using home computers. Such problems require a better understanding of the significance of the timing of travel, and of the
relationships between travel and non-travel activities.

From a methodological point of view, therefore, there still remain a number of areas requiring further work, that have not been resolved fully by developments over the last decade. These include:

(a) the modelling of complex travel patterns
(b) the definition of choice sets (especially for non-mode choices)
(c) the handling of issues relating to the timing of travel
(d) linkages between travel events and between the behaviour of household members
(e) the analysis and modelling of secondary policy impacts
(f) relationships between travel and other aspects of daily life.

Recent Policy Issues

In addition to the policy concerns of the early seventies (i.e. to influence travel behaviour and plan for a 'balance' between private and public transport), which led to the methodological developments and problems discussed above, there have been a number of more recent policy interests that have placed new demands on the methods used.

Section 2.4 listed a number of short and longer term policy issues that have arisen during the latter part of the seventies. Short term issues now include a much greater concern with public transport service provision, the restraint of vehicle traffic, and the social impact of transport policies on people's lives. Questions that now arise in assessing the provision of subsidy or a car restraint policy include:

- what social value is derived from trips that are subsidised?
- how do we define travel need, as a criterion for service
provision?

does it matter if some trips are suppressed altogether by restraint measures?

Although these questions involve political judgement, they require data to inform such decisions which is not provided by the operational, economic and environmental assessment procedures now in use. There is thus a need for an additional, social assessment procedure that can take direct account of the impact of transport policy on life styles and social conditions.

There are a number of examples of a growing interest in the impacts of transport policy on daily life. Section 2.4 referred to the formal objectives of U.S. urban transportation planning, one of which requires authorities to assess the impacts of proposed measures on neighbourhoods and life styles in affected areas. In the U.K., the recent concern with labour relations in transport supply industries (e.g. the introduction of flexible rostering on British Rail) reflects another aspect of this problem, which has arisen in part because of labour force worries over the impact of changing shift patterns and unsocial hours on their family life. Such wider issues are also becoming apparent in a research context. Gurin (1976), for example, examines a very wide range of strategies for reducing teenage travel which extend well beyond the scope of any of the approaches on which transportation planning methodologies are now based; these strategies include attempts to reduce psychological stresses through the use of counselling services or improving home design.

The medium and longer term policy issues listed in section 2.4 also indicate a general concern with transport in the context of social and economic life. They deal with the effects of factors such as energy and other material shortages, changes in patterns of urbanisation, new
technological developments, and increases in the amount of leisure
time. Although the methods used for long-term forecasting often
differ from those used to examine more immediate problems, the basic
areas of concern are similar.

Summary and Assessment

The basic change in transport policy perspective in the early
seventies (from a supply-expansion to a demand-restraint approach),
together with the identification of important methodological deficien-
cies in the transportation modelling procedures of the sixties, led
to a rapid growth of transport research in a number of related areas.
As a consequence, some of the problems have largely been resolved
(e.g. development of simplified modelling procedures), while others —
especially those dealing with the complexities of household travel
(e.g. choice set definition, or journey structure) — have not proved
amenable to analysis using existing approaches.

Policy issues that have arisen during the seventies have tended
to highlight the need to resolve these outstanding methodological
problems. The interest in public transport service provision, for
example, puts a much greater emphasis on analysing the timing of
travel — particularly when tackling questions of minimum service
provision. Similarly, many of the newer policy issues relate, in one
way or another, to the associations between travel and other aspects
of daily life.

One aspect which does make additional, though related, methodol-
ogical demands, is the requirement for a procedure to evaluate trans-
port policies in social terms, to compliment the operational, economic
and environmental procedures now in use. This suggests there is a
need to develop an approach to studying travel that contains elements
providing social measures of change — and again emphasises the importance of an improved understanding of linkages between people and events, and the secondary impacts of transport policy. Although the development of a new evaluation framework is beyond the scope of this study, we can add to the six methodological requirements (a-f) listed earlier in this section, a seventh: the need for social measures of impact.

Most of the unresolved methodological problems identified in this thesis can be viewed as lying at the 'fringe' of conventional transportation planning, in that they require either a more detailed understanding and analysis of travel than is now customary (e.g. to include detailed questions of trip timing, or linkages between trips) or that travel be analysed in a broader context, than hitherto.

It is argued here that the difficulties of resolution are due primarily to conceptual rather than technical limitations in the way in which travel is analysed. Hence resolving these problems and meeting current policy requirements will require yet another approach to be added to the armoury of concepts and techniques now available to the transportation planner.

Before formally setting out the requirements of a new approach, the next section looks more closely at the conceptual basis of many of the existing methods of studying travel, to see how this affects the way in which travel behaviour has been measured and analysed.

4.2 The Definition and Measurement of Travel

Much of the present transportation planning methodology is based on a set of common assumptions and presumptions (some of which are implicit) about the nature of travel, and the way in which it should be measured and analysed. This is true, for example, of most aggregate and dis-aggregate models which, despite their differences, define
and measure travel in a very similar way. Indeed, this representation of travel has become so well established that Wells (1975) felt able to state with confidence that: 'the general approach and the basic principles are unlikely to change.'

Despite the many developments in urban transportation planning methodology since the fifties, the basic means of representing travel has changed very little. For the purpose of measurement and analysis, travel is recorded in units of 'trips', defined by the U.S. Bureau of Public Roads (1954, p. 39) as:

> . . . the one-way travel from one point to another for a particular purpose.

A more recent British transportation study used a very similar definition (Freeman Fox and Associates, 1976, p. 374):

> A one-way movement from one place to another for a particular purpose.

The only significant change has been the recognition of person trips, in addition to the early emphasis on vehicle trips (see section 3.2).

In a historical review of Japanese urban transportation planning, Niitani (1976, p. 5) sees the invention of the trip as a necessary precondition to the modern analytical studies:

> Previously no quantitative concept corresponding precisely to the movement of people and vehicles existed, yet with (the) introduction of the concept of trips, quantitative analysis of transportation within entire urban areas became possible.

However, while the concept of the trip has made it possible to analyse travel, it has also placed limitations on the way in which that analysis can be performed, as is shown below (see also section 7.2).

Three aspects are considered in this section:

(a) The effects of the way in which travel is represented (i.e. as it is recorded, coded and analysed).
(b) Practical problems associated with the definition of travel.
(c) The context in which travel is analysed.

**Representation of Travel Behaviour**

Figure 4.1 illustrates the way in which a very simple household travel pattern is represented in most travel demand models, whether aggregate or disaggregate. The household comprises a retired couple, who make one journey together, to visit a friend (Figure 4.1a).

The first simplification of these events occurs in the form in which they are usually recorded in the trip diary (Figure 4.1b). The sequence of events is broken, and the travel information is abstracted and recorded in the trip format shown; information about the visit is only recorded indirectly via the trip purpose classification.

A second transformation, from diary record to model input, involves a more drastic modification of the data (Figure 4.1c); two operations occur simultaneously:

1. **Generalisation** of the unit of analysis. This involves varying degrees of aggregation; time of day is usually aggregated to two groups, while travel mode is reduced to 3-6 categories and travel duration is used at the level at which it is recorded.**

2. **Division** of trip characteristics into inputs suitable for calibration of the choice submodels. Different aspects are incorporated in each submodel. In particular,

---

*The representation is different in most models of complex travel patterns (see Jones, 1978a).

**In many studies, however, travel times have been derived synthetically from network data.
(a) **Actual Situation:**
Household comprises husband and wife, both retired and without a car. On the survey day they only make one journey each: they go out together at 2 pm on foot to visit a friend living at 21 York Road. They arrive at 2.20 pm, stay for a chat and some tea and walk home at 5.30 pm, reaching home at 5.50 pm.

(b) **Trip Diary Record:**

<table>
<thead>
<tr>
<th>Person</th>
<th>Start Time</th>
<th>Origin</th>
<th>Mode</th>
<th>Destination</th>
<th>Finish Time</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Husband)</td>
<td>2pm</td>
<td>Home</td>
<td>Walk</td>
<td>21 York Rd.</td>
<td>2.20pm</td>
<td>Social</td>
</tr>
<tr>
<td>1 (Husband)</td>
<td>5.30pm</td>
<td>21 York Rd.</td>
<td>Walk</td>
<td>Home</td>
<td>5.50pm</td>
<td>Return</td>
</tr>
<tr>
<td>2 (Wife)</td>
<td>2pm</td>
<td>Home</td>
<td>Walk</td>
<td>21 York Rd.</td>
<td>2.20pm</td>
<td>Social</td>
</tr>
<tr>
<td>2 (Wife)</td>
<td>5.30pm</td>
<td>21 York Rd.</td>
<td>Walk</td>
<td>Home</td>
<td>5.50pm</td>
<td>Return</td>
</tr>
</tbody>
</table>

(c) **Model Representation:**

(1) **Aggregation:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Trip Diary Record</th>
<th>Model Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traveller</td>
<td>Specific Person</td>
<td>Unspecified member of a household type</td>
</tr>
<tr>
<td>Trip Purpose</td>
<td>Social Visit</td>
<td>Social/Recreational</td>
</tr>
<tr>
<td>Location</td>
<td>Actual Address</td>
<td>Zone*</td>
</tr>
<tr>
<td>Mode</td>
<td>Walk</td>
<td>Walk</td>
</tr>
<tr>
<td>Time of Day</td>
<td>Actual Time</td>
<td>Actual travel duration; Peak/Off-Peak timing</td>
</tr>
</tbody>
</table>

(2) **Division into Submodels:**

Example: Peak Period Journeys

```
0 ————> D

Trip Production: 2 home-based trips (soc/rec; no car)
Trip Distribution: 2 trips, 20 min, Zone 0 - Zone D (soc/rec)
Trip Attraction: 2 trips (soc/rec)
```

*Locations may not be aggregated into zones in individual choice models, but the other conventions usually apply.*
trip generation excludes information on the duration or
spatial linkage of the trip; while trip distribution
incorporates a much coarser household classification
and transforms data on the direction of travel (by link-
ing productions and attractions, rather than origins and
destinations).

Because of the loss of information resulting from this translation
from events to model inputs, there is not a one-to-one correspondence
between behaviour and model representation. As a consequence,
behaviour patterns with different characteristics and varying respons-
siveness to transport or land use policies may not be distinguishable
during analysis.

In Figure 4.1, for example, the behaviour is represented in a
trip model as four home-based trip productions (two peak, two off-
peak) and four trip attractions (two peak and two off-peak) for
social/recreational purposes, made on foot between two zones by members
of a given household. There are many other patterns of behaviour,
with different timing constraints and arrangements between people in
a household that would be recorded in a similar way. For example:

(a) The couple travel together, but to a club (open once a week)
rather than to their friend's house (which they can visit at
any time).

(b) The couple visit their friend together, but at a different
time of day than that recorded in the diary (e.g. leave home
at 5 pm, return home at 10 pm).

(c) The couple travel to different destinations within the zone,
at the same time or at different times of day.

(d) Only one person makes the trips, going out twice on the
survey day to visit a friend.
(e) Only one person travels from home: in the morning they go for a walk and in the late afternoon visit a club to play bingo.

The model representation has lost information on the travel linkages between the couple, and the pattern of events in time — even though we were only considering one household. Once a number of travel patterns have been divided and categorised according to these conventions and the components aggregated, only the broadest generalisations about the observed travel behaviour of the population are possible. This makes it virtually impossible to forecast people's responses to policy measures when the processes of activity pattern adaptation described in Chapter 6 result in major changes in behaviour, because the model representation does not incorporate sufficient information about linkages between people or events in space and time.

The problems of representation, and the scope for misinterpretation, increase considerably when more complex patterns of daily travel are examined within a trip framework. Figure 4.2 provides two examples of the problems that may arise when analysing multi-trip journeys.

In Figure 4.2a the frequently encountered sequence: work — shop — home is translated by the trip model into a home-based shopping trip and a non home-based trip, both made during the evening peak. The shopping centre visited en route from work to home may be the only one that the traveller can reach at that time of day (i.e. in the time available between finishing work and shop closing time); yet it may be a relatively unattractive facility that would never be chosen as the destination of a shopping trip from home. However, its characterisation as the destination of a home-based shopping trip implies the opposite — that it is the most attractive of the local centres! This leads to a mis-specification of the destination choice decision because
Figure 4.2
Problems Associated with Complex Travel Patterns

(a) **Ambiguous Representation**

Actual Pattern

Model Representation

(b) **Response to Changes in Land Use Pattern**

(1) Before

Actual Pattern

Model Representation

(2) After *(when new shopping centre has opened)*

Actual Pattern

Model Representation
other centres will be included in the modelled choice set.*

In forecasting future travel patterns it is often assumed that the ratio of home-based to non-home-based trips will remain constant; yet changes in land use patterns can have a marked effect on the structure of travel and the number of trips that are made. In Figure 4.2b, for example, a person makes a three-trip journey: from home to the shops, then visits a friend and finally returns home. Over time a new shopping centre might be built nearer the traveller’s home (but in a different direction from home). This might be much more attractive than the old shops, and so it would now make more sense for the person to make separate journeys to go shopping and visit her friend. The same objectives are served by the new travel pattern, and no extra time or distance may be involved - but the number of trips will have increased from three to four, and the ratio of home to non-home based trips will also have increased. Land use policies which encourage the location of shopping centres close to major industrial estates, for example, might thus have a serious impact on the aggregate pattern of travel, which could not be adequately reflected in the trip model forecasts.

It is obviously essential that some form of categorisation and aggregation be employed when analysing travel behaviour, but there would in some cases be advantages in adopting a representation of travel which did not have the limitations of the trip-based approaches.

**Definitional Problems**

The preceding discussion has examined a number of problems associated with the representation of travel at a conceptual level. When

---

*The two trip attractions at the shopping centre might also in some circumstances imply that two visits were made there, not one.*
travel is measured and analysed in practice further definitional problems can arise, because of difficulties of interpretation or the need to simplify the measure further on pragmatic grounds. Three examples are considered here.

(1) How short a movement may be considered as a trip? In most urban transportation studies a trip has been defined as any vehicular movement from an origin to a destination, or a movement on foot of at least five minutes or quarter mile in length. Such a definition could clearly result in part of a travel sequence being omitted entirely, and in whether certain journey structures are recorded as two-trip or multi-trip journeys. One Dutch study which recorded all movements between buildings found that 50-60 per cent of journeys were 'complex'; whereas the 1971 Greater London Transportation Study, which only recorded walk trips associated with the purpose of work reported that 20 per cent of journeys comprised more than two trips (Heggie, 1976).

A further consequence of this definition is that trip rates for some groups of people may be under-represented. Typically, non car-owning households make fewer vehicle trips than car-owning households, but this may at least in part be compensated by a higher number of walking trips that go unrecorded because they are shorter than the quarter mile cut-off. Further, a switch from walk to car, or a general lowering of densities (leading to more walk trips above the threshold level) would apparently result in generated trips whereas in fact they were already being made. The omission of certain types of travel may make it difficult to obtain an accurate picture of some social impacts of transport or land use policy.
(2) Where does one trip end and the next begin? In the case of a change of travel mode, the convention has been modified so that this purpose is now subsumed under one multi-stage trip, which enables alternative ways of accomplishing the same trip to be examined. But there remains the more general question of whether breaking a journey to undertake some minor activity should be treated as an 'incidental' stop (and therefore ignored) or as a 'fundamental' break of journey, and thus the end of one trip and the prelude to the next. To use a simple example, if someone stops to buy a newspaper on the way to work, do we count this as one or two trips? Does it depend on whether he buys it on the street, or in a shop? Does it depend on whether it affects his route or might have generated a journey in its own right? Where do we draw the line? Again, this will affect whether a journey is regarded as two-trip or multi-trip. Hensher (1976) has proposed some operational definitions of fundamental and incidental stops, based on the degree of spatio-temporal detour involved, but there is no generally accepted or wholly appropriate definitional convention.

(3) What constitutes the main trip purpose? Transport surveys normally ask only for information on the main purpose of each trip, on the grounds that this is the primary determinant of the observed travel behaviour (and because it would be more difficult analytically to attach more than one purpose to a trip). This may be misleading, however, since a trip may be undertaken for a combination of purposes, none of which alone would have justified the trip being made. Conversely, supplementary purposes may have produced distinct trips in their own right if they could not have been undertaken in combination.
with the main purpose. Clearly, the care with which trip purposes are recorded will greatly affect the numbers of multi-purpose journeys that are identified. Information on such journeys could be an important factor in determining appropriate land use mixes in an area, and an increase in multi-purpose trips might be one response to rising travel costs or increased traffic restraint.

Contextual Limitations

The majority of travel is not undertaken for its own sake, but is a 'derived demand', reflecting the non-obiquity of resources and the need for social interaction. The trip-based models, however, model the demand for travel itself and do not consider factors affecting changes in the demand for the goods and services consumed at the trip destination (other than indirectly via changes in the input land use data). Relevant factors include the price of products, consumer preferences, disposable incomes, quality or changing product availability and technological developments (e.g. home freezers, video systems). Travel is sensitive to these changes in patterns of consumption, but it is very difficult to incorporate this sensitivity in trip-based models, for reasons discussed here (and in Chapter 7).

Two devices are used in the trip-based models to take account of the characteristics of the underlying consumption patterns:

(i) Measurement of the attractiveness of destinations
(ii) Stratification of travel by trip purpose.

The former helps to account for why people visit one location rather than another of similar type, but does not account for why they wish to visit that type of location at all.

Issues relating to the consumption of final goods and services are
subsumed within the trip generation submodel, using the trip purpose stratification, but this raises an important question about causality. There is assumed to be a direct link \( f_x \) between household characteristics and observed travel behaviour, whereas it is largely an indirect one (via \( f_1 \) and \( f_2 \)):

By concentrating on the proximate relationship \( f_x \) only a partial analysis can be undertaken, since some factors which affect the demand for final goods and services are not considered.

These difficulties could probably be ameliorated to some extent using a trip-based approach, but their resolution really requires more explicit attention to the demand for final goods and services.

By focusing on travel per se, it is also very difficult to examine the role that travel plays in daily life, or the value which people derive from travel (other than on a 'willingness-to-pay' basis), because it is not examined in a broader context. The policy issues listed in section 4.1 are of this form: what benefit do people derive from a subsidised bus journey? Does it matter to society if people make fewer trips? If travel becomes difficult or expensive, are people able to maintain their lifestyle by consolidating trips or relying on other people or delivery services? The observation made by Gakenheimer (1973, p. 87) appears still to be largely true:

Most of the actively pursued issues in transportation planning are matters of effects external to the movement system itself, and, therefore, external also to the methodology.
This largely reflects the way in which travel is represented within the transportation planning methodology.

Conclusion

Most approaches to the study of travel have used the trip in some form or another as the basic unit of analysis. While helping to facilitate the rigorous analysis of travel behaviour, this concept has placed limits on the way in which and the extent to which this can be done. Methodologically, it has been difficult to examine complete patterns of individuals' travel, to identify linkages between people, define choice sets or relate the travel and non-travel aspects of behaviour; and in policy terms it is difficult to handle issues relating to travel need, social impacts, substitution effects, etc.

A new approach is needed to deal with these problems and issues. As Hart (1976, p. x) has observed, in his review of the problems associated with the evolution of transportation planning in London:

... planning, although concerned with ordering change, must also continuously incorporate changing concepts of order, because of the changing nature of the urban environment and the changing means of control available for actually implementing solutions.

The next section examines some of the requirements of a new approach embodying 'changing concepts of order'.

4.3 Some Requirements of a New Approach

Although different writers might vary in their list of requirements and priorities, one of the main features that emerges from the preceding review is the need for a better understanding of travel behaviour, in terms both of depth and breadth of subject matter. The seven areas of methodological difficulty identified in section 4.1 all
reflect this emphasis; they comprised:

- modelling of complex travel patterns
- definition of choice sets
- timing of travel
- linkages between trips and between people
- secondary impacts
- relationships between travel and other aspects of daily life
- incorporation of social measures of impact

Section 4.2 examined some ways in which the use of the trip as the basic unit constrains the analyst's ability to deal with these problems, suggesting that some other basis for study be used.

It is proposed, therefore, that these issues be tackled using a different approach. Arising from the unresolved methodological problems and recent policy issues, we can now identify a number of requirements of this new approach:*

1. Travel should be treated explicitly as a derived demand.
2. Travel should be analysed as a pattern, not as a series of independent events.
3. The timing of travel should be a basic feature of the approach.
4. The approach should be capable of handling linkages between people and between trips.
5. It should be possible to examine the interdependencies between travel and non-travel aspects of behaviour.

*This list does not purport to be a catalogue of all the present requirements for new transportation planning methodologies. Rather it contains a number of items which together provide a specification for a particular kind of new approach involving the analysis of travel patterns within the wider context of daily behaviour.
(6) The approach should be able to measure the direct and secondary impacts of policies on people's lives.

Before describing the proposed approach in Part Two, detailed examples are given of three features that we will attempt to incorporate into the conceptual framework of the approach:

(i) The examination of travel as a pattern at the household level.

(ii) The incorporation of temporal factors in travel choice.

(iii) Interrelationships between travel and other aspects of consumption.

The reader interested only in the general line of argument may omit the remainder of this section.

Examples of Aspects to be Incorporated

(i) Household Travel as a Pattern. The advantage of viewing travel as a pattern at the household level is illustrated by the following example (Table 4.1) taken from a survey in Banbury, Oxfordshire. It summarises one day's travel for a one car, four person household. Expressed in conventional terms (i.e. 20 home-based and 6 non-home based trips) the household travel arrangements appear quite complex, but when examined as part of a daily pattern of events they begin to take on a simpler appearance.

The household comprises a husband (H), wife (W) and two daughters, C₁ aged 8 and C₂ aged 3. The following factors play an important part in shaping their travel pattern:

(a) The husband has a daily work journey and is able (and wishes) to return home for lunch.

(b) The elder daughter has to attend school and the parents wish her to be accompanied on her journey.

(c) The wife has the responsibility of looking after the younger daughter all day and thus C₂ has to accompany her mother on all journeys - unless being looked after by a responsible adult.

(d) The younger child goes to play school; this is considered
Table 4.1

Summary of Household Travel

<table>
<thead>
<tr>
<th>Role</th>
<th>Trips</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Husband (H)</td>
<td>9</td>
<td>Home - drop off C₁ - drop off C₂/W - work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Work - pick up W/C₂ - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Work - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - drop off C₁ - home</td>
</tr>
<tr>
<td>Wife (W)</td>
<td>9</td>
<td>Home - drop off C₂ - shop - social - pick up C₂ - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - pick up C₁ - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - pick up C₁ - home</td>
</tr>
<tr>
<td>Elder Child (C₁)</td>
<td>4</td>
<td>Home - school - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - brownies - home</td>
</tr>
<tr>
<td>Younger Child (C₂)</td>
<td>4</td>
<td>Home - playschool - home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Home - pick up C₁ - home</td>
</tr>
<tr>
<td>Trip Summary</td>
<td>26</td>
<td>20 HB Serve passenger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 HB work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 HB school</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 HB social</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 NHB</td>
</tr>
</tbody>
</table>
desirable for the child and 'releases' the wife to get on with her shopping and visit a friend without the burden of child care.

(e) As travel is difficult, the husband attempts to chauffeur his family where possible.

The resulting pattern may be summarised as follows. The husband makes two return trips per day to work (i.e. he comes home for lunch). He is able to adjust his morning departure to drop C_1 at school and W and C_2 at play school — where he picks up his younger daughter on his way home. The wife leaves C_2 at play school and is free to spend the morning shopping and visiting, or as she wishes. The elder child has to be met from school by the mother in the afternoon (as the husband is still working) and the younger child has to go too as she cannot be left. In the evening the elder child goes to Brownies and has to be escorted both ways; this is shared by the husband and wife, while the partner looks after the younger child at home and sets about doing the household chores.

It is evident that this travel pattern can only be understood as a whole, and that this requires information about who is doing what, where, when and why, with what degree of choice. A decision to stop sending the elder daughter (C_1) to Brownies, for example, would save 6HB trips; and the extent to which the husband is able to chauffeur his family is very dependent on his ability to synchronise his timing with that of the other household members.

(ii) Incorporation of Temporal Factors. This example illustrates the importance of considering temporal as well as spatial constraints when examining mode and destination choice sets. It is based on a (hypothetical) couple with two young children, living in a suburban residential area. The husband uses the family car to drive to work and is away from home between 08.00 and 18.00. The young children go to nursery school two mornings a week, between 09.15 and 12.00, which enables the wife to go shopping and obtain the basic convenience goods needed by the household.

There are three shopping destinations from which she may choose (see Figure 4.3):

(A) The local shopping centre, about 15 minutes walk away, where prices are high and several items required for the children are not available (not shown on Figure 4.3).
Figure 4.3: Time-Space Constraints on Choice of Shopping Centre

**KEY:**

- **---** Feasible options
- **--** Infeasible option
- **----------** Scope for extending shopping time
(B) The city centre where the required goods are readily available and prices reasonable; this necessitates a bus journey taking approximately half an hour in each direction (two buses per hour).

(C) A large edge-of-town shopping centre in another suburb of the city, with good selection and cheap prices, which also requires a bus journey lasting half an hour (one bus per hour).

The need to visit the bank, and make a number of shopping purchases means that the wife has to spend at least one hour at her chosen destination.

The wife has a clear preference order for visiting the centres: (C), (B) and (A). In theory she has ample time to complete the shopping before her young children return home (i.e. 2½ hours in which to do a minimum of 1 hour's shopping and up to 1 hour travelling time). Were she to travel by car, she would thus be able to visit centre (C) with time to spare, but her reliance on the local bus service precludes this option. Figure 4.3 illustrates the time-space constraints on her choice, with time represented on the horizontal axis and space (distance from home) on the vertical.

The period the wife is able to set aside for shopping extends from 09.15 to 12.00. It is clear from the diagram that if she visited centre (C) she would not be able to return home until 12.30, which eliminates this option from her choice set. Conversely, the more frequent, half-hourly bus service to the city centre (B) not only enables the wife to visit this centre, but provides a half hour flexibility in her schedule, enabling her to vary her departure time, or spend ½ hours at (B). Practical timing problems, coupled with her dislike of the local centre (A), thus constrain the wife to visit centre (B). Existing travel demand models take no account of such constraints and so would wrongly infer that she preferred centre (B) to centre (C).

(iii) Travel and Other Aspects of Consumption. Very little is known of the relationship between travel and other aspects of consumption, because they have not been the subject of study. They are likely to be extensive and complex, however, as the following example suggests.

During the U.K. oil shortages (and the coal strike and a related cut-back in industrial production) during the winter of 1973/74, road traffic counts taken at five West London sites showed a considerable reduction in car journeys:
Car journeys into London have fallen by about 9 per cent on weekdays since the petrol crisis, but the main reduction has been in weekend trips for social, shopping and pleasure purposes. Surveys by the Greater London Council over a 12 week period from mid-November to early February showed a reduction of 22 per cent on Sundays and 11 per cent on Saturdays.

Planning No. 54, 8/3/74

At the same time, other producers were apparently benefitting from the situation:

'We have noticed a remarkable increase in viewing during the past three weeks' says Cyril Bennett, programme controller of London Weekend Television. 'Figures for London alone are up 10 per cent over last year which means 1½m more viewers; this is doubtless due to petrol and other shortages.'

Sunday Times Business News 16/12/73

The overall impacts of the shortages were clearly much more complex than this; but it is indicative of the potential range of effects which we are entirely ignorant of, because of the way in which monitoring procedures currently focus directly on travel and ignore non-travel aspects of behaviour. The 1973/74 oil 'crisis' prompted a number of studies to investigate travellers' responses to the shortages which, without exception, confined their attention to the impact on travel patterns (e.g. U.S. Department of Transportation 1974; Pisarski and de Terra, 1975).

4.4 Conclusion

The first part of this thesis has sought to demonstrate that in the course of the evolution of urban transportation planning, it has proved necessary to develop a number of additional methodological approaches to deal with new types of policy or problem as they have become apparent, based on different sets of concepts and techniques. Analysts now have several sets of procedures, for different purposes; for example, link-based vehicle flow models for assessing local traffic management measures and person trip based individual choice models for
policies affecting the use of travel modes.

During the seventies considerable research was undertaken in recognition of the need to understand and model behavioural response to change, and several problems were overcome through disaggregation or more attention to the detail of travel choice options and structures. It is argued, however, that there remain a number of methodological problems and policy needs which could best be met by adding another level to the analysts' armoury — this time by broadening as well as deepening the area of study.

In order to meet the requirements identified in section 4.3, it is proposed that travel behaviour be studied in the context of household activity patterns. An activity pattern approach enables travel to be treated as a derived demand and provides a framework for examining the timing of events, and for incorporating some of the interdependencies among people and between travel and non-travel aspects of behaviour.

Several transport researchers have perceived the importance of activities in relation to travel, but have not explored the full implications of this viewpoint. In a review of the value of micro-economic approaches to studying household behaviour, for example, Wilson (1971) has pointed out the advantages of using the activity as the prime entity if space and time are to be fully incorporated into the analysis, but has not developed this idea further. Similarly, Hartgen and Tanner (1971) and Kutter (1973) both saw activities as the primary means by which people satisfy needs and wants, but used this as a basic input to travel demand models, rather than a starting point for an alternative formulation of travel behaviour.

The only comprehensive attempt to account for travel behaviour in the wider context of activities has been in the development of 'Time Geography' by Hagastrand and co-workers in the Department of Geography
at Lund in Sweden (see Appendix I). This has provided many useful concepts and insights, but the approach was not designed as a framework for explaining and predicting daily travel behaviour for the following reasons:

(a) It is concerned with what people could do, not with what they will do.

(b) It incorporates only certain objective constraints and is not concerned with the many subjective factors that affect travel behaviour.

(c) The approach is based on the notion of a path through time and space; this provides a useful basis for describing behaviour and defining feasible choice options, but it is less appropriate as a means of examining the structures of daily behaviour and the process of adaptation to change.

(d) The mapping system which is used emphasises the location (or station) where behaviour takes place rather than the activity itself, and this tends to be true of much of the research as well.*

This thesis therefore attempts to go further than previous writers, and to develop in Part Two a framework for analysing and predicting travel behaviour in the context of household activity patterns. Chapter 5 sets out the basis of the proposed framework in terms of an understanding of the role of travel in daily life. This is extended in Chapter 6 to look at the ways in which households respond to changes by adapting their behaviour, and Chapter 7 compares and contrasts the activity- and more conventional trip-based approaches. Questions of practicability are considered in Part Three.

*For example, much modelling work (e.g. Lenntorp, 1976) is couched in terms of the 'need to visit' a post office, child care centre, etc., rather than as a need to participate in an activity; in some instances the distinction is an important one.
PART TWO

A NEW APPROACH TO UNDERSTANDING TRAVEL BEHAVIOUR
5. A FRAMEWORK FOR STUDYING TRAVEL BEHAVIOUR

5.1 Introduction

The literature on human activity studies is rich in concepts and findings, many of which are of great relevance to an understanding of household travel behaviour. This literature is reviewed in some detail in Appendix I; some of the main features can be summarised as follows:

(a) The motivation for daily behaviour can be characterised as the satisfaction of a range of needs, which can be met to varying degrees by participation in particular kinds of activity, using specific types of facility.

(b) Participation in a discretionary activity may be viewed as a choice process, in which people select a preferred activity from options prescribed by a set of objective and subjective constraints. Sometimes there may only be one option — then effectively there is no choice.

(c) Time budget studies suggest that there is an apparent stability in time allocation for sub-groups of the population among broad groups of activity, both between countries and through time.

(d) By examining time allocation to the full range of human activity it is possible to regard daily behaviour as taking place within a closed system* and to examine trade-offs between time spent in different kinds of activity.

(e) Biological and psychological factors have a strong influence on both the timing and sequencing of activities and the way the urban area is used, although as yet the extent of this influence has not been fully determined.

(f) The time-geographic (space-time) framework provides a useful means of continuously mapping behaviour and of linking space and time. It has a deductive logic which demonstrates the ways in which behaviour is channelled, and helps to account

---

*Although there is always the possibility of a person postponing an activity until another day.
for the timing and sequencing of events.

(g) Constraints on behaviour imposed by the transport system can be demonstrated using the concept of the space-time prism. This defines the physical reach of an individual and the 'window' of opportunities, in space and time.

(h) The occurrence of joint activities and other inter-dependencies between household members results in important interpersonal linkages.

(i) Daily behaviour is largely routinised, with pockets of choice enmeshed in a structure of committed activity. Many of these commitments arise out of longer-term choices related to locational decisions or certain life cycle changes.

(j) An understanding of the structure and scheduling of daily behaviour requires an emphasis on the pattern of time and space use, and a conceptualisation that allows for the re-arrangement of activity 'blocks' in space and time.

The objective of this and the following chapter is to adapt and extend this work, in order to provide a new conceptual framework for understanding travel behaviour. We first identify a number of factors which help to shape the observed patterns of activity and travel (section 5.3), and then go on to examine various features of household adaptation (section 6.2). In both cases practical examples are given, drawing on field surveys of household activity-travel patterns (section 5.4), and household response to change (section 6.4), respectively.

Before focussing on travel in the context of activities, however, we briefly consider broader issues relating to the nature of human behaviour — some of which are treated only implicitly in later sections.

5.2 Basic Determinants of Behaviour

Reasons for Activity Participation

A detailed understanding of human behaviour is still the goal of
scholars in many disciplines, and the problem has been approached from a number of directions. Economists, for example, have emphasised the importance of resource allocation and the objective of utility maximisation in daily life. Sociologists have paid particular attention to role specialisation, both within and outside the family, and to the interaction between individuals and the organisations to which they belong; while psychologists have contributed an understanding of the importance of motivation as an initiator of human action. These various interacting influences on behaviour operate in turn within a physical environment that imposes its own spatio-temporal structure on behaviour.

Figure 5.1 suggests how some of these factors may combine to influence behaviour. The basic motivation for activity participation is taken to lie in the satisfaction of human needs and the desire to complete tasks associated with a particular role. The opportunities for participation are related to the availability of specialised facilities offering goods and services,* and the resources of time, money, effort, etc., which the individual can contribute; travel may have an important role here, in enabling the individual to reach the specialised facility appropriate for a particular form of activity participation. The act of undertaking an activity in turn provides need satisfaction and role accomplishment, and so affects the immediate priorities for action. Activity participation also alters the resources available for subsequent activities, either by depleting them or by adding, say, to the amount of money available (e.g. work) or the level of physical energy (e.g. by eating).

In a general way, it is possible to group activities according to the type of function which they perform, namely:

---

*The process is a two-way one, however, because the supply of goods and services is sensitive to the local demand for specialised facilities.
Figure 5.1: Factors Influencing Activity Participation

Priorities among competing felt needs & role requirements

Activity Participation

Supply of facilities:
- Services
- Goods

Personal inputs:
- Time: frequency, duration, timing
- Money: price, payment
- Effort, etc.

Outputs:
- Need satisfaction
- Role accomplishment
- Implications for:
  - Time budgets
  - Money budgets
  - Energy, etc.
(1) **Primary activities** \( (A_p) \), which are carried out in order to directly satisfy human needs.

(2) **Secondary activities** \( (A_s) \), which — directly or indirectly — provide inputs to the primary activities, in the form of services, or the production or maintenance of goods and infrastructure. These are often undertaken as part of a role commitment.

(3) **Other activities** \( (A_o) \), which essentially fill in time that is not devoted to \( A_p \) or \( A_s \) type activities.

For example, the need for sustenance is met through the primary activities of eating and drinking, which in turn requires that food be grown, harvested, prepared, cooked and served and that various goods be produced and maintained to facilitate the running of the secondary activities.

As societies become more sophisticated and technologically complex there is a marked change in the activity set of most of its members. For any one individual the range of primary activities undertaken increases (because people acquire the resources to satisfy more needs and are provided with a greater range of opportunities for doing so), but the diversity of secondary activities decreases. In the aggregate, however, the range and complexity of secondary activity provision increases enormously, with a tendency for the responsibility for many of these activities to be transferred from the individual, household or family unit, to an institutional organisation. The extremes may be seen in the self-sufficient crofter largely servicing his own needs, and the family staying in a hotel on a package holiday when the need to undertake secondary activities is almost completely absent.

On a day-to-day basis, therefore differences in behaviour are in large part caused by the social divisions of responsibility for
secondary activity provision, through the specialised roles which people perform.* Words such as 'wife', 'child', 'teacher' convey much about the likely behaviour and attitudes of the person while in that role position. This not only determines which secondary activities are to be performed, but may also influence primary activity participation, either because a need has already been met while performing the role, or because it is created by the role (either socially, physiologically or psychologically).

Basic needs tend to be directly associated with a specific type of primary activity; for example, the awareness of hunger indicates the need for sustenance, which can only be met by food intake (i.e. primary activity: eat/drink). In other cases, however, the relationships between a felt need and its translation into a suitable primary activity may be varied and complex, ranging from one-to-one, through one-to-many, to many-to-many. The complexities are most apparent in the area of leisure, where many activities may substitute for each other and where one activity (e.g. watching T.V.) may satisfy a range of needs (e.g. stimulation, relaxation, education), or may simply be a means of filling time.

Thus, even if we were to assume that individuals in a society shared a common, ordered set of needs the primary activities which people were observed to engage in might vary according to:

(i) The number of needs they have been able to satisfy (depending on their resources and the opportunities available).

(ii) Where appropriate, their 'choice' of activity to meet a

*Fried et al. (1977) have stressed the importance of roles and role expectations of behaviour in their attempt to develop a 'social psychological' theory of travel behaviour. They regard roles as being more stable than personal attitudes and hence better predictors of behaviour, and identify four underlying role complexes around which most behaviour and attitudes are centred: household/family, work/career, interpersonal/social and leisure/recreation.
particular need (varying in accordance with personal preference and local availability).

The Use of Activity as a Proxy for Need

Although a fundamental understanding of human behaviour awaits further research into the nature of needs and the relationship between needs and activities, it is argued here that considerable progress can be made in the understanding of travel behaviour by using activities (or activity groupings) as a proxy for need and as a basis for defining role requirements. While there is a danger that this could lead to a rather mechanistic interpretation of behaviour (particularly if analysis were limited to quantitative data), there are several reasons for focussing on activities:

(a) Pragmatically, activity is a much more tangible concept than need or role, and one which can be measured more readily.

(b) Role playing and need satisfaction are expressed through activity participation, and so the latter offers a reasonable proxy for the former.

(c) Activities provide basic building blocks around which patterns of behaviour are formed, in time and space.

At the broadest level, it is possible to devise a three-fold classification of activities, which takes account of the severity of the felt need and the role commitments of the individual:

(A) Obligatory activities for everyone: certain types of $A_p$ activity that are considered necessary for survival (e.g. sleep, medical care, eating, personal care).

(B) Obligatory activities for some individuals: mainly $A_s$ activities which relate to roles in the family and in society (e.g. paid work, schooling, shopping, child care, domestic duties).
Discretionary activities: both $A_p$ and $A_s$ activities (e.g. voluntary service or recreational activities). Activities may be discretionary because they are associated with higher level, less urgent needs and/or because there are many substitute activities available.

A practical example of this classification is shown in Table 5.1, which presents some very aggregate time budget data from 14 studies in different countries. The mean time spent on subsistence activities is very similar across the three person types, and has a relatively low standard deviation between studies; this group of activities covers eating, sleeping, etc. and broadly corresponds to category (A). The category (B) activities generally correspond to work and household tasks in Table 5.1; here time allocations vary markedly between the groups, since the person classification is closely related to social roles. Finally, category (C) is broadly equivalent to the leisure category, and tends to be a residual category. Thus working wives, who combine two traditional roles and spend considerable periods on paid work and household tasks, have least time for leisure activities on an average weekday — and, because of these pressures, spend slightly less time on subsistence activities.

Summary and Conclusion

The basic determinants of behaviour can be related to need satisfaction and role accomplishment, set in the context of local social, economic and environmental conditions and as mediated by personal perceptions and preferences. Many aspects of behaviour can be described in terms of activity participation, which provides a convenient (if partial) proxy for the motivations underlying behaviour.

The activities which make up an individual's behaviour will vary
<table>
<thead>
<tr>
<th>Activity Group</th>
<th>Activity Type*</th>
<th>Population Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Married Men</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Married Women:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not in Paid Work</td>
</tr>
<tr>
<td>Subsistence</td>
<td>(A)</td>
<td>10.4 (0.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.1 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.6 (0.4)</td>
</tr>
<tr>
<td>Paid work and</td>
<td>(B)</td>
<td>7.2 (0.4)</td>
</tr>
<tr>
<td>travel to/from work</td>
<td></td>
<td>5.7 (0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.2 (0.2)</td>
</tr>
<tr>
<td>Household tasks</td>
<td>(B)</td>
<td>1.5 (0.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.6 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.8 (0.8)</td>
</tr>
<tr>
<td>Leisure</td>
<td>(C)</td>
<td>4.4 (0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.1 (0.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7 (1.0)</td>
</tr>
<tr>
<td>Non-work travel</td>
<td>(B &amp; C)</td>
<td>0.5 (0.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5 (0.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7 (0.3)</td>
</tr>
</tbody>
</table>

Mean Time Allocations in Hours (Standard Deviations in Parenthesis)

Source: Computed from Young and Willmott (1973), Table A10, based on information from studies in the following countries or cities: Belgium, Bulgaria, Czechoslovakia, England (London region), France, Hungary, Poland, U.S.A. (cities), Jackson (U.S.A.), U.S.S.R., West Germany (National), Osnabruck (West Germany), Kragujavac (Yugoslavia), Maribor (Yugoslavia).

*Key:  
A = Obligatory activities for everyone  
B = Obligatory activities for some individuals  
C = Discretionary activities
according to the number of needs that are being met, the alternative ways in which this can be achieved, and the subset of secondary activities which that individual undertakes in fulfilment of role commitments. A pragmatic, three-fold classification of activities is proposed, which broadly corresponds with the reason why an activity is performed and whether it is obligatory, discretionary or not relevant to an individual.

The historical shift of responsibility for certain secondary activities away from the home has reduced the number of such activities undertaken by any one individual, and led to increased role specialisation. But rather than freeing that person, in many cases it has reduced his/her flexibility by limiting the times at which goods and services can be obtained, from less accessible sites. This has increased the complexities of scheduling daily behaviour, and has resulted in secondary rather than primary activities being the 'pacers' in many people's lives.

5.3 The Formation of an Activity-Travel Pattern

In this section we examine a number of factors that affect the formation of activity-travel patterns, and which help to account for many of the distinctive differences in pattern between population sub-groups. Emphasis is given here and in section 6.2 to aspects which can be quantified. As such the analysis is partial, but it provides a basic framework to which can be added a range of more qualitative factors such as the meaning of activities or satisfaction with different patterns of behaviour. Examples of how this integration can be achieved in practice may be found in Chapter 9, and to a more limited extent in findings reported in sections 5.4 and 6.4.

People are rarely in a position to construct a completely new
activity pattern for themselves, except perhaps on first leaving home or upon retirement. Even then, in most societies behaviour is conditioned by routines developed soon after birth and is then subsequently adjusted to cope with changing needs and circumstances. Nevertheless, it is possible to obtain some understanding of daily behaviour patterns by examining how various features contribute to the formation of an observed activity pattern. The scheduling of daily behaviour is described here in four stages, covering: elements of activity pattern formation; the temporal structure of the day; the spatio-temporal organisation of behaviour; and, the effects of inter-personal linkages.

Most of the examples used in this section relate to a hypothetical one-person household who lives in the suburbs of a town. The behaviour we seek to analyse is recorded in the one day activity diary shown in Figure 5.2. This describes a day's events, from getting up until going to bed, for a single person who is in full-time employment but does not own or have regular use of a car. On this particular day the main pattern of activities comprises going to work, shopping after work, returning home for an evening meal, then going out again to an evening class, staying for a drink afterwards and finally returning home about 10 p.m. (22.00).

Elements of Activity Pattern Formation

Some of the main elements affecting the composition and structure of an activity-travel pattern are illustrated in Figure 5.3, using as an example the behaviour recorded in Figure 5.2. At the core of Figure 5.3 is a space-time representation of behaviour which was used in the exploratory studies described in Chapter 9. Briefly, the location of activity and travel facilities and the spatial trajectory of daily behaviour are indicated on the upper part of a display board;
Figure 5.2
One Day Activity Diary
For a Hypothetical One Person Household

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Activity</th>
<th>Location</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>06.50</td>
<td>Wash and dress</td>
<td>Home</td>
<td>-</td>
</tr>
<tr>
<td>07.15</td>
<td>Prepare and eat breakfast</td>
<td>Home</td>
<td>-</td>
</tr>
<tr>
<td>08.00</td>
<td>Travel</td>
<td>-</td>
<td>Bus</td>
</tr>
<tr>
<td>08.30</td>
<td>Work</td>
<td>Town Hall</td>
<td>-</td>
</tr>
<tr>
<td>12.15</td>
<td>Lunch</td>
<td>Town Hall</td>
<td>-</td>
</tr>
<tr>
<td>13.00</td>
<td>Work</td>
<td>Town Hall</td>
<td>-</td>
</tr>
<tr>
<td>17.00</td>
<td>Travel</td>
<td>-</td>
<td>Walk</td>
</tr>
<tr>
<td>17.05</td>
<td>Shopping</td>
<td>High Street</td>
<td>-</td>
</tr>
<tr>
<td>17.30</td>
<td>Wait for bus</td>
<td>High Street</td>
<td>-</td>
</tr>
<tr>
<td>17.35</td>
<td>Travel</td>
<td>-</td>
<td>Bus</td>
</tr>
<tr>
<td>18.00</td>
<td>Prepare and eat meal</td>
<td>Home</td>
<td>-</td>
</tr>
<tr>
<td>18.45</td>
<td>Travel</td>
<td>-</td>
<td>Walk</td>
</tr>
<tr>
<td>19.00</td>
<td>Evening class</td>
<td>Community Hall</td>
<td>-</td>
</tr>
<tr>
<td>21.00</td>
<td>Drink and chat</td>
<td>Community Hall</td>
<td>-</td>
</tr>
<tr>
<td>22.00</td>
<td>Travel</td>
<td>-</td>
<td>Walk</td>
</tr>
<tr>
<td>22.15</td>
<td>Bath</td>
<td>Home</td>
<td>-</td>
</tr>
<tr>
<td>22.45</td>
<td>Sleep</td>
<td>Home</td>
<td>-</td>
</tr>
</tbody>
</table>

NB: Trip stages have not been recorded separately.
below this is a set of time scales (relating to in-home, travel, and out-of-home activities, respectively), on which activity participation is recorded using a series of blocks of correct duration set against the appropriate time scale (see also Appendix II).

Around this central picture are depicted a number of elements that contribute to the formation of the observed pattern. They comprise:

1. The set of activities which the individual undertakes and their characteristics.

2. The location and characteristics of the activity and travel facilities available to the individual — which delimit opportunities for participation.

3. Limitations imposed by the level of information as perceived by the individual.

4. Various timing constraints imposed on activity participation both by the facilities and the activities themselves.

The activity set selected by an individual has a range of different characteristics and requirements. Two aspects are shown in Figure 5.3: the extent of obligation attached to activity participation (specifically, whether the activity is obligatory or discretionary), and whether the activity is of fixed or variable duration; other features relating to frequency and timing are considered below.

Each activity has associated with it a set of facilities that provide specialised inputs for activity participation, the number available depending on the type of activity. In this example home and work are assumed to be fixed, but there are a variety of options for shopping and social/recreational activity participation. Characteristics of the activity facilities include:

(a) Location of the facility in space.

(b) Price of admission to the facility and cost of activity
Figure 5.3: Factors Contributing to the Activity Pattern of Figure 5.2

**ACTIVITIES:**

<table>
<thead>
<tr>
<th>Obligatory:</th>
<th>Discretionary:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>Evening Class</td>
</tr>
<tr>
<td>Sleep</td>
<td>Drink</td>
</tr>
<tr>
<td>Eat</td>
<td></td>
</tr>
<tr>
<td>Shop</td>
<td></td>
</tr>
<tr>
<td>Wash, etc</td>
<td></td>
</tr>
</tbody>
</table>

**Fixed Duration:**

<table>
<thead>
<tr>
<th>Work</th>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evening Class</td>
<td></td>
</tr>
</tbody>
</table>

**Flexible Duration:**

<table>
<thead>
<tr>
<th>Work</th>
<th>Shop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eat</td>
<td>Wash, etc</td>
</tr>
<tr>
<td>Drink</td>
<td></td>
</tr>
</tbody>
</table>

**ACTUAL PATTERN**

**TIMING CONSTRAINTS:**

- Hourly Bus Service: Home - Work = On the hour
- Work - Home = On the half hour

**FACILITIES:**

*For activities (Perceived Options)*

<table>
<thead>
<tr>
<th>Pubs</th>
<th>Shops</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*Home*

*Community Hall*

<table>
<thead>
<tr>
<th>Work</th>
</tr>
</thead>
</table>

*For travel (Footpaths not Shown)*

<table>
<thead>
<tr>
<th>Non-Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Home</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Bus Routes</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
participation.
(c) Availability of the facility in time (see below).
(d) Other restrictions on its use (e.g. available to members only).
(e) A set of detailed attributes relating to the quality of the facility.

The association between an activity and the type of facility it requires is often so specific that the two are not clearly distinguished in everyday speech; we talk, for example, of shopping at the shops or of 'going to' the bank or library, as a proxy for the activity to be undertaken there.

Paralleling the set of relevant activity facilities are the travel facilities – the various transport networks and modes available in an area that link together the elements of the land use pattern. An individual may only have access to some of these networks (in this example, the footpaths and local bus service), each of which has associated with it characteristic costs, travel times, energy expenditures, quality of service, etc. Individuals are only likely to have partial information about a subset of the potential land uses and transport modes – and these are only of relevance if they are accessible in space-time terms.

Although timing is an attribute of activities and facilities, it is shown separately in Figure 5.3 because it is a shared characteristic and it is often difficult to identify whether it is strictly an attribute of one or the other. Evidence for the existence of biological clocks was cited in Appendix I, but increasingly in modern society timing is becoming socially and technically determined (though the periodicity and duration of certain activities may be controlled biologically). With the advent of artificial light, for example, there is no longer an automatic association between darkness and sleep. Examples of facility-determined timings include the activities available at set
times (e.g. work or evening classes), or between set hours (e.g. shopping), or at discrete points in time (e.g. bus service schedules); local timing constraints are depicted in Figure 5.3.

Other factors not shown here, will also affect the activity pattern. They include:

(a) The personal resources available to the individual, notably money and physical fitness.
(b) Additional constraints on action due to commitments to carry out joint activities with other people.
(c) Personal preferences, which will affect the choices made among more optional activities.

These additional elements are introduced at appropriate points later in the chapter, as we go on to examine how the scheduling of daily behaviour relates to interactions between the desired activity set and the various objective and subjective constraints on action.

The Temporal Structure of the Day

It is axiomatic that participating in an activity consumes time resources and, since time also provides 'signals' for pacing daily events and synchronising behaviour (Parkes, 1973), it represents a convenient basis for measuring and analysing how people structure and co-ordinate their lives.

Most activities require distinctive forms of time commitment. The daily, rhythmic pattern of sleep, for example, leaves an approximately sixteen hour time 'window' each day for people to slot in other activities between getting up and going to bed. Each waking day can thus be viewed as a semi-closed system, in which people attempt to schedule certain activities, though they may have the option of transferring some to another day if necessary. Other, more institutionally constrained activities help to impose a weekly rhythm on behaviour (e.g.
market days, closure of schools on Saturdays and Sundays).

Only one major activity can normally be undertaken at a time, so that the various obligatory activities to which an individual is committed may rapidly delimit the broad structure of the waking day and so heavily constrain the amount and distribution of 'free' time. This is particularly true of people who undertake activities involving large amounts of institutionally controlled time, such as employees or school children, but other people may also become involved and have their day indirectly shaped by such factors (see Figures 5.8 and 5.10).

As an example of the constraints on temporal scheduling, consider the characteristics of the activities undertaken by the single, employed person of Figure 5.2. The 'obligatory' activities in his day account for approximately 85 per cent of the time budget,* made up as follows:

<table>
<thead>
<tr>
<th>Type A Activities</th>
<th>Duration</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td>8 hrs. 5 min.</td>
<td>(34%)</td>
</tr>
<tr>
<td>Personal Care</td>
<td>55 min.</td>
<td>(4%)</td>
</tr>
<tr>
<td>Eating (and food preparation)</td>
<td>2 hrs. 15 min.</td>
<td>(9%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type B Activities</th>
<th>Duration</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>25 min.</td>
<td>(2%)</td>
</tr>
<tr>
<td>Work</td>
<td>7 hrs. 45 min.</td>
<td>(32%)</td>
</tr>
<tr>
<td>Travel (work/shopping only)</td>
<td>1 hr. 00 min.</td>
<td>(4%)</td>
</tr>
</tbody>
</table>

It would clearly be possible to make marginal reductions in the time spent in sleep, washing or eating, etc., but it is apparent that the great majority of time available in this individual's day is taken up with meeting physiological needs and role commitments.

When we look at the timing, as well as the duration, of activities, it is apparent that here too the individual is heavily constrained on

*This assumes that evening class attendance is regarded as a 'discretionary' activity.
a day-to-day basis. Figure 5.4 illustrates the timing constraints associated with each type of activity. Some are institutionally or biologically determined, while others are restrained by sequence requirements (e.g. personal care before and after sleep). For this working adult, the structure of his weekday is largely pre-determined by the requirements of work and the activities which directly support it (e.g. morning preparation and travel to/from work). Discretionary activities are concentrated into a window of 'free' time, from around 18.00 to 22.00, but even here the timing and order of activities is determined by the fixed hours of the evening class — should he decide to attend.

The duration and timing requirements of the various activities and facilities can impose a varying degree of structure on the day,* ranging from minimal in the case of a retired person, to a very rigid structure in the case of some employed people. When the spatial dimension is considered a further set of restrictions is introduced, association with the characteristics of the land use pattern and the transport systems.

*For some groups money rather than time may be the key constraint on activity participation.
Figure 5.4: Temporal Scheduling Constraints on the Activity Pattern of Figure 5.2
(excluding an allowance for travel time)

Semi-fixed Duration & Timing

SLEEP

Semi-fixed Duration; Timing keyed to SLEEP

PERSONAL CARE

Semi-fixed Duration & Timing

EATING

Fixed Duration

SHOPPING

and Bounded Timing

Fixed Duration

Fixed Timing

TIME OF DAY
requires that time be set aside for travelling between facilities at different locations. The availability of transport facilities may now be an important additional limitation on the composition and sequencing of daily behaviour. At this point a further subjective constraint is introduced, in that people may be unaware of the existence of certain activity or transport facilities.

Returning to the example of Figure 5.2, consider the perceived options which the individual apparently has for carrying out shopping (see Figure 5.5). This has to be carried out either at lunchtime or after work, since none of the shops open until after he has started work. Three sites are available:

- Site 1: 5 min. walk from work
- Site 2: 10 min. walk from home
- Site 3: 15 min. by bus (midway between work and home)

When account is taken of travel time and the timing of the bus services, the individual is restricted to Site 1 for his weekday shopping, even if he were to reduce the duration of the activity. This site could be reached at lunchtime or after work, but since a lunchtime trip would leave very little time for eating and as there is a half hour wait for a bus home after work, the latter option is to be preferred (and also saves storing food and other goods in the office during the day). On occasions when it is necessary to visit a bank, however, the latter's restricted opening hours make it necessary to pay a lunchtime visit.

A combination of geographical factors and the time requirements of various obligatory activities may thus determine the broad structure of much of a person's day, and his basic travel pattern. Within this skeletal structure there will be 'windows' of more discretionary time which allow the individual greater choice in terms of what is done, where and when. Some will be used to fit in more 'flexible', but
Figure 5.5: Space-Time Constraints on Behaviour: 
Fitting Shopping into the Activity Pattern of Fig. 5.2

LAND USE PATTERN:

CONSTRAINTS ON BEHAVIOUR:

SHOPPING OPTIONS:

<table>
<thead>
<tr>
<th>Shopping centre</th>
<th>Travel time (min)</th>
<th>Shopping time (min)</th>
<th>Total time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 1</td>
<td>10</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>II 1</td>
<td>5</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>III 3</td>
<td>45*</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>IV 2</td>
<td>70*</td>
<td>45</td>
<td>115</td>
</tr>
</tbody>
</table>

*Includes waiting time, for hourly bus service.

Feasible
But no time for lunch
Preferred option
Uses slack time while awaiting bus
Not feasible
Arrive after shops close at 17.30
Not feasible
Arrive after shops close at 17.30
essentially obligatory activities such as home maintenance, but much of this time will be available for participation in discretionary activities. The notion is thus one of choice in the context of constraints \(^4\) (Figure 5.6a), though clearly there will be occasions when the more obligatory activities will deliberately be re-arranged to allow a sufficient block of uncommitted time for a more discretionary activity.

Activity choices among the more discretionary activities are based on the evaluation of three groups of factors:

1. The possible set of activities that could substitute for each other and satisfy the felt need(s).
2. The available set of activity facilities (both in the sense of being objectively available at that time and subjectively perceived to be available), and their characteristics.
3. The accessibility of each facility to the individual at his present position in space-time (including his ability to reach his next space-time commitment from the facility).

In cases where the perceived set of activity options all make use of facilities at a person's current location, then only the first two factors enter the evaluation. Otherwise, transport system characteristics may be an important element in the activity decision.

Figure 5.6b illustrates the simple case of an individual who has a block of uncommitted time between 18.30 and 22.30 and wishes to participate in some form of entertainment activity. He perceives his choice to lie between watching television at home (his current location), or seeing a film at his local cinema; this is a feasible

---

*As is emphasised in Appendix I, there is no rigid distinction between the two concepts, since short term constraints (e.g. hours of work, travel time required to reach work, location of shops, etc.) may be altered by longer term choices (e.g. relocate home or workplace, purchase a car, etc.).
The decision is taken to visit the cinema (and consequently make two home-based social/recreational trips) if:

\[ B_{A1} - C_{Al} - 2C_T < B_{A2} \]

Where:
- \( B_{A1} \) = benefits of seeing film at local cinema
- \( B_{A2} \) = benefits of watching television at home
- \( C_{Al} \) = price of cinema ticket
- \( C_T \) = cost of travel
alternative, since he has enough money for a ticket, the programme lasts from 19.00-22.00, and the cinema is a 20 minute walk away. His options are thus: staying at home (i.e. making no trips) and enjoying perceived benefits $B_{A2}$; or going to the local cinema (i.e. making two home-based trips) and achieving net benefits $B_{A1} - C_{A1} - 2C_T$. It may reasonably be assumed, *ceteris paribus*, that he chooses the course of action that gives him the greater perceived benefit (although a probabilistic interpretation would allow for the desire for a change, etc.).

Although in theory one might expect an individual to have a complex set of options, in practice they are considerably reduced by other factors such as: personal preferences for certain types of activity, the perceived availability of local activity and travel facilities and the effect of habit responses. In addition, most people form part of a larger household unit and have to co-ordinate their activities with other people, which may further constrain choice. This is considered next.

The Effect of Inter-Personal Linkages

The discussion so far has dealt with the activity patterns of individuals living alone, whose behaviour has only to take account of the servicing of their own needs (through role performance and direct need satisfaction) and certain institutional constraints on work hours, shop opening hours, etc. The majority of individuals, however, live in multi-person households and so have to contend with the additional complication of inter-personal linkages when scheduling their behaviour.

The results of this closer association between people can be observed in three respects:

1) **Greater role specialisation.** When two or more adults share a dwelling unit it enables duplication of effort to be avoided
and some activity consolidation among the group (e.g. with regard to meal preparation or house maintenance) which, ceteris paribus, reduces the amount and range of secondary activity which each person has to undertake. Conversely when dependent children form part of the household the extent of, and commitment to, secondary activities may increase substantially, leading to a considerable decrease in uncommitted time and an increase in space-time constraints on adult members (see point 3) — although, here again, tasks can be shared where there is more than one adult present.

(2) **Competition for resources.** Although larger households will tend to have more resources in total than single person households (e.g. more living space, higher incomes), many resources are still relatively scarce and have to be allocated (e.g. money) or scheduled (e.g. space, at different times) between members who often have competing claims. The necessity for bargaining for resources is an important element in family life and may be a source of uncertainty and tension. 'Classic' examples include decisions about who has priority in use of the household's car under different circumstances, and the tendency for larger families to evolve a timetable to cover the use of the bathroom in the morning.

(3) **Joint activity participation.** The sharing of secondary activity tasks within a household tends to reduce the amount of time that each individual has to set aside for such activities, but the associated increase in inter-dependence between members results in a higher level of spatio-temporal constraint that offsets the scheduling benefits of this reduction. Figure 5.7 illustrates some of the constraining effects of joint activity participation. In order to take part in one or more joint
Figure 5.7: Constraints Imposed by Joint Activity Participation

**TWO OR MORE PEOPLE:**

1. Are limited to activities of joint interest or concern:

   ![Diagram showing Activity Preference Set for Person 1 and Activity Preference Set for Person 2 intersecting at Joint Set.](image)

   For example, parents are restricted to activities in which children are interested, and are allowed to attend (problems of visiting pubs etc)

2. Have to plan to be in the same place at the same time: (coupling constraint)

   ![Diagram showing two circles overlapping at the same point.](image)

   Except where joint participation is via telecommunications.

3. Are limited to occasions when both/all have a common block of discretionary time:

   ![Diagram showing Constrained Activities for Person 1 and Person 2 with Activity Options.](image)

   ...which in this example amounts to less than half the total discretionary time.

**Source:** Jones, Dix, Clarke and Heggie (1983), Fig. 3.3.
activities it is necessary for participants first to agree on the activity, and then to perform it at the same time and in the same place (with the exception of telephone calls, etc.); consequently they may be difficult to schedule. Similar problems occur in the organisation of firms, where business meetings may have to be arranged several weeks in advance, because of the difficulty of finding a common block of uncommitted time.

Members of multi-person households usually engage in a relatively high proportion of joint activities, through such events as shared evening meals or the need to babysit during the evening, and this complicates and constrains their activity scheduling options.* The tendency towards role specialisation in multi-person households also makes joint activity arrangements intrinsically more difficult than between similar people in single person households, because there are more likely to be conflicts of resource and activity commitment among members of larger households.

Inter-personal linkages can have complex and varied impacts on daily activity patterns that have not been given detailed consideration in the work reviewed in Appendix I. The 'typical' family comprising husband, wife and one or two children are most affected by this kind of scheduling factor, because of the wide range of roles and secondary activities which its members have to perform (some rigidly constrained, such as school hours) and because of the high level of dependency of the young on the adults. The importance of these linkages becomes apparent when families attempt to adapt their behaviour in response to some change (see Chapter 6).

Figure 5.8 illustrates the scheduling complexities which can arise from the interplay of temporal, space-time and inter-personal

*As do factors such as the need for adults to engage in quieter activities once any children are asleep.
constraints in multi-person households comprising adults and children. Superficially, the housewife's day may appear to be the least constrained in the family because of the lack of institutional constraints on her activities, but once account is taken of her role inside the household and her commitments to its other members, then she may in fact be the most restricted person.

The example depicts a three person household: a husband (H) and wife (W) in their late twenties/early thirties, and a six year old son (S). The husband has a fairly typical working day: from 08.45 to 17.15 with an hour for lunch and a three quarter hour commute to and from work, giving him an effective working day from 08.00 to 18.00. Their son has to be at school between 09.00-12.30 and 14.00-15.30; he comes home for lunch and is a quarter hour walk from the school. The wife has no such institutional commitment, but has to set aside time in her role as housewife and mother to look after her son and maintain the household. Much of her daily behaviour is determined by that of her husband and son, including:

(a) Meal times: breakfast and evening meals are dictated by H; lunch is constrained by S's free period.

(b) Bathroom arrangements: the morning routine hinges around H. W goes in before H and S follows, after having breakfast with his parents.

(c) Meal preparation: this is mainly done immediately prior to the meal, so W prepares breakfasts while H is in the bathroom and S is asleep; she prepares lunch before meeting S (it's easier) and also spends an hour before dinner in meal preparation.

(d) Travel: her basic travel pattern is based on escorting S to/from school; H leaves too early and gets back too late to help with this. It is most efficient for W to fit in other
Figure 5.8: Constraints on Household Behaviour

KEY:
- PC = Personal care
- MP = Meal preparation
non-home activities around this routine; shopping is done in the morning, after dropping off S — it's easier without him around — with a second 'chance' on the way home from school in the afternoon. Social visits are made between 14.00 and 15.30 en route to the school when friends with children at school are also free to chat and relax.

(e) Child care: W has primary responsibility for looking after S from 08.00-18.00, while H is away (except when S is in school); at other times it is a joint responsibility.

(f) Housework: W gets most of it out of the way in the morning (2½ hrs. net), leaving one and a half hours in the afternoon for a 'break' before collecting S from school and having to devote time to him.

(g) Leisure: W has a restricted opportunity for leisure participation during a window of 'free' time in the early afternoon. There are also opportunities for leisure activity in the evening after S has gone to bed, although these can only be pursued away from home if she goes alone, or the couple are able to arrange a babysitter.

Conclusion

In this section we have identified a number of key elements of behaviour and have shown how these contribute to the formation of an individual's activity travel pattern. The daily rhythms of sleeping and eating, coupled with the demands placed on people through a variety of role requirements, means that many people have very little choice — in the short term — about the structure or content of their daily activity or travel pattern, particularly during weekdays.

In the case of the hypothetical individual referred to in earlier sections, for example, it is possible to understand why his travel
pattern takes the form shown in Figure 5.3, given information about his desired activity set and the local availability (in time and space) of activity and travel facilities. Bus is the only mode available for journeys to/from work, and the timing of this journey is jointly determined by his hours of work and the bus timetable. Other destinations visited during the day are accessible on foot from his home or work base; here the mode does not impose a timing constraint, rather the times of travel are largely determined indirectly by the activity facilities (i.e. shop hours and times of evening class). The only element of flexibility occurs in the later part of the evening, after the individual finishes his evening class: had he decided to have a drink at a local public house, instead of in the community hall, this would have 'generated' an extra walk trip.

When the additional linkages in multi-person households are considered, together with the influence of factors such as socialisation, it is not surprising that much of daily life is habitual and routinised—both because of the limits on choice and the impracticability of renegotiating resource allocations, inter-personal linkages, etc., every day.

Using empirical data, the final section of this chapter illustrates how differences between people and households in terms of activity needs and role requirements, linked with various time-space and inter-personal constraints, help to shape behaviour and the associated patterns of travel in distinctive and characteristic ways.

5.4 Some Evidence from an Activity-Travel Survey

This section illustrates how the concepts and relationships presented in earlier sections in a hypothetical way can be observed in the everyday patterns of behaviour of households in a small market town in
Oxfordshire. In particular:

(a) Travel patterns can be explained largely in terms of activity requirements and space-time constraints and inter-personal linkages.

(b) Households with similar needs and constraints tend to exhibit activity-travel patterns which are broadly similar.

The examples are based on an activity-travel survey in Banbury organised by Martin Dix and the writer, in which approximately 200 households kept a record of the activities of all their members for a consecutive seven day period. The study was supported by the U.K. Social Science Research Council, and full details of the survey, coding and analysis may be found in the final project report (Jones, Dix, Clarke and Heggie, 1980). Most of the material presented in this section is based on qualitative and quantitative analysis of the Banbury data by Mike Clarke and Martin Dix.*

Earlier exploratory surveys by Dix (1975) and Heggie (1976a) had shown that important differences in activity needs and constraints could be related to stage in the family life cycle (see also Zimmerman, 1982). An eight-fold classification was adopted in the Banbury analysis and results relating to two of the groups are presented here:

(i) Lifecycle stage 'A': Households comprising single or married adults without children, where the youngest person is under 35.

(ii) Lifecycle stage 'C': Families with school and pre-school children, where the youngest child is under 5 and there is at least one other over 5.

*The findings discussed here are reported in greater detail in Clarke and Dix (1980), Clarke and Dix (1983), and Chapters 5-7 of Jones, Dix, Clarke and Heggie (1983).
**Household Activity Patterns**

Basic time budget information for heads and spouses in these two lifecycle groups is presented in Table 5.2, with activities classified according to the three-fold division outlined in section 5.2. For household heads (predominantly male), the allocation of time to non-travel activities varies little between stages A and C, although about 20 minutes per day is spent on child care activities in stage C when the group becomes slightly more home centred; there are also slight decreases in time devoted to sleep and personal care.

For spouses (i.e. wives), however, the picture is very different, with a marked switch in roles from joint breadwinner in stage A to mother in stage C, with the addition of two or more children to the household. Few wives in our sample worked at this point in their lives, but instead spent considerable periods of time on household chores, shopping and child care activities in and close to home; stage C spouses spend only 15 per cent of their time away from home, compared with 38 per cent for those in stage A. Although role differentiation is particularly marked in stage C, there are also some notable differences between heads and spouses during stage A — when spouses spend, on average, over twice as much time on household chores and 50 per cent more time shopping than their partners (which is roughly compensated for by fewer hours average paid work).

Figure 5.9 shows how these differences in broad time allocation translate into differences in activity patterns between stage A and C, for individual household members. The diagrams show 'prototypical' activity patterns, based on what people described as their usual weekday routines during unstructured, in-depth interviews. Figure 5.9a shows the prototypical activity pattern for households in stage A, where both adults are usually employed. At this stage most activities
Table 5.2
Time Allocation to Activities (in minutes)
for Lifecycle Groups A and C

<table>
<thead>
<tr>
<th>Activity Groupings*</th>
<th>Heads of Household</th>
<th>Wives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (N=24)**</td>
<td>C (N=27)</td>
</tr>
<tr>
<td>(A) Obligatory for all</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep &amp; personal care</td>
<td>551</td>
<td>516</td>
</tr>
<tr>
<td>Eating and drinking</td>
<td>58</td>
<td>62</td>
</tr>
<tr>
<td>(B) Obligatory for some</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paid work</td>
<td>474</td>
<td>480</td>
</tr>
<tr>
<td>Household chores</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Shopping &amp; services</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Child Care</td>
<td>-</td>
<td>19</td>
</tr>
<tr>
<td>(C) Discretionary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>69</td>
<td>44</td>
</tr>
<tr>
<td>Leisure/Hobbies/</td>
<td>137</td>
<td>172</td>
</tr>
<tr>
<td>Recreation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Time at home</td>
<td>56</td>
<td>59</td>
</tr>
<tr>
<td>% Time non-home</td>
<td>44</td>
<td>41</td>
</tr>
</tbody>
</table>

* These do not include travel or miscellaneous activities
** N = sample size

Source: Banbury Activity-Travel Survey, based on analysis by Mike Clarke
Figure 5.9: Prototypical Activity Patterns for Two Life Cycle Groups

(a) Life Cycle Stage A:

Number of husbands working shift systems is now more significant, due to greater economic imperatives, and relaxed needs to synchronize activities with those of spouse.

WEEKEND TRAVELLING OFTEN ACHIEVED THROUGH CHEAPER RATES AND POSSIBILITIES OF CANCELLATION OF JOURNEYS.

LUNCHTIME SCHEDULE NOW EXTREMELY TIGHT. YOUNGER SCHOOL CHILDREN NEED ESCORTING. HENCE PROLIFERATION OF SPOUSES' TRIPS.

Evening patterns similar to group B, except that older schoolchildren are demanding outside activities and hence escorting or chauffeuring.

(b) Life Cycle Stage B:

Number of husbands working shift systems is now more significant, due to greater economic imperatives, and relaxed needs to synchronize activities with those of spouse.

Meals are usually taken jointly at times which vary. Social or recreational activities direct from work, without prior return home, are quite common.

Outings typically involve both adults, travelling in one car.

Time of Day

sleep

work

work

work

work

work

work

work

sleep

sleep

Source: Jones, Dix, Clarke and Heggie (1983), Figures 5.1(a) & 5.3(a).

Prototypical patterns devised by Martin Dix from analysis of in-depth interviews.
tend to be synchronised and carried out jointly whenever possible; husbands and wives often share a car to travel to/from work and go out together frequently in the evening. Shopping tends to be carried out near the workplace, either by the wife shopping in her lunch hour, or jointly by both adults en route home after work.

By stage C, however, the activity-travel patterns of the head and spouse have become highly differentiated (see Figure 5.9b), with very little joint activity participation outside the home. The structure of the husband's day has changed little, although he now spends less time out-of-home in the evening and joins in some activities with his children. Evening outings from home are often without the wife and involve chauffeuring or escorting older children to cubs or club activities, or going out alone to play squash, visit the pub, etc., while the wife looks after the children.

Conversely, the wife is now very home centred, in her roles as mother and housewife, spending little time away from the residence, although generating a large number of trips. These are associated mainly with escorting the elder child(ren) to/from school(s) — up to four return trips each day — and fitting in shopping and social/leisure activities within this very constrained schedule. Shopping is now undertaken close to home and school, rather than near the workplace, and performs an important social as well as a domestic function. The elder child(ren)'s day is based around educational activities (i.e. school and associated after school activities), with most evenings spent at home or (in the summer) playing in the immediate neighbourhood. The younger, pre-school child(ren) tends to be home centred, like his/her mother, and mirrors her activities except in the rare cases (in our sample) where a wife has a part-time job.

The aggregate effects of these various factors on the activity patterns of Banbury households in stage C are shown in a quantified
way in Figure 5.10. Five person types are distinguished (i.e. head, spouse and 3 age groups for the children); for each is shown the percentage taking part in one of six non-travel activities at different periods during the day, with band widths summing to 100 per cent. Note, in particular, the following features:

- Most household heads have a basic home-work-home pattern, but in a significant number of cases this is reversed, because of night shift work (mainly at Alcan and General Foods).
- Few wives work, and where they do it is either during the day (when children are at school) or in the evening once husbands have returned home and are able to mind the children.
- For school-aged children, there is a very clear pattern of home-school-home, with the addition of some later afternoon and early evening activities, extending later into the evening for the older children.
- Husbands are much more likely to go out in the evening than wives, and are mainly responsible for fetching and collecting children from evening activities.
- The activity patterns of pre-school children mirror very closely those of their mothers; in cases where the latter are in paid work during the day, the former are at play school or with a child minder.

It is thus evident that activity needs (particularly those associated with role fulfilment), coupled with related space-time and interpersonal constraints, have a strong influence on the content and overall structure of people's activity patterns, to the extent that distinctive patterns — in these examples, associated with life cycle stage — can be observed at an aggregate level.
Figure 5.10: Aggregate Activity Patterns for Sampled Households in Life Cycle Stage C.

Husband (sample of 21)

NON-HOME
- work
- school
- other

IN-HOME
- eat
- domestic
- other

Wife (sample of 21)

NON-HOME
- work
- school
- other

IN-HOME
- eat
- domestic
- other

Child 12-16 (sample of 10)

NON-HOME
- work
- school
- other

IN-HOME
- eat
- domestic
- other

Child 6-11 (sample of 33)

NON-HOME
- work
- school
- other

IN-HOME
- eat
- domestic
- other

Child 0-5 (sample of 21)

NON-HOME
- work
- school
- other

IN-HOME
- eat
- domestic
- other

Source: Jones, Dix Clarke and Heggie (1983), Fig. 5.3(b).
Analysis by Mike clarke.

Plots show proportion engaged in each activity.
Resulting Patterns of Travel

The factors shaping the activity patterns give rise, in turn, to characteristic patterns of travel that can be identified using conventional trip-based and chain-based measures. Figure 5.11 is also based on the Banbury survey data and shows trip rates, by purpose, for lifecycle groups A and C. Note in particular the very much higher 'home-based other' trip rate in stage C, mainly associated with escorting children to/from school and social/recreational activities. By definition, education trips become a significant component of household travel in stage C, and we can also observe the expected reduction in work trips in C compared with A — although this is less marked than might be expected, for two reasons: some single person households are included in group A, so there are some one-worker households in both A and C, and in group C some husbands now come home for lunch to be with their family, resulting in four rather than two work trips each day.

Shopping trips also increase in frequency in stage C, although part of the differences are observed within the 'non home-based' category. This is made clearer in Table 5.3 which looks at the composition of trip circuits or chains, rather than trip rates, for respondents in lifecycle stages A and C. It tabulates the percentage of trip circuits from home during which the traveller takes part in the activities or combinations of activities that are listed. There are a number of features of interest here, which relate to the earlier discussion about roles and constraints; in particular:

(a) Specific activities. For household heads work retains its relative importance in the daily travel pattern, but note the relative decline in shopping and 'other' activities, and the sharp increase in serve passenger events, related particularly to chauffeuring children to/from evening activities and in
**Figure 5.11: Mean Household Trip Rates, by Purpose, for Two Life Cycle Groups**

- **KEY:**
  - Shading denotes areas within 95% confidence limits around mean trip rates
  - Arrows indicate mean household size (on same scale as used for trip rates)

- **Source:** Jones, Dix, Clarke and Heggie (1983), Figure 7.9
  - Analysis by Mike Clarke
Table 5.3
Weekday Trip Circuits, by Life Cycle Group

<table>
<thead>
<tr>
<th>Life Cycle Group</th>
<th>Household Head</th>
<th>Spouses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>C</td>
<td>A</td>
</tr>
</tbody>
</table>

Percentage of circuits which include:

(a) Specific activities:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Household Head</th>
<th>Spouses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>work</td>
<td>56</td>
<td>55</td>
<td>53</td>
</tr>
<tr>
<td>shopping</td>
<td>26</td>
<td>17</td>
<td>46</td>
</tr>
<tr>
<td>serve passenger</td>
<td>15</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>other</td>
<td>39</td>
<td>27</td>
<td>50</td>
</tr>
</tbody>
</table>

(b) Activity combinations:*

<table>
<thead>
<tr>
<th>Activity Combination</th>
<th>Household Head</th>
<th>Spouses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>work and shop</td>
<td>14</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>work and serve passenger</td>
<td>12</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>work and other</td>
<td>9</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>shop and serve passenger</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>shop and other</td>
<td>5</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>serve passenger and other</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

% of simple circuits (1 stop) | 69 | 72 | 58 | 67 |

* No sequence implied

Source: Jones, Dix, Clarke and Heggie, (1983), Table 7.2. Analysis by Mike Clarke.
some cases dropping them off at school on the way to work.

For **wives**, the level of trip making is higher in stage C than stage A. In percentage terms, the largest changes are associated with the switch in roles, with work and serve passenger activities exchanging positions as the most and least frequent activity in a circuit.

(b) *Activity combinations.* The percentage of simple, one-stop circuits stays approximately the same for **household heads** in stages A and C, at around 70 per cent. For this group, the pattern of participation in combinations of non-home activities is largely unchanged, with the exception of 'work and shop'. In group A shopping is often done jointly, by head and spouse, during a shared journey home from work; in group C, however, shopping is either done by the spouse alone, or if the household head is involved, it is carried out on a separate circuit from home.

In the case of the **wife**, most activity combinations change significantly in relative importance; in general, those involving a work activity decline sharply between A and C (expect 'work and serve passenger', which relates back to the use of play school facilities, discussed in connection with Figure 5.10), and those involving serve passenger increase markedly in relative importance, for reasons already discussed. Note, in particular, the importance of 'shop and serve passenger' in stage C, where shopping is fitted in during escorting trips to/from school. Table 5.3 also confirms the more home-oriented nature of the wives' travel, with an increase in simple circuits from 58 per cent to 67 per cent.
Some Evidence from Larger Studies

The results presented in this section were obtained from a small specially designed survey conducted in a Midlands market town. Although they demonstrate some important relationships between activities, constraints and travel patterns, the general applicability of the findings is questionable, on grounds of statistical validity and the geographical limitations of the sample. Since completing and publicising this work, several other writers have examined these and related hypotheses by analysing large, conventional travel data sets in unconventional ways,* with encouraging results. Just a few examples are mentioned here.

In the U.K., two writers have used National Travel Survey data to examine relationships between life cycle and travel patterns. Hayfield (1978) looked at trip rates by life cycle stage and found differences in trip rates between groups which were at least as significant statistically as the values obtained using conventional discriminators such as car ownership, income and household size. In a more detailed analysis, which involved reconstructing out-of-home activity patterns from the trip data, Knapp (1983) was able to confirm a number of the characteristics of household behaviour described in the prototypical patterns in Figure 5.9. For example, he found a marked switch from work (Group A) to domestic-type travel (i.e. shopping, chauffeuring) during the day for wives in group C, and a sharp drop in evening activities among adults when comparing groups A and C: over a seven-day period, group A members in his sample spent most time out of home in the evening, with an average of about 30 per cent of them being out between 9 pm and 10.30 pm each evening.

Kitamura (1983), and Kostyniuk and Kitamura (1983) report on

*Other examples are presented in Chapter 10.
findings from recent studies which have analysed the 1965 Detroit Area Transportation and Land Use Study data from an activity perspective. Despite important differences between Britain and North America (for example, with regard to shop opening hours), the authors were able to confirm several of the results presented here. With regard to journey structure, for example, Kitamura (1983) found that households in life cycle group A linked their trips into chains more often than those in group C, which the author attributed to the fewer constraints acting on and the greater non-home orientation of the former group (because of work roles, absence of children, etc.). He also found, using a canonical correlation analysis, that the structure of travel patterns related much more closely to social roles and the non-home activity set than to conventional measures of individual characteristics.

In the second study (Kostyniuk and Kitamura, 1983), the authors looked more closely at inter-personal linkages among evening non-home activities and travel. They noted in general that 'the presence of children in the household has substantial impacts on adult members activities and travel', and were able to confirm several of the differences between household behaviour in life cycle stages A and C reported earlier. For example, they found that: 'young couples without children jointly pursue evening activities more frequently than those with preschool or school-age children'.

The concepts embodied in an activity-oriented approach to studying travel behaviour thus provide the basis for a new understanding of travel and its role in daily life, which can be verified empirically and that leads to new insights and quantitative relationships.
6. HOUSEHOLD ADAPTATION

6.1 Factors Promoting Changes in Behaviour

A household's basic activity-travel pattern may alter little over a number of years, once habitual routines have become established, but eventually one or more household members will be confronted by circumstances that demand or invite some form of response. Such a stimulus may arise from three main sources:

(a) **Changes in role.** This is most commonly associated with moves between stages in the family life cycle, or perhaps the death of a spouse. In present circumstances, redundancy and unemployment can also have a large impact on a household's behaviour, because of role re-assignments and:

(b) **Changes in resources.** Household activity patterns are adapted to the resources available (e.g. income level, number of cars owned, size of house) and so an increase or decrease in the resource level — usually brought about (directly or indirectly) by financial circumstances — will lead to a revised pattern of behaviour.

(c) **Changes in the external environment.** The stimulus for action may lie outside the home. Often it is associated with an improvement (e.g. new shopping centre) or a deterioration (e.g. reduction in bus service) in the quality or number of activity and travel facilities available. Sometimes it may be a more general factor (e.g. a growing fear of going out at night on foot) and, on a day-to-day basis, weather conditions may strongly influence the more discretionary aspects of the activity-travel pattern (e.g. see Duffell, 1972).

Although any of the three stimuli may be responsible for initiating a change in behaviour it is often easier to identify the
individuals affected by role and resource changes. External changes may apply to everyone in an area, but yet may have little or no impact on many of them because it is not relevant to their lifestyle. A habitual car user may be unconcerned about — and indeed will probably be unaware of — a proposal to withdraw a local bus service, while a retired couple may have no interest in changes in education policy — unless they have a grandchild who is affected.

One advantage of studying travel in the context of activities is that it is usually the activities that are directly affected by a change and which then, in turn, may require adjustments to the original travel pattern. This can be seen, for example, in Table 6.1 which shows the effects on activity patterns of seasonal variations in weather and daylight hours. Marked differences can be observed between winter and summer activity patterns, with a switch from T.V. to out-of-home leisure activities as the daylight hours increase; there is also a tendency to complete domestic activities during weekday evenings in the summer, to leave the weekend free for other activities. These differences have important consequences for social/recreational travel.

The framework developed in Chapter 5 to account for the content and structure of household activity patterns also provides a useful basis from which to examine how households adapt to changed circumstances. Much can be learnt in this respect from cross-sectional data; the examples of characteristic activity-travel patterns for lifecycle stages A and C (section 5.4) demonstrate some of the effects that a change in role for a wife (from wage-earner in A to mother in C) can have both on her own and her husband's daily behaviour.* This chapter goes somewhat further, however, and uses the activity approach to

*Clarke and Dix (1983) have proposed that stage in family lifecycle be used as the basis of a dynamic approach to the long-term forecasting of travel behaviour.
Table 6.1
Impact of Seasonal Changes on Activity Patterns

<table>
<thead>
<tr>
<th></th>
<th>Sundays 16.00 - 16.30</th>
<th>Mondays — Fridays 19.00 — 19.30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winter %</td>
<td>Summer %</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>70</td>
<td>54⁻</td>
</tr>
<tr>
<td>Not at home</td>
<td>27</td>
<td>40⁺</td>
</tr>
<tr>
<td>No information</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td><strong>Main activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watching television</td>
<td>28</td>
<td>19⁻</td>
</tr>
<tr>
<td>Personal care and meals</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Work and school time</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Domestic duties</td>
<td>13</td>
<td>9⁻</td>
</tr>
<tr>
<td>Other at home type activities</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Not at home — indoor activities</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Not at home — outdoor activities</td>
<td>9</td>
<td>20⁺</td>
</tr>
<tr>
<td>Asleep or in bed</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>No information</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**NB** Percentages may not sum to 100%
Figures based on samples of approximately 1800 persons

**Key**
'⁺' = Higher Activity Participation in the Summer
(As Compared to the Winter)

'⁻' = Lower Activity Participation in the Summer
Than in the Winter

**Source** — B.B.C. (1975)
examine the nature of adaptation at an individual and household level, in order to understand the processes at work behind observed aggregate changes in behaviour.

In particular, we concentrate on the effects that changes in conditions external to the household can have on activity-travel patterns, emphasising in the empirical examples changes that relate to transport or land use policy. The next two sections examine the nature of household adaptation and the response strategies which households adopt. Section 6.4 then presents some findings from a detailed study of household adaptation in relation to proposals for school hour changes.

6.2 Elements of Household Adaptation

By its nature, household adaptation is a complex, dynamic process, often involving group decision-making in the context of imperfect knowledge, with many factors to be taken into account. In this section we consider four main elements of adaptation (the dimensions of impact, the secondary consequences of such impacts, threshold effects, and the influence of subjective factors on response), drawing where appropriate on simple examples. For an overall picture of how these elements combine to provide an explanation of response to change, the reader is referred to section 6.4.

Dimensions of Impact

People experience the effects of external changes in terms of their impacts on the activities they take part in and the facilities they use. Some changes directly affect the activity itself (e.g. consequences of the drink-and-drive legislation for drinking habits), but in most cases it is the characteristics of the facilities that are modified (e.g. from revised shopping hours to refurbished public transport vehicles),
and which in turn call for (or invite*) changes in the characteristics of the activities undertaken.

The dimensions of behaviour that may be directly affected in this way by an external change and which can be measured within the activity framework are shown in Figure 6.1. They comprise:

(a) The range of activities within the activity set
(b) The attribute characteristics of which an activity is composed.
(c) The time spent on an activity.
(d) The spatial location of activities and routes of travel.
(e) The timing of activity participation.
(f) Linkages between individuals participating jointly in an activity.

In most cases an external change will affect several dimensions simultaneously. Thus, an increase in travelling time to work will affect both the duration and timing of the activity (although the converse is not necessarily true: a change in timing may leave activity duration unaffected), and spatial changes in behaviour usually require associated changes in activity timing and (possibly) duration.

Secondary Consequences

The impacts on behaviour described above arise as a direct consequence of an external change and are integral with it. In most cases, however, there are important secondary effects that can be measured. These arise either out of the ramifications of accepting the direct effects, or because people are not prepared to accept, or are unable to accommodate, the consequences of the external change and so adopt a different form of behaviour (e.g. find another way of satisfying a

*Depending on whether the external change is 'forced' or 'permissive' in nature (e.g. closing or opening a facility, respectively); see Heggie and Jones (1978).
Figure 6.1: Dimensions of Behaviour Affected Directly by a Change

(a) Activity Set:
\[ A_1, A_2, A_3, A_4, \ldots, A_n \]

(b) Activity Quality:

(c) Activity Duration:

(d) Activity Location:

(e) Activity Timing:

(f) Inter-Personal Linkages:
particular need). An important feature of the activity framework as set out in Chapter 5 is that, because it provides a continuous measure of human behaviour throughout the day, it is able to examine — and indeed it forces consideration of — these secondary impacts.

Some examples of how secondary effects are taken into account are given in Figure 6.2. Case (1) illustrates how a change in time allocation to one activity automatically requires a compensating adjustment to the time spent on one or more other activities (assuming that it is not possible to carry out two major activities at the same time), in order to preserve the 24 hour time budget.

In the second case a change in travel time brought about by a reduction in bus service frequency affects the timing of adjacent activities at both the trip origin and trip destination. Indeed, the timing of several subsequent activities will also have to be adjusted to compensate (as shown), unless the retarding effect of the later journey can be 'absorbed' within the activity pattern, by shortening the duration of one or more activities, or by cutting out an activity altogether. The next example shows the reverse situation, namely the secondary effects on travel of changes in non-travel activities. The diagram illustrates, in a very simple way, how travel is commonly generated: as a consequence of a decision to engage in an out-of-home activity in place of an in-home one.

Case (4) is more complex and shows how, through inter-personal linkages, other people may become involved as the individual affected directly by a change attempts to re-adjust his/her daily activity-travel pattern. Two types of transmitted effect are depicted here: the re-assignment of an activity from one person to another, and the need for Person Two to adjust the timing of a joint activity in phase with a change 'forced' on Person One. If this cannot be done the linkage may have to be broken, as a result of which the activity may be
Figure 6.2: Mechanisms for Transmitting Secondary Effects

(1) Adjustments to the Time Budget:

\[ dj = d_1 + d_2 + d_3 \]

Where: \( d_1 = d_2 + d_3 \)

(2) Secondary Repercussions on Activity Timing:

TOWN CENTRE → Shopping → Wait → e.g. withdraw a bus

TRAVEL

HOME

TIME OF DAY

(3) Consequences for Travel of Changing Activity Travel Facility:

NON-HOME

TRAFFIC

HOME → WATCH TELEVISION

TIME OF DAY

(4) Adjustments to Inter-Personal Linkages:

PERSON ONE

Re-Assign Activity

PERSON TWO

Change in timing for Person 1...

Joint Activity

...forces corresponding change for Person 2
abandoned by one or both people.

Threshold Effects

The examples in Figure 6.2 dealt with a number of mechanisms through which the outcome of a change may extend beyond its immediate impact. In some cases, because of limits on the amount of flexibility in timing within an activity-travel pattern (due to restraints on inter-personal linkages, and time-space constraints of an institutional or physiological/psychological nature), a threshold point may be reached beyond which adjustment involves a more fundamental restructuring of the individual's activity-travel pattern.

Figure 6.3 attempts to set out at a conceptual level some circumstances in which threshold effects may arise, and indicates how they might be accommodated. Threshold effects are difficult to identify or describe in a static way, using cross-sectional data, as they have an essentially dynamic character. Figure 6.3 should thus be seen as a representation of a process of change (the compressing of an activity, a slippage in timing, etc) which operates until the point where this adjustment cannot be taken further and a threshold is crossed that demands a more fundamental adjustment in behaviour.

The figure is in three parts. Part I illustrates some ways in which threshold points may arise, because of absolute limits on the amount of change that can be absorbed along a particular dimension. Part II tries to show how pressure to delay the start of activity A may be accommodated by adjusting the timing and/or reducing the duration of the activity, until threshold points are reached. And Part III sets out some ways in which behaviour might be adapted if the delay to activity A were to push it beyond the threshold point.

A rather more practical example, showing how the concept of a threshold may affect a complete activity-travel pattern, is shown in
Figure 6.3: The Generation and Resolution of Threshold effects

I. HOW THEY ARISE

(1) Adjustment Limited by a Fixed Timing Constraint:

(Fixed duration)

(2) Minimum Activity Duration:

(3) Threshold Introduced via Inter-personal Linkages:

II. THE CONSEQUENCE

III. STRATEGIES FOR RESOLVING THE PROBLEM

- Reduce or give up activity 'B'
- Reduce travel time 'T', by:
  (i) Using a faster method of travel
  (ii) Reducing journey length, through trip chaining or selecting new location
- Re-arrange the activity-travel pattern, in order to carry out activity 'A' at a different time of day
- Re-assign activity 'A' to another person
- Postpone activity 'A' until another day
- Consolidate activity 'A' (ie undertake less often)
Figure 6.4. It is based on the behaviour of the hypothetical individual used to illustrate concepts in Chapter 5, (see especially Figures 5.2 and 5.3) and assumes that the same land use and transport facilities are available to him. The figure shows how a gradual, but continuous change in work hours (expressed in terms of a later starting time) would trigger a series of thresholds, each of which would lead to some restructuring of the activity-travel pattern.

The original work hours are as in Figure 5.3; that is, from 08.30 to 17.00, with 45 minutes for lunch. As work hours are made progressively later, four threshold points are crossed, each of which has repercussions both on activities and travel. The main effects are summarised in Table 6.2; note, that for illustrative purposes this assumes that the person tries to maintain the same activity set.

**Subjective Factors**

So far we have examined the role of a number of dimensions and mechanisms that affect household adaptation. Note, however, that in the examples that have been used there has been an element of discretion, in which personal preferences and household decision rules affect the form and extent of direct and secondary effects.

Consider Figure 6.2, for example. In case (1) there is probably some choice over how to allocate the time budget cutbacks arising from an increased time allocation to activity A2; in case (2) there is some discretion as to when and how to absorb the travel delay within the remainder of the day's activity pattern, and in (4) there is the question of whether or not the two people decide to maintain the activity linkage in some way. Finally, example (3) is discretionary by nature, and arises from a choice between alternative leisure activities; here personal preferences are an important factor.
Figure 6.4: Impact of an Increasing Retarding of Work Hours on the Activity Pattern of Figures 5.2/3.

a) 10 minutes or less:

Shop at lunchtime, instead of after work.

b) 10-30 minutes later:

Shop at lunchtime, instead of after work.

NO CHANGE

c) 30-60 minutes later:

Shop at lunchtime; travel straight to college after work.

d) 60-90 minutes later:

Shop before work; travel straight to college after work.
<table>
<thead>
<tr>
<th>Size of Retardation in Work Hours</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 10 Minutes or Less</td>
<td>Behaviour unchanged and shopping activity compressed. The person originally has 25 minutes after work to complete his shopping and it is likely that he would condense this if he had slightly less time for the activity — perhaps putting off larger purchases until the week-end.</td>
</tr>
<tr>
<td></td>
<td><strong>Threshold 1</strong> — 17.10</td>
</tr>
<tr>
<td>(b) 10-30 Minutes Later</td>
<td>Re-schedule shopping activity. This would leave insufficient time after work for shopping, which would have to be carried out at the same shopping centre at lunchtime (unless it were postponed to the weekend).</td>
</tr>
<tr>
<td></td>
<td><strong>Threshold 2</strong> — 17.30</td>
</tr>
<tr>
<td>(c) 30-60 Minutes Later</td>
<td>Lose the opportunity to return home between work and evening class. The person would not be able to catch the 17.30 bus and would have to wait until 18.30. If he decided to continue at evening class he would have to eat at or near work and travel straight to the college. Lunchtime shopping would still be required.</td>
</tr>
<tr>
<td></td>
<td><strong>Threshold 3</strong> — 18.00</td>
</tr>
<tr>
<td>(d) 60-90 Minutes Later</td>
<td>Opportunity to shop before work is added. With shops opening at 09.00 and work starting at 09.30 it would be possible to do the shopping on the way to work, again releasing the lunch period for a full meal. This becomes more essential because the time available for eating after work before catching the bus to evening class is becoming insufficient.</td>
</tr>
<tr>
<td></td>
<td><strong>Threshold 4</strong> — 18.30</td>
</tr>
<tr>
<td>(e) Over 90 Minutes Later</td>
<td>No longer possible to complete the activity set. The individual would now miss the 18.30 bus and so be unable to attend evening class, unless he could obtain a lift. At this point he might consider buying a car — or changing his job because of the unsocial hours that were being demanded of him.</td>
</tr>
</tbody>
</table>
Among the more subjective factors affecting household adaptation we can identify: individual and group preferences and perceptions; subjective constraints on choice (e.g. a decision to make certain activities like dinner a joint event, or about the age at which a child is allowed out alone); the generation and evaluation of response options; and household trade-offs and decision rules. With regard to the last factor, Clarke and Dix (1980) suggest that it is possible to identify differences in decision rules between the various life cycle groups; we saw in section 5.4, for example, how group 'A' household members attempt to maximise joint free time, but this may not be a major objective for people in other groups.

Figure 6.5 illustrates the way in which subjective factors can operate in conjunction with more 'objective' linkages and constraints to produce a particular household response to changed external circumstances. It shows reported differences in the behaviour of one household as a consequence of the husband working different shift times.

This is a three person family, comprising husband, wife and young daughter, who live in a suburb of Reading. The husband works an alternating shift system, with two weeks on early shift (06.00-14.00), followed by two weeks on late shift (14.00-22.00). There is one car in the household, which the husband uses for work.

When the husband is on early shift (Figure 6.5a) he leaves home before the rest of the family get up, and returns by early afternoon. The wife has breakfast with her daughter and escorts her to school (on foot) and then catches a bus to work. The daughter has lunch at school and in the afternoon returns home to be looked after by her father; this means that the wife does not have to rush home to meet her daughter, so is able to spend time after work in shopping or social activities, on her way home by bus. The family have dinner together, and the husband remains home in the evening; this gives the
Figure 6.5: Effect of Husband's Alternate Shifts on the Household's Activity-Travel Pattern

(a) Early Shift (06.00-14.00)

HUSBAND

6  8  10  12  14  16  18  20  22

SCHOOL

DAUGHTER

WORK

WIFE

(b) Late Shift (14.00-22.00)

HUSBAND

6  8  10  12  14  16  18  20  22

SCHOOL

DAUGHTER

WORK

WIFE

key:

- Joint household activities
- Arrangements for child supervision

Source: Jones and Dix (1978)
wife a chance to make local social visits using the household car.

The change from early to late shift not only affects the husband's activity pattern in a major way, but those of the daughter and wife as well. When the husband is on late shift (Figure 6.5b) the family have breakfast together, and the husband drives his daughter and wife to school and work, respectively. He then takes part in shopping, service or social activities before returning home to cook lunch for himself and his daughter; he then leaves for work. The daughter now comes home from school during the day, and on her return home from school in the afternoon is met by her mother. For the wife, this means having to rush home by bus from work after a hurried shop, to be there in time for her daughter's return; after which she has to remain at home for the rest of the day in order to look after the child (and partly because of lack of transport which would enable them both to go visiting together).

The timing of the husband's work activity thus has a major impact on the whole family, in part because of the role switching at different times of day (relating to who is available to look after the daughter), but mainly because of his wish to spend as much time as possible with his daughter, and the parent's wish to make full use of the car.

Implications for Travel

The human activity approach offers a very attractive basis on which to study household adaptation. It deals directly with the spatial and temporal components of behaviour and provides a framework within which the more subjective aspects of behaviour can be incorporated. It is able to measure various elements of response and to identify a number of mechanisms that can lead to secondary effects on behaviour. In this way it is possible to examine the repercussions of an external
change on the activity patterns of those either directly or indirectly affected. From the viewpoint of understanding travel behaviour, the activity approach is able to take account of a range of non-travel (as well as travel-related) factors which may affect the way in which travel patterns are modified in response to change.

This is evident when we re-examine two of the earlier examples of household adaptation from a trip-based perspective. In the case of the multi-person household (Figure 6.5), the impact on travel for the family as a whole of the change in the husband's hours of work is shown in Table 6.3a. The alternating shift system in itself does not produce a different travel pattern (since the husband makes two home-based car driver trips on both shifts); rather, it is the way in which the family take advantage of the re-timing of the activity to maximise car use and personal contact that leads to the change in travel pattern.

The example of the single person household faced with an increasing retardation of work hours (Figure 6.4 and Table 6.2) shows even more clearly the importance of timing and space-time constraints as factors affecting travel behaviour. Here trip rates at first increase and then decrease as work hours become successively later (see Table 6.3b). It would clearly have been impossible to explain or anticipate these consequences without viewing travel as one element of a pattern of daily behaviour in space and time.*

*Although both these examples discuss changes in behaviour brought about by obligatory changes in activity timing affecting working hours, similar mechanisms would apply where changes were made for optional reasons (e.g. to pursue a new activity, or take advantage of an external change to release a tension in the activity pattern), with the subjective factors in most cases assuming a greater importance.
Table 6.3a
Effects on Household Travel of the Response to Alternative Shifts Illustrated in Figure 6.5.

<table>
<thead>
<tr>
<th>Trips by</th>
<th>Early Shift</th>
<th>Late Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car (driver)</td>
<td>2 - 4</td>
<td>4 - 5</td>
</tr>
<tr>
<td>Car (passenger)</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Bus</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Walk</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>7 - 9</strong></td>
<td><strong>11 - 12</strong></td>
</tr>
</tbody>
</table>

Table 6.3b
Changes in Travel Associated with the Revisions to Work Hours in Figure 6.4.

<table>
<thead>
<tr>
<th>Adjustment to Work Hours</th>
<th>Corresponding Travel Pattern</th>
<th>Total Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Original hours</td>
<td>4 Home-based</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1 Non home-based</td>
<td></td>
</tr>
<tr>
<td>(2) 10 minutes or less</td>
<td>NO CHANGE</td>
<td>5</td>
</tr>
<tr>
<td>(3) 10 - 30 minutes later</td>
<td>4 Home-based</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2 Non Home-based</td>
<td></td>
</tr>
<tr>
<td>(4) 30 - 60 minutes later</td>
<td>3 Non Home-based</td>
<td>5</td>
</tr>
<tr>
<td>(5) 60 - 90 minutes</td>
<td>2 Home-based</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2 Non Home-based</td>
<td></td>
</tr>
</tbody>
</table>
6.3 Household Response Strategies

Once households have developed a routine activity-travel pattern which enables them to meet role commitments and satisfy needs and wants, studies reviewed in Appendix I suggest that there is often a tendency to resist change. Wherever possible, external changes are absorbed into the current activity pattern without disturbing the basic routine — unless the perceived benefits outweigh the inertia, psychological and other costs of change.

As we have seen, however, there are limits to how much change an activity pattern can absorb, because of the existence of various threshold points within the pattern (see Figures 6.3 and 6.4). In some ways an activity pattern is analogous to a kaleidoscope. A small policy change usually has only a minor impact — taking up some slack in a person's day, or reducing the pressure they find themselves under — but as the change increases in magnitude a point may be reached where a fundamentally different pattern is formed.

On the basis of work described in section 6.4 and Chapter 9 and other research findings, there is tentative support for the notion of classifying household adaptation into a series of response strategies of varying composition and complexity. Some examples of different levels and types of response strategy are given in Table 6.4; the concept is discussed more fully in Jones, Dix, Clarke and Heggie (1983), Chapter 10. The six responses listed in Table 6.4 range from psychological adjustment through to major structural changes in household resource allocation, and are ordered approximately in terms of increasing magnitude of response. Four levels of response are identified: no change in behaviour; changes to specific activity events; larger changes involving some restructuring of activity patterns; and major structural change.
Table 6.4: Some Household Response Strategies

<table>
<thead>
<tr>
<th>Level of Impact of Change</th>
<th>Level of Response</th>
<th>Nature of Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVENT (Qualitative Change)</td>
<td>NO CHANGE IN BEHAVIOUR</td>
<td>(1) Adjusts psychologically</td>
</tr>
<tr>
<td>EVENT (Quantitative Change)</td>
<td>ADJUST EVENT IN SPACE/TIME</td>
<td>(2) Minor adjustments to timings, but preserve activity sequence, by adding some filling-in time, or by reducing (or extending) time spent on major activities.</td>
</tr>
<tr>
<td>PATTERN</td>
<td>RE-STRUCTURE ACTIVITY PATTERN</td>
<td>(3) Maintain same (or similar) activity sequence, but make minor changes to location of events and characteristics of the travel pattern (eg. transfer from walk to bus mode).</td>
</tr>
<tr>
<td>RESOURCE ALLOCATION</td>
<td>MAJOR STRUCTURAL CHANGE</td>
<td>(4) Preserve existing activity set (and maintain same roles), but re-arrange the activity pattern in space and time; this will normally have a more radical impact on travel than (3).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5) Revise activity set, either by substantially altering household activities, or by re-assigning tasks to other household members (ie. changing roles within the household or extended family).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6) Make a structural change in household resource allocation, by buying a car or changing house or place of employment.</td>
</tr>
</tbody>
</table>
Policy measures may have a direct impact at any one of these four levels. The person affected may attempt to resolve the problems caused (or the opportunities afforded) by this change at the level at which it first arises, but if this is not possible or desirable he/she will move down to the next level of response to seek a resolution. In the extreme, therefore, an increase in crowding on a commuter rail journey (i.e. a 'qualitative' change in an event), may in the end lead to the purchase of an additional car in the household, or even trigger a residential relocation. Cullen (1978) and Michelson (1977) have shown how such major, long term decisions can be precipitated by changes that cause pressures at the day-to-day level.

The findings presented in the next section provide examples of response at the event and the pattern re-structuring levels. The notion of household response strategies has important implications for the modelling of travel behaviour, which are examined in some detail in Chapter 10.

6.4 A Study of Household Response to School Hour Changes

This section provides some examples of the mechanisms of adaptation and the levels of response that were identified in a study of the impacts of school hour and school bus changes in West Oxfordshire. The study is reported in detail in Jones (1978c).

From the start of the 1976 autumn term, school hours at Burford comprehensive school, West Oxfordshire, were advanced by half an hour, from 09.00-16.00 to 08.30-15.30. Most pupils travelled to/from school using school buses, and the local authority introduced this change in order to stagger hours at nearby schools and so reduce their peak school bus fleet requirement. Because children from different areas travelled on separate buses, they were affected differently by the
revised school bus schedules: some left or arrived home at the same
time after reorganisation as previously, whereas others were travelling up to one hour earlier. Rather than everyone responding similarly to a half hour change in school hours, therefore, families were affected by between a zero and one hour change in the time of their children leaving for or returning home from school. Accordingly, the effective impact of the policy ranged from insignificant to quite major.

The main interviews were carried out in August 1976, a few weeks before the school hour changes were introduced, and the exercise involved an examination of the probable impacts of the changes for a typical school day.* In order to explore the processes involved, particularly the group dynamics of adaptation, a gaming simulation technique known as 'HATS' (Household Activity-Travel Simulator) was used in the main interviews; the technique is described in section 9.2. Thirty-four households were successfully interviewed by the writer and others using HATS, with a total of 149 people taking part, of whom 62 were pupils who attended the affected school.

The results reported here are thus for simulated rather than observed responses. A subsequent mailback questionnaire confirmed that households had in general responded in the ways anticipated. However, it was not possible to carry out a quantitative comparison because in several cases school bus times were re-adjusted soon after the start of the term (and anyway responses had been discussed in relation to a typical day not an actual one). A test of the reliability of the results using the HATS technique was subsequently carried out in another context, however (see Table 9.1 and section 9.2), with very encouraging results: HATS seemed to produce reasonable predictions.

*The preferred option of discussing an actual school day could not be adopted, because pupils had been on holiday for 3-4 weeks at the time of interview and so it seemed unreasonable to expect reliable recall of activities for a predetermined term time day.
of behaviour and provided a unique opportunity to examine the dynamics of the processes involved.

Aggregate Changes in Behaviour*

If the aggregate responses to the revised school hours are examined in terms of changes in average daily time budget (i.e. as in Figure 6.2, example 1), the overall impact on the pupils attending Burford school appears to be relatively small (Table 6.5). The major effect was due to the introduction of more efficient school bus schedules, which on average meant that pupils saved 0.4 hours per day which they had previously spent waiting around for transport before or after school. About three quarters of this extra time was spent relaxing or watching television and the remainder (0.1 hrs) was used in more active recreation, usually outside the home. Shopping and the use of services also showed a slight increase, but averaged across the whole sample it was hardly detectable. Overall, increased participation in out-of-home activities led to a 12 per cent increase in trip making for non-educational activities. Table 6.5 also shows a small increase (0.1 hrs) in time devoted to educational activities (mainly homework), matched by a fall in sleep time; this reflects a change in the school year between the 'before' diaries (for a typical summer term day) and the HATS simulation which related to changed conditions in the autumn term.

When the effects on household activity patterns are disaggregated by time of day, however, the impacts are more extensive and it becomes apparent that many pupils were affected for periods well outside normal school hours. In total about 30 per cent of other household members (drawn from half the households interviewed) also found it necessary

---

*Most analysis used a 15 minute duration as the basic unit, and this limits the resolution at which responses can be examined.
### Table 6.5

**Effects of Revised School Hours on the Time Budgets of Sampled Pupils**

**Comparison of 'before' and simulated 'after' diaries**

<table>
<thead>
<tr>
<th>Activity Group</th>
<th>Average Change in Time Budget (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep</td>
<td>-0.1*</td>
</tr>
<tr>
<td>Personal Care</td>
<td>-</td>
</tr>
<tr>
<td>Meals</td>
<td>-</td>
</tr>
<tr>
<td>Domestic Chores</td>
<td>-</td>
</tr>
<tr>
<td>Shopping/services</td>
<td>-†</td>
</tr>
<tr>
<td>Education</td>
<td>+0.1*</td>
</tr>
<tr>
<td>Work</td>
<td>-</td>
</tr>
<tr>
<td>Social</td>
<td>-0.4**</td>
</tr>
<tr>
<td>Recreation</td>
<td>+0.1</td>
</tr>
<tr>
<td>T.V./Relaxation</td>
<td>+0.3</td>
</tr>
<tr>
<td>Travel</td>
<td>-†</td>
</tr>
</tbody>
</table>

* Associated with pupils going up a year at school

** Mainly accounted for by reduced waiting time for school transport

† Increase less than 0.05 hours on average.

**Source** Jones (1978c), Table III.1
to make some adjustment to their weekday routines. Figures 6.6 and 6.7 illustrate different ways of measuring the impact of the policy on activity patterns. Distributions are presented separately for Burford pupils and other household members who were affected. Activities were classified into eleven groups (i.e. sleep, personal care, eating, domestic, shopping/services, work, education, social, recreation, relaxation and travel), and the set of locations comprised the respondents' homes, schools or workplaces and about 40 local towns or villages.

Figure 6.6 depicts changes in activity patterns by recording the number of respondents who altered the type or location of their activity (as defined above) as a result of the school hour change, for each 15 minute time period through the day. The figure distinguishes between changes entirely within the home (e.g. now eating over the period 07.45-08.00 instead of washing) and those which affect the use of out-of-home facilities (e.g. now travelling at time period t instead of waiting at school, or visiting a youth club instead of watching television at home). The Burford pupils were forced to modify their behaviour in the periods when school hours changed (i.e. 08.30-09.00 and 15.30-16.00), as well as a varying additional amount due to the local school bus service revisions, but Figure 6.6 shows how the mechanisms illustrated in Figure 6.2 led to secondary effects at other times of day and involving other household members. It is apparent that household activity patterns were affected up to two hours either side of the school hour changes, and that about 20 percent of Burford pupils were affected well into the evening.

A broader measure of change is used in Figure 6.7. This records for each 15 minute time period, the number of people who were carrying out an activity at that time which had changed in some way at some point in its duration — not necessarily in that time period. This
Figure 6.6: Simulated Changes in Activity Patterns Due to School Hour Revisions, Using a Restricted Definition of Change

Burford School Children (N=62):

- All recorded changes in activity or location
- Changes affecting only out-of-home activities

Source: Jones (1978c), Figure III.4.

Other Household Members (N=87):
Figure 6.7: Simulated Impacts of School Hour Revisions Using a Broader Measure of Change

Burford School Children:

Source: Jones (1978c), Fig III.5
measure allows for the fact that an activity may change significantly in a qualitative sense if part of it has been affected in some way: a 15 minute breakfast may be a very different experience from a 30 minute one. To illustrate the effect of these different measures consider a person who changes his evening meal time from 18.00-19.00 to 18.15-19.15. The simple measure used in Figure 6.6 will record a difference in behaviour during two time periods (i.e. 18.00-18.15 and 19.00-19.15), while the more complex measure will register a difference for all five time periods (i.e. 18.00-19.15) and probably beyond — until such time as the adjustment has been completely absorbed within the activity pattern.

The two measures thus provide upper and lower indices of the degree of change in daily activity-travel patterns. The simpler measure provides a minimum, more 'objective' measure of change, while the more complex form attempts to measure the maximum impact of the subjective effect of timing or duration changes — though it cannot indicate the strength or direction of such effects, in an evaluative sense. A comparison of the simple and complex measures in Figures 6.6/7 emphasises the way in which the children's activities are affected well outside the timing range of the policy change, with a tapering effect right through the evening. The full extent of indirect effects on other household members is also made explicit.

Figure 6.8 stratifies the two measures of pattern adjustment by the degree of change in home departure and arrival times experienced by each pupil (rounded to the nearest 15 minutes). Note how even a 15 minute adjustment in the morning led to quite significant changes in pre-school activities for many of those affected, whereas in the evening adjustments were rapidly absorbed for up to a 30 minute earlier arrival home — at which point there appears to be a threshold effect, with secondary changes occurring well into the evening.
Figure 6.8: Simulated Impacts, Stratified by Change in Home Departure/Arrival Times, Using Both Measures of Change (Burford Pupils ONLY)

**MORNING DEPARTURE:**

- **DEPARTURE UNCHANGED**
- **15 MINS EARLIER**
- **30 MINS EARLIER**
- **45 MINS EARLIER**
- **60 MINS EARLIER**

**AFTERNOON ARRIVAL:**

- **ARRIVAL UNCHANGED**
- **15 MINS EARLIER**
- **30 MINS EARLIER**
- **45 MINS EARLIER**
- **60 MINS EARLIER**

**KEY:** Measures of adjustment

- Change in activity/location, by individual time period.
- Change in activity or location or overall duration/timing.

**Source:** Jones (1978c), Figure III.7
The Processes Involved

The study examined not only the results of adaptation, but the processes involved as well. The various aggregate changes in behaviour described above represent three distinct types of response to the policy change, involving: the school journey, adjustments to in-home activity patterns, and secondary effects on travel and out-of-home activities in the late afternoon and evening. Each is considered briefly below.

(a) Changes in school journey. Most children travelled to/from Burford school by contract bus at local authority expense and any change to their school journey resulted from revisions to the service pattern. In about 10 per cent of the households interviewed, however, part or all of the school journey was made in the household car and this meant that chauffering arrangements had to be modified in some way; in each case this led to a reduction in vehicle mileage. In two instances, the earlier return home enabled the family to combine meeting the children off the school bus with another travel-generating activity, so saving a return car trip in each household. The adjustment mechanism is illustrated in Figure 6.9

(b) Changes to in-home activities. The majority of households experienced some change in their in-home activity patterns. In most cases the wife was particularly affected by the need to rise earlier to prepare her children's breakfast and get them ready in time for school. The extent to which the husband was involved depended on whether the temporal adjustments caused by the Burford changes impinged on his established work routine: 'It won't affect me whatsoever, because I'm gone before they start, and I don't come home until after they get home', was a common response. In nearly all families the time of the evening meal remained unchanged, being more directly
Figure 6.9: Adjustments to Chauffeuring Arrangements in One Household Arising from the Proposed Changes in School Hours:

Before: Husband meets child

After: Wife meets child

The school child travels to/from Burford school on the school bus, but lives on a farm and has a 2km. walk from the bus stop in the evening. In the before situation, the wife returns home from work and prepares the evening meal while the husband goes out from the farm in her car to meet their son at the bus stop. After school hours are brought forward, the wife is able to make a slight detour on her way home to pick up the son — thereby saving the husband a 4km. round trip.

Source: Jones (1978c), Figure III.6A
related to the husband's work routine (except where he worked late or was often away). This therefore acted as a fixed point around which other activities might be re-arranged to take advantage of the earlier return home, (see response (c)).

(c) Other changes in travel and out-of-home activities. In cases where the school hour revisions resulted in children arriving home considerably earlier (and hence relaxing the time pressure in the afternoon), this created opportunities for two types of trip making shown in Figure 6.10:

(1) To attend late-afternoon activities which previously had to be foregone or carried out at weekends, because closing times precluded attendance after school. Visits to a nearby town for shopping or medical purposes were cited as examples of 'generated' trips.

(2) Arriving home earlier enabled in-home commitments to be completed before tea, thus leaving the evening free for a range of family-based or individual out-of-home activities. Youth club and sports centre activities were frequently mentioned. One girl commented that she preferred the new system: 'Because we can get our homework done and then have the rest of the evening free, whereas when we came home normal time we had to come in and have our tea and then do our homework ... so you couldn't go out, or anything.'

Assessment

The gaming simulation technique was able to identify a range of consequences of the school hour/bus changes for household activity-travel patterns, and to examine various mechanisms and decision
Figure 6.10: Opportunities for Participation in New Activities As a Result of Proposals to Advance School Hours

Original Pattern:

Option 1: Extra Activities in the Late Afternoon

Option 2: Extra Activities in the Evening

Key: Fixed Activities

Source: Jones (1982c), Figure B4c
processes that led to the simulated responses of the families interviewed. Although it was not possible to check the results of the simulation against actual behaviour in detail, comparisons carried out in other studies give strong grounds for believing that the technique does provide a reliable guide to household adaptations — and enables insights to be obtained that would not be apparent from a simple before and after study.

In the course of the exercise, for example, it became apparent that although the effects of transport-related policies on in-home and secondary out-of-home activities are usually not considered, in this instance the families regarded these effects as being more significant than the change in school hours itself. Particularly interesting was many households' concern with the secondary impacts on in-home activities. One wife observed, for example, that she was: 'Happier to have the girls home before dark in winter and glad to have an extra hour for homework before the battle with the T.V. begins'. Another was delighted to find that the earlier departure of her children would in future enable her to 'tidy up' before going out: '... that means a lot to me, to get things straight'. In another instance, a father was very distressed to find that the earlier start would result in the loss of a morning game of table tennis or golf with his son — something he valued very highly.

The inclusion of activity patterns inside as well as outside the home is thus not only helpful in terms of an understanding of the mechanisms of more complex household adaptations — it may provide an important measure of public reaction to a proposed policy as well. These points are considered more fully in Chapters 9 and 10.
7. **A COMPARISON OF ACTIVITY AND PERSON TRIP APPROACHES**

7.1 **Introduction**

The first part of this thesis has shown the important role which the concept of the 'trip' has played in the advancement of urban transport planning methodology, over the last twenty to thirty years — initially using vehicle trips as a basic analysis unit, and then extending this in certain types of study to include person trips. There remain, however, a number of policy issues and methodological problems that have not been resolved satisfactorily using these trip-based approaches; they include the analysis and forecasting of some of the more complex behavioural responses to transport policy measures, and policy issues which involve an understanding of the role of travel in daily life and the non-travel aspects of behaviour.

In an attempt to resolve some of these outstanding issues and problems, the thesis has proposed the development of another approach to studying travel behaviour, based on an examination of travel in the context of household activity patterns.

Chapter 5 set out the broad framework of the proposed approach, which takes activities rather than trips as the starting point. Activity participation enables individuals to satisfy needs and fulfil role commitments, by making use of specialised facilities available at discrete points in space and time. The structure of activity patterns can be related to sets of temporal and spatio-temporal constraints and the effects of inter-personal linkages, in the context of personal perceptions and preferences. Section 5.4 presented some evidence from an activity-travel survey to show how the differences in roles and constraints associated with life cycle stage can result in characteristic differences in activity and travel patterns.

Chapter 6 extended the discussion to consider ways in which
routine activity-travel patterns are adapted as households respond to change. Four elements were considered: the various dimensions of impact, the mechanisms that facilitate secondary repercussions, threshold effects and subjective factors. It was proposed that household adaptation could be categorised into an ordered set of response strategies; and, in section 6.4, some findings were presented from a study of school hour changes, dealing both with the aggregate impacts and the processes involved.

This chapter assesses the value of the proposed activity-based approach at a conceptual level. Section 7.2 highlights some of the basic differences between the activity- and conventional trip-based approaches, in terms of the way in which travel is represented and the implications this has for analysing travel behaviour. Section 7.3 returns to the list of requirements of a new approach which was established at the end of Part One of the thesis (section 4.3), and considers the extent to which the activity framework offers a basis for meeting them. A general assessment of the activity approach is made in the final section. The emphasis in this chapter is on conceptual limitations and potential; questions of practicability are considered in Part Three.

7.2 Some Essential Differences Between the Two Approaches

At a conceptual level there are important differences between the person trip and human activity approaches, in terms of general perspective adopted and the depth and breadth of analysis. Three aspects are examined here, in relation to the discussion in Chapter 4: differences in the representation of travel, ability to deal with a wider range of responses, and the question of definitional problems.
Contrasts in the Representation of Travel Behaviour

Some of the contrasts between the trip-based and activity-based representations of travel behaviour are illustrated in Figure 7.1, using a time-space framework. The example is based on the hypothetical individual used to illustrate concepts in Chapters 5 and 6 (e.g. see Figures 5.3 and 6.4).

It will be recalled from section 4.2 that in analysing travel most trip-based approaches make the following simplifications:*

(i) During the recording process, travel is separated from other events in the day and each travel episode is noted separately (i.e. as a trip); as a result the daily context of travel is lost.

(ii) The information is then generalised, to the extent that time of day is reduced to a peak/off-peak measure; because of the severe simplification of the timing information the order of travel is lost.

(iii) The division of trip characteristics into the choice elements of mode, destination, etc has further consequences; in particular, the use of trip productions and attractions, rather than origins and destinations, means that information on the original direction of travel is not retained.

(iv) These three factors together also mean that linkages between trips are also lost (unless transition probabilities are derived from the basic data).

The consequences of this are shown diagrammatically in Figure 7.1a. Travel information is abstracted from the person's daily behaviour, and represented as five trips (here shown as vectors of movement

*An additional problem is the loss of travel linkages between people, which is not shown in Figure 7.1
(a) TRADITIONAL TRIP-BASED PERSPECTIVE:

Nominal Level Groupings

(b) HUMAN ACTIVITY PERSPECTIVE:

Figure 7.1: Alternative Representations of the Travel Behaviour Recorded in Figure 5.2.
between points in space, over time); four are home-based and one is non home-based. Each trip is treated as an independent entity, grouped by main trip purpose. The location of the trip ends in space are usually recorded and analysed to a medium-to-high level of precision (i.e. using traffic zones or grid references), but on the temporal dimension only the duration of travel is recorded in detail.

This is contrasted with the human activity view of travel in Figure 7.1b. Here travel is one element in a continuous sequence of events in time and space (occurring both in-home and out-of-home), where travel and non-travel activities are regarded as being interlinked and interdependent. Although in terms of time allocation travel is a relatively unimportant activity — the average person devotes only about 4 per cent of their daily budget to travel — in spatial terms it is of crucial importance, since it represents the means by which people move between sites in order to take part in successive facility-dependent activities. It is thus primarily a space-shifting mechanism, although in many instances people do derive a positive utility from travel and it may become a desired activity in its own right (e.g. going for a walk or a ride); this feature of travel as an activity is discussed by Matalon (1978).

In contrast to the trip-based framework, the activity framework thus preserves the context, order and direction of travel, as well as the major linkages between trips and between people. This breadth and depth of analysis enables a fuller understanding of household travel behaviour.* Consider, for example, the evening behaviour of

---

*Inevitably, however, this deeper insight is gained at the cost of more detailed data collection and more complex analysis. This emphasises the point made in Part One that each methodological approach in transportation planning has its own strengths and weaknesses, and hence a specific role to play. The activity-based approach is suited to dealing with issues of complex response and the interrelationships between travel and other activities. How this can be achieved is demonstrated in Part Three.
the individual in Figure 7.1. It is apparent from Figure 7.1b that he attends an evening class, after which stays on for a drink at the community hall; in the trip-based representation (Fig. 7.1a), however, the events are recorded as two home-based education trips, and there is no reference to the social activity at all— which may partly explain the evening class attendance.

The activity approach thus retains a number of aspects of behaviour during analysis that are usually 'lost' in trip-based approaches, but which may help to account for travel behaviour. In the case of mode choice, for example, the precise timing of public transport services is not considered in conventional studies. This makes it very difficult to take full account of a basic advantage of walk, cycle and car (when available) over public transport services; namely, the unrestricted availability of the former in space and time, compared with the limited number of potential space-time paths provided by the latter. (Examples of insights into mode choice generated by activity-based studies are cited in Chapter 9.)

Similarly, with trip generation, the activity perspective provides an interpretation that introduces fresh explanatory variables into the analysis. Trips are generated as a consequence of people changing location after using facilities at one site and wishing to move to a different site in order to pursue another activity. Some trips enable compulsory activities to be successfully completed; here travel arises largely as a result of role and institutional factors and has to be undertaken (in some form) if the basic demands on the individual are to be met. In the case of more discretionary activity, transport factors may play a more prominent role in determining the specific activity which is chosen and the location at which it is carried out, since there is greater scope for substitution among activity facilities—and, in particular, between in-home and out-of-home activities.
Here three factors influence the amount of optional travel (see section 5.3): the space-time availability, cost and quality of the transport system; the equivalent characteristics of the land use pattern; and the perceived set of activities which may satisfy a felt need.

**Ability to Deal with a Wider Range of Response**

Because the activity approach incorporates a measure of all forms of daily behaviour, it is able to consider a very wide range of ways in which people are able to satisfy needs and meet role commitments, which may extend beyond or cut across the trip-based view of travel. It is thus possible, at a conceptual level, to look at trip chaining and substitutes for travel within the same framework. By emphasising the activity as the object of interest it is possible to examine a wide range of alternative strategies that are available to a person, in a way that would not be possible using a trip-based analytical framework.

Figure 7.2 illustrates four options available to a person wishing to purchase goods, chat to her friend, and see a film. She could:

(a) Visit activity facilities on separate journeys from home, in order to participate in these three activities (i.e. by visiting a shopping centre, her friend's house, and a cinema). This involves making six home-based trips in order to undertake the set of activities.

(b) Visit the same destinations, but combine the shopping and social visits on one round trip from home. This would involve a re-timing of one of the activities (e.g. visit friend on the way home from the shops in the morning). As a result, trips would be reduced in number from six to five.

(c) Switch destinations, carrying out two activities at the same
Figure 7.2: Alternative Strategies for Satisfying Activity Needs

(a) Single Purpose Journeys:

(b) Multi-Purpose Journeys:

(c) Consolidate Use of Sites:

(d) Substitutes for Personal Travel:

Substitute $A_1$ = Different method of transport
Substitute $A_2$ = Different form of communication
Substitute $A_3$ = Different entertainment activity
site. It might be possible, for example, to shop at another shopping centre in the vicinity of her friend's house—or meet her friend for tea at a shopping centre accessible to both people. This would save a further trip, reducing the trip rate from six to four.

(d) We can also consider ways in which the individual might have met her needs without travelling from home (e.g. if the car had been unavailable). She could have telephoned her friend for a chat; telephoned the shop and arranged for the required goods to be delivered; and stayed at home in the evening and watched television instead of going to the cinema. This would have reduced her person trip rate from six to zero.

There are also other options open to the individual (not shown here); for example, she could consolidate her activities (i.e. spend the same amount of time on an activity over a period, but in fewer time blocks each of longer duration); or, if she were part of a multi-person household, there might be scope for some re-definition of roles.

It is clear that had the options (b) – (d) depicted in Figure 7.2 actually been adopted by people, as a result of a cut-back in supplies of oil or perhaps the introduction of a policy of car restraint, it would have been impossible to measure, interpret, explain or predict these responses using the conventional approaches to monitoring and analysing travel behaviour. The reductions in travel would have been observed, but the spatial consolidation of activities in option (c) would have gone unnoticed, because only the main purpose at a destination is recorded. There would also have been no indication of whether the complete suppression of trips in option (d) was a very serious matter or only of marginal concern: the reduction in the trip rate from six to zero appears drastic in travel terms, but it may still be
possible for the individual to satisfy basically similar needs.

A further feature of the activity framework (not illustrated in Figures 7.1 or 7.2) is its ability to identify the secondary impacts of a policy measure, extending to other times of day and on people indirectly affected. This is not possible to the same degree with the trip-based framework, for three reasons:

(i) The only linkages between people that are considered explicitly are those which relate to travel (i.e. serve passenger trips and car availability), yet there are other ways in which impacts can be transmitted between people, involving non-travel activities.

(ii) The trip-based approach does not normally deal with time of day in any detail, so it is difficult to take account of temporal constraints on re-adjustment, or to identify specific threshold points.

(iii) Each trip is measured as an entity and (except in some cases where transition probabilities are used) successive trips are not linked in any way: it is thus difficult conceptually to know whether or how a change in one trip (e.g. to work) may affect another (e.g. to shop).

The emphasis on pattern in the activity approach means that the analyst becomes very aware of secondary impacts — which, in terms of their effects on activities, tend to be the rule rather than the exception. People are always engaged in some activity (even if it is only 'doing nothing'); they can't be in two places at once, and they can't increase the time spent on one activity or in one location, or alter the timing of an activity, without making corresponding adjustments to other elements of the activity pattern — often with associated consequences for travel behaviour. The activity framework thus uses a deductive logic within a bounded system, incorporating many
factors which may affect travel that are not handled explicitly in the trip-based approaches.

Resolution of Definitional Problems

In addition to the methodological problems and conceptual implications already considered, Chapter 4 identified three problems associated with the definition of travel within a trip-based framework. These were: (1) how short a movement may be considered as a trip? (2) where does one trip end and the next begin? and, (3) what constitutes the main trip purpose? To what extent are these resolved from an activity perspective?

What is immediately clear is that the activity framework changes the nature of the way in which behaviour is measured, and hence the definitional problems that arise. Question (1), about the minimum distance for a movement to count as a trip, no longer exists in this form, but is replaced by a decision about where one facility ends and the next begins (e.g. are we interested only in shopping centres, or in individual shops?).* Similarly, the problem of deciding when one trip ends and another begins (2) has as its parallel the question of how fine a categorisation of activities is to be used — do shopping for bread and shopping for meat count as one or two activities? Only with question (3) dealing with main trip purpose, do we find no parallel, because by focussing on activities this problem no longer arises — a person may take part in several activities at the same location (i.e. destination).

*There is a related practical problem of whether a travel activity is of sufficient duration to be recorded in an activity diary that may take 1, 5, 10, 15 or 30 minutes as its basic unit; but the key is really the definition of facilities, since missing 'short' trips can then be 'reconstructed' and added to the data (e.g. see Van der Hoorn, 1979).
Thus, although the activity approach alters the nature of the definitional problems, and reduces the number of them, it brings with it its own practical problems of classification. Rather than relating to the definition of travel per se, however, they concern the classification of activities and facilities, since it is these which define the separate episodes of behaviour of which the activity pattern is composed.

7.3 An Assessment of the Activity Approach

In the first part of this thesis a number of methodological problems were identified, associated with changing policy perspectives and issues, that had not been resolved satisfactorily using the existing (mainly trip-based) approaches. It was argued in Chapter 4 that a number of these difficulties might be resolved by developing an additional conceptual approach, capable of handling complex behavioural response and issues relating to the role of travel in daily life. Section 4.3 identified six requirements of a new approach. To what extent has the activity framework set out in Part Two been able to meet these points, at a conceptual level?

Satisfaction of General Requirements

In general terms, the activity approach does seem able to go a long way towards meeting each of these requirements. Travel is explicitly treated as a derived demand (point (1)), in that it is viewed as the means by which people change location in order to participate in activities at different sites, so that it arises primarily from choices between alternative activities. The use of a time-space framework for recording behaviour means that the timing of travel (and other activities) is a basic feature of the approach (3) and enables travel to be
analysed as a pattern, rather than as a series of independent events (2). The identification of inter-personal linkages (via joint activity participation) and various time-space constraints enables many forms of interrelationships between events and among people to be examined (4). Finally, the approach does bring out many of the interdependencies between travel and non-travel aspects of behaviour (5) and, because of the semi-closed nature of the system, is able to identify the direct and secondary impacts of transport policy on people's lives (6) that have a behavioural (rather than, say, a psychological) effect.

In terms of the three detailed examples of aspects to be incorporated contained in section 4.3, the approach is clearly able to handle features such as: chauffeuring and other linkages between household members; the effect of the timing of bus services on destination choice; and the secondary impacts of travel cut-backs on both in-home and out-of-home activity patterns.

One important factor largely omitted from the discussion in Part Two, however, has been the financial aspects of activity participation. Thus, little explicit account has been taken of the price of using transport and activity facilities, or how behaviour is constrained by an individual's or household's money budget. This aspect was not given a high priority when formulating the requirements of a new approach in Chapter 4, because the money dimension is well handled in some of the trip-based work (e.g. using concepts of generalised cost and utility maximisation), and it was decided to focus on some areas of major deficiency. Travel studies often take detailed account of the costs of using alternative transport facilities (parking charges, bus fares, etc) and conceptually this could be extended to include the cost of activity facilities as well.

Some of the examples to be cited in Part Three do consider monetary aspects of behaviour, alongside the spatial and temporal ones;
but the lack of a comprehensive conceptual framework fully incorporating cost is an important restriction on the work reported here and represents an area of priority for future work. It is evident, for example, that the content of the activity set is related to personal or household income level (e.g. type of leisure activity undertaken or whether a wife is in paid employment), as is the general pattern of expenditure. Yet very little is known about the way in which monetary factors affect the detailed scheduling of daily behaviour or strategies for adapting to change — apart from the direct influence of transport costs on travel choices. Research in this area is currently hampered by the lack of suitable data on the location, timing and cost of activity participation. *

Relevance to Current Policy Issues

Changes in transport policy since the war have provided an important impetus for the development of a succession of new approaches. Section 4.1 discussed a number of recent policy issues not handled adequately by existing methodologies, which the activity approach sought to address. They included:

• The wider impacts of transport policy on people's lives
• The impacts of non-transport policies on travel behaviour
• The definition of travel needs and the value of travel
• Definition of minimum provision level and the timing of services
• Substitution effects between travel, communications and non-travel activities

*An important exception is a recent study by Barnard (1981) in Adelaide, Australia, which collected information on expenditure as part of an activity diary survey. Findings have not yet been published.
• Impact of future technological developments on the demand for travel

By examining travel in the context of daily household activity patterns, the activity approach is intrinsically suited to dealing with the interrelationships between travel and non-travel aspects of behaviour, which lie behind a number of these issues. Given an understanding of the mechanisms that lead to secondary effects, it is further able to trace the wider impacts of both transport and non-transport policies, to a much greater degree than is possible with trip-based approaches. It is particularly suited to investigating policies that affect the timing of travel or other activities (e.g. school bus changes in section 6.4), or their location, or that interfere with inter-personal linkages in some way. Because financial aspects are not well handled at present, it is weaker at handling policies relating, say to the impact of changes in taxation on travel behaviour.

By treating travel explicitly as a derived demand, the approach offers an explanation of when and why people travel, and the role it plays in their daily lives — distinguishing, for example, between factors relating to travel in connection with obligatory activities, discretionary activities, or for its own sake. More importantly, it tends to steer attention away from travel need to more basic questions concerning activity needs. One of the problems with the trip-based approaches is that they tend to focus attention on people who travel rather than those who don't or can't, and make it difficult to consider non-transport solutions to social problems. The activity framework is potentially much more useful in this respect, although an assessment of the 'value' of travel requires some further development of the approach.

Questions concerning service provision and timing relate closely to the definition of the travel needs of different groups of people,
requiring information on activity needs, facility preferences, and the various inter-personal and space-time constraints which limit when, where and for how long people can undertake an activity and associated travel. The explicit incorporation of time of day into the activity approach makes it particularly suitable for identifying appropriate public transport service patterns (which can be interpreted as the provision of time-space paths that mesh well with people's activity patterns). A related question that it cannot handle satisfactorily, however, is the level at which fares should be set on a subsidised public transport system.

With regard to the final two policy issues (i.e. substitution effects and impacts of technological developments), the activity work provides a useful framework within which to examine such issues — because it offers a general basis for studying behaviour and can help to identify the secondary impacts of changes — but only in association with techniques developed in marketing and elsewhere to look at choices between different products.

The activity approach thus has much to offer in a policy context but would need to be extended and augmented if all of the outstanding transport issues were to be handled satisfactorily.

7.4 Summary and Conclusions

Travel is sometimes a primary activity in its own right (e.g. going for a walk) but more commonly within the activity framework it is viewed as a derived demand — the means which people use to reach facilities where they can participate in primary activities. Instead of focussing on trips per se, travel becomes one element of a daily household activity pattern. In one sense this perspective appears to reduce the significance of travel (because it is a very minor element
in the daily time budget and does not satisfy basic physiological needs), yet at the same time it makes explicit its crucial role. Travel becomes an important sustaining and integrating element in daily life, acting as a 'lubricant' in the scheduling of behaviour, by enabling people to move swiftly and easily from one activity facility to another.

The activity approach incorporates information on activity needs, time-space constraints and inter-personal linkages, and identifies mechanisms by which the impacts of policy measures may spread, in time, space and between people. A recent American study cited 'the ability of a theory to anticipate otherwise unanticipated consequences of policies or plans' as being a key criterion for evaluating the usefulness of a claimed theoretical advance (Fried et al., 1977, p. 63). It is apparent that the activity framework does have the potential for measuring and anticipating the likely direct and secondary impacts of proposed policy measures, even outside the range of current experience, in a way which would not be possible using more orthodox analytical and modelling approaches, because they do not explore the mechanisms of travel pattern formation and restructuring.

One of the major differences between the trip-based and activity-based approaches is in the general perspective from which travel is viewed. This is apparent from a quick visual comparison of Figures 7.1a (trip-based approach) and 7.1b (activity-based approach). The former has a strong spatial emphasis, while the latter adds to this a detailed consideration of temporal aspects and provides a context for studying travel behaviour — travel becomes secondary, instead of primary.

To an extent, therefore, the activity approach inverts the traditional view of travel, by placing emphasis on the background pattern of behaviour, from which the travel pattern emerges. This conceptual
shift in emphasis is analogous to the visual illusion reproduced alongside, in which the background suddenly replaces the foreground as the primary focus of interest. This feature of switching the conceptual focus of study is discussed further in Chapter 9, in an educational context.

Thus, although the thesis set out to develop another new approach to studying travel behaviour, to resolve some specific methodological problems and policy issues, it is apparent that the activity approach is fundamentally different to the approaches now in use. It is based on different concepts and adopts a very different perspective on travel. In effect, it offers a different paradigm for the study of travel behaviour, and is as basic a change as was the development of the notion of the person trip in the fifties.

The activity framework is broader in scope than the trip-based approaches and also provides a deeper understanding of household travel decisions. Thus, with further work, it could be seen, at a conceptual level, as capable of subsuming the trip-based approaches. This is clearly some way off and unlikely to be helpful in practice. We may perhaps draw an analogy with physics, where quantum mechanics is regarded as offering a more accurate and general description of physical laws than Newtonian physics, yet the latter is still widely used because it is simpler and easier to apply and is a more appropriate framework within which to examine many types of problem. Rather like quantum mechanics, it is appropriate to see the activity approach as being reserved for applications where the simpler approaches are inapplicable, or inadequate in some respect.

This chapter has shown that the activity approach is capable of meeting the requirements set out in section 4.3, and that it is relevant
to many of the policy issues that now transcend current methodologies. Its major weaknesses are in the handling of monetary aspects, and in some applications it will need to draw heavily on the literature on consumer behaviour and product (and activity) attributes.

All the discussion in this chapter has, however, been couched at a conceptual level. The activity framework has been shown to have the capability of dealing with certain problems and issues, but no consideration has yet been given to the practicality of using the approach. A conceptual assessment is a necessary but not a sufficient condition to guarantee the value of a new approach to transportation planning—how are concepts translated into practical measures? How can the greater detail of the approach be handled analytically? The final part of the thesis examines ways in which this new approach to understanding travel behaviour has or could be applied to transportation planning, and considers a number of more general implications of the approach.
PART THREE

APPLICATIONS AND IMPLICATIONS
8. AN OVERVIEW OF DEVELOPMENTS

8.1 A Typology of Activity-Related Studies

In addition to the ten methodological developments during the seventies that were reviewed in section 3.4, a growing number of writers in the last few years have made use of activity-related concepts to study travel behaviour. The various reports which now refer to 'activities' or an 'activity approach' vary widely in their objectives, scope, methods of enquiry and the type of dependent and independent variables that they have incorporated in their work. The different authors share, however, a common awareness of the need to study travel in a broader context, which often involves using something other than the traditional trip-based unit as the focus of analysis.

Figure 8.1 provides a typology that attempts to group these various studies into a five-level hierarchy of increasing conceptual and data complexity, in which each stage is more comprehensive than, and subsumes its predecessor. The representation of the conceptual approach at each level is shown in a two-dimensional diagram, with space along the vertical axis and Time of Day across the horizontal, following the convention adopted in Part Two of the thesis. Below each diagram are listed the main concepts applying at or below that level; the additional elements introduced at each particular level are shown in bold type, both on the diagram and in the text beneath.

The base level (Figure 8.1a) represents the conventional trip-based approach, discussed in detail in section 7.2. To recap, travel is represented as vectors of movement, from one location to another, with attributes such as mode and trip purpose. Trip times (and costs) are recorded in detail, but time of day of travel is usually grouped into peak or off-peak periods; trips are aggregated by type, and the sequence and direction of travel is usually ignored. Despite these
Figure 8.1: A Typology of Conceptual Levels Used in the Analysis of Travel Behaviour

(a) Level I: Conventional Trip-Based Approach

Concepts:
- Person Trips
- Home-based & Non Home-based
- Trip Purpose
- Trip Time (and Cost)
- Peak/Off-peak Travel
- Mode of Travel

(b) Level II: Analysis of Journey Structure

Concepts:
- Person Trips
- Home-based & Non Home-based
- Trip Purpose
- Trip Time (and Cost)
- Peak/Off-peak Travel
- Mode of Travel

Mult-trip & Multi-purpose Journeys
- Tours, Trip Chains, Trip Sequence
- Stops, Sojourns
- Duration & Frequency of Stops and of Travel

Source: Jones (1983a), Figures 1(a)-(e).
restrictions, however, it is possible to interpret this data in a broader social context, and this has been a feature of the activity work carried out at the U.K. Transport and Road Research Laboratory. Mitchell and Town (1977), for example, use trip length frequency distributions as a measure of the accessibility of various social groups to different activities, and Hopkin, Robson and Town (1978) carried out a sociological study of the mobility of old people in Guildford, using trip rates as their measure.

The first increase in complexity is shown in Figure 8.1b, where travel is analysed in terms of journey structure. Each excursion from home is now treated as a single entity comprising two or more trips and referred to as a 'tour', 'sortie', or 'trip chain'; it may be both multi-trip and multi-purpose in character. Attention is paid both to the number of stops or sojourns and the amount of time spent in travel and at destinations. The sequence of events in the chain now becomes an important feature, although the order of the chains in a day may not be known, nor the timing of each tour. Most of the work on complex travel patterns has been at this level of analysis, and has been reviewed in Jones (1978a) and Hanson (1979). One example is the serial queue model developed by Kobayashi (1976) which, given information about the average travel times and costs between destinations and the mean activity duration at each destination, predicts the number of destinations visited on a journey and the total time spent away from home. Other examples were given in section 3.4.

Figure 8.1c introduces a third level of complexity in the study of travel behaviour: the examination of out-of-home activity patterns. Here the analyst is more directly concerned with the pattern of non-home activities over the day, rather than with particular sequences of trips. The temporal dimension now assumes a greater importance and there is interest in the location and timing of activity facilities and in
(c) Level III: Out-of-Home Activity Patterns

SPACE

Concepts:
- Person Trips
- Home-based & Non Home-based
- Trip Purpose
- Trip Time (and Cost)
- Peak/Off-peak Travel
- Mode of Travel

Activities
- Frequency & Duration of Activities

Facilities
- Activity Patterns/Structure

TIME

Multi-trip & Multi-purpose journeys
- Tours, Trip Chains, Trip Sequence
- Stops, Sojourns
- Duration & Frequency of Stops and of Travel

(d) Level IV: Full Home/Non-home Activity Patterns

SPACE

Concepts:
- Person Trips
- Home-based & Non Home-based
- Trip Purpose
- Trip Time (and Cost)
- Peak/Off-peak Travel
- Mode of Travel

Activities
- Frequency & Duration of Activities

Facilities
- Activity Patterns/Structure

TIME

Multi-trip & Multi-purpose Journeys
- Tours, Trip Chains, Trip Sequence
- Stops, Sojourns
- Duration & Frequency of Stops and of Travel

Activity Time Budgets
- Trade-offs (Home vs. Non-home Activities)
- Time-space Constraints
- Re-scheduling of Activity Patterns
- Threshold Effects
measures of activity participation and linkages between activities.

Damm (1979), for example, describes an individual choice model that examines the daily travel and non-home activity patterns of individual workers in a household. It predicts the probability of participating in a discretionary activity outside the home (and away from the workplace), and the duration of participation, for five periods during the day defined around the basic work trip pattern (i.e. pre-work, homework, at work, work-home and post-work). It was not possible however to take account of activity scheduling across the day, although there was an attempt to include simple spatio-temporal and inter-personal linkages in the model.

Kutter (1973) describes an early attempt to make fuller use of travel data at this level by introducing activity timing and sequencing into a modified aggregate trip model. He argues that observed behaviour reflects the satisfaction of needs, and begins by classifying the population into groups with different needs (and hence activity 'patterns'), on the basis of age and role. For each group he then derives activity profiles from empirical data which show the propensity to travel to or from home, by time of day. This information replaces the standard trip rate categories usually output by the trip generation submodel and may be used with the trip distribution, modal split and assignment stages in the normal way. A modified version of this procedure has been adopted by the Bavarian Government for its urban transport planning studies (Kutter 1977). His approach demonstrates that time of day can be added to standard travel demand models and that it is possible, for example, to look at some consequences of altering work or school hours. The procedure is largely descriptive, however; there is no way of determining whether or how other types of non-home activity would be affected by a specific space-time change nor any mechanism for looking at inter-personal linkages.
This is really as far as conventional travel data can be adapted for analysis, although by treating time at home (i.e. time not accounted for in a travel diary as being spent in travel or at destinations other than home) as a single activity, it is possible to incorporate certain features of level IV: the analysis of full daily activity patterns. The main features are shown in Figure 8.1d, and many of the concepts have been reviewed in Appendix I. In addition to carrying out the preceding analyses it is now possible (with appropriate activity diary data) to measure daily activity time budgets and to identify trade-offs between in-home and out-of-home activities, in the context of various time-space constraints. Given complete temporal information on activity participation, it also becomes possible to examine the general re-structuring of activity patterns and the operation of threshold effects (see section 6.2). Most of the Swedish work carried out at Lund (e.g. Lenntorp, 1976) has involved concepts derived from this level of analysis.

Finally, we come to level V (Figure 8.1e), which lists additional, more subjective, elements which may be added to the analysis of daily activity patterns. These include environmental perception, subjective constraints and preferences, and the process of bargaining which takes place between members of a household (e.g. about who has use of the household car) or some other social group. Several English studies have dealt with aspects of analysis at this level (e.g. Cullen and Phelps, 1975; Jones, Dix, Clarke and Heggie, 1983; and Young and Willmott, 1973), and this is the level to which the conceptual framework discussed in Chapter 5 and 6 belongs (see especially sections 5.3 and 6.2).

In the next section we go on to look at the way in which activity concepts and techniques have been or could be applied to practical problems encountered in transportation planning. Most examples are taken
(e) Level V: Additional Elements

Concepts:

Person Trips
Home-based & Non Home-based
Trip Purpose
Trip Time (and Cost)
Peak/Off-peak Travel
Mode of Travel

Multi-trip & Multi-purpose Journeys
Tours, Trip Chains, Trip Sequence
Stops, Sojourns
Duration & Frequency of Stops and of Travel

Activities
Facilities
Activity Patterns/Structure
Frequency & Duration of Activities

Activity Time Budgets
Trade-offs (Home v Non-home Activities)
Time-space Constraints
Re-scheduling of Activity Patterns
Threshold Effects

Bargaining & Inter-personal Linkages
Subjective Constraints & Restraints
Preferences and Priorities
Perception of the Environment

...etc.
from studies that used concepts at levels IV and V of Figure 8.1

8.2 Applications of Activity-Based Work in Transportation Planning

Traditionally, the main role of the researcher in relation to the transport planning process has been perceived as making improvements to the trip forecasting procedures — by offering a better assignment algorithm, or by introducing attitude measures into a mode choice model. There are many more aspects to the transportation planning process, however, and researchers have had a strong influence on the non-modelling stages of the planning process, although at times this may have been largely implicit. Thus:

(a) The data demands of a forecasting model strongly influence the survey methodology employed, and the model outputs influence the types and range of policy measures that can be assessed and the criteria by which options are evaluated.

(b) The content and structure of a model can also indirectly affect the planning process by providing a conceptual model of transport and traveller behaviour which presents the practitioner with a particular perspective or view of the world. This can influence the types of problems that are perceived, as well as the solutions which are apparently available.

Because the human activity framework embodies a view of travel that is very different to the trip-based perspective underlying many of the existing procedures, it has its own implications for the various aspects of the transportation planning process — from data collection to evaluation, and beyond.

There is now considerable interest in and use of activity-related approaches to travel. Most of the studies referred to in section 8.1
have been carried out by academic bodies or government research institutes, rather than by practitioners. But increasingly there are signs that these approaches are being taken on board by planning agencies to deal with specific problems and policy issues, particularly in instances where the more conventional procedures have proved to be inadequate or unreliable.

These new developments cover a very wide range of topics (e.g. see the papers in Carpenter and Jones, 1983). Some examples of the ways in which activity-based approaches have already been applied, or could be used, to deal with methodological problems and policy issues in transportation planning are listed in Table 8.1. Here applications are grouped into six broad areas: problem recognition and policy generation, data collection, data analysis, modelling, evaluation, and public participation and policy coordination.

An overview of developments in each area is given below, with selected topics being examined in greater detail in Chapters 9 and 10.

Problem Recognition and Policy Generation

A new conceptual approach to a subject area such as transport brings with it a fresh and significantly different perspective from which to view problems and generate policy options. Although this effect may be very difficult to document or quantify, there are indications that the activity-based work is having a major impact on attitudes and understanding among both researchers and practitioners. From the writer's experience, this is particularly so in an exploratory and educational context; these aspects are described in detail in Chapter 9 and only a few general examples are provided here.

In a research context, the use of exploratory research techniques such as HATS (section 9.2) often leads to unexpected results. A study
Table 8.1

Areas of Recent or Potential Application of Activity Approaches in Transportation Planning

A. Problem recognition and policy generation
   1. General understanding of the role of travel in the community
   2. Identification of travel and activity needs of specific groups
   3. Scope for reducing travel, through trip chaining, consolidation and substitutes for travel
   4. Use of non-transport measures to achieve transport objectives

B. Data collection
   1. Better specification of data requirements (e.g. to include major direct and secondary impacts in monitoring studies)
   2. Improved reliability of conventional survey instruments
   3. Complementary use of qualitative and quantitative surveys
   4. Development of new types of data collection procedure

C. Data analysis
   1. New ways of analysing conventional travel data sets (e.g. linked trips, out-of-home activity patterns)
   2. New categories for data aggregation (e.g. stage in life cycle)
   3. Development of techniques specifically to measure and analyse activity patterns (e.g. n dimensional vectors, pattern recognition)

D. Modelling
   1. More rigorous definition of choice sets (taking account of time-space and interpersonal constraints)
   2. Specification of appropriate variables and model structures to deal with different forms of adaptation
   3. Development of new forms of model (gaming, simulation, programming)

E. Evaluation
   1. Improved estimates of conventional measures of user benefit (e.g. values of time)
   2. New measures of user and non-user benefit (e.g. based on time budgets or measures of disruption to the activity pattern)

F. Public participation and policy coordination
   1. Presenting policies in a way which is meaningful to the layman
   2. Scope for coordinating the planning activities of different agencies, via their common impact on the activity patterns of the population

Source: Jones (1983a), Table 2.
currently underway into the travel requirements of villagers in deep rural areas in Southern Scotland (Massingham, 1983), for example, is finding that the population is much more concerned to use resources to preserve local village schools than to provide public transport services — something that would never have become apparent from a conventional travel survey.

Practical applications of HATS in the U.K. (section 9.3) in a transport planning context have usually been prompted by the desire of the engineer or planner to better anticipate the likely impact of a proposed policy measure on the transport system(s). In the course of the study, however, the practitioner has often found that he was able to derive wider benefits from the work, as a result of the deeper understanding of local travel behaviour which was obtained. This enabled him to better formulate the original problem that led to the proposed measure, and to devise alternative ways in which it might be alleviated.

There are two areas of current concern to the transport planner where the activity-related work has much to offer; namely, the identification of the travel and activity needs of specific groups and the time management of activity and travel facilities. Ampt (1982), for example, has shown the potential for examining new issues from an activity perspective in her study of the characteristics and needs of the non-traveller. With regard to the second area, several researchers have examined the potential for and impact of work hour re-scheduling schemes (e.g. Damm, 1981), but there are also possibilities for modifying, say, school or shopping hours. Some consequences of changing school hours in West Oxfordshire were identified in section 6.4, and are discussed further in section 9.3. In a different context, the relaxation of pub licencing hours in Melbourne, Australia, some years ago, is also reported to have had a very marked effect on the evening peak travel patterns in the city.
A further example of the relevance of activity-based work to policy issues is with regard to the heightened concern with energy savings, which has given rise to a large number of studies into ways in which travel might be reduced, without seriously affecting people's life styles or the quality of their lives. Here, too, the activity approaches provide a variety of concepts and techniques for studying behavioural change which involves trip linking or chaining, the consolidation of travel (through visiting fewer sites or making less frequent visits to sites), and substitutes for travel (by using other means of communication, or by substituting an activity which does not require travel or communication). Examples of activity-based studies in this area are provided in sections 9.3 and 10.3.

Data Collection

Data collection requirements are affected both by the perception of transport problems and policy issues and the input requirements of analytical procedures used in the transportation planning process. The activity framework has important implications for the range, type and quality of data used in transport studies, and has developed or imported a number of survey techniques to obtain appropriate data.

Examples of 'unconventional' forms of data collection procedure that have been used in activity-oriented travel studies include:

(a) Activity-diaries: a convenient way of recording full activity behaviour, in terms of who is doing what, when, where and with whom (see Hedges, 1974 for examples); some researchers (such as Cullen and Phelps, 1975) have added information on stress, or on how constrained the respondent was in the way in which he organised his activities.

(b) Unstructured interviews: these provide an important means of exploring the complexity of behaviour and identifying the
perceptions of respondents, before attempting to develop a more structured framework. They enable respondents to describe their behaviour in their own terms and can also provide a degree of quantitative information; see Dix and Spencer, 1980, for a discussion of the technique and its uses.

(c) **Gaming simulation:** a semi-structured procedure whereby household members are invited to describe their existing behaviour and explore the implications of future changes as a group, using display procedures to visually represent the complexity of daily activity-travel patterns. Gaming procedures have been successfully used to identify constraints, decision rules, priorities and probable patterns of response (section 9.2); for a recent review of travel applications see Burnett and Hanson (1982).

There is also considerable scope for developing hybrid approaches to the collection of travel information. One obvious candidate is the development of a travel diary which collected complete information on out-of-home activity patterns. This would have many of the advantages of the full activity diary — such as the recall of complete sequences of events — without incurring the expense or privacy problems which might be associated with the full activity diary. In addition, it would avoid the definitional problems associated with trip cut-off points and the need to specify only one major trip purpose (see section 4.2). The facility for listing several activities at one destination would be a particularly valuable innovation at a time when multi-purpose stops may be one response to the higher travel costs. Another hybrid approach is reported by Ampt (1981) and discussed in section 9.4.

An important, but sometimes overlooked, aspect of data collection concerns the range of information that should be collected for a particular purpose — such as a policy monitoring study. In monitoring the
effects of peak period car restraint, for example, the activity literature makes clear that it is important to monitor not only what happens to patronage of all other modes (including walking), but also to cover travel at other times of day and on other days of the week (trip re-timing), and to include the travel of the other household members (to allow for re-assignment of activities).

A study by Heggie (1976a) into the effects of car restraint and rising bus fares in Oxford found that as a consequence people were travelling less often into the centre of the city for shopping and service activities (i.e. lower trip rate per person), but spending longer in the city centre on each trip to compensate (high duration per episode). Unless both pieces of information were recorded, it would not be possible to obtain a full picture of the impact of the transport policy.

**Data Analysis**

Rather than being seen primarily as an adjunct or prelude to formal modelling, data analysis is now being used increasingly as a planning procedure in its own right. This is apparent, for example, at the PTRC Summer Annual Meeting, where the 'Traffic Models' stream of the mid seventies first became 'Transportation Analysis and Models', and has recently been renamed 'Transport Planning Methods'. Data analysis is examined in detail in section 10.1, and so only a few general observations are made here.

An important practical contribution of the activity-based work has been to highlight the importance of certain hitherto neglected variables as major factors affecting travel behaviour. Examples include time of day and stage in family life cycle; as was demonstrated in section 5.4, the latter has proved to be a particularly powerful discriminator between different patterns of activities and travel.
One of the most difficult analytical problems raised by the activity work involves the measurement and analysis of complete activity patterns. These patterns are multi-dimensional (activity, time, space, etc.), interdependent, and interlinked and can be modified in a large number of ways. The long-established analysis of time budget data provides one simple measure of daily behaviour but takes no account of the sequencing, timing or location of events. A number of ingenious approaches are being developed to measure and analyse behaviour in the form of complete activity patterns. These include the use of graphical procedures, the measurement of pattern as a succession of vectors of attributes in n dimensional space, and the application of various pattern recognition techniques.

A particularly attractive feature to the transportation planner of much of this work, is that many of the analysis techniques can be applied to conventional travel data sets, if such data are reconstructed in the form of a simple out-of-home activity pattern. Indeed, most of the research has used this type of data. It should be born in mind, however, that the majority of travel data sets are incomplete, because of their exclusion of short walk trips and (more commonly) their stipulation that a traveller can only take part in one main non-home activity (or trip purpose) at a destination. In some cases it is conceivable that the analysis may give misleading results if incomplete data of this type were used; hence this data transformation should be used with care.

Modelling

Modelling aspects are considered in Chapter 10 (sections 10.2 and 10.3), but briefly we can identify three ways in which activity-based approaches can assist in the modelling of household travel behaviour:
(i) Better definition of choice sets
(ii) Specification of appropriate variables and model structures
(iii) Development of new forms of model.

When calibrating travel demand models, it is important that the choice set faced by travellers be properly specified, otherwise the parameter estimates may be of the wrong magnitude and sometimes have the wrong sign. In the case of mode choice, for example, it is now common to use car availability rather than car ownership as the key to defining mode options; as a result, the proportion of people with a 'choice' of mode is now perceived to be much smaller, and the weights attached to travel times and costs in the models have also been affected. Similarly, activity studies are showing that destination choice sets are often much more restricted than had been appreciated in the past, when account is taken of time/space constraints on travel (e.g. see the hypothetical examples used in sections 4.2 and 4.3).

The discussion of household adaptation in Chapter 6 demonstrated the complex ways in which people can respond to change, and introduced the notion of 'response strategies' (section 6.3). Here it was argued that households and individuals initially tend to resist change (unless they have a strong latent demand for activities); but if an adjustment is necessary it may involve other people within or outside the household and lead to a basic restructuring of the activity pattern and a possible change of residential or workplace location, or in the stock of household cars. Operational travel demand models inevitably simplify reality to a high degree, and so it is important to select a model with the appropriate variables and structure, reflecting the type and level of response which a population are likely to make when faced with a particular environmental or policy change. This has been expressed in terms of selecting models from an appropriate *domain* (Heggie and Jones, 1978) and is discussed more fully in section 10.2.
Insights into both choice set definition and domain selection have been obtained from the exploratory studies described in Chapter 9.

Trip-based models are limited in the extent to which they can deal with more complex forms of adaptation (e.g. involving multi-trip journeys), because the conceptual framework on which they are based takes little direct account of the mechanisms that lead to secondary effects. Activity-based models are intrinsically more suited to dealing with this type of problem, and a range of model forms is reviewed in section 10.3.

Evaluation

Researchers have so far paid little attention to the implications of activity-based studies for the evaluation of policy measures in transportation planning, yet in the longer term these are likely to be both wide ranging and highly significant. The activity framework provides a deeper understanding of travel behaviour within a broader social context, and is thus likely to lead both to improved estimates of conventional measures of user and non-user benefit, and provide a number of new measures of policy impact.

A brief assessment of the role that an activity-based approach could play in providing improved estimates of values of travel time was made by the writer and others for the U.K. Department of Transport (VOT Study Team, 1981). The study team identified three components of the value travellers place on time: the disutility of travel, its resource cost and its opportunity cost. They concluded that the activity approaches were particularly relevant to an understanding of the opportunity cost of time, through the insights this work can provide on the alternative uses of time, and the scheduling constraints which affect the ways in which people can respond to travel time savings or losses. A number of different measures of time benefits were also proposed, as well as several unconventional variables for stratifying time values.
Further details are provided in section 10.4.

At the moment, transport planners often tend — explicitly or implicitly — to use travel-based measures as indicators of success: in some sense, higher trip rates or increased annual vehicle mileages are seen as positive outcomes. This may not always be the case. A mother with young school children may make several trips each day escorting them to/from school because it is not safe to let them travel alone; and a rural household car may incur a higher annual vehicle mileage over a period of several years, because physical access to hospitals, shops, educational facilities, etc. declines as service provision becomes concentrated in larger centres. In these cases travel seems to be inversely correlated with quality of life. Here direct activity-based measures would provide a better guide to social effects.

Simple measures of daily time budgets or activity participation rates have been used in a number of sociological or anthropological studies as a measure of the richness or quality of life (e.g. see Szalai and Andrews, 1980). Meier (1959) has suggested that time budgets could provide the planner with a useful measure of social account against which to assess deprivation and the success of different policies, but this idea has not yet been adopted by transport planners.

A number of more sophisticated measures are reviewed in Jones (1983b), and considered in section 10.4. Possibilities include a measure of the disruption which a policy measure may have on family life, or the extent to which it decreases or increases freedom of action. There is also some evidence to show that difficult journeys to work can lead to stress or illness, so that there may be health consequences of transport policies in addition to measures of casualties and fatalities. The study of the effects on families of school hour/bus changes, reported in section 6.4, found evidence of benefits and disbenefits to in-home as well as out-of-home activities, suggesting that wide
ranging attitudinal questionnaires should be used as part of transport policy assessment.

Public Participation and Policy Coordination

This is the last of the six areas of application listed in Table 8.1, and the one where least has yet been achieved in practice. However, from the writer's own experience of using an activity-based approach to examine transport issues, it is clear that placing transport directly in the context of daily life makes it much easier to identify the problems faced by individuals and families, and to present policy options in a way which is meaningful both to the layman and the local politician.

Authorities often experience difficulties in communicating effectively with local residents because of the technical form of the material or its rarefied nature (e.g. as with some structure plan issues); this makes it appear irrelevant or incomprehensible to many sections of the public. By explaining the likely consequences of alternative proposals in terms of how they will affect the daily life of 'the man in the street', it is likely that people will be able to relate more fully to the proposals, which in turn would lead to a more meaningful participation exercise. It is here that the use of a mixture of qualitative and quantitative methods has proved most useful. In a HATS study of public transport improvements in Reading (Jones and Dix, 1978), for example, the authors found that by using the display equipment with case study examples, it was possible to explain the policy implications of different options to local politicians in a very detailed and realistic way.

Another possible development mentioned under this heading in Table 8.1 is the scope for closer coordination of planning policies. Considerable administrative changes took place in many countries when urban
land use/transportation studies became an established feature (see section 2.2), and in the long term the activity-based work could have an even greater impact. There are obvious advantages, for example, in planning agencies combining to collect household activity data (covering travel, shopping, leisure etc), particularly at a time when survey resources are scarce.

Beyond this, however, activity procedures not only offer a basis for examining the impact of a policy on the activity patterns of a population; they could also be used to identify the secondary effects of policies and the interactions between policies administered by different agencies. A lot of public money may presently be used inefficiently because policies overlap in their coverage, leave important gaps or simply pull in different directions. In studying activity-travel patterns we are learning as much about the demand for activity facilities as about the use of travel facilities, and hence the work offers opportunities for the closer integration of transport, land use and other public sector planning. These more speculative aspects are considered in section 11.2.

8.4 Conclusion

This chapter has attempted to provide a brief overview of the work using activity-based concepts to study travel behaviour, and has documented a number of areas in which these methods have or could be used by the transportation planner. Given the recent emergence of this area, it is hardly surprising that there are more 'potential' than 'completed' applications to report, yet it is clear that the implications of the activity-based work are wide-ranging and that, if they could be operationalised successfully, would make an important contribution to contemporary planning.
In the next two chapters we focus more specifically on achievements to date. Chapter 9 deals with the exploratory and educational applications of the approach set out in Part Two of the thesis, and provides examples of the insights that have been obtained from this small scale and more qualitative work — and some of the consequences the findings have had for urban transportation planning. Chapter 10 then examines applications in three, more conventional, areas of transport methodology (i.e. data analysis, modelling and evaluation), and shows the progress that has been made in the last few years. In selecting material for these two chapters, the writer has tended to concentrate on applications in which he has been personally involved, or where ideas developed at the Transport Studies Unit have had an acknowledged influence on the study.
9. EXPLORATORY AND EDUCATIONAL APPLICATIONS

9.1 Introduction

A distinctive feature of much of the applied work on household travel behaviour within an activity framework has been the emphasis on exploratory studies, to a degree not found at a comparable stage in the development of earlier trip-based approaches or associated with them since. In addition, there has been a widespread introduction of activity-related concepts into transport courses in engineering, planning and geography departments even though the use of activity-based procedures in transportation planning practice is as yet fairly restricted. The exploratory and educational uses of the approach are reviewed in this chapter.

The educational appeal of the activity framework at a conceptual level is apparent from the presentation and discussion in the second part of this thesis. The approach provides an explanation of the role of travel in daily life and the means by which people adapt to change, both directly and indirectly; it also offers a basis for dealing with a number of unresolved issues, such as travel need, service timing, or the handling of complex travel patterns. Even though much of this information is only available in the form of insights at a qualitative level, because the trip-based framework can be regarded largely as a subset of the activity framework (e.g. as in Figure 8.1) the latter does offer a perspective from which to assess the merits of different trip-based procedures* and can help in the interpretation of conventional transportation study outputs. Educational aspects are considered further in section 9.5

*See also the discussion of model domains in section 10.2.
Three related reasons can be advanced for the emphasis on an exploratory approach to studying travel from an activity perspective:

(a) This is a very new area of work, where there are many gaps in our knowledge; hence the need for procedures that will provide insights and help to generate rather than simply test hypotheses.

(b) The activity approach requires that travel be studied in greater depth and in a broader context than hitherto. In order to do this, it is often necessary to work with small samples, using procedures that enable a very detailed and flexible analysis of the data.

(c) In association with the introduction of new concepts to transportation planning, researchers have also adopted and adapted a number of socio-psychological techniques for investigating travel behaviour (Dix, 1981) — particularly suited to exploratory investigations.

The exploratory studies can thus be characterised by their use of small sample sizes, an emphasis on qualitative rather than quantitative techniques (although both may be used in a complementary way), and a concern with obtaining insights into various aspects of travel behaviour and response, rather than with testing pre-formed hypotheses or collecting data for a particular computer package.

A variety of methods have been used to obtain information in exploratory studies, including activity diaries linked with attitudinal questionnaires, in-depth unstructured interview procedures (e.g. Dix and Spencer, 1980), group discussions (e.g. Jones, 1982a), the use of visual displays (e.g. Bottom and Jones, 1982) and gaming simulation techniques; a general overview is provided in Jones (1982b), where the advantages and disadvantages of each are discussed. Of these various methods, gaming simulation has come to be particularly associated with
activity-based exploratory studies of household travel behaviour, and is discussed further in section 9.2.

Exploratory studies may serve a variety of purposes within transportation planning. They may help define problems and issues, act as a pre-pilot phase for a study design, suggest hypotheses for quantitative analysis, or be used to provide a richness of detail and expression which can be reported alongside the results of a subsequent, larger scale statistical analysis. Often the study may have unexpected benefits; in a HATS study of public response to planned bus service improvements in Basildon new town, for example, the planners obtained information which helped to guide the subsequent marketing exercise that accompanied the service changes (Basildon Development Corporation, 1980).

Examples of exploratory study findings dealing with transport policy and transportation planning methodology (i.e. data collection, analysis and modelling) are discussed in sections 9.3 and 9.4 respectively. Some of the latter relate directly to the more quantitative analytical procedures examined in Chapter 10.

9.2 Gaming Simulation As An Exploratory Technique

Characteristics of the Method

As the review in Burnett and Hanson (1982) demonstrates, gaming simulation has been used in geography and planning over a number of years to examine aspects of human behaviour; however, it is only recently that the methodology has been applied to the study of household travel behaviour, where it has been developed mainly within a human activity framework. Gaming simulation techniques of this type share three key features:

(a) The use of a group discussion format, usually involving the members of a selected household, who interact with one another to recreate the constraints, linkages and information flows
associated with everyday living.

(b) Equipment providing a visual display of daily household activity-travel patterns. This is a particularly valuable feature when examining issues as complex as activity patterns and their adaptation.*

(c) The introduction during the interview of some change in circumstances to which respondents are asked to simulate their response. This provides a vehicle for examining the process of adaptation, covering the options considered, decision rules, priorities, trade-offs, etc.

These studies may also involve the use of ancillary survey instruments, such as activity diaries and socio-demographic and attitudinal questionnaires (e.g., see Kam, 1982).

Gaming simulation offers a very flexible exploratory approach to the study of household travel behaviour, and may be used to examine a variety of research and policy issues (see Appendix II). Examples are included among the results of the studies reviewed in sections 9.3 and 9.4, but in general most aspects of the framework presented in Chapters 5 and 6 can be probed in this way, including:

- activity sets, role commitments and activity preferences
- household routines and day-to-day variations
- the degree of fixity or flexibility among elements of the activity pattern
- the nature of inter-personal linkages
- perceived choice sets and strategies for coping with change
- the nature and operation of threshold effects

*In a recent study of bus driver attitudes to shift work in London, Bottom and Jones (1982) found that respondents were much better able to discuss the complexities of shift work when provided with a visual medium for doing so. The study is discussed in section 11.2.
-  household decision rules and priorities in resource allocation (e.g. use of household car)
-  individual preferences and trade-offs
-  outcomes of adaptation to policy change (direct and secondary)
-  the evaluation of policy impacts (at an individual and at a household level).

Examples of gaming simulation techniques with these characteristics include 'HATS' (Household Activity-Travel Simulator — see Jones, 1979), 'REACT' (Response to Energy and Activity Constraints on Travel — see Phifer, Neveu and Hartgen, 1980) and 'HIG' (Household Interaction Game — see Burnett and Hanson, 1982). Brög and Erl (1980) also describe several interactive measurement methods which are multi-instrument in nature and involve similar types of simulation procedure; an application of their own work is described in Brög and Erl (1983).

The Household Activity-Travel Simulator represents the prototype of this new form of survey approach, which is designed to study dynamic aspects of travel behaviour within an activity framework. It is taken as the example of a gaming simulation technique in the remainder of this section, both because of the writer's personal involvement and familiarity with the technique, and because it is better documented and has been applied in a wider range of situations than the other versions. This section concentrates on the survey procedure used in the interview. Examples of survey findings are provided in sections 9.3 and 9.4, and details of the equipment used and other potential applications are given in Appendix II.

The HATS Technique

The HATS technique uses the richness of the group, in-depth
interview to advantage in a more structured context, which enables many of the constraints and commitments which circumscribe behaviour to be made explicit. This is achieved through the use of display boards, on which respondents simulate reactions to policy changes, by first building and then manipulating a representation of their daily behaviour.

The visual display equipment comprises a set of boards on which behaviour is depicted (one board for each household member) and a components box containing coloured blocks and markers which are used to represent time spent on different activities and to record the type and location of facilities that are used. Between ten and twelve types of activity are distinguished by colour (e.g. work by red blocks, shopping by green).

An example of a completed HATS display board, showing one person's daily activity-travel pattern, is illustrated in Figure 9.1. The timing and duration of activity participation is recorded along one of three time scales, differentiated according to whether the activity took place in-home, away from home, or involved travelling. The precise locations of the activity facilities that were visited and the modes and routes by which they were reached are recorded on a map area above the time scales. Note that, by using an activity representation, there is a continuous representation of behaviour along the temporal axis.

Figure 9.2 shows a typical HATS interview procedure, which is designed to explore three aspects of household response (to varying degrees, depending on the nature of the study):

(a) The decision context: the nature of the activity/travel choices which have to be made, and the constraints which determine the available options.

(b) The decision process: the mechanism by which the preferred option is selected. It includes an investigation of bargaining processes, trade-offs, etc.
Figure 9.1: A Completed HATS Display Board

MAP OF AREA WITH COLOURED MARKERS TO SHOW LOCATION OF ACTIVITIES

MODES & ROUTES

TIME OF DAY

ACTIVITIES REPRESENTED BY COLOUR-CODED BLOCKS

3-FOLD SPATIAL CLASSIFICATION

NON-HOME ACTIVITIES

TRAVEL

HOME ACTIVITIES
(c) The decision outcome: the adjustments to daily behaviour patterns considered necessary to cope with the new situation; this includes both the direct and secondary repercussions.

Prior to the main interview participating household members keep a record of their behaviour for a specified number of days on forms provided; these ask for details of what they are doing and where, by time of day. The HATS interview commences with each participant building a visual representation of one day from his or her diary record using the equipment provided (as shown in Figure 9.1). Once the family have created a set of displays showing the structure of their day, the interviewer initiates a discussion of the reasons for the observed behaviour and explores with the household their main linkages and constraints — the degree of flexibility in timing or location of activities, the extent to which household members perform joint activities, etc. Awareness of alternative activity or travel facilities may also be probed in detail.

The interviewer next invites the family to consider how they would be affected by a policy measure or some other change — either with the intention of assessing the impacts of the proposal, or simply as a device for exploring the process of adaptation during the simulation. Attention is first directed to individuals most clearly affected (for example, children attending a school where hours are to be revised), who discuss possible adaptations with the group and try out different strategies on their boards, to see if they are feasible. These modifications may lead to linked changes which affect other household members (for example, husband who drops children at school), causing them in turn to modify their boards and consider further repercussions.

The procedure is iterative until a joint set of activity-travel patterns has been established that is acceptable to all. The interviewer
Pre-interview

- Completion of diary records by participating household members

Main HATS interview

- Representation of diary data on HATS display boards
- Discussion of household activity-travel patterns:
  - Specify change in policy
  - Examination of impacts on household members
  - Group discussion
  - Test possible responses on HATS display boards
  - Agreed revisions to household activity-travel patterns
  - Household evaluation of policy impacts

Post-interview

- Record revisions on second set of diary sheets

Analysis

- Qualitative: tape recording of discussion
- Qualitative: coded diaries

Topics investigated:

- Routines, roles, constraints, linkages, options, preferences

- Changes in timing, location or cost of activity/travel facilities; change in car ownership, etc.

- Response strategies, priorities, decision rules, trade-offs, options considered, ranking of options

- Perceived impacts; gains and losses for each person; overall assessment

Figure 9.2
Typical HATS Interview Procedure
then asks the participants for their overall evaluation of the policy. There is much useful discussion about possible adaptations to the policy and it is possible to gain insights into many aspects of the processes by which household decisions are made.

This completes the HATS interview. The interviewer subsequently records the modifications to activity patterns brought about by the policy change; this provides the analyst with a set of quantitative 'before' and simulated 'after' diaries, and a taped record of the discussion and bargaining process. Examples of numerical analysis of a HATS study of school hour changes were given in section 6.4.

Assessment of the HATS Technique

The combination of the group interview and display equipment results in a survey procedure with built-in checks that appears able to obtain quite realistic responses from household members. Some of these checks are illustrated in Figure 9.3.

The display boards perform two important functions. First, they provide a focus around which to discuss household behaviour, one that is easy to relate to, and in which the respondent is less self-conscious than in an in-depth interview. Experience indicates that people are less inhibited about discussing aspects of their daily lives in this way than when asked to answer a series of direct questions.

The second role of the boards is as a test bed for trying out possible responses to a proposed change. The representation used on the boards incorporates many features of the activity framework, including the deductive logic of the time-space format and a number of the temporal and spatial mechanisms which precipitate secondary effects that were identified in Chapter 6. It is immediately apparent, for example, whether a proposed modification to behaviour has resulted in
Figure 9.3: Major Elements of the HATS Procedure

(I) The **GROUP DISCUSSION** Identifies:
- Time-Space Constraints
- Inter-Personal Linkages
- Household Decision Rules
- Preferences and Priorities
- Possible Options and Sources of Information
- Checks on Realism of Proposed Responses

(II) The **HATS REPRESENTATION** Checks For:
- Overlaps and Unaccounted for Time, Being in Two Places at Once:
- Secondary Repercussions of a Timing/Duration/Location Change;
unaccounted for gaps in the day, or in the respondent attempting to be in two places at once, or doing several things at once (see Figure 9.3). The completed boards thus act as experimental, semi-closed systems, in which the respondent is forced to consider many of the direct and secondary repercussions of any change in his environment.

Through group interaction and the general structure of the inter-
view, it is also possible to examine the ramifications in a broader social context and consider aspects not directly incorporated on the boards, such as the cost or convenience of travel by different modes. Starting the interview by reconstructing existing patterns of behaviour both enables respondents to familiarise themselves with the equipment and concepts, and ensures that subsequent discussion takes place in terms of modifying established behaviour, rather than as an idealistic assessment of the effects of the policy measure, divorced from their actual situation. The group interview format helps to identify interpersonal linkages (for example, chauffering or shared meal times) and introduces the social pressures and other checks or encouragements which influence household behaviour; the group may point to problems or options of which the individual had not been aware — but which would have been brought to his attention during the process of real world adaptation.

The technique has generally been well received, both by inter-
viewers and by households. The concepts upon which it is based appear readily intelligible to most respondents, yet the novelty and dynamic of the approach is able to sustain interest and concentration throughout an interview lasting for one to two hours. The gaming approach has proved particularly successful among larger households comprising parents and children. These households are sometimes difficult to interview in depth by more traditional means, but are affected by a wide range of policies and, because of the greater incidence of linkages
and constraints, show complex patterns of adjustment which are particularly well handled using a gaming simulation technique of this type.

Shortly after HATS was first developed, the U.K. Transport and Road Research Laboratory commissioned Martin and Voorhees Associates to carry out an assessment of the technique (see Martin and Voorhees Associates, 1978). Two aspects of this evaluation are shown in Figure 9.4 and Table 9.1: the role of the technique and the realism of the responses from the simulation. Respondents express intentions about future behaviour in normal attitudinal interviews which, after implementation of the change, are modified by experience until an acceptable pattern of behaviour can become established. HATS helps to short-circuit this learning process (Figure 9.4) by making respondents more aware of the practical, everyday context in which adjustments have to be made. As a result, we would expect the technique to give reasonably reliable 'forecasts' of behaviour.

Field trials have confirmed that the technique is able to improve on people's intuitive assessment of the likely effect that a proposed change will have on their behaviour. The consultants were able to examine this more objectively by comparing the 'forecasts' of the impact of bus service cutbacks on users in a rural area with their reported behaviour after the cuts had been implemented. Members of twenty-two households agreed to take part in HATS interviews and provide diary records of their behaviour before and after the change. The results are shown in Table 9.1; variations were to be expected, because of seasonal factors and the small sample size, but the figures are encouraging and suggest that the technique is providing genuine insights into the outcomes and processes of household adaptation.

Gaming simulation thus has an important role to play in exploratory studies of complex household travel patterns and response strategies. HATS is a very flexible technique, in terms of the way it represents
Figure 9.4: The Role of HATS in Obtaining an Understanding of the Process and Outcome of Adaptation.

Table 9.1: The Reliability of the Simulation Results, in a HATS Study of Bus Service Reductions.

<table>
<thead>
<tr>
<th>Travel mode</th>
<th>Travel pattern before reduction</th>
<th>'HATS' forecast</th>
<th>Travel pattern after reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Village bus</td>
<td>29</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Walk plus other bus</td>
<td>5</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Cycle plus other bus</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Car passenger plus other bus</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car passenger</td>
<td>14</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Car driver</td>
<td>4</td>
<td>4</td>
<td>12a</td>
</tr>
<tr>
<td>Cycle</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Walk</td>
<td>34</td>
<td>31</td>
<td>37a</td>
</tr>
</tbody>
</table>

* Increases due to special trips on sampled 'after' days, plus seasonal effects.

Source: Martin and Voorhees Associates (1978), Figure 6.8
behaviour, the structure and content of the interviews and the purposes for which the technique may be used. It is also a very transparent technique which can be quickly assimilated by respondents, and the study procedures and findings can be easily communicated to decision makers and the public at large. Some examples of practical findings from studies using gaming simulation and other exploratory survey techniques are presented in the next two sections, covering policy issues (section 9.3) and methodological insights (section 9.4).

9.3 Policy Insights From Exploratory Studies

Although by their nature, the sample sizes used and the types of data collected in exploratory studies are not designed to produce statistically significant results, nevertheless insights gained from such work may be very useful in a policy context and provide reliable guidelines as to the impact or relevance of proposed policy measures. Often, too, the findings are of a nature that were not anticipated prior to the study.

Two examples can be given from the writer's own experience in policy studies using HATS. The first involved a study carried out in the Reading area to look at proposals to upgrade a local railway line (i.e. more frequent services and additional stations) and provide feeder bus services, to cater for demand from a large area of new residential housing (Jones and Dix, 1978). About thirty households were interviewed, during which it became apparent that the feeder bus service would not be used in this capacity, but that it would perform an important function as an outer-suburban bus service linking schools, shops, leisure centres, etc. The local planners had not considered it in these terms, and were able to re-design the service to better meet this need revealed during the HATS interviews. The second study was carried out by planners in Basildon new town, to look at
proposals to improve bus services from one suburb to the city centre (Basildon Development Corporation, 1980). During the interviews the planners found an unexpected demand for a service from this suburb to the main industrial estate (which most workers reached by car), so that the household car could be released for use by housebound wives, to do shopping, chauffeur children, etc., on one or more weekdays.

Useful insights relating to local bus planning have been found in many other instances, too. Gregg (1980), for example, describes a small study of single member pensioner households carried out in Hobart, Tasmania, using activity-based, in-depth interviews.* The author, a planner with the local bus company, found that considerable traffic could be generated by running buses between pensioner units and the main shopping centres on a Thursday (when pensions could be collected), and suggested that bus fleet scheduling could be improved and specially adapted buses provided, if the day of payment of pensions could be staggered in different areas of the city.

Activity-based travel studies also have implications for many other aspects of transport policy. Burns (1979), for example, used Hagerstrand's concept of the time-space prism (Appendix I) to explore the accessibility implications of different Transportation Systems Management schemes. He was able to show that policies designed to increase travel velocities (higher speeds or reduced headways) were less effective at increasing personal accessibility than policies which reduced individuals' timing constraints (e.g. flexible work hours) or the amount of committed time (e.g. labour-saving devices in the home).

In a small study of single and two-parent families with workers and young children, Kam (1982) was able to substantiate this finding

---

*The study formed a research project carried out on a Master of Transport Economics course at the University of Tasmania, under the writer's supervision.
using HATS, in conjunction with activity diaries and attitudinal questionnaires. He found that the introduction of flexitime '... not only releases more uncoupled time to individuals, but also redresses the "imbalances" in family role sharing' — which, he concluded, were as much caused by the time-space constraints as by sociological factors. He also found that (p. 179):

... a flexible work starting time can introduce a relaxed feeling in individuals. Although the real increase in discretionary time during the morning hours is only marginal in most instances, the removal of a perceived constraint which lead to the feeling that individuals can schedule their activities at their own pace is a significant contribution to feelings of well-being.

An indication of the feelings of people affected by policy measures often forms an important component of the output of exploratory studies.

In the remainder of this section we examine the findings of two studies in greater detail. Both used gaming simulation techniques; the first concerned proposals to change school hours in West Oxfordshire (aspects of which were considered in section 6.4), and the second looked at household reaction to different petrol saving policy options in New York State.

**Changes in School Hours**

Many U.K. local authorities have recognised the potential transport savings to be gained from changes in school hours (i.e. reduced peak period road congestion and smaller bus fleets), particularly in areas like South Yorkshire, where education trips account for approximately half the peak public transport journeys (Neffendorf and Brudene11, 1976). However, when staggering policies have been proposed they have often run into opposition from parents and staff. A memorandum on school hour staggering in Southampton (City of Southampton Education Committee, 1973), stressed this point:
All concerned recognise the city's transport problems but are anxious lest action taken to alleviate one set of problems, with the intention of benefitting the community as a whole, should create another equally intractable set of problems for children, parents, teachers and the staff on the ancillary services.

Although trip-based models cannot deal very effectively with issues relating to time management (for reasons discussed in Chapter 7), it is possible to get some idea of the potential impacts of change from available data, if it is interpreted from an activity viewpoint. For example, a number of studies of mode choice for the school journey have shown that only about half the number of children taken to school by car return home by that mode (T.S.M. Jones, 1975; Mukherjee, 1978; Rigby and Hyde, 1977). This suggests that there are significant morning trip linkages with other car-based journeys, in particular a parent dropping children at school on the way to work, but being unable to collect them in the afternoon. It is therefore conceivable that, under certain circumstances, a major revision to school hours that was introduced to separate the morning school and work peaks, so as to spread the demand for contract or service buses, might actually lead to an increase in demand for public transport services (e.g. child transfers from car to bus because trip linkage is broken, or wife keeps the household car to chauffeur their child and the husband travels by bus).

A small HATS-based study in West Oxfordshire was able to examine these issues in greater detail (Jones 1978c). The main findings were reported in section 6.4; the study found that a move towards earlier start times (08.30 instead of 09.00) at this rural comprehensive school was generally well received by local parents and the earlier return home provided opportunities for increased late afternoon or evening travel by pupils and parents. From a policy viewpoint, the interest is
in why school hour changes appear acceptable in some cases but not in others. Insights from the Burford study suggest that the impact of such a change on family life will depend on two main factors: the strength of the linkages between household members (related to the age of the child, mode of travel to/from school and the out-of-home commitments of the parents), and the direction and severity of the effective changes in timings.

In the HATS study, the severity and direction of change was related to revisions in the times at which the child(ren) left and re-entered the parents' care. Where parents took the child to/from school this equated with the school hour shift, but if the local authority was responsible for the school journey it was measured by the change in home departure and arrival times.* In general, the degree of impact was broadly related to the size of the timing change, but families were more sensitive to such changes in the morning than the afternoon. A fifteen minute change usually modified family routines in the morning, but a thirty minute change was required in the afternoon before it really made any difference. There were also suggestions that parents were happier to have children start and finish school earlier, rather than later.

The strength of linkages between household members (and hence repercussion on others) depended on the degree of shared activity and competition for in-home facilities (e.g. bathroom). The former was closely related to the age of the child and the role and occupation of the parents. Older children tended to be more 'independent' (i.e. have fewer or looser linkages with the rest of the household) and so secondary effects were more limited — unless the son or daughter was

*Unless the child was old enough not to require parental supervision at home — in which case it related to how shared activities were affected.
reliant on household transport to get to school. In the predominantly rural HATS sample few wives with younger children were employed outside the home, and so most were readily able to adapt to changes in the hours of child supervision. Very few husbands were affected, but largely because of characteristics peculiar to the study area, including:

(a) the high proportion of RAF personnel (c. 20%) with irregular working hours and frequent periods away from home

(b) the long working hours associated with rural occupations such as farming

(c) the long work journeys for people employed in Oxford (or London)

(d) in all nearly one third were self employed and either spent many hours away from home, or had a very flexible pattern.

Whether the overall impacts of school hour changes on families are evaluated by them as being 'good' or 'bad' depends on the direct effects on the school child, and on the ease with which the rest of the family can adapt. The rural-based households largely evaluated the changes as beneficial. Few parents had a responsibility to transport their children to/from school; wives only worked where children were older (unless a neighbour or extended family member could be relied on); and husbands were largely unaffected through being away from home for long hours, or having a very adaptable schedule.

In urban areas, however, we might expect school hour changes to create more problems, on the basis of what was learnt about behaviour at Burford. Most parents are responsible for their children's journey to school — and so have the worry of stage bus services no longer running at convenient times, or problems of adjusting established chauffering arrangements. More wives work part-time, with factory or shop hours which fitted in with the old school hours, but cannot be readily adjusted to the new. Husbands work locally, in factories or
offices and have fixed hours. They leave home later and return earlier than many of their rural counterparts and are used to a regular daily routine - they would thus be more affected than the Burford sample and would find it more difficult to adjust.

The rural-urban distinction drawn here is clearly an oversimplification, but it was Oxfordshire's experience that greater objections were raised to changing school hours in urban areas. A proposal to retard school hours at a nearby urban comprehensive school in West Oxfordshire was strongly opposed by parents and eventually dropped by the authorities as a result. Exploratory studies can thus provide useful insights into the scope for school hour staggering — and could be used to devise an appropriate scheme.*

Assessment of Alternative Petrol-Saving Policies

The second study was carried out by staff of the New York State Department of Transportation, using a gaming simulation technique called 'REACT' (Response to Energy and Activity Constraints on Travel). The equipment and survey procedures are similar to those used in the HATS technique, which were summarised in section 9.2. The American study is described in Phifer, Neveu and Hartgen (1980).

The authors described the rationale behind using this rather unconventional approach in a planning context as follows (p. 12):

As a result of the present ongoing energy shortage, various policies to curtail automobile fuel consumption have been considered. They have been arrived at by various methods, and each implies differing levels of control of the use and allocation of fuel. Unfortunately, it is often difficult to obtain an accurate estimate of the public's likely direct and indirect

*There was a proposal to carry out such a study for Nottinghamshire County Council in Worksop, but this was abandoned when the local bus company claimed that no savings in operating costs could be obtained from any staggering of school hours.
responses to a particular policy. Some directives might seem to bring about the desired effect but result in severe hardship on certain individuals or families, and frequently there are responses to policies that are not in accord with the intent of those who designed them... Traditional survey techniques, even trip diaries, generally overlook secondary effects.

Four different policies were investigated using the REACT technique:

(1) One no-drive day per weekday (Monday - Thursday) for each car in the household.
(2) One no-drive day per weekend, for each car in the household.
(3) A 20 per cent reduction in car travel on weekdays.*
(4) A 20 per cent reduction in car travel at weekends.*

Policies were introduced in the order: 1, 3, 2, 4.

Twelve families were involved in the pilot study. Strategies for coping with the reduction in fuel consumption included mode switching, trip chaining or re-planning and trip suppression; there were also important non-travel effects, such as changes in role allocation and the re-assignment of tasks among household members.

These responses seemed to be generally in line with previous findings, but the study was able to look more deeply at the impacts of the different types of policy option. It concluded, in particular, that the policies involving a 20 per cent reduction in fuel consumption were much more robust than those that involved a no-drive day. The former resulted in at least a 20 per cent reduction in travel among both one and two-car households, but the no-drive day had a much more limited impact. Households were able to circumvent the latter by transferring trips between days of the week or by borrowing other people's cars; in two-car families the usable car was often made to do the work of both cars - so that in half the two-car households interviewed there was no reduction in travel under the no-drive policy for

*Achieved by introducing some form of petrol rationing.
the weekday. Indeed, in one family there was a net increase in total
vehicle mileage on the no-drive day, thereby resulting in a net
increase in petrol consumption! The authors conclude that (p. 14):*

This type of response and result would not have
been uncovered by using most data collection
methods.

and propose that gaming simulation be developed further as an important
exploratory technique for policy formulation purposes.

9.4 Methodological Insights From Exploratory Studies

Aside from their policy-relevance, exploratory studies can also
help to deepen our understanding of many of the concepts and relation-
ships discussed in Chapters 5 and 6. An investigation of response
strategies by the writer and others, for example, led to the notion of
model domains (Heggie and Jones, 1978) discussed in section 10.2. Policy-
oriented studies have also had methodological repercussions. In the
Basildon study described in the previous section, for example, the
discovery of the importance of household car allocation and inter-
personal linkages as influences on bus patronage led the Development
Corporation to re-arrange their data files from a conventional trans-
portation study so that these issues could be explored quantitatively.

The activity-based exploratory studies often encourage new forms
of data analysis, or suggest new types of approach to modelling or
evaluation. They can also, however, provide insights which can improve
the ways in which more conventional trip-based data analysis and modell-
ing are carried out. Three examples of the latter are given in this
section, relating to: the identification of new explanatory variables,

*From personal communications with researchers in countries such as
Venezuela, where no-drive days have been introduced, it appears that
they have been much less successful in reducing VMT than expected, for
reasons brought out by this small gaming simulation exercise.
the improvement of the conventional travel diary, and improvements
in the modelling of mode choice.

A New Explanatory Variable

One of the key features of much activity-based work has been the
use of stage-in-the-family-life cycle as an important classificatory
variable (e.g. see section 5.4), for stratifying families according to
their activity needs, space-time constraints and inter-personal link-
ages. Within this typology, the presence of young children in a house-
hold has been an important contributory variable.

In the HATS-based study of single and two-parent families with
young children referred to in section 9.3, Kam (1982) found that the
time at which the children woke in the morning had an important influ-
ence on the mother's activity pattern during the day; and further,
that (p. 176):

Routines like the child's bath time, feeding time,
and nap time also create structuring elements which
prescribe the scheduling of chores, shopping trips,
and other out-of-home activities of the housewives.
Those with children attending preschool/play school
were found to combine their shopping, both for per-
sonal and household needs, and other 'servicing'
activities together with the 'serve passenger' trip.
Those whose children are not in either play school
or preschool generally shop when the child is free
of any specific essential routines, and they bring
the child along for the trip. Alternatively, they
shop after their husbands return from work when
children can be left behind with fathers.

He was also able to detect a number of indirect effects on the adult's
travel patterns; including, restrictions on evening social/recreation-
al activity outside the home unless child care help could be obtained,
and (less well documented) the tendancy for husbands to schedule evening
errand trips to avoid times when their wives were fully occupied with
the children and might need to call on them for help.

It was only recently, however, that the presence of young children
in a household was considered to be an important explanatory variable — directly as a result of the type of exploratory study cited here. As a consequence, many conventional travel data sets do not include this variable, and thus cannot be fully utilised to examine out-of-home activity patterns. Reference is made in section 10.1, for example, to the work of Knapp (1983) who has used U.K. National Travel Survey data to carry out some very ingenious activity-based analysis. Unfortunately, this had to be carried out on 1972/3 N.T.S. data, because the 'presence of young children under three' was excluded from the edited tapes of the 1975/6 data, apparently because it was not felt to be a significant influence on household travel behaviour at that time.

Improvements to Conventional Data Collection Procedures

Most urban transportation studies have used trip-based analytical procedures, and have collected household travel information using a one-day trip diary, asking for the origin, destination, purpose, mode and timing of each trip (e.g. see Figure 4.1b). When this has been grossed-up to represent the movements of all residents in the study area, a discrepancy has usually been found between this measure of travel and the volumes observed crossing screen lines and cordon points. The home interview survey invariably seems to underestimate travel, and correction factors have to be applied to the data to compensate for this effect. This shortfall is normally between 10-15 per cent of observed travel overall, with greatest accuracy for work and educational trips and least for social/recreational travel. In the 1972 Reading Travel Survey, for example, (Downes and Root, 1974), correction factors of 1.00 were applied to 'regular' journeys and 1.96 to 'non-regular' ones. The problem is thus a serious one, especially when examining patterns of non-work travel — an aspect which has
been of greater concern with the recent interest in social implications of travel and transport policy.

A number of explanations have been advanced by different writers to account for this shortfall, including: inaccuracies in screen line counts, internal trips made by non-residents, biased sample of households providing complete responses, and measurement and coding problems. These are discussed more fully in Clarke, Dix and Jones (1981), where the writers identify another important reason first confirmed in an exploratory study: incomplete trip recall by respondents, due to difficulties in relating to the trip-based framework embodied in the travel diary.

A priori, one might expect to derive more complete information on travel from an activity diary than a trip diary, because the former records all aspects of behaviour and so it is much easier to spot missing information — for example, a change of location of activity without a record of travel — and correct for it.* Also, one might hypothesise that people would be able to relate more readily to a framework dealing with travel in the context of daily life than one in which travel is presented in rather more mechanistic terms. But would the framework actually affect the accuracy with which trip information was recalled?

In an exploratory study using in-depth interviews, Dix (1975) examined respondents' recall of travel information within five reference frameworks and found that it did make a substantial difference according to which was used. The largest differences were between responses within the 'trip' recall and 'full activity' recall frameworks (in the latter respondents were asked to describe all activities...)

*The logic of the activity diary has been used by Van der Hoorn (1979) to reconstruct missing short trips in a Dutch survey that used a 15 minute recording unit.
undertaken during the day, from rising in the morning to going to bed at night). Not only did the full activity framework produce the most lucid and detailed information about travel (including details of motivations, constraints, etc), but it also led to the recall of more travel episodes than the trip framework. The former seemed a more 'natural' recall framework; shortfalls in travel recall within the trip framework seemed to be due both to respondents 'missing' travel episodes when mentally scanning through the day's activities and ignoring some trips, such as 'visiting my friend' or 'popping to the shops', because they were not immediately construed as travel by the respondent.

An opportunity subsequently arose to test the quantitative effects of using activity rather than trip diaries on respondents in the same area, as part of the SSRC project on 'Understanding Travel Behaviour' at the Transport Studies Unit. An activity diary survey was carried out in Banbury, Oxfordshire, in September/October 1976, exactly twelve months after a conventional trip diary had been administered to respondents in the same town in a survey conducted by Oxfordshire County Council. Examples of the diaries used in the two surveys are provided in Figure 9.5. This shows how the behaviour of the same person might be recorded in a travel and an activity diary, illustrating typical omissions from the former; in this case, a visit to the bank on the way to lunch, and dropping off a friend on the way home.

A general comparison of differences in the volume of travel per person recorded in the two surveys is shown in Table 9.2. Overall, the activity survey recorded 13 per cent more trips per person than the travel survey (4.37 v. 3.86), and an increase in daily travel time of 16 per cent (65.9 v. 56.9 mins). More detailed results (stratified by

*Some results from this survey were presented in Section 5.4
Figure 9.5: Comparison of Diary Formats

(a) Banbury travel survey (Oxfordshire County Council)

<table>
<thead>
<tr>
<th>START OF TRIP ADDRESS</th>
<th>START TIME</th>
<th>METHOD OF TRAVEL</th>
<th>REASON FOR TRIP</th>
<th>END OF TRIP ADDRESS</th>
<th>END TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOME</td>
<td>8.50am</td>
<td>My car</td>
<td>To work</td>
<td>High Street</td>
<td>8.45am</td>
</tr>
<tr>
<td>I LEFT THERE</td>
<td>12:30pm</td>
<td>Bus</td>
<td>To work</td>
<td>Kings Head, Fri St.</td>
<td>1:05pm</td>
</tr>
<tr>
<td>I LEFT THERE</td>
<td>2:00pm</td>
<td>My car</td>
<td>Home</td>
<td></td>
<td>2:25pm</td>
</tr>
</tbody>
</table>

(b) Banbury activity survey (TSU)

<table>
<thead>
<tr>
<th>TIME OF START</th>
<th>ACTIVITY</th>
<th>DETAILS OF TRAVEL</th>
<th>LOCATION</th>
<th>TIME OF FINISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.30</td>
<td>Wash and Dress</td>
<td></td>
<td></td>
<td>8.00</td>
</tr>
<tr>
<td>8.00</td>
<td>Eat Breakfast</td>
<td></td>
<td></td>
<td>8.30</td>
</tr>
<tr>
<td>8.20</td>
<td>Get up</td>
<td></td>
<td></td>
<td>8.30</td>
</tr>
<tr>
<td>8.30</td>
<td>Start &amp; Work</td>
<td>Drive own car</td>
<td>Kings Head, High Street</td>
<td>8.30</td>
</tr>
<tr>
<td>8.45</td>
<td>Work &amp; Shop</td>
<td></td>
<td>Kings Head, High Street</td>
<td>8.55</td>
</tr>
<tr>
<td>12.30</td>
<td>Do own Shopping</td>
<td></td>
<td>Kings Head, High Street</td>
<td>12.50</td>
</tr>
<tr>
<td>12.50</td>
<td>Leave work</td>
<td>Lunch</td>
<td></td>
<td>1:30</td>
</tr>
<tr>
<td>13.00</td>
<td>Cash, Cheque</td>
<td></td>
<td>Markets, High Street</td>
<td>1.50</td>
</tr>
<tr>
<td>13.50</td>
<td>Off for Lunch</td>
<td>Lunch</td>
<td>Markets, High Street</td>
<td>1.50</td>
</tr>
<tr>
<td>1:05</td>
<td>Lunch, home</td>
<td></td>
<td></td>
<td>2:05</td>
</tr>
<tr>
<td>2:00</td>
<td>Get home</td>
<td>Lunch</td>
<td></td>
<td>2:05</td>
</tr>
<tr>
<td>2:05</td>
<td>Get back car</td>
<td></td>
<td>Markets, High Street</td>
<td>2:07</td>
</tr>
<tr>
<td>2:07</td>
<td>Drive own car</td>
<td></td>
<td></td>
<td>2:30</td>
</tr>
<tr>
<td>2:20</td>
<td>Drop off friends</td>
<td></td>
<td>47 Darby's Road</td>
<td>2:21</td>
</tr>
<tr>
<td>2:21</td>
<td>Complete journey</td>
<td></td>
<td></td>
<td>2:35</td>
</tr>
<tr>
<td>2:35</td>
<td>Unpaid shopping</td>
<td></td>
<td></td>
<td>3:00</td>
</tr>
</tbody>
</table>

Source: Clarke, Dix and Jones (1981), Fig. 2
mode and purpose) are provided in Clarke, Dix and Jones (1981), where
other possible reasons for the observed differences are also consid-
ered; the writers conclude, however, that the differences in Banbury
do seem to be mainly due to the survey instruments. The fact that the
travel time increase is larger than the trip rate increase shows that
the extra trips 'captured' in the activity diary are not just trivial
movements (e.g. popping next door to borrow some sugar), but include
trips of average length and above — such as a husband returning home
by car for lunch.

The example demonstrates how methodological insights obtained
from exploratory surveys can be tested on quantitative data sets —
and ultimately incorporated into transportation planning practice.
This last step is reported in Ampt (1981) who, following the results
reported above, carried out an exploratory survey in Sydney, to com-
pare trip rates from questionnaires using a standard and modified
travel survey approach. For the latter, Ampt experimented with an
activity recall framework used by the interviewer, in conjunction with
the diary shown in Figure 9.6.* That is, people were asked what they
did next, but information was only recorded when a journey was made
(note also that it includes reasons for returning home).

Using the modified travel diary within an activity context, Ampt
found that she obtained an increase in trip rate of 14 per cent over
the conventional interview procedure (i.e. up from 4.2 to 4.8 trips
per person). On the basis of this finding from the exploratory survey,
the modified instrument was used in the main 20,000 household survey
carried out in Sydney in 1981.

*The writer contributed to the design of the survey procedure and
questionnaire while acting as a consultant to the State Transport
Study Group of New South Wales, during a visit to Australia in 1980.
Table 9.2: Comparison of Levels of Travel Information from Travel and Activity Surveys in Banbury.

Source: Clarke, Dix and Jones (1981), Tables V & VI
Analysis by Mike Clarke.

Figure 9.6: Modified Travel Diary Used in the 1981 Sydney Travel Survey.
Insights Into Mode Choice Behaviour and Modelling

Section 9.3 included reference to a HATS study carried out in the Reading area (Jones and Dix, 1978), which was designed to investigate the travel needs of residents of a proposed new housing area, including the scope for upgrading rail services in the corridor and introducing feeder bus services. The proposals had been evaluated using conventional procedures, including a doubly constrained gravity model with simultaneous distribution and mode split (see Bright, Garratt and Kinder, 1978); the morning peak period (06:45-09:15) was found to contain the highest proportion of trips, and was used as the basis for detailed evaluation of the proposals. One of the objectives of the exploratory study was to see whether insights could be obtained into mode choice behaviour that could either be directly incorporated into the aggregate model (or a disaggregate version which the authority had just acquired), or could be used to qualify the findings of the evaluation.

As with most trip-based models (see Chapter 7), the mode split model used by the County treated the morning peak as an entity, separately from the rest of the day, and took no account of the travel behaviour of other household members.* The HATS interviews found that there were significant interdependencies, between people as well as in time and space, that were affecting the mode choice decisions for the morning journey to work. In particular:

(a) Travel choices were found to be based on the characteristics of the round trip to/from work, not just the conditions prevailing during the morning peak period.

*The standard procedure is to allocate cars for peak period work journeys and then transfer the residual for use by off-peak travellers (Lamb et al, 1976), so that peak users are not affected by the travel of other household members.
(b) The decision to travel to work by car (where available) was strongly influenced by the need to make trips from the work base during the day, either on business or to run errands in the lunch break.

(c) Mode choice decisions were sometimes taken at the household rather than the individual level, particularly in households with young children; here instances were cited of husbands foregoing the use of the car to travel to/from work, in order for the wife to be able to chauffeur their children, or control them more easily while shopping, visiting, etc.

These interdependencies could be incorporated into the mode choice models available to the County to varying degrees and in different ways (and 'best practice' models already incorporate some of these refinements). Case (b) for example, might be represented by adding a dummy variable to show whether trips were made from the workplace during the day, or the population could be stratified according to whether they made simple or complex journeys. Case (c) demonstrates that, at least among households in lifecycle groups B and C (see section 5.4), the assumption that work journeys have priority over non-work journeys for household car allocation is not completely valid. This is implicitly taken account of during the calibration of peak period mode choice models, by virtue of the fact that not everyone with a car available uses it (for this and other reasons), but there are ways in which it could be made explicit — for example, by stratifying by life cycle group or using the presence of young children in the household as an explanatory variable, perhaps with a measure of accessibility to facilities for the wife and child(ren).

Probably the most significant mis-specification of the model used by the County related to Case (a), the need to take account of characteristics of the journey from as well as the journey to work. Reading
has a large number of commuters who travel to London, and we came across several respondents who drove into the centre of Reading in the morning peak (thereby adding considerably to local congestion), parked their car at the station and travelled to central London by rail. Without exception, the group commented that it would be quicker, cheaper and more convenient to travel into Reading by bus in the morning (along routes with long stretches of bus lane), but that they chose to drive in because there was only a low frequency public transport service operating by the time they had returned from London in the evening. The risk of a long wait was not considered acceptable after a long day in London, and most families felt it would not be feasible for wives to collect their husbands, because of the need to prepare the evening meal and get young children ready for bed.

This finding suggests that the mode choice model calibrated on the basis of morning peak travel characteristics was underestimating the attractiveness of public transport access modes to rail commuting motorists, because it 'assumed' that the choice was based on this period of the day. It is an important mis-specification, for two reasons:

(i) It gives operators and planners a misleading idea of the extent to which public transport is competitive with the private car for town centre journeys — and does not alert them to the possible advantages of extending the period of the evening peak service.

(ii) If the relative importance of Reading as an employment centre were to change, with say the proportion of London commuters decreasing, then public transport usage would be higher than predicted by the model.

Having been alerted to this problem, there are clearly a number of ways of dealing with it (e.g. stratify by peak/peak and peak/off-peak
travellers, model round trips, or use a dummy variable). This example does demonstrate, however, how exploratory activity-based studies can provide insights that can be of value to the transportation planner — even without developing new quantitative methodologies. It also raises other questions; for example, whether the attractiveness of public transport for inter-peak travel is underestimated by models that do not distinguish between inter-peak and evening services, even though the latter are less attractive because of the more restricted service level and the higher car availability than during the day.

9.5 Educational Applications

Activity-based approaches are now having an important educational impact on transportation planning. This is occurring both formally (as outlined below), and informally through the insights being gained by staff in planning agencies who co-operate in the kinds of exploratory studies described in sections 9.3 and 9.4.

Although the concepts of Time Geography developed at the Lund Geography Department in Sweden are an established part of many transport courses in geography and planning departments (e.g. using the summary provided by Thrift, 1977a), the acceptance of activity-based ideas into specialist transport courses has awaited the extension and application of these ideas to specific transport questions. The recent interest in accessibility in transportation planning, for example (e.g. see Pirie 1979) was triggered by the work of Moseley (1979) and others who showed how the concept could be developed in a practical transport context.

The emphasis on developing an activity-based approach specifically designed to examine transport problems in this thesis (and the SSRC project on Understanding Travel Behaviour) has led to considerable interest among educationalists in the approach, and the writer and
other staff of the Transport Studies Unit have been invited to lecture on this subject on many transport courses in this country and abroad. Educational material prepared by the present writer may be found in Jones (1980, and 1982c).

The framework set out in Chapters 5 and 6 is specifically designed to show the role of travel in daily life, the factors which influence household travel patterns, and the way in which households adapt their behaviour in response to changed circumstances. Some of this material has been included in an Educational Manual recently prepared by the writer for use by lecturers on transport courses (Jones, 1982c). Much of it is in the form of overhead projector displays, and one page from the Manual is reproduced in Figure 9.7; this shows some of the components of an individual's activity-travel pattern, and is based on Figure 5.3, in Chapter 5.

Two aspects of the educational use of activity-based approaches are looked at in this section:

(1) The provision of an alternative basis for examining transport problems and generating possible solutions.

(2) The use of the HATS technique as an educational gaming simulation procedure.

'Problems' and 'Solutions'

One of the important features of the activity framework is that it encourages planners and engineers to adopt more of a 'lateral thinking' approach to transport problems. Some examples were given in Chapter 7 and in sections 9.3 and 9.4, but consider the possible ways in which people can substitute other activities for personal travel. These might include:

(a) Deliveries of goods to the home (e.g. mail order shopping).

(b) Use of mobile facilities adjacent to the home (e.g. travelling
Figure 9.7: Example Page From the HATS Educational Manual, Showing O.H.P. Display Sheets.

Source: Jones (1982c), Figure B3.
library service).

(c) Provision of services in the home (e.g. hairdresser, chiropodist).

(d) Communication using telecommunications (especially the telephone and viewdata).*

(e) Visits from friends, relatives, etc. (as substitutes for visits to their homes).

(f) Errands run by others (e.g. neighbour doing shopping for a disabled person).

(g) Self-sufficiency (e.g. growing own food, making own clothes).

(h) Increased attraction of home as an entertainment centre (e.g. music systems, colour television, video recorders).

The activity approach both increases awareness of ways in which travel might be reduced without a corresponding drop in the standard of living or quality of life, and provides a basis from which appropriate methodologies could be developed to monitor, predict and evaluate these responses to changing economic, social and technological conditions.

A second example is provided by the 'problem' of transport congestion, which is often regarded as a symptom of the 'failure' of urban transportation planning. The activity framework provides some additional solutions for tackling this problem, through better time management of the urban system (e.g. the introduction of flexitime, or changes in work or school hours), but it also raises more general questions about the nature and importance of congestion. In particular, the following issues are raised with students for discussion:

*Much has been written about the future role of telecommunications and its likely impact on transportation. See, for example, Day (1973), Niles et al (1976) and Clark et al (1978).
(i) *Congestion is a common phenomenon* and not confined to transport: people queue in staff canteens, on Friday evenings at supermarkets and on many other occasions. It is a common feature of activities when there is a strong peaking of demand, and considered acceptable in these situations — so why not in transport as well?

(ii) *Congestion is not necessarily inefficient*, in two senses: firstly, it may be uneconomic to provide infrastructure for peak requirements that would remain idle during most of the day (this is well documented). Secondly, the concept of congestion is analogous to a weed — which is defined as a plant growing in the wrong place. There are certain activities for which it *is* desirable or necessary to have people come together in the same place at the same time, whether it be for entertainment purposes (e.g. attending a football match, or the theatre), or for the efficient functioning of an industrial or office complex. The concomitant peaking of demand for other facilities which don't benefit from joint utilization follows naturally from this, since people can only be at one place at a time. It forms part of the resulting ebb and flow of daily life. Thus, although traffic congestion may appear to be inefficient, wasteful or harmful in its own right, these disbenefits may be considerably outweighed in a broader context by the economic and social benefits which arise from people assembling in large groups for other activities.

(iii) *Alleviating congestion by restraint measures may be harmful*, because there may be significant secondary costs associated with forced changes to activity patterns brought about by attempts to reduce road or public transport congestion through demand management. The operational benefits of spreading demand may be significant and readily apparent (e.g. higher vehicle speeds, fewer buses), but the institutional and private social costs are less easily measured — and in some cases could heavily outweigh
the benefits. Such proposals might also raise strong public opposition (see, for example, the discussion of school hour changes, in sections 6.4 and 9.3).

Gaming Simulation As An Educational Device

Although visual displays and lecture material can provide many insights into household travel patterns and adaptation, the process is rather abstract and does not provide students with a 'feel' for household problems and responses; nor is it easy to deal with the interactions among large households, or very complex forms of adaptation.

To overcome these difficulties, the HATS technique was modified by the writer for use as a laboratory simulation exercise, in which students form groups and take on the roles of household members — learning how their household organises its daily life and then simulating responses to a range of policy proposals. Compared with the visual display exercises, the gaming simulation introduces a dynamic element, capturing the process of adjustment rather than simply observing its outcome, through group interaction, bargaining and personal trade-offs. It also introduces other subjective factors such as perceptions, preferences and evaluations which cannot be represented directly on the boards.

The HATS simulation exercise has now been run at several educational establishments and at conferences in this country and abroad (including the World Bank, the Transportation Research Board Annual Meeting and in a number of geography, planning and engineering departments in the U.K.). Participants have included undergraduates, postgraduates, practising engineers, planners, decision makers and trainee interviewers. A HATS Manual has been prepared so that lecturers can run their own simulation exercises (Jones, 1982c), and only a summary is provided here.
The main stages of the exercise comprise:

(a) Participants are assigned to roles as household members, and each given a briefing sheet and an activity diary describing one day's behaviour in detail.

(b) Participants then use HATS display equipment (described in section 9.2) to represent current behaviour, and 'household members' examine their activity patterns jointly to identify common linkages, constraints, etc.

(c) Participants are briefed about the proposed policy change, and about the local activity and transport facilities that are available.

(d) The 'households' simulate their response to the proposed change, keeping a record of changes made, problems encountered, etc.

(e) The exercise concludes with a presentation of results by participants and discussion of the value and implications of the exercise.

The complete exercise lasts up to two hours.

An example household which has been used in the simulation exercise is briefly described, in order to give an idea of what is involved and the types of adjustment that are made by participants. The description is necessarily simplified and does not cover all aspects of the simulation.

The household lives in the western suburbs of a new town and comprises a husband, wife and ten year old son; the family do not own a car and neither adult has a driving licence. Their one-day activity-travel pattern is summarised in Figure 9.8. The husband works in London; he commutes by train and is away from home between 08:00 and 18:00. His wife has a job as a shop assistant in the town centre (09:00-16:00), which she also reaches by train; and their son attends a school in the north of the town, to which
Figure 9.8: Activity-Travel Pattern of Example Household in the HATS Educational Simulation Exercise

HUSBAND

- Age 40
- Office Clerk

WIFE

- Age 37
- Shop Assistant

SON

- Age 10
- Student

KEY

* Joint shopping and travel
= Shared evening meal
Work/Education activity

Railway line
Bus route
he travels by bus. After school the son catches a bus to the town centre, where he is met by his mother (who has been carrying out family shopping); he then has his hair cut, is bought some clothing and the two return home together on the train. The wife has three quarters of an hour to complete the preparation of the evening meal, which the family eat together at about 18:30, after the husband's return from London.

The son relies heavily on the local bus service, but it is poorly patronised and there is a proposal to reduce its frequency from half-hourly to hourly in each direction. The object of the exercise is to see how this particular family would be affected by such a change and how they might adapt. The local public transport fares and timetable, and key elements of the land use pattern are presented in Figure 9.9. This shows the various places in the town which are used by the household on this particular day and also identifies a large district shopping centre, which the family do not visit at present. The superiority of the train over the bus for trips to the town centre is apparent (5 min. v. 20 min. journey), and the figure also shows the present timing of the bus service that is proposed for withdrawal.

A quick check of the activity-travel patterns of the three household members shows that the son would be the only person who might be directly affected by the service reduction, as he is the only bus user in the family. Closer inspection shows that his morning trip to school is unaffected, but that the bus he catches to meet his mother in town would be withdrawn — so that the mother would also be affected indirectly by the proposed change. The two consider how they might overcome the problem.

The immediate suggestion is that the son wait for the next bus to the town centre, but he is not very keen on the idea of hanging around at school for half an hour after it closes, so he suggests he walks instead. Neither parent is very happy about this; it involves a long walk (over 2 miles) crossing several busy roads and he would only arrive tired and not feeling up to going round the shops. Further thought shows that anyway he would take as long to get there on foot as if he had waited for the next bus, so there is no advantage in the idea.
Figure 9.9: Local Public Transport Timetable and Fares Used in the HATS Educational Exercise.

**ROUTES:**

![Diagram of local public transport routes]

**SERVICES:**

**Bus Timetable:** (mins past each hour)

<table>
<thead>
<tr>
<th>Stop</th>
<th>(HH)</th>
<th>Service</th>
<th>Stop</th>
<th>(HH)</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>00</td>
<td>30</td>
<td>6</td>
<td>00</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>05</td>
<td>35</td>
<td>5</td>
<td>05</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>40</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>45</td>
<td>3</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>50</td>
<td>2</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>55</td>
<td>1</td>
<td>25</td>
<td>55</td>
</tr>
</tbody>
</table>

( ) = Service proposed for withdrawal

**Rail Timetable:** (mins past each hour)

<table>
<thead>
<tr>
<th>Stop</th>
<th>(HH)</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>55</td>
</tr>
</tbody>
</table>

**FARES:**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Stage Description</th>
<th>Adult</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus:</strong></td>
<td>Travel 1 Fare Stage</td>
<td>10p</td>
<td>5p</td>
</tr>
<tr>
<td></td>
<td>2-3 Stages</td>
<td>15p</td>
<td>10p</td>
</tr>
<tr>
<td></td>
<td>4+ Stages</td>
<td>20p</td>
<td>10p</td>
</tr>
<tr>
<td><strong>Rail:</strong></td>
<td>Single Fare (suburb-centre)</td>
<td>25p</td>
<td>15p</td>
</tr>
<tr>
<td></td>
<td>Local Day Return</td>
<td>35p</td>
<td>25p</td>
</tr>
</tbody>
</table>

**Source:** Jones (1978c), Figure C.3g.
The earliest the son can reach the town centre is around 17:00 and since the shops close at 17:30 it is clearly no longer possible to have a hair cut and then shop. One possibility is to spread the activities over two afternoons (i.e. 2 x half hour visits, instead of 1 x 1 hour visit), but the son is not keen on giving up two afternoons and neither is his mother: she would have to wait around for him for half an hour on two days — and it's such a rush getting the evening meal when she isn't home until 17:45. Another option might be to switch the activities around (i.e. shop then hair cut), because the barbers will stay open until they have dealt with all customers who turn up by 17:30; but nobody likes this idea, which is risky and anyway would result in mother and son arriving home after the father, at 18:15. It would mean a long afternoon for the two of them and the husband is not at all keen on returning home to an empty house — and having to wait a lot longer for his evening meal.

Using the town centre no longer seems very attractive: it means a lot of waiting around for both mother and son, because of the poor bus service, and the activities can no longer conveniently be fitted in. After some thought the son suggests a different idea: why not use the district shops nearer the school, which he could reach on foot? He could have his hair cut and there are some reasonable clothes shops — he's seen them from the bus. The wife is not sure the choice is so good, but it's worth considering: they have a look at the timetable . . . and . . . after some debate, conclude that it could work quite well. The wife would catch a bus straight after work to the district shopping centre and the son would join the bus as it passed his school. They would arrive at the centre at about 16:15 and immediately go in search of clothes. Once these had been found the son would have his hair cut, while the mother completed household shopping. This would enable them to leave the centre by 17:15, in time to catch a bus home, which they would reach well before 17:30 — giving the wife longer to prepare the evening meal and providing the son with a decent interval in which to complete his homework, or go out to play before his meal.

The changes in travel which arise from this decision are shown in Figure 9.10. Students are surprised to find after the exercise that
**Figure 9.10:** One Possible Response to the Bus Service Cutbacks in the Educational Exercise.

**REVISED TRAVEL PATTERNS:**

**Wife:**

**Before:**

**Son:**

**After:**

**TRIP AND FARE IMPLICATIONS:**

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
<th>Rail</th>
<th>Walk</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Trips</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Revised Trips</td>
<td>5</td>
<td>1</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Existing Expenditure</td>
<td>20p</td>
<td>50p</td>
<td>-</td>
<td>70p</td>
</tr>
<tr>
<td>Revised Expenditure</td>
<td>45p</td>
<td>25p</td>
<td>-</td>
<td>70p</td>
</tr>
</tbody>
</table>

*Source: Jones (1982c), Figure C.3h*
while the trip rate and travel expenditure for wife and son has remained constant, the distribution between modes has changed considerably, with a reduction in rail and walk journeys and an increase in bus use. In this instance, a reduction in bus service frequency has increased bus usage and fare revenue, and has led to a switch in patronage from the town centre to the district shopping centre.* The example is not meant to suggest that bus patronage will normally increase if services are reduced, but rather it demonstrates the importance of service timing on low frequency routes, and the way in which time-space constraints and inter-personal linkages can lead to counter-intuitive forms of adaptation.

Other examples, covering school hour changes, revised work hours and changes in life cycle stage are provided in Jones (1982c). Two case studies are also included showing how the simulation exercises can be adapted to meet course requirements — in one case dealing with rural accessibility and in the other with problems of urban congestion.

The HATS simulation exercises have been very well received by groups as diverse as practising engineers, civil servants and undergraduates, and it appears that participants are able to adopt the roles they have been given and simulate the decision processes of real households to a remarkable degree. There are perceptible differences, however, in the ways in which students and practitioners respond to and benefit from the exercise.

Students readily adapt to the exercise and take it in their stride, alongside lectures on conventional transport modelling, etc — though for some the presentations at the close of the exercise represent their first attempt at addressing an audience. Practitioners are generally

*This example has been used on at least twelve occasions, with very different groups, yet the outcome is surprisingly consistent.
much more skilled at the latter, but find the idea of the exercise rather strange and approach it more warily. Once involved, however, they usually make very good participants (having had more experience of some of the roles) and show more immediate benefits from the experience: it presents them with a different view of their everyday problems and many are genuinely surprised and excited by this — especially when they have already become aware of certain problems with the conventional approaches. The format of the exercise makes both groups of participants relaxed and rapidly breaks down any inhibitions, leading to a level of realism in the bargaining and debate which it would be very difficult to achieve without the display equipment.

Clearly the laboratory simulation cannot fully represent all influences on household decision making (such as historical background, aspirations, perceptions) and is no substitute for field surveys. But it does represent a very powerful means for getting across activity-based concepts, and makes practitioners more aware of the nature of household travel behaviour and the implications of this new approach for transportation planning.
10. IMPLICATIONS FOR ANALYSIS, MODELLING AND EVALUATION

In this chapter we examine some of the more established areas of transportation planning methodology, to see what implications the activity-based work has for these types of application. Chapter 9 and Part Two of this thesis have demonstrated some of the complexities of behaviour which can be handled conceptually and qualitatively using this framework; but to what extent have these ideas and insights been translated into operational procedures, or been investigated quantitatively using larger scale data sets?

This question is addressed here by looking at the following implications for transportation planning methodology:

10.1 : The analysis of travel and activity data
10.2 : A strategy for modelling household travel behaviour
10.3 : Models incorporating activity-based concepts
10.4 : The evaluation of policy measures

An assessment of these developments is made in Chapter 11.

10.1 Data Analysis

One feature of the activity-based studies is the very wide variety of data sources that have been used, requiring a corresponding diversity in the methods employed for data analysis.* Morris (1982) classifies these data according to the sample size/geographical scale of coverage (ranging from micro to macro), and the time period covered by the survey (from one day to many years). Her typology is reproduced in Figure 10.1, where I have grouped the survey procedures into three broad categories.

The first group (I) comprises a number of mainly qualitative research methods, such as in-depth interviews and interactive

*See, for example, the review of empirical studies in Damm (1983).
Figure 10.1: Range of Data Sources Used in Activity-Based Research

(micro) ——— (macro)

(survey day)

In-depth interviews
Interactive measurement techniques (e.g. gaming)
Focus groups
Cross-section interviews
Experimental design (e.g. conjoint analysis)
Disaggregate travel surveys
Transportation studies

Activity diary studies
Before & After surveys

Panel surveys

Backtrack interviews
Rotating & duplicate survey
Continuous surveys

Time-series (repeated cross-section surveys)

Source: Morris (1982), Figure 3.
measurement techniques; these are characteristic of small scale, exploratory studies and examples of data analysis at this level have been provided in Chapter 9. Group II is distinguished not so much by its methodological approach — it includes a mixture of qualitative and quantitative procedures and small and large sample sizes — but rather by the time horizon of the studies, which usually range over several years. In these studies the objective is to identify 'macrodynamico' effects, as described by Clarke, Dix and Goodwin (1982); they include demographic changes, residential relocation, car ownership etc., and lie outside the scope of this thesis. The emphasis in this section is on some of the data sources classified in group III, which covers various types of (cross-sectional) travel or activity surveys.

The analysis of household activity-travel patterns is a much more complex subject than conventional travel data analysis, involving as it does a variety of activities with different attributes, behaviour in time as well as space, and various forms of constraint and inter-personal linkage. Not surprisingly, therefore, there have been a wide variety of approaches to activity data analysis, ranging from studies of time allocation to work on the structure of activity patterns. Several of these studies are reviewed in Appendix I, and a more detailed description of some analytical methods is provided in Parkes and Thrift (1980), covering measures of time use, the determination of space-time prisms and time series analysis of activity patterns.

In their review of activity-oriented analysis in travel research, Burnett and Hanson (1982) conclude that the majority of researchers have tackled the problem of complexity by analysing only one or two aspects of travel behaviour. Examples of 'dependent variables' used in these studies include: timing, duration, location (e.g. distance from home, or travel time from previous stop), mode, frequency, sequence of events, priority, or planning horizon. Recently, however, there have been a
number of attempts to measure travel as part of a pattern of behaviour, covering both trip sequences and the out-of-home activities which they link together.

In the remainder of this section we examine three aspects of this work, namely:

(a) The operationalisation of concepts.
(b) The measurement of complete activity-travel patterns.
(c) The identification of variables affecting activity patterns.

The type of data analysis described here is not an area in which the writer has been directly involved, and so the objective of this section is to give a general indication of the work now underway. Note that unless otherwise stated, the analyses have been carried out using modified travel data sets, rather than full activity data.

**Operationalisation of Concepts**

The activity framework introduces many new concepts into transportation planning, a number of which bring with them considerable problems of translation into an operational form. In some cases this may be because the concept is difficult to quantify (e.g. the 'flexibility' of an activity pattern), and in others because a mechanism operates at a micro level and may be difficult to identify within aggregate data sets. Despite these difficulties, however, considerable progress is being made. Three recent examples are given below.

Holzapfel (1982) has carried out a detailed activity-based analysis on a sample of over 10,000 households from a travel survey in West Berlin, in which he looked at five main groups of activity (other than travel): work, education, shop, leisure and in-home. He was able to examine issues such as the uniformity of activity patterns for selected population groups, by computing the standard deviation of activity
participation by time of day; and went on to define a measure of activity 'fixity', which was the proportion of the total time spent on activity $a$ by group $g$ which fell within the modal time block (i.e. a block of time corresponding with the average duration of $a$, and timed so as to maximise this proportion). He was then able to rank activities in order of their fixity for each population group.

In the second part of his study, Holzapfel looked at the distance to activity facilities from people's homes (measured in terms of travel times) and compared this with the spatial pattern of opportunities. From this he was able to identify a latent measure of 'resistance to spending time in travel', which was negative exponential in form. He found that the rate of decay differed between groups, but was consistent between cities, and was able to demonstrate that this resistance to travel was directly related to the temporal constraints faced by different groups. In particular, employees who finished work later than average on weekdays were shown to have a lower home-based shopping trip rate and a higher resistance to travel for shopping after work than those who finished earlier. This is a very significant finding, as it suggests that parameters in a conventional gravity distribution model could be related to temporal constraints on behaviour.

Notions of 'fixity' have also been examined in a less direct way by Kitamura (1983) in a study of 'serve-passenger' trips, using a sample of over 4,500 households from the 1965 Detroit Area Transportation and Land Use Study. The author argues that serve-passenger trips act as a constraint on individuals' scheduling possibilities, because of their tight space-time definition, and hypotheses that this will lead to travel patterns that are distinctively different from those of people who do not generate such trips. This is confirmed: the effect of serve passenger trips on the number of home-based trip chains (of both workers and non-workers) is extremely large, and Kitamura is able
to identify characteristic ways in which these trips are linked to other non-home activities. On the basis of these findings, he is able to make a number of inferences about the ways in which serve-passenger trips shape individuals' travel patterns.

A third example of the operationalisation of concepts is provided by Herz (1983), who uses German data from a national continuous survey of travel behaviour and several urban transportation studies to look at aspects of the stability, variability and flexibility of the daily travel and out-of-home activity patterns of different groups. He was able to define precise measures for each concept; for example, using a Fourier analysis to examine the stability of behaviour of population groups over time, and the extent of atypical activity sequencies among different groups as a measure of their flexibility of behaviour. His work shows that very useful empirical analyses can be undertaken using aggregate data, although the author cautions that (p. 399):

The mean acts here as the great illusionist levelling off almost all the behavioural differences which are observed in reality.

and argues that an explanation of individual behaviour has ultimately to be sought at a micro level.*

Measurement of Activity-Travel Patterns

The activity framework emphasises the importance of viewing travel as part of a pattern of daily behaviour, and so faces the analyst with the problem of measuring complete activity-travel patterns, rather than discrete trips. This has been achieved at a descriptive level through the development of the 'prototypical activity pattern', as illustrated

*The HATS school hour study reported in section 6.4 also demonstrated how an apparent stability in aggregate time budgets before and after a change can mask important adjustment to activity and travel patterns at a more detailed level.
in Figure 5.9, but there have also been a number of attempts to develop quantitative measures of pattern. Three distinct approaches can be identified in the literature:

(i) The use of graphical procedures  
(ii) Use of pattern recognition techniques  
(iii) Measurement of characteristics of stops

Graphical procedures are used to plot the probability of taking part in activities at different times of day, in a visual form which enables the reader to rapidly assimilate the information. Kutter (1973), for example, devised a series of 'activity profiles', using transportation study data, that each show the probability of taking part in one activity by time of day. Clarke (in Jones, Dix, Clarke and Heggie, 1983) has presented similar information, with the addition of in-home activities, on a composite diagram using 'tube' plots to show the proportion of people engaged in each of six types of activity by time of day; an example was provided in Figure 5.10. Similar plots have been prepared using travel rather than activity diary data, and are reproduced in Dix et al. (1983).

Further examples of the diverse ways in which information on activity patterns can be displayed are provided in Knapp (1983), who used the 1972/73 National Travel Survey as his data base. One of his diagrams is reproduced as Figure 10.2; this shows the proportion of heads and wives in different life cycle groups who were engaged in a paid work activity on an average day, by time of day. It brings out very clearly the stability of the husbands' role and daily routine across life cycle groups (at least until retirement), in contrast with the major changes faced by wives. Note also the higher probability of the latter being employed in the morning than in the afternoon — and the way in which the sharp change in probabilities of participation for all groups at
Figure 10.2: Deriving Patterns of Work Activity, by Life Cycle Stage, Using Conventional Travel Data

Source: Knapp (1983), Figure 4.
certain times of day contribute to the morning and evening peak travel periods. Graphical procedures are clearly a very powerful means of presenting pattern information.

Having devised a means of visually representing activity-travel patterns, the second approach goes somewhat further and tries to identify characteristic patterns of behaviour. This can be done simply by devising an exhaustive classification of patterns, or in a more sophisticated way by using some formal procedure for grouping the patterns. An example of the former is given in Figure 10.3 from a study of the evening activity patterns of married couples, by Kostyniuk and Kitamura (1983). The authors identified six different types of path a priori, based on location and coupling criteria, and then examined to what extent their incidence varied by life cycle group and other characteristics.

A more formal approach is adopted by Recker, McNally and Root (1983), who used pattern recognition techniques to classify the activity-travel patterns of respondents in a Southern California travel survey. They measured behaviour according to three criteria: type of activity, distance from home, and time of day (see Figure 10.4) and were able to decompose the activity pattern into two components for analysis, based on activity type by time of day, and distance from home by time of day. About fifty transform coefficients were used to represent each image, and respondents were best classified into nine distinct groups.

Rather than dealing directly with the measurement of pattern, either visually or mathematically, the third approach concentrates on the characteristics of the 'stops' made along a daily path. These are represented by vectors in 'n' dimensional space; Burnett and Hanson (1979), who first proposed the approach, suggest that the following attributes be measured: time of arrival at stop, distance from last
Figure 10.3: A Classification of Path Types

1. NO ACTIVITY

2. INDEPENDENT PATH, HUSBAND ALONE

3. INDEPENDENT PATH, WIFE ALONE

4. INDEPENDENT PATH, HUSBAND AND WIFE

5. JOINT PATH, CONTACT POINT OTHER THAN HOME

6. JOINT PATH, CONTACT POINT HOME

Source: Kostyniuk and Kitamure (1983), Figure 1.

Figure 10.4: Decomposition of an Activity-Travel Pattern

Source: Recker, McNally and Root (1983), Figure 2.
stop, location of present stop, mode used to get to stop, activity conducted at stop, and land use at the stop.

Pas (1980) shows how this approach can be operationalised in a study using data from the 1977 Baltimore Travel Demand Survey. For each stop, he records the type of activity (four categories, including home) and the time of day (using five time periods over the day). He then develops a measure of similarity between patterns, in which he weights the activity component as twice the time of day component (but ignores the sequence as this is implicit in the time of day measure). Patterns are then grouped using a cluster analysis technique; each cluster is represented by the actual sequence of stop characteristics closest to the centroid, except that in the more heterogeneous groups more than one set is used. In one example, the patterns were grouped into twelve clusters, which were characterised using 24 representative patterns; a description of the characteristics of each pattern is provided in Table 10.1.

A more complex example of this approach is given in a small scale study by Kam (1982), which uses full activity diary data. Kam divides the day into four time periods, and for each period uses cluster analysis to group behaviour into similar activity-travel patterns. Eighteen types of activity are identified (7 in-home, 4 types of travel and 7 out-of-home), distinguishing whether behaviour is discretionary or obligatory and coupled or uncoupled, and four measures are used: duration, frequency, number of activity types and number of transitions per time period. Having identified clusters, the sequence of activities in a period is then examined qualitatively and a representative pattern produced for each cluster. The activity-travel patterns associated with the five-cluster solution for the early morning period are reproduced in Figure 10.5. This is among the most ambitious work on pattern structure so far reported in the literature, and the author was able to
Table 10.1

Daily Travel/Activity Pattern Types (12 Cluster Solution)

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single non-home stop patterns for a maintenance activity, with movements in the midday period</td>
</tr>
<tr>
<td>2</td>
<td>Similar to type 1, except that movements are in the evening period</td>
</tr>
<tr>
<td>3</td>
<td>Single non-home stop patterns for a leisure activity, non-peak period movements</td>
</tr>
<tr>
<td>4</td>
<td>Single non-home stop for subsistence activity, movements in the morning and afternoon peak periods</td>
</tr>
<tr>
<td>5</td>
<td>Similar to type 4, except that the movements are in non-peak periods</td>
</tr>
<tr>
<td>6</td>
<td>Similar to type 5, except that movements take place in other non-peak periods</td>
</tr>
<tr>
<td>7</td>
<td>Two non-home stops separated by a return home after the first stop. First stop is for a subsistence activity, with peak period movements. The second non-home stop is for a leisure activity, with movements generally in the evening period</td>
</tr>
<tr>
<td>8</td>
<td>Similar to type 7, except that the second non-home stop is for a maintenance activity</td>
</tr>
<tr>
<td>9</td>
<td>Two non-home stop patterns, with a return home after the first stop, as for type 7 and 8. Both stops for leisure activity, with movements mainly in the midday period</td>
</tr>
<tr>
<td>10</td>
<td>Multiple maintenance stop patterns, all movements in the midday period</td>
</tr>
<tr>
<td>11</td>
<td>Many out-of-home activities, generally including one stop for a subsistence activity. Many maintenance stops, with one or more leisure stops. At least two returns home during the twenty-four period. Movements in many time periods</td>
</tr>
<tr>
<td>12</td>
<td>Similar to type 11, except that these patterns contain at least two subsistence activities, and generally not more than one non-subsistence activity</td>
</tr>
</tbody>
</table>

Source: Pas (1980), Table 5.9
Figure 10.5: A Classification of Activity Patterns
For the Morning Hours (06.00 - 09.30)

Source: Kam (1982), Figure 11.
demonstrate a clear relationship with social role (see below).

Identification of Variables Affecting Activity Patterns

A very thorough and detailed review of empirical findings from work that has used activity-based approaches to studying travel behaviour is reported in Damm (1983), to which the reader is referred for an assessment of the state of the art, up to 1981. Morris (1982) has produced a summary of Damm's main conclusions, which is reproduced in Table 10.2. The variables known or thought to influence the structure of activity patterns are grouped under three headings: individual characteristics, household characteristics and constraints.

Most of the studies reported earlier in this section have gone on to relate their measures of activity-travel patterns to various socio-demographic characteristics of the population or features of the local environment. Pas (1980) for example, in a series of logit models, finds that his patterns of stops can be related to employment status, marital status and the presence of young children below 12 years of age. Recker et al. (1983) also examine how the groupings they obtain from the pattern recognition techniques relate to a number of variables, and their findings are reproduced in Table 10.3; note how, in addition to the variables reported by Pas, they find that mode, income and density have an important influence.

One of the more detailed classifications of individuals is provided by Holzapfel, who used cluster analysis to group members of the 10,000 households in his sample into 43 categories, based on similarities in behaviour as measured by activity-time and activity-space profiles. The main dimensions of his classification included: household size (single or multi-person), employment status, social status, age and sex.

The importance of life cycle stage as a classificatory variable was discussed in section 5.4, where it was shown to influence both the time
## Table 10.2
Summary of Empirical Findings of Activity-based Research
Based on a Comparative Study by Damm

<table>
<thead>
<tr>
<th>Variables of Known Importance in Structuring Activity Patterns</th>
<th>Variables Whose Importance is only Partly Established</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Education</td>
</tr>
<tr>
<td>Work status</td>
<td>Occupation</td>
</tr>
<tr>
<td></td>
<td>Age</td>
</tr>
<tr>
<td><strong>Household Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Life cycle stage</td>
<td>Hierarchical structure</td>
</tr>
<tr>
<td>(esp. age and number of children)</td>
<td>Role differentiation</td>
</tr>
<tr>
<td></td>
<td>Car availability</td>
</tr>
<tr>
<td></td>
<td>Income</td>
</tr>
<tr>
<td><strong>Constraints</strong></td>
<td></td>
</tr>
<tr>
<td>Time of day</td>
<td>Time of week (weekday vs. weekend)</td>
</tr>
<tr>
<td>Interactions</td>
<td>Flexibility of start and finish times</td>
</tr>
<tr>
<td>Fixity of activities</td>
<td>Familiarity with surroundings</td>
</tr>
<tr>
<td>(in time, space or both)</td>
<td></td>
</tr>
<tr>
<td>Spatial accessibility</td>
<td></td>
</tr>
<tr>
<td>(computed separately for home, work or other 'fixed' base)</td>
<td></td>
</tr>
<tr>
<td>Mode of transport (motorised)</td>
<td>Non-motorised modes</td>
</tr>
</tbody>
</table>

Source: Morris (1982) Table 2
<table>
<thead>
<tr>
<th>Number (X)</th>
<th>Travel/Activity Characteristics</th>
<th>Socio-Economic Characteristics</th>
<th>Urban Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 32 (4.8)</td>
<td>Single work trip of about 25 miles</td>
<td>Predominantly employed, male household heads Age (25-34) 97% Drivers</td>
<td>Low density/high income</td>
</tr>
<tr>
<td>B 56 (8.4)</td>
<td>Single work trip of about 7 miles Evening shopping trip</td>
<td>Predominantly employed, male household heads Age (35-44) 93% Drivers</td>
<td>Low density/high income</td>
</tr>
<tr>
<td>C 83 (12.5)</td>
<td>Work/school activity within 3 miles of home, evening social/recreation activity</td>
<td>Non-employed spouses and children, even sex and age distributions 572 Drivers</td>
<td>High density/low income</td>
</tr>
<tr>
<td>D 62 (9.3)</td>
<td>Multiple non-work sojourns within 3 miles of home, no evening travel</td>
<td>Predominantly female non-employed Age (&gt; 25) 71% Drivers</td>
<td>Low density/high income</td>
</tr>
<tr>
<td>E 47 (7.1)</td>
<td>Single work trip of about 15 miles Evening work/school activity within 2 miles</td>
<td>Predominantly employed male household heads Age (25-54) 96% Drivers</td>
<td>Low density/high income</td>
</tr>
<tr>
<td>F 6 (0.9)</td>
<td>Single work trip of about 2 miles Multiple non-work evening sojourns (no return trip home before 12.00 A.M.)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>G 306 (66.1)</td>
<td>Single school/work trip of about 1 mile, no evening travel</td>
<td>Predominantly female 50% employed adults 50% school aged children 47% Drivers</td>
<td>High density/low income</td>
</tr>
<tr>
<td>H 66 (9.9)</td>
<td>Single work trip of about 7 miles No evening travel</td>
<td>Predominantly employed even sex distribution Age (25-54) 76% Drivers</td>
<td>High density/low income</td>
</tr>
<tr>
<td>I 6 (0.9)</td>
<td>Extremely long travel (not identified)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Source: Recker, McNally and Root (1983), Table 3.
budgets and activity-travel patterns of households. This variable is classified by Damm (see Table 10.2) as one of known importance; the reader is referred to Jones, Dix, Clarke and Heggie (1983) and de la Morsangliere (1982) for case studies, and Zimmerman (1982) for a general review of this work. Another variable which Damm reported to be less well established was the significance of role differentiation as an influence on activity pattern formulation. Work completed since he prepared his review is showing that this is indeed an important determinant of behaviour.

It was reported in section 5.4 that in his study of serve-passenger trips, Kitamura (1983) found that the structure of the travel patterns he analysed were more closely associated with social roles and the non-home activity set, than with more conventional measures of individual and household characteristics. Kam (1982) confirmed the importance of role in his study referred to earlier where, in addition to classifying full activity-travel patterns in some detail, he attempted to define family role structures.

Kam used 22 variables to measure family role structure relating to time spent on work, child care and housekeeping activities (both in-home and out-of-home) by time of day, both by the respondent and spouse, together with socioeconomic and attitudinal measures. He then reduced the number of variables using cluster analysis, with factor analysis on some of the larger clusters, to produce several distinct 'role situational types' at different times of day. He compared these with the previously defined representative activity patterns (see Figure 10.5) and found that "... role enactment significantly influences activity scheduling behaviour." Table 10.4 is taken from this study and shows the close association between the two; note, in particular, that no two role situational types share the same dominant activity scheduling pattern. This conclusion is very encouraging, but
Table 10.4: Relationship Between Role Situational Type and A Pattern of Activity Scheduling:

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>ROLE SITUATIONAL TYPE</th>
<th>PATTERN OF ACTIVITY SCHEDULING</th>
<th>PROBABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Morning Hours</td>
<td>1. The Early Hour Provider</td>
<td>1. Straight to Work</td>
<td>90.9</td>
</tr>
<tr>
<td></td>
<td>2. The Long-distance Traveller to Work</td>
<td>2. Minor Chores Child Care Before Work</td>
<td>58.4</td>
</tr>
<tr>
<td></td>
<td>3. The Child-concerned Provider</td>
<td>3. Home-care and Errand Before Work</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>4. The Leisure Careraker</td>
<td>4. Organized Homemaking</td>
<td>66.8</td>
</tr>
<tr>
<td></td>
<td>5. The Hectic Careraker</td>
<td>5. Recurring Housework - Child Care</td>
<td>80.0</td>
</tr>
<tr>
<td>6 a.m. to 9 a.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. The Part-time Provider</td>
<td>2. Multiple Travel After Work</td>
<td>66.6</td>
</tr>
<tr>
<td></td>
<td>3. The Work-at-home Provider</td>
<td>3. Multipurpose Trip After Work</td>
<td>76.0</td>
</tr>
<tr>
<td></td>
<td>4. The Housewife</td>
<td>4. Mixed Activity</td>
<td>100.0</td>
</tr>
<tr>
<td>9 a.m. to 4 p.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Early Evening Hours</td>
<td>1. The Long-hour Provider</td>
<td>1. Work-Dominant</td>
<td>61.3</td>
</tr>
<tr>
<td></td>
<td>2. The Easy Provider</td>
<td>2. Mixed Activities After Work</td>
<td>41.2</td>
</tr>
<tr>
<td></td>
<td>3. The Long-distance Traveller from Work</td>
<td>3. Chores and Child Care After Work</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td>4. The Easy Homemaker</td>
<td>4. Multiple Travel Activities</td>
<td>81.3</td>
</tr>
<tr>
<td></td>
<td>5. The Active Homemaker</td>
<td>5. Busy Homemaking</td>
<td>71.4</td>
</tr>
<tr>
<td>4 p.m. to 7 p.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Late Evening Hours</td>
<td>1. Constrained by Children</td>
<td>1. Limited Uncoupled Time</td>
<td>36.0</td>
</tr>
<tr>
<td></td>
<td>2. Enthusiastic about Outdoor Recreation</td>
<td>2. Recurring Uncoupled Activity</td>
<td>67.1</td>
</tr>
<tr>
<td></td>
<td>3. Not keen on Outdoor Recreation</td>
<td>3. Uncoupled Time After 9:30 p.m.</td>
<td>56.7</td>
</tr>
<tr>
<td>7 p.m. to 12 a.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Probability of Correct Assignment of Roles to Patterns

Source: Kam (1982), Table 31.
awaits confirmation using a much larger data set also containing complete activity records.

Assessment

These recent studies give a broad indication of the types of work now underway to operationalise activity-based concepts and measure relationships. Note that in most instances these advances have been made using conventional travel data. However, as Holzapfel comments and Kam's work confirms, there are advantages in having some information on in-home activities when examining roles and constraints on the timing of travel.

Although there is still some way to go in the measurement of concepts and relationships, and in reaching agreement on the best way of incorporating these developments into transportation planning practice, nevertheless the indications are that most of the remaining analytical problems are tractable and can be overcome in time.

10.2 A Strategy for Modelling Household Travel Behaviour

Heggie (1978) has suggested that travel demand models fulfil three main roles:

(i) They help people to understand and explain behaviour
(ii) They assist with policy formulation
(iii) They provide accurate predictions for design and evaluation.

As we have already seen, roles (i) and (ii) can also be partly fulfilled in other ways, such as through the development of an explicit conceptual framework of travel behaviour (Chapters 5 and 6), or the use of exploratory study procedures (Chapter 9). In the next two sections we concentrate on the role which has traditionally been regarded as the primary function of models within transportation planning: the
accurate forecasting of travel behaviour.

Many of the methodological developments during the seventies that were reviewed in section 3.4 represented attempts to meet predictive deficiencies in the contemporary four-stage aggregate models used in transportation planning, which became apparent as the emphasis switched from projecting demand to forecasting response to change. These developments were successful to varying degrees (section 4.1), but left a number of methodological problems un-resolved including:

- The modelling of complex travel patterns
- The improved definition of choice sets
- The handling of linkages, both among people and between discrete events in space and time, and
- The forecasting of secondary impacts.

It was concluded in Chapter 7 that the activity framework provides an appropriate conceptual basis for resolving these issues; but that, because of their complexity, this is a necessary rather than a sufficient condition, and there might be difficulties in developing appropriate techniques for practical use. The discussion in the preceding section has shown, however, that despite these difficulties considerable progress has been made in the operationalization of concepts and the establishment of empirical relationships, both of which are important prerequisites for the development of activity-based forecasting procedures.

The contribution of activity-based approaches to improvements in the modelling of household travel behaviour takes two forms:

(a) It can provide a strategy for modelling, in which the appropriateness of models for different applications is identified.

(b) Through the development of forecasting models incorporating activity-based concepts.
The remainder of this section considers the first of these, while the second is examined in section 10.3

Response Patterns and Model Domains

The activity framework helps us to understand how, in certain circumstances, household response to some external change in conditions may result in complex forms of adaptation: by invoking mechanisms identified in Chapter 6 (e.g. see Figure 6.2), a person may affect the lives of others, or completely restructure his/her own activity pattern. On other occasions, however, a different set of mechanisms may be involved, or the effects of a change may be contained within the activity pattern and lead to only slight adjustments to adjacent activities, at the most. There is thus no single response strategy and no one type of model that is uniquely suited to predicting changes in household travel patterns.

It is apparent from the discussion in Chapters 3 and 4 that transportation planning models have been developed for a number of different purposes (e.g. see section 3.5) and that those already developed are capable of handling most of the simpler forms of household adaptation. What is required from the activity approach are models for dealing with complex responses, and a set of criteria for deciding when one model rather than another is appropriate for a particular application. With regard to the latter requirement, there are three ways in which the activity-based work can make a useful contribution:

(i) By making explicit the assumptions upon which different types of travel demand model are based.
(ii) By identifying key elements of different forms of household response, that would have to be incorporated into a model dealing with that type of response.
(iii) By providing guidance as to which response pattern is likely
to be invoked by a policy measure, and hence the kind of
predictive model that would be appropriate.

Modellers are generally well aware that the models they develop
are based on a set of assumptions about travel behaviour, concerning
both the factors that are the key explanatory variables and how these
relate to the dependent variable, and they usually document this as
part of the description of the model. Often, however, there are also
a number of implicit assumptions of which the modeller may be unaware
—or unable to control for—because of an incomplete understanding of
travel behaviour.

The activity framework provides a basis for developing both a
deeper and broader understanding of household travel behaviour and thus
is able to make explicit some of these underlying assumptions. A
number relate to the view of travel embodied in the trip-based concep-
tual approaches, which were illustrated and discussed in Chapters 4 and
7. Examples include the mis-specification inherent in destination
choice models that do not take account of space-time constraints when
defining choice sets, or the biases that may arise in mode choice
modelling if the decision elements are not incorporated fully (see
section 9.2). This aspect is not considered further here.

Chapter 6 discussed in some detail how households adapt to change,
and suggested that we could identify a number of distinct response
strategies, arranged in a hierarchical order to reflect the complexity
of response. Heggie and Jones (1978) have argued that we should similar-
ly define a set of model domains, corresponding to areas where
different response mechanisms operate and hence where different modell-
ing assumptions would be appropriate.

We can perhaps draw a broad analogy by likening the response mech-
anisms to the various cogs in a complex gearbox; most actions only
bring a sub-set of the cogs into operation, and in attempting to represent the processes invoked by the actions we can simplify the problem and ignore those elements not involved. The appropriate simplifications will vary according to the type of action invoked. It is widely accepted in the physical and applied sciences that empirical relationships only apply under certain conditions (e.g. over a certain range of temperature or pressure), and the authors suggest that this notion should be applied in the social sciences as well. They set out a simple, four-domain categorisation, based on the importance of inter-personal and spatio-temporal linkages.

As a basis for modelling responses in the more complex, higher-order domains, Clarke (1980) suggests that we characterise decision processes as comprising five sets of behavioural rules:

1. **Personal** rules, relating to the perceptions and preferences of the individual.

2. **Inter-personal** rules, which govern linkages between people, both within and outside the family, and affect both the allocation of activities and resources.

3. **Scheduling** rules, which affect the ways in which people develop and attempt to maintain daily routines.

4. **Environmental** rules, representing decisions concerning home and work place location and the level of car ownership, which affect the local availability of activity and travel facilities, in space and time.

5. **Logical** rules, which by their nature cannot be broken; they include the impossibility of being in two places at once, or carrying out two or more primary activities at the same time.

Figure 10.6 attempts to set out some relationships between response strategies, model domains and behavioural rules, based on a categorisation of response strategies in Jones, Dix, Clarke and Heggie (1983).
Figure 10.6: Relationships Between Response Strategies, Model Domains and Behavioural Rules.

Level of Response:

E V E N T

P A T T E R N

S T R U C T U R A L

Rule Status:

(1) Adjustable
(2)-(5) Fixed
(1)&(2) Adjustable
(3)-(5) Fixed
(1)&(3) Adjustable
(2),(4)&(5) Fixed
(1)-(3) Adjustable
(4)&(5) Fixed
(1)-(4) Adjustable
(5) Fixed

ENVIROMENTAL CHANGES:

Buy a Car
Move House
Give up Job
...etc

KEY:

---→ = Secondary Effects

Rule (1) = Personal
Rule (2) = Inter-Personal
Rule (3) = Scheduling
Rule (4) = Environmental
Rule (5) = Logical

I - V = Domain Numbers

Source: Derived from Jones, Dix, Clarke and Heggie (1983), Figs 10.1 & 10.2
Here five model domains are distinguished:

(a) At the EVENT level:

*Domain I: Independence* between successive travel or activity episodes undertaken by one individual and between decisions taken by different people (although there may be indirect interactions at an aggregate level, as when there is local congestion). Here personal (type 1) rules may be modified, but the others are assumed to be unaffected by the change.

*Domain II: Inter-Personal Linkages*, where a travel or activity decision is taken jointly by members of a group (e.g. a household) or where decisions taken by one person will directly affect the behaviour of others, without leading to significant changes in the structure of their activity patterns. Both personal (1) and inter-personal (2) rules may be modified.

(b) At the PATTERN level:

*Domain III: Spatio-Temporal Linkages*, where the individual is again an independent decision taker, but here changes to one activity or travel episode do significantly affect the overall structure of his/her activity pattern (e.g. shopping affected by changes in the work journey). Here personal (1) and scheduling (3) rules may be modified, but the others are assumed to be unaffected.

*Domain IV: Full Interdependence*, where both inter-personal and spatio-temporal linkages operate to affect the activity-travel patterns of a group of people, but where more major decisions such as residential

*Strictly speaking, few responses are made at the event level, because where the timing and/or location of one activity is affected this must affect at least one other activity. However, we may regard responses that do not disturb the activity pattern significantly as occurring at this level.*
location or car ownership are assumed to be unaffected. Types (1), (2) or (3) rules may be modified within this domain.

(c) At the **ENVIRONMENTAL** level:

**Domain V: Higher-Order Effects**, in which adaptation involves more fundamental 'long term' changes to the set of environmental factors (e.g. change in residential or work place location); these, in turn, may lead to re-adjustments to the lower order rules (e.g. live with a different group of people, or adopt a different daily routine). Thus, types (1) - (4) may be modified within this domain.

A properly calibrated model would be expected to perform satisfactorily within the domain for which it was developed, but would lose credibility if it were used in situations where higher order domain assumptions applied — although there would be cases where simpler structures might be acceptable on pragmatic grounds.

Models incorporating more complex representations of response (in which many of the behavioural rules are taken account of explicitly) could in principle be used in the simpler domains, but in practice this would generally be inappropriate. The more comprehensive models would usually be more data hungry and more expensive to operate than the simpler models, and the breadth of coverage would have been achieved at the expense of depth of treatment; thus, a pattern-level model is unlikely to deal with the characteristics of a particular event in as much detail as an event-based model. Models developed for different domains are therefore likely to be complementary rather than competitive in function, and indeed there are now instances of hybrid models being developed that use modules from more than one domain (see section 10.3).

The existing transportation planning models reviewed in Chapter 3 are thus likely to continue to have an important role to play, but need to be augmented by models that can function effectively in the higher
order domains. Before describing examples of recent activity-based models of this type, in Section 10.3, we briefly consider another aspect of the domain approach to modelling travel behaviour—how to decide the appropriate domain from which to select a model for a particular application.

Determining the Appropriate Domain

In more established areas of the physical and social sciences the role of different domains has been determined from case histories, theories and the development of empirical rules and relationships. There have, however, been few monitoring studies of travel behaviour that have been sufficiently broadly based to identify possible secondary effects on travel and non-travel activities. At the moment, therefore, we have to rely on exploratory studies and the conceptual framework itself to provide this guidance. From the material presented in Chapters 6 and 9, for example, we can identify at least three dimensions that will influence domain selection: the type of change, whether it is 'forced' or 'permissive', and the kinds of person and household affected.

The nature and severity of a change is a prime indicator of the type of response which is likely to result. Changes in the cost or quality of a travel mode, for example, are more likely to impact at the event level, whereas timing changes may have repercussions at the pattern level—which is why conventional travel demand models are better able to deal with the former. Also, the larger the change in the timing, location, cost or other activity attributes, the less likely it is that the overall activity pattern will remain unaffected and the more likely that other people will become involved,* because of

*Some of these factors are more likely to trigger substantial secondary effects than others, or to do so at a lower threshold point.
the operation of mechanisms discussed in Chapter 6.

The effect of the second factor (i.e. whether a change is forced or permissive) lies not so much in the type of response pattern that it produces, but in the certainty of a response. With a forced change, the affected group can usually be readily identified; it can be assumed that they are aware of the change and that they will adjust to the new situation in some way. By their nature, permissive changes tend to increase choice and invite rather than demand a response. As a result it is more difficult to identify the groups who might benefit, or to be sure to what extent people will become aware of the change.

Evidence suggests that when the magnitude of a policy change is small, forced changes are usually more effective at modifying behaviour than permissive ones: increased parking difficulty is more likely to change the mode or destination of trips than a public transport improvement. When the change is perceived to be substantial, however, a permissive change may lead to as radical a restructuring of behaviour as a forced one. For example, the opening of a new hypermarket may affect the destination, mode, timing, frequency and travel group for household shopping trips and significantly change daily activity patterns; similarly, an increase in discretionary income may precipitate a change in residential location.

Household and person characteristics are a third important factor affecting response to a change. They determine whether a change is relevant to a person, how much scope they have for marginal adjustment and whether other people are likely to become involved. Retired people, for example, have less tightly packed or constrained activity patterns than younger individuals and so are usually able to absorb larger changes than the latter by taking up slack in their schedules; further, because they are usually also more home-centred, there are likely to be fewer repercussions on spatio-temporal linkages. Children, by contrast,
are closely tied to their parents and the clock and so the whole family is usually involved in any change which affects them. As the children grow up they become more independent until, once they have their own job and car, they have few daily links with other household members and may respond to many policies as though they were embryonic one-person households.

These generalisations are only indicative. In reality, many external changes will trigger a whole range of responses, to varying degrees, from no change through to moving house — 'it was the last straw' — and it is a case of identifying the more significant effects. Specific insights of this nature can be obtained from a small exploratory study, designed to establish the main responses to a change and the modelling requirements of a policy assessment; an example of this process was given in Section 9.4.

One general point to emerge is that the responses of different population groups appear to lie predominantly within different domains: retired people commonly adapt at levels I or II, whereas families with children often respond at the Domain IV level. Further discussion of these points is provided in Heggie and Jones (1978) and Jones, Dix, Clarke and Heggie (1983).

10.3 Models Incorporating Activity-Based Concepts

Most trip-based models operate within Domains I and II, at the event level, and thus have considerable difficulty in handling the more complex forms of behavioural response. The present modelling difficulties are particularly apparent in the case of the 'typical' family, comprising husband, wife and one or more children. This type of household unit is affected by a wide range of policies (e.g. health, education, social services, transport) because its members perform many roles
and cover a wide age range; here the strong spatio-temporal and inter-
personal linkages mean that the internal ramifications of a change on
the unit's members may be considerable.

Activity-based models have a particular contribution to make at the
pattern level (Domains III and IV). They also enable more comprehensive
models to be developed at the event level (Domains I and II), because
they treat travel explicitly as a derived demand — through the modelling
of activity choices — and enable timing considerations to be introduced
into the choice process. Models operating within Domain V are not con-
sidered here, as they lie outside the scope of the thesis.

There are now a considerable number of activity-based travel models
at different stages of development, which vary widely in their structure
and scope. Several examples are included in the papers in Carpenter
and Jones (1983), and a brief overview has been provided by Morris
(1982). Some more general activity models, not designed specifically
for transport application, are reviewed in Appendix I. It would be
impracticable to describe all these models in detail; in this section
I attempt to give an indication of the variety and potential of this
work by examining three types of development:

(a) Improvements to individual choice models, at the event level.
(b) Event models, within a pattern-oriented simulation system.
(c) Models developed explicitly at the pattern level.

Examples of other types of model are given briefly at the end of this
section.

Improvements to Individual Choice Models

One of the main limitations of models at the event level is that
they fail to take account of the effects of space-time constraints on
behaviour — which may be significant even if we assume that the basic
pattern of activities and travel remains unaffected. Landau, Prashker and Alpert (1982) attempt to meet this problem by developing a procedure for defining constrained destination choice sets, rather than adopting the conventional assumption that all destinations are available to all travellers; these sets are then input into a simultaneous mode and destination choice shopping model.

Choice sets are derived on an individual basis, by assuming that a person is not prepared to spend longer on shopping plus travel than at present (although the distribution between the two might vary), and taking explicit account of shop opening hours and (where appropriate) work and school hours. The procedure was used on Israeli data and was found to reduce the size of the choice set and lead to modest improvements in predictive accuracy. The main problem was to decide the boundary to place on a person's 'reach'; it was arbitrarily assumed at first that there was a complete trade-off between travel time and shopping time, and the procedure was subsequently improved by introducing the requirement that a minimum proportion of the time be spent shopping.

A second approach to incorporating timing considerations in individual choice models has been to model behaviour separately for different periods of the day. Some of the analyses described in section 10.1 (e.g. Kam, 1982) also found that the significant variables and relationships vary by time of day, which provides an additional reason for proceeding in this direction.

One of the best documented models of this type has been developed by Damm (1979), who looked at the daily travel patterns of employed persons and forecast the incidence and duration of any deviations around the basic 'home — work — home' weekday routine. The day was divided into five periods (i.e. pre-work, home-work, at work, work-home, at home) and for each period models were developed to predict the probability of a non-home activity (other than work) and the
duration of that activity. The models were able to incorporate some features of Domain II and III responses by:

(i) Allowing for some inter-personal linkage effects, through variables such as car availability and the number of trips made by other people in the household.

(ii) Introducing some interaction between time periods, by using a variable which measured the amount of non-home/work discretionary time in the other time periods.

A limitation of Damh's work is that it does not explicitly include timing constraints. Landau, Prashker and Hirsh (1981) have moved in this direction by modifying Damh's approach. They develop two sequential models, the first to establish whether a household makes a trip for a particular purpose at any time of day; then, if so, which time of day will be selected (for the latter choice, there is both a household and household member version of the model). Two trip purposes are examined in separate models, covering maintenance and leisure activities, and four time periods are used, namely: pre-work, start of work journey to end of work activity, end of work activity until 7 p.m. (when shops close in Israel) and after 7 p.m. Thus, shopping cannot be carried out in the fourth time period.

Temporal constraints are also included in a number of the variables in the models, in addition to more conventional land use and socio-economic variables. The former include:

(a) Morning free time (defined as the difference between the time at which the worker leaves home and 8 a.m., when most shops and offices open).*

(b) Working time (in hours).

*If the difference is negative, the variable is set to zero.
(c) Duration of work journey.

(d) After-work free time (defined as the difference between work finish time and 7 p.m.). *

Additional independent variables are incorporated to represent interactions between household members and time periods as in Damm's model, using dummy variables.

Forms of individual choice models are thus now being developed that can handle time-space constraints at an event level, and can also provide some indication as to whether changes are likely to occur at the pattern level too.

*If the difference is negative, the variable is set to zero.

Event Models In a Simulation System

Two devices were described at the event level to extend the behavioural range of the individual choice models: the use of such a model in conjunction with a choice set definition model, and a finer segmentation by time of day than the conventional distinction between peak and off-peak periods. The second approach described here takes both these strategies somewhat further, by encasing a choice model within a simulation system that replicates the behaviour of a population for a large number of time periods through the day.

An early version of a hybrid simulation/choice model of this type was developed by the writer and is described in detail in Jones (1974) and in Appendix III of this thesis. In this model, the simulation system performs three main functions:

(1) *Allocation:* it determines the number of people who are ready to undertake each broad category of activity at the start of a simulation time period.
(2) **Accounting:** it keeps a record of the simulated behaviour patterns, by zone and time period.

(3) **Constraint:** it identifies a number of constraints on the choice process (both objective and subjective) and identifies specific sets of choice options.

The model is designed to simulate the aggregate activity/travel patterns of an urban population over a 24 hour period, showing the use made of the various activity and travel facilities at different sites throughout the day, and the way in which such behaviour is affected by changes in facility provision.

The broad structure of the model is illustrated in Figure 10.7. It simulates activity/travel choice by time period, given information on the general pattern of demand for activities (by person type) and the supply of activity and travel facilities. At the commencement of a new simulation time period the model identifies the numbers of people (of a given type) from each residential zone who are about to undertake each broad category of activity. Where the activity might (e.g. leisure), or must (e.g. shopping) be carried out away from home a feasible set of activity/destination and mode options are identified (including, where appropriate the non-travel option) and the choice model predicts locational and travel decisions; activity duration may be a standard mean value or be represented by a frequency distribution. The program checks the feasibility of the choices (e.g. it ensures that people are not still shopping after the shops close) and records the choices made. People (and cars) are stored until they have completed their allocated activities and are then released at the appropriate time to make another choice.

Two forms of output are provided by the model:

(i) The numbers of people using facilities in each zone (stratified
Figure 10.7:

Structure of the Hybrid Activity-Travel Model

**INPUTS:**
- Pattern of Activity Demands
- Supply Characteristics: Activity and Travel Facilities

**CONTROL PROGRAM**
- Number of Cars available
- Number of People Starting New Activity
- Availability of Activity and Travel Facilities

**OUTPUTS:**
- Numbers of People x Activity x Zone
- Numbers of People x Mode x Link
by activity and person type) during each time period.

(ii) The numbers of people (and vehicles) travelling between zones, by mode, purpose and time period.

It thus provides an indication of aggregate patterns of behaviour across an urban area over a day, highlighting the ebb and flow of daily life, and may be used to indicate the general impacts of policy changes on the use of facilities in the study area. An example of how the model could be used to demonstrate the effects of evening bus service cut-backs in different areas and at different times of day is shown in Figure 10.8.

The model is able to take quite detailed account of a number of factors which constrain choice. It establishes which facilities are open during the current period and whether transport is available for the outward and return journey, and at what cost. It also takes account of forward commitments to subsequent activities (in an aggregate way), is able to simulate the effects of car availability, and treats trip generation for leisure activities as a trade-off between in-home and out-of-home activities. However, it also has a number of serious limitations. It is not able to predict basic changes in the pattern of demand for broad activity groups during the day (since this is provided as an input) and, being aggregate in nature, cannot take detailed account of person-specific, inter-personal and time-space constraints.

Thrift (1977c) considers that it is impracticable to model activity patterns in any detail at an aggregate level, because of what he calls the 'time-space budget paradox', which he explains as follows (p. 441):

The reason would seem to be that by aggregation information is lost in a tangled time-space skein which cannot then be unravelled again. In particular individual identities are aggregated (although the individual as a number may retain a co-ordinate) and then randomly reallocated when the model is run.
Figure 10.8: Modelled Impact of a Policy Change on the Urban System: Effects of a Reduction in Evening Bus Services.
Van der Hoorn (1983) has recently described a simulation system based on a set of logit-based disaggregate travel demand models, which being micro-based has the potential for avoiding some of these problems. It has some similarities with the model described above, but is more closely related to an entropy-based activity model developed by Tomlinson et al. (1973), and described in Appendix I. The disaggregate models are used to predict choices between 16 activities and three types of location: at home, in 'town' and out of 'town'. There are separate models for each of five person types, for weekday and weekend, and for each of the three previous location types.

Van der Hoorn describes the operation of the simulation system as follows (p. 338):

The day is divided into 96 quarter hours. The program starts at t=1 and finishes at t=96. For each quarter hour the fraction of the population engaged in mandatory activities at each location is set equal to the observed fraction in the SCP database. The remainder of the population is either engaged in previously started discretionary activities or belongs to the so-called 'free-population' at each location. The free populations are assigned to activities and locations using the logit models. Because of various restrictions, not all activities and locations are available at a particular time-of-day. The choice set at each time t, therefore, has to be defined carefully. The result of the calculations is a distribution across activities and locations which can be compared with the distribution of the previous quarter hour. By examining the changes in location the number of trips made can be derived.

This is similar in concept to Tomlinson et al.'s model, except that it is disaggregate and replaces the fixed a priori probabilities in the earlier model with probabilities derived from the logit models, as a function of exogenous variables.

The model has been developed using data from a one-week activity diary survey of around 1,300 people in the Netherlands, and early results are promising. Like the model developed by the writer (but not made operational), Van der Hoorn's model is able to take account of opening hours
and other restrictions, and to trade off between in-home and out-of-home activities; it places relatively less emphasis on travel choices, however, and more on a fine division of activity choices. A number of refinements are proposed by Van der Hoorn, which include:

- Estimate models conditional upon previous activity as well as location.
- Make activity durations a function of exogenous variables.
- Use a distribution of activity durations, rather than the mean value.
- Predict time budgets for certain activities, rather than taking them as given.

The simulation approach has a number of attractive features as a framework within which to use individual choice, or aggregate, models of travel and activity behaviour. Apart from providing an accounting mechanism to record who completes an activity, when and where, it offers a very flexible and transparent structure which enables it to be adapted in a number of ways. In particular, it allows modules to be added or removed and the complexity of measures to be varied. Information can be input at varying levels of detail and one variable could be exchanged for a complete sub-model. In general, however, in order to provide the detailed outputs by activity, location and time of day, these models make correspondingly heavier demands on the data inputs than models firmly within the 'event' domains.

**Pattern-Based Models**

The simulation models provide something of a bridge between the event and pattern levels, by simulating the pattern of activities during the day as a series of sequential choices at the event level. Thus, although the output is at the pattern level, these models are not able to deal effectively with the complete restructuring of activity
patterns — though they can accommodate certain adjustments between time periods.

A third group of activity-based models have been developed to deal explicitly with the restructuring of daily activity/travel patterns. Two semi-operational models are available: 'PESASP' (Program Evaluating the Set of Alternative Sample Paths), developed by Lenntorp (1976)* and 'CARLA' (Combinatorial Algorithm for Rescheduling Lists of Activities) by Clarke (1980).

PESASP is a simulation model which estimates the number of ways in which an individual can perform a set of activities in a given environment. It requires information on the activity programme (i.e. the set of activities, when and where they can be undertaken), and on the space-time structure of the environment (i.e. opening hours, travel times, bus timetables etc.). The simulation then generates possible ways in which the individual can perform his/her programme by:

(i) Considering permutations of the sequences of activities.
(ii) Testing the possibility of performing activities at different sites or 'stations'.

It does not take explicit account of linkages between the activity programmes of members of a household. The outcome of a simulation is a measure of the number of ways in which a person could accomplish his activity programme, which can be used to see whether a policy increases or reduces freedom of action or whether some groups benefit at the expense of others.

CARLA uses a different type of algorithm for generating possible combinations of activities, based on a combinatorial approach. It was developed as part of the SSRC project on 'Understanding Travel Behaviour'.

*PESASP has also been used in non-transport applications and is discussed more fully in Appendix I.
(Jones, Dix, Clarke and Heggie, 1980), and incorporates some of the elements of the HATS conceptualisation of behaviour (see Section 9.2). A diagrammatic representation of its operation is reproduced in Figure 10.9. The algorithm takes an existing activity pattern, decomposes it into its elements and examines the number of feasible ways in which the pattern might be re-assembled, given constraints on the timing and duration of activities; certain leisure activities are excluded, as they are assumed to represent 'filling-in' time. Constraints include the timing of work and school activities, shop and pub opening hours, selected limits on changes in the duration of activities, and limits on the extent to which activities can be brought forward or delayed in time (e.g. meals may be moved up to 1 hour either way). Any of these constraints can be altered in the model.

Some results from early model runs are provided in Clarke (1980), and were based on data from the school hour study described in section 6.4. There are nearly 40 million permutations of 11 activities, but when the temporal constraints and logical rules are included, typically around 100 feasible activity programmes result, which produce around 5 different travel patterns. CARLA is also able to reproduce the threshold effects and some of the other aspects of adaptation discussed in Chapter 6. These results were for runs on individual activity patterns, taking account of detailed temporal constraints, but only simple spatial ones. CARLA is modular in form and is now being extended to include a more detailed spatial representation and explicit inter-personal link-ages between the activity programmes of household members.

Although PESASP and CARLA share some similarities in the kind of input data they require, there are a number of important philosophical differences between the two models, apart from the difference in algorithm. PESASP is primarily concerned with what people could do, rather than what they will do, and examines the space-time environment
Figure 10.9:
Schematic Representation of the Operation of CARLA

Source: Clarke (1980), Figure 3.
in minute detail; Parkes and Thrift (1980) report that in one study in which 230 activity programmes were to be simulated, 14,000 pieces of data on stations, transport networks, etc., were required and the study produced 3,500 pages of computer output. CARLA, by contrast is seen as a step in the modelling of household travel behaviour (Clarke and Dix, 1980), and is thus more concerned ultimately with what people will do — although at present it cannot predict actual choices (except where these are constrained to one option). It is based on a computationally more efficient algorithm then PESASP and is intended to work with data at a more general level of spatial detail associated with the conventional transportation studies.

Even without the facility to forecast behaviour both models have found practical application in the examination of public transport service levels — something which cannot be handled satisfactorily at an event level. Lenntorp (1978) describes the use of PESASP to examine public transport travel in the city of Karlsted; and CARLA is currently being applied in a Dutch study to look at the scope for reducing rural bus service frequencies without severely disrupting people's activity-travel patterns (Clarke, Van Kippenberg and Splinter, 1983).

The prospects for developing operational pattern-based models to forecast household adaptation thus look encouraging. Ways in which CARLA could be extended to fulfil this function are discussed in Clarke and Dix (1980). The main requirements are for the development of a choice sub-model to be used in conjunction with CARLA, either based on an objective function or on measures of the utility of different activity patterns, and for an efficient procedure for aggregating and generalising the results. These problems appear to be surmountable: exploratory studies are providing insights into possible objective functions, and the activity pattern measures reviewed in section 10.1 offer a means of characterising patterns and thus deriving utility measures. With regard
to aggregation, Clarke and Dix suggest a number of possibilities, including the preparation of results for selected prototypical groups (when it is only necessary to assess the types of impact on different groups), and the use of sample enumeration procedures (e.g. see Daly, 1982).

Other pattern-based models are also likely to be developed in the near future. Root and Recker (1983), for example, present a theoretical specification for a dynamic model of individual activity pattern formation that uses a multi-objective dynamic programming approach, able to deal with conflicting objectives and with random disturbances during the course of the day.

Assessment and Further Applications

We are now beginning to see a rapid growth in the development of a wide range of activity based models of travel behaviour which embody a number of the concepts set out in earlier chapters and build on the greater awareness of the determinants of travel that is being obtained from the many empirical and exploratory studies reported in the literature. Modellers are also being consciously selective in the variables they incorporate and the types of response pattern with which they seek to deal, and several have found the concept of 'domains' to be a useful basis for model development — although the very crude categorisation now used needs to be refined.

The notion of model domains also helps to define a role for the conventional trip-based models, which at times have come under heavy criticism (see Chapter 3); it is not so much that these models are poorly specified — although there is always scope for improvement — but rather that they have been applied to situations outside the range of their limiting assumptions. To an extent, therefore, we can see the ideas of model domains and the levels of conceptual complexity
described in Section 3.1 as being similar in approach: both emphasise
the need to relate methodology to requirements and to use techniques
in a complementary way. To draw a parallel with the field of medicine,
we have moved away from the expectation of finding an elixir for all
our ills, to the notion of ailment-specific prescriptions, each best
able to tackle a particular type of problem, or a general problem in a
characteristic way.

The selective review of activity-based models in this section has
shown that the transport research community is able to develop models
which incorporate activity concepts and in many cases are able to
handle more complex types of response; further, a number of these
procedures seem capable of being modified for use in practical trans-
portation planning contexts. The explicit incorporation of linkages,
in time-space and/or among people, is a characteristic feature of all
the models reviewed above. Their ability to handle the structure of
travel patterns increases, as expected, as we move from the event to
the pattern level: the individual choice models take account only of
broad associations between time periods, the simulation systems are
able to look at the detailed 'knock-on' effects of a change through the
day, and the pattern-based models deal with the complete restructuring
of activity patterns. Inevitably, however, data requirements also
increase as we model household adaptation at more detailed levels.

There are interesting differences in the way in which problems of
choice set definition are handled in the various models. At the event
level, it is only an explicit feature in one model reviewed here, where
it is achieved by using an additional sub-model. In the hybrid, simula-
tion/choice models it is handled by the simulation system itself, which
is able to take account of forward time-space commitments, and so
identify a person's feasible choice set at any point in time. The
pattern-based models are even more advanced in this respect, because
they are able to look at choice sets comprising completely different patterns of activities, rather than just alternative locations for a specific activity — and indeed, in their present form both PESASP and CARLA can themselves be viewed as sophisticated choice set definition models.

As Clarke and Dix (1980) have suggested, an operational model of complex household travel behaviour might be developed by combining CARLA with some form of individual choice model, in which the options are complete activity patterns, rather than individual activity events. The hybrid approach has proved to be a successful strategy in the simulation/choice models, and looks a very promising way of developing a model system for use in transportation planning practice.

The models described here represent some of the main developments in attempts to model activity-travel patterns quantitatively. There are also other methods of assessing policy impacts, however, not reviewed in this section for a number of reasons. For example, because they are only partially activity-based, or do not consider, say, the spatial or time-of-day dimensions, do not forecast behaviour but simply analyse existing patterns, or are based on the use of exploratory research techniques. These diverse types of approach also offer procedures that may have a useful role in transportation planning.

A number of examples of how these other techniques have been used to assess the impacts of energy shortages are provided in Jones (1983a). One of these was described in section 9.3: the REACT gaming simulation method (Phifer et al., 1980). This was able to identify ways in which two-car households would be able to circumvent the effects of a 'no-drive day' policy, by using the alternative car more intensively, and the types of simulated response corresponded well with the observed aggregate effects of petrol shortages and restraint measures in other
countries – despite the very small sample sizes used.

The analytical techniques described in section 10.1 have also been used directly in a policy context. Recker et al. (1980), for example, used pattern recognition techniques to identify Representative Activity Patterns among residents of Southern California, and were then able to identify groups who would be most severely affected by energy constraint policies; they examined whether each group could adapt through trip chaining, etc., or whether some more basic change in their activity set would be necessary. The study highlighted the fact that for those segments of the population most severely affected by conservation policies, the responses examined (namely trip chaining, utilisation of more energy-efficient vehicles and activity site substitution) would be insufficient and a fundamental change in life style would be necessary.

An example of a quasi-activity computer simulation model is provided by Poeck and Zumkeller (1978), who simulated the effects of energy shortages on regional travel patterns. The authors grouped the population into categories with homogeneous travel patterns; within each group, specific trip chain sequences characteristic of that group were ranked in order of priority and according to their sensitivity to changes in travel time and travel cost (some were elastic with respect to time or cost, others were inelastic). Personal time and money budgets were introduced as overall constraints in the model, which was used to examine the probable impact of a 300 per cent increase in petrol prices. Responses predicted by the model included the cancellation of trips, switches in destination and mode, and an increase in trip chaining.

A final example uses the closed system property of the daily time budget to look at the effect of a change in time allocation to one activity on the time spent on all other activities. Allamanu, Tardiff and Dunbar (1982) developed a Time Derivative Matrix, which is based on
information recovered from the residuals of time allocation regression equations. Specifically the elements of the TDM give the partial derivative of time allocation for a particular activity, with respect to a unit increase in time allocation to another activity. Using this approach it is possible, for example, to look at the effect of time spent queueing for petrol on time allocation throughout the remainder of the day — including any secondary effects on other time spent in travel activities. The latter can, in turn, be used to estimate changes in overall Vehicle Miles Travelled.

These different approaches give an indication of the breadth of the methodological advances which are being made in association with activity-oriented studies. Some wider implications of this work are discussed in Chapter 11.

10.4 Evaluation of Policy Measures

To date, very little work has been carried out explicitly on the implications of the activity approach for transport evaluation, although we noted in section 7.3 that several of the activity concepts could provide elements of a framework for a social evaluation of transport policies. This section is thus inevitably shorter and more speculative than the others in this chapter.

Broadly speaking, transportation studies incorporate three distinct types of formal evaluation procedure (e.g. see Dalvi and Martín, 1973), which have been added incrementally as transportation planning policy and methodology have evolved:

(i) **Operational**, based on measures of system performance (e.g. vehicle hours of travel, link overloading, intersection delays).

(ii) **Economic**, which measures benefits to travellers, in monetary
terms and assesses the resource costs of the scheme.

(iii) Environmental, an attempt to measure external effects on non-travellers (e.g. noise and visual intrusion, social disruption).

The operational evaluation tends to be used as a filter, to select schemes which would cater for predicted 'demand' (whether by car or using public transport). The main ranking of alternatives and justification for investment is provided by the economic evaluation, with the environmental evaluation being used to subjectively adjust the output of the economic evaluation.

As we noted in section 3.3 and elsewhere, a particular approach to studying travel carries with it implications both for policy and methodology. Thus, the trip-based approaches are associated with certain perceptions of transport problems and solutions and this affects the kinds of data that are collected and the ways in which they are analysed. In terms of forecasting policy impacts, it means that certain types of policy measure can be better handled (via model inputs) than others, and that the models provide outputs that enable evaluation to take account of particular dimensions of impact, with varying degrees of accuracy.

Because the activity approach provides a different perspective for studying travel behaviour, it automatically carries with it a predisposition towards identifying particular types of transport problem and solution (e.g. involving urban time management), and uses its own characteristic data collection and analysis procedures (e.g. focusing on patterns of behaviour). It thus encourages different types of policy measure to be brought forward for evaluation,* and enables them to

---

*This was in fact one of the main reasons for developing a new approach: that it would be able to handle certain policy issues better than do the existing approaches (see Chapter 4).
be evaluated on dimensions other than those conventionally employed. Further, to the extent that the activity-based models prove themselves capable of providing better predictions of complex responses, they will also improve the accuracy with which certain aspects of the evaluation can be undertaken.

In this section we briefly examine two kinds of contribution that the activity-based work could make to transportation evaluation:

(a) Through improvements to the conventional measures of user benefit.

(b) Through the development of new measures of user and non-user benefit.

**Improvements to the Conventional Measures of User Benefit**

Benefits to travellers arising from transport improvements are measured by the economic evaluation, and comprise savings in vehicle operating costs, accident costs and savings in travel time. The latter are converted to a monetary equivalent using a value of travel time, which is assumed to be equivalent to the wage rate for business travel, and to some agreed fraction of this for non-work travel. Time savings typically account for about 80 per cent of the monetary benefits of U.K. road improvement schemes and for up to half the benefits in major rail investment projects.

The value of non-working travel time (i.e. journeys to/from work, shopping, recreation, etc.) is usually derived as a behavioural value from revealed preference studies which infer how much people are prepared to pay to save time (e.g. see Bruzelius, 1979). This involves modelling the behaviour of travellers in an area who use a particular mode or route, assuming that they have chosen this in preference to the alternative modes and routes on the basis of time and cost differences.
between the two, and deriving a time value from the ratio of the two coefficients. It is further assumed that time has a constant value, irrespective of the size of the saving (i.e. 60 people saving 10 seconds = 1 person saving 10 minutes), and procedures are then used to convert behavioural values into resource values for the economic evaluation.

Activity-based studies have implications for the derivation of behavioural values of time, in at least four respects:

(a) Better definition of choice sets (e.g. feasible alternative modes), leading to more reliable estimates of time values.
(b) Increased awareness of other variables which may be entering the choice process and thus affecting the implied values of time.
(c) Improved understanding of factors which directly affect values of time.
(d) Insights into alternative ways in which values of time might be measured.

Examples of the first two effects are apparent from the exploratory studies in Chapter 9 and discussion elsewhere in this thesis. Although a bus may appear to be a valid alternative for a car driver, it may not form part of that person's choice set, because it gets him to work too late, or he may need to use the car during the day, or to use a vehicle to carry heavy equipment to/from work. Similarly a husband in a car-owning household who travels by bus may not have the car as an alternative because the household have agreed that the wife has a greater need for it — even though the husband appears to be behaving 'irrationally' by choosing a slower and more expensive mode. Examples were given in section 9.4 of how such effects may lead to misspecified mode choice models, and they would also bias any values of time derived from such data.
Attitudinal studies have brought to light many variables other than time and cost that influence mode choice (e.g. see the review by Dix, 1981). Comfort, safety and convenience are frequently cited examples; Kam (1982) has suggested that from an activity point of view, convenience may be defined (p. 181) as '... one's ability to schedule activities based on role situations', which involves many other aspects of time other than simply the duration of travel. Value of time studies invariably find people in their samples who appear to choose slower and more expensive modes, and these 'non-traders' are usually excluded from the analysis. But it is also probable that some people classified as 'traders' are not actually choosers — at least in the sense normally implied — and this may bias value of time estimates. It is thus important to use insights from the activity and other approaches to improve choice set definition and the identification of variables affecting choice behaviour.

The Department of Transport's present time values are related to the mode used, the purpose of the trip (i.e. whether employer's business, or 'non-work') and the income of the traveller (employer's business trips only). Activity studies have suggested a number of other variables which may influence time valuation (point c); in section 10.1, for example, reference was made to the finding of Holzapfel (1982) that the timing of work affects people's 'resistance to spending time in travel' and, by implication, their value of time.

A detailed review of the activity literature has been carried out for the Department by the present writer and others as part of an assessment of current value of time methodology (VOT Study Team, 1981). It concluded that factors other than mode, purpose and income appear to influence value of time, including:

- **Direction of travel:** timing constraints may be more binding in one direction than the other (e.g. to, rather than from, an
appointment).

- **Journey Length:** longer distance trips provide greater opportunities for supplementary activity participation and are usually associated with greater variability in journey times.

- **Type of area:** because of different densities of activity opportunities in urban and rural areas, area type provides a proxy for the opportunity cost of time and differences in scheduling convenience.

- **Time of day:** the opportunity cost of time varies by time of day (as the set of activity opportunities changes), as do the amount of slack time in the schedule and the incidence of interpersonal linkages. This variable also acts as a proxy for the level of congestion or crowding on the network.

- **Person type:** role commitments largely determine the set of activities that a person undertakes, and the inter-personal and time-space constraints under which he/she operates.

There is inevitably some redundancy between these dimensions and the study team concluded that the most significant variables affecting value of time are likely to be: person type, mode of travel, time of day and type of area.

This study also provided limited evidence from the activity literature and elsewhere to suggest that time changes should be measured in three ways (point d), rather than by the single measure now used, namely:

1. **Variance of travel time:** reducing variance may be useful, even when mean travel time is unchanged, because it helps the scheduling of activities and can allow a reduction in the amount of slack time built into the activity pattern in case of delays.

2. **Size of time change:** it is likely that large time changes will have a greater unit value than small ones, because of the
greater opportunity cost of significant changes and their rescheduling implications.

(3) *Time gains v. time losses:* at least outside working hours, the activity work suggests that most groups are likely to value time lost more highly than time gained (or give it the higher unit value at a lower threshold point), because of its disruptive effect on the activity pattern.

The findings of this project are still being considered by the Department, but it is evident that the activity work can help both in the improved estimation of current time values, and suggest ways in which the evaluation procedures might be refined.

**New Measures of User and Non-User Benefit**

In the longer term, it is probably in the development of new kinds of measure that the activity approach could make the greater contribution to transport evaluation methodology. As yet, however, very little work has been carried out in this area; hence, the comments in this short section represent a provisional assessment and are indicative of what might rather than what has been achieved.

We can conceive of the activity work contributing to transport evaluation in two distinct ways:

(a) The development of indices to measure the *direct* benefits derived from a trip.

(b) Through measures of the *secondary* impacts, both on the affected individual at other times of day, and on others indirectly affected through inter-personal linkages.

At present, the *direct* benefits deriving from transport improvements tend to be evaluated in a negative way — by measuring the reduction in the disutility of travel associated with the improvement. If people
don't reduce their journey time/cost (i.e. they switch to a destination further away), then the benefit derived from so doing is inferred to be equal to or greater than the travel saving foregone. Although this may be a reasonable approximation where cost savings are involved, this is clearly not the case for time savings — since threshold points may be crossed which open up new 'windows' of opportunity (see section 6.3) once access times fall below a certain level. In such cases it would be more appropriate to measure directly the benefits of a transport improvement via the net gain in utility associated with the new combination of activity and facility, compared with the previous behaviour.

Similarly, in cases of trip suppression, existing methods assume the trip to be 'valued' at less than the new cost/travel time level, and do not make allowance for journeys that become infeasible, nor do they distinguish between cases where the travel-generating activity is consolidated into another trip, carried out at home, or foregone entirely. It is possible to distinguish between these in an activity-based analysis, and it would be possible to derive measures of net benefit that relate to differences in utility between the current and 'best alternative' activity.

Another example of travel costs/benefits that are not measured adequately by conventional methodology concerns changes in the timing/frequency of public transport services. The conventional economic evaluation measures the benefits/costs of increased/reduced public transport service frequencies in terms of the effect this has on overall travel time, through changes in average waiting time. The rationale for this is based on evidence that waiting time increases as frequency falls, though not uniformly (e.g. Seddon and Day, 1974). This may provide a useful measure of benefit where services are reasonably frequent (say at least half hourly), but once frequencies fall below this level the measure loses its value, since:
(a) There tends to be a maximum time people wait for a service; as service frequency drops they are more likely to check the timetable than arrive at random. Hence, the average waiting times for a half hourly or two hourly service may be indistinguishable.

(b) As service frequencies fall it is the timing rather than frequency of service which is crucial. Tyson (1978) has identified two effects here:

(i) the ability of the public transport network to offer journeys when they are desired;

(ii) the amount of time which a traveller can spend at his destination.

In order to measure the benefits of improved service frequency, or the benefits of changes in service timing, we thus need to look at the impact of travel on people's activity patterns and so turn to measures of the wider or secondary impacts of transport policies.

With the exception of environmental evaluation, there has been very little attempt to date to measure the secondary impacts of policy measures. The evaluation framework is closely associated with the conventional, trip-based modelling approaches and has largely been restricted to the Domain I (independence) level of impact. Within an activity framework, it is possible to expand this to take account of indirect effects transmitted via the inter-personal or space-time linkages and to use additional, non-travel measures of impact. Hoorn (1981) has stressed the need to broaden the basis of the evaluation in this way (pp. 28/9):

Benefits should not be associated only with those people whose mobility increases. They should be assessed for different segments of the population whose daily activity patterns may be changed.

There are a number of ways in which these wider effects of
transport policies might be measured (and are considered in the context of social well-being in Jones, 1983b). Figure 6.2, for example, identified four types of mechanism for transmitting and registering secondary effects, which could form the basis of a number of measures of change. They comprised:

(i) Adjustments to the time budget (and activity set).
(ii) Secondary repercussions on activity timing.
(iii) Repercussions on activity location.
(iv) Changes in inter-personal linkages, leading to further changes in (i) - (iii), plus possible changes in the amount of time spent in joint activities with others.

The first of these measures, the time budget has been widely used as a general comparative measure of the quality of life (e.g. Szalai and Andrews 1980) between areas, cultures and over time (see also Appendix I). Over 20 years ago, Meier (1959) argued for the use of time rather than money as the social unit of account; he suggested the use of indices such as the amount of uncommitted time or the variety of activity participation. Time has the advantage that it is a more equitable base — since everyone has the same time allowance per day — and it can be applied to all activity participation and not just that which can have a monetary value associated with it.

Time budget data can also be used more selectively. Appleyard and Lintell (1975), for example, illustrate how street life varies in roads with different levels of traffic flow and show this factor is an important element in the quality of life experienced by residents; this could be measured in terms of outdoor activity patterns. The Wilson Committee report on noise (Committee on the Problem of Noise, 1963) recommended maximum noise levels which vary according to the type of activity which is undertaken; crude data on activity patterns would
enable the exposure of people to different levels of noise (and other forms of pollution) to be estimated, allowing for the changing incidence of the pollutant by time of day and the varying behaviour of the population.

One of the limitations of the time budget is that it provides a very restricted measure of change and can result in an underestimation of the impacts of change. This was apparent in the analysis of the effect on household activity patterns of changes in school hours, in section 6.4: it was not until the data was disaggregated by activity timing, location and changes in joint activity (i.e. measures ii - iv) that the full impacts became apparent — either to the interviewer or the interviewees. Writers such as Pirie (1979) have thus suggested that measures be developed to represent the amount of disruption to an activity pattern brought about by a policy change.

Another approach to this problem has involved measuring not what people actually do, but how a policy can alter their freedom of action by modifying what they could do. This approach to evaluation lies behind much of the work on accessibility (e.g. Moseley 1979), and forms the philosophical basis of the work on Time Geography in Sweden. Thus, Lenntorp (1978) has used his simulation model 'PESASP' in several studies to show how changing the physical environment in some way (e.g. new child care centres, improved bus services) can lead to an increase or decrease in the amount of flexibility people have in the way in which they arrange their activities (by measuring the number of possible ways in which a person could accomplish his observed activity programme). This approach has also been followed in a joint study for the Dutch Ministry of Transport using 'CARLA', to see whether rural bus services frequencies could be reduced without seriously affecting people's activity patterns, through a careful choice of service timings; findings are reported in Clarke, Van Kippenberg and Splinter,
A rather different, but potentially very powerful approach, is to examine the degree of stress, boredom or illness associated with different types of activity/travel pattern. It is clear from a number of qualitative studies, for example, that many retired people have too little stimulation, whereas working adults may have too much. Cullen and Phelps (1975) found that workers who had long or difficult journeys to work by public transport in the morning were showing relatively high levels of stress at work by mid-afternoon, and there is other evidence to suggest that people making two or more interchanges en route to work have a higher number of days sick leave than people with simpler work journeys. Kam (1982) also cites several studies which point to a relationship between social roles and depression and mental illness. These examples point to the need for work on the influence of lifestyle and travel behaviour on health.

None of these approaches has as yet become established in transportation planning and there is clearly considerable development work yet to be undertaken. Two cautionary lessons can be drawn from this early work, however:

(a) Different measures of impact may lead to alternative interpretations of the effectiveness of a policy.

(b) Measures of impact may bear little relationship to the value which people place on elements of their response.

An example of the first problem was cited in section 8.2, under the heading of data collection, and concerned evidence for the impact of car restraint policies in Oxford (Heggie, 1976a). Consider the inferences that might be drawn from the following measures of impact:

(1) Trip rates to the city centre have fallen, for shopping trips.
Implication: the restraint policy is leading to the decline of the centre and has been unsuccessful.

(2) ... but time spent in town on each trip has risen to compensate. Implication: the policy has been very successful, in that the viability of the centre has been maintained, but roads and parking spaces are being used more efficiently.

In general, more information should enable a more balanced assessment to be made, but given that information is always partial then the selection of appropriate measures is a very significant matter.

The second danger leads on from this, and concerns the lack of consistent correlation between objective and subjective measures of the impact of change. Robinson (1977), for example, cites evidence to suggest that satisfaction with activity participation correlates well with time spent on the activity, but Kelly (1973) found only a very low correlation between time and perceived value of the activity — and none between time and money expenditure. Similarly, the results of HATS work suggests that strength of feeling may not correlate highly with the extent of measured disruption — since people may choose to make more extensive changes than are strictly necessary.* The relationship between subjective and objective measures of change is as yet poorly understood, and this underlies the need to include some form of attitudinal measurement in any broadly based study of transport policy impact.

Chapter 4 identified the need for a social framework for evaluation and, although this has not yet been developed, there do appear to be a number of activity-based measures which could contribute to such a framework — subject to the caveats discussed above. Indeed, even before

*Examples of this happening in the Burford school study are shown in Figure 6.10
the formal development of a new approach to evaluation (to be used alongside the operational, economic and environmental procedures), insights from the activity work (at both conceptual and empirical levels) can provide a useful guide to the development of new evaluation methodology.

Burns has suggested something similar in his Introductory Review to the PATRAC Symposium on Environmental Evaluation in Canterbury in September 1975:

We do not always have to study everything but we should not miss anything of real importance. The decision making process is now so complex that in evolving a methodology it is essential to have an overview — a structured framework of the key topics that might contribute to better evaluation techniques.

The activity approach can not only contribute to a transport-based evaluation methodology in this way, but also has wider implications for methodology in urban planning. Some of these wider implications are considered in the final chapter.
11. CONCLUSIONS

This thesis has set out the framework of a new approach to studying travel behaviour, and has examined its ability to resolve a number of current methodological problems and deal with some outstanding policy issues. The final chapter provides a general overview and assessment of this work; firstly (11.1), by summarising the main line of argument and assessing the progress that has been made; secondly (11.2), by speculating on some broader implications that lie beyond the scope of the thesis; and finally (11.3) by drawing general conclusions and making recommendations for further work.

11.1 Summary and Assessment

The objectives of this study were set out in section 1.2; they comprised three elements:

(1) To review the historical development of urban transportation planning and methodology in the U.K., and to identify a number of unresolved methodological problems.

(2) To set out the framework of a new approach to studying travel behaviour based on the analysis of daily household activity patterns, which prima-facie looks capable of resolving some of these problems.

(3) To demonstrate that this new approach is relevant to transport planning and can resolve some problems at a practical level; and to discuss its further potential and implications for transportation planning.

The structure in the main body of the thesis (Chapters 2-10) has closely followed this sequence, by presenting the material in three parts:

(1) Urban Transportation Planning, (2) A New Approach to Understanding
Travel Behaviour, and (3) Applications and Implications.

Summary

Part One examined the evolution of U.K. urban transportation planning since the fifties, by identifying changes in the nature of the transport 'problems' and the policy measures introduced to deal with them, and the methodological responses to these changing policy requirements. In general, policy perspectives have tended to broaden over time (Chapter 2), moving from a simple concern to cater for vehicle movements in particular areas, through an emphasis on road network planning, to an interest in developing more 'balanced' transport policies that recognise the role of both private and public transport in urban areas. Recently, this has raised questions about the efficiency of public transport, the type of service it should offer and the provision of subsidy. In an evaluative sense, too, perspectives have broadened from a simple operational assessment of road schemes to the incorporation of economic, then environmental and, most recently, social factors.

Changing policy requirements have demanded corresponding advances in the development of transportation planning methodology (Chapter 3) — although, on occasions, it has been methodology that has influenced policy. In general, we can identify a process of methodological accretion rather than one of replacement, with new 'levels' or generations of methods being added to the analyst's armoury of techniques as new policy issues arise. Four levels were identified up to the early seventies, each being conceptually or technically more sophisticated or advanced than its predecessors.

By the early seventies, a switch in policy emphasis from catering for the motor vehicle to one of restricting its use in urban areas required a major change in the approach to modelling travel demand —
from extrapolating past trends to forecasting travel behaviour under changed conditions. This, together with a broadening of the evaluation framework, put a great strain on the transportation planning methodology of the late sixties, and led to a rapid growth in research during the seventies, to resolve a number of methodological problems. Ten main strands of work were identified, ranging from the development of individual choice models to attitudinal research, and the investigation of error and uncertainty.

The transport research of the seventies was able to overcome several of these methodological problems; a few remained unresolved, however, and this methodological shortfall tended to be accentuated by the changing policy requirements of the late seventies (Chapter 4). Aspects not handled satisfactorily included the modelling of more complex types of behavioural response (including secondary effects), issues relating to the timing of travel, and relationships between travel and non-travel aspects of daily life. It was argued that these problems remain unresolved using existing methods because of inherent conceptual limitations in the trip-based perspectives which underlie most of them; conventional methods of recording and analysis remove travel from its broader context and discard information on the order and direction of travel, and the linkages between trips. Requirements for a particular kind of additional level or approach were set out in Section 4.3, which it was proposed be met by developing a framework for studying travel in the context of household activity patterns.

Part Two set out the main features of this framework and examined its implications, at a conceptual level. Activities provide a proxy measure of the more basic determinants of behaviour, since it is by participating in activities at sites offering appropriate facilities that needs are satisfied and role commitments are met. Given a desired activity set, the structure of an activity-travel pattern (Chapter 5)
is viewed as arising from the effects of three related processes: the temporal structuring of behaviour, the spatio-temporal organisation of supply, and the effects of inter-personal linkages. Travel has a unique role in this process, since it represents the space-shifting mechanism that enables people to transfer between facilities at different sites, to take part in a succession of primary activities.

Having established the elements of a new representation of travel behaviour, Chapter 6 then examined the process of household adaptation, in response to changes in resources, roles or the external environment. Several measures of change can be derived from the framework, covering modifications to the duration, timing or location of activities, and changes to the activity set and in the extent of joint activities. Through the various linkages that are embodied in the framework, it is possible to identify a number of mechanisms for inducing secondary impacts which affect activities at other times or places, and/or involve other people. Some of these mechanisms are triggered at specific threshold points, and this produces a succession of more complex household response strategies; a provisional classification of response strategies is proposed in section 6.3.

Various hypothetical and empirical examples are used to illustrate how travel behaviour can be understood more fully when seen in the context of household activity patterns. Households in different life cycle groups, for example, have different activity needs and operate within particular constraints that give rise to characteristic patterns of travel (section 5.4). Similarly, an examination of the processes of pattern re-structuring reveal ways in which changes in travel arise from alterations to basic household routines (sections 6.2 and 6.4).

A comparison with the existing, trip-based levels of travel analysis in Chapter 7 confirmed that because the activity approach retains important information on the context, order and direction of travel,
this enables it to deal with issues that lie outside the scope of the existing levels; in particular, the emphasis on linkages enables secondary ramifications of policies to be identified. Conceptually, the framework is able to satisfy the general requirements of a new approach set out in Part One and looks capable of resolving a number of the outstanding methodological problems and policy issues, although the very restricted treatment of cost factors is an important limitation. The activity approach provides both a broader and deeper perspective on travel than the existing levels — of equal significance to the development of the notion of the person trip twenty years ago — but its complexity and more detailed data demands mean that its use is likely to be limited to the examination of complex responses and wider issues.

Part Three focused on the practicality of the activity-based approach, as a basis for developing techniques for transportation planning practice. A number of researchers have recently begun to study travel in a broader context, and there are now a variety of studies using different approaches that have been carried out under the 'activity' umbrella (Chapter 8). These are grouped into a five-level hierarchy, according to the conceptual complexity of their representation of travel, and examples of each type are given.

Because the more sophisticated of the activity-based studies adopt an unconventional perspective for studying travel behaviour, they have their own implications for all stages of the transportation planning process. Examples of applications and implications are considered under six broad headings: problem recognition and policy generation, data collection, data analysis, modelling, evaluation, and public participation and policy coordination. Some of these aspects are examined further in the next two chapters.

One unusual feature of a number of the applied studies has been
their use of both qualitative and quantitative techniques in an exploratory context (Chapter 9), in which policy and methodological issues have been examined in depth, using small samples of respondents. This work usually produces valuable insights into unresolved problems and, because of the loosely structured nature of the approach, often leads to unexpected findings. Results are given from policy studies into energy savings and school hour changes, and from methodological studies dealing with data collection and the modelling of travel behaviour. Many of the exploratory studies have involved the use of gaming techniques to explore the dynamics of response; equipment and survey procedures used in one method are described in section 9.2, and Appendix II.

The activity-based work has also been incorporated into a number of transport courses, where the conceptual framework provides a vantage point from which to view the present transportation planning methodology and consider transport problems and alternative policy measures. Gaming simulation techniques also have a useful role in this context, as they enable students to become familiar with activity concepts — in particular with the processes of adaptation and the complexities of response.

Chapter 10 concludes Part Three of the thesis by looking at activity-related developments in more established areas of transportation methodology, namely data analysis, modelling and evaluation. The inherent complexity of the activity framework means that the analyst is faced with more severe problems of operationalisation than when using trip-based approaches. Although these difficulties have only been partially overcome to date, they have resulted in some very creative work and the indications are promising.

With regard to data analysis, considerable progress has been made in the operationalisation of activity concepts (e.g. 'fixity' of
activities), in the measurement of complete activity-travel patterns
(using graphical procedures, pattern recognition techniques and
measures of daily paths as stops in 'n' dimensional space), and in the
identification of variables affecting activity patterns (e.g. role
structures and life cycle stage). One encouraging feature of much of
this work has been the use of conventional travel data sets, re-inter-
preted as non-home activity patterns — although there are some dangers
with this approach.

Implications for modelling lie in two main directions: establish-
ing relationships between household response strategies and the
'domains' of operation of different types of travel demand model, and
the development of models incorporating activity-based concepts. Three
forms of model are identified, covering improvements to individual
choice models (through the incorporation of timing variables and choice
set definition), the use of choice models as part of a simulation
system capable of handling certain aspects of behaviour patterns, and
the development of full, pattern-based models using simulation or com-
binatorial programming techniques. Examples of other activity-based
methods that have been used to study energy impacts are also provided
to illustrate the diversity of the methodological developments.

The evaluation of policy measures from an activity perspective was
the last aspect to be considered. Two main areas were identified:
improvements to conventional measures of user benefit, and the develop-
ment of new measures of user and non-user benefit. In the former area,
improvements in the estimation of values of time was cited as a poten-
tial beneficiary, both through refinements to the conventional estima-
tion procedures (brought about by better choice set definition and the
incorporation of additional independent variables) and through the
development of new measures and estimation methods. In the latter area,
the main prospects were seen to lie in the development of measures for
evaluating secondary impacts of policies. Possibilities include the use of time budget data, measures of pattern flexibility or the disruption to activity patterns caused by a change, and attitudinal and medical measures of well-being. Although relatively little attention has been paid so far to the implications of the activity work for evaluation, they are likely to be considerable and wide ranging.

Assessment

This thesis appears to have been broadly successful in meeting the requirements set out in section 1.2, although by their nature the measures of success that can be applied are inevitably qualitative, rather than being based on statistical or logical criteria. It has been possible to identify a significant gap between methodological capability and policy requirement, to develop a new conceptual approach to understanding travel behaviour that, a priori, seems capable of overcoming some of the problems, and to demonstrate ways in which it has been, or could be used, to assist in urban transportation planning. A full assessment of the potential of the approach in planning practice cannot be made, however, without the benefit of hindsight stretching over several decades of application.

This work has been set in the context of earlier conceptual and methodological developments, and represents an additional level at which the analyst can operate when attempting to deal with certain kinds of problem. Those best suited to the activity-based approach involve complex patterns of response to change, or require an understanding of the role of travel within a broader social context. Section 4.1 listed six methodological problems that were first identified in the early seventies, but which had not been successfully resolved by research carried out during the remainder of the decade; these were:
(a) The modelling of complex travel patterns
(b) The definition of choice sets
(c) The timing aspects of travel
(d) Linkages between travel events and between household members
(e) Analysis and modelling of secondary policy impacts
(f) Relationships between travel and other aspects of daily life.

The activity framework set out in Part Two appears to offer a promising basis for handling these problems — indeed it was designed largely with this aim in mind — and several examples of success in tackling them at a practical level were given in Part Three. One particularly useful feature is that the activity approach is able to indicate certain conceptual limitations of the trip-based approaches that were making it very difficult to resolve these research problems within a conventional framework.

With regard to the newer policy issues identified in section 2.4, however the verdict is less certain. Taking the activity framework as set out in Part Two, we can consider its relevance to policy under three headings:

(i) Policies which can be handled adequately by the framework;
the clearest examples are the various time management policies (e.g. revised shop hours, flexitime), including questions of the timing of low frequency public transport services, as well as work on certain types of impact of car restraint policies.

(ii) Policies which could probably be addressed by the framework, but where sufficient work has not yet been carried out. Examples here include questions of the definition of travel need and the appropriate level of provision of service, and (possibly), certain types of labour problem in the transport
supply industry (see section 11.2). It is also probable that the approach could supply measures for a social framework of evaluation.

(iii) Policies for which the activity framework can only provide a partial understanding. Examples include work on telecommunications and a variety of substitution effects between activities (where consumer research techniques have a major role to play), and questions relating to the level and allocation of public transport subsidy — where the activity concepts can point to some of the consequences of adopting different subsidy levels, but do not in themselves provide a framework for resource allocation or for establishing the 'worth' of services.

Point (iii) raises much more fundamental issues about the role of the activity-based work: should it be developed as an additional level in the analyst's armoury of conceptual and technical aids, to be used in a complementary way with existing approaches, or should it be expanded to offer a replacement for the earlier work? From the discussion in Chapter 7 it appears that the approach has the potential for adopting the second role, as it offers both a conceptually broader and deeper framework than its predecessors — but this more ambitious aim is beyond the scope of this thesis.

A conscious decision was taken in this work to concentrate on areas of known deficiency in the existing approaches. This accounted for the neglect of cost aspects in the specification for a new approach in section 4.3, and has also meant that relatively little attention has been paid to two other important features of household travel behaviour:

(i) Characteristics of the supply of activity and travel facili-
ties.
(ii) Psychological aspects of activity choices, covering the cognitive and evaluative aspects of behaviour (e.g. Benwell, 1982).

As a consequence, there has been a tendency in this thesis to take the supply aspects as given, and to treat certain elements of household activity/travel behaviour in a slightly mechanistic way. It should prove possible to redress this balance in further development of this work.

At a detailed level, this has meant among other things that the analytical work reported here has:

(a) Concentrated on the temporal aspects of behaviour, at the expense of spatial aspects.

(b) Considered elements affecting activity and travel choices in less detail than the nature of the various constraints on behaviour.

In practice this does not appear to have created difficulties, since analysts are able to draw on existing techniques that incorporate both these neglected aspects — and perhaps explains why hybrid modelling approaches (e.g. constraint-based activity model, plus individual choice model) are proving to be so popular.

Turning to questions of application, one striking feature of the activity work is that, being based on a different view of travel behaviour, it has its own set of implications for all stages of the transportation planning process, from problem recognition to policy evaluation. As a consequence it encourages the analyst to make more explicit many of assumptions and presumptions that lie behind the trip-based approaches — and is one reason why the activity approach is proving so popular among educationalists.

Exploratory studies based on activity concepts have been particularly successful in obtaining insights into household travel behaviour,
of relevance both to policy and methodology. The techniques used are particularly suited to dealing with the complexities and uncertainties involved, and one encouraging result has been the emergence of a number of important but unexpected findings. Policy applications are still fairly limited in number, and require skills which most engineers and planners were not taught during their period of formal training; but the findings from the studies completed to date have proved very useful and show the potential of this approach to deal with some of the more complex issues in the areas of car use and public transport service provision (section 9.3).

Methodologically, too, the exploratory approach appears to be very promising, not only as a preparatory phase in the development of new activity-based procedures (some of which were reviewed in Chapter 10), but as a means of improving on the performance of existing trip-based methodologies. Examples were given in section 9.4 of how insights obtained from exploratory studies have led to improvements in conventional forms of data collection, analysis and modelling. Probably the most striking demonstration of the practicability of the ideas discussed in this thesis has been the incorporation of activity concepts into the 1981 Sydney Transport Study, which involved interviews with over 20,000 households. Not only has this enabled the study team to obtain a more thorough record of household travel behaviour than previously, it also provides opportunities to examine new issues. Ampt (1982), for example, describes a preliminary analysis of 'the needs of the non-traveller', using this new data base.

The practicability of the activity-based work has so far been less clearly demonstrated in the more conventional areas of large-scale data application (Chapter 10), but considering the complexity of the problems involved the results do appear to be very encouraging. Note, in particular, the high proportion of references to work completed within the
last two or three years, indicating that these problems are now begin-
ing to be seriously tackled by a number of researchers—helped, in
part, by the findings from some of the earlier exploratory studies.

Already, serious attempts have been made to devise operational
measures of some of the more complex activity concepts, to face the
difficult problems of measuring and classifying complete patterns of
behaviour, and to establish significant relationships between behaviour
and independent variables such as role and life cycle stage. These are
all prerequisites for successful modelling and, although there are
still a number of classificatory and other problems to be resolved,
section 10.3 was able to document a number of promising model develop-
ments, some of which are likely to lead to operational forms of model
by the mid-eighties.

One of the major problems to be faced in the application of activ-
ity-based predictive models is their need for more detailed information
on person characteristics and the pattern of land use and transport
facilities, in time as well as space, than is required by more conven-
tional trip-based models. Some practitioners have cited this as a
major disadvantage of this approach to modelling, in that it increases
the problems of forecasting the independent variables; from another
viewpoint however, this can be seen as one of the strengths of the
approach. If variables such as the proportion of young children in the
population and the length of the working week do have an important
influence on travel, then it is surely better to be aware of this, and:

- attempt to predict future values for these variables (Clarke and
  Dix, 1983, have developed a simple model for forecasting popula-
  tion by life cycle stage); or
- develop alternative scenarios and look at travel trends in each;
or
- carry out sensitivity analyses on specific variables, to establish
whether their inclusion is important, rather than not face up to the problem at all.*

Much of the model development and activity analyses have been carried out using modified trip data from large scale, conventional transportation studies. This has the advantages of ready access to large data sets (as compared with the very restricted availability of activity data) and the likelihood that techniques developed from trip data will be more readily accepted by practitioners; but it also carries a number of dangers and limitations. We saw in the Burford study (section 6.4), for example, how public reaction to the school hour changes was partly related to the effects on family in-home routines, and Kam (1982) and others have shown the need for such information when defining roles.

Conceptually, too there are important reasons for considering in-home activities; in particular:

(a) In-home activities may substitute for out-of home activities and hence travel. To understand trip suppression or the release of latent demand it is thus necessary to know about the alternatives which an individual has — including home-based activities. Many technological developments (e.g. colour television, stereo systems) have made home a much more attractive destination in the last decade, and in this way have affected the demand for travel.

(b) Commitment to in-home activities may prevent travel and the use of out-of-home facilities at certain times of day — no matter how attractive they are made. The simplistic example is most people's need to spend nearly one third of their day asleep at

*There is a tendency among some practitioners to assume that if you exclude a variable from a model that it won't affect future travel behaviour!
home, but the requirements of home maintenance and child care also restrict the times at which people can travel.

Here again, the existence of an explicit conceptual framework coupled with exploratory studies provides a basis for determining whether and when it is necessary to consider in-home activities. Ideally, this requires full activity data but, given further research, it may prove possible to synthesise in-home activity data and add it to conventional trip data files.

Rather than reporting on an area of completed work, this thesis is thus dealing with a new and rapidly expanding field of research, which is becoming an area of major priority and interest among travel researchers. Before drawing some general conclusions on the state-of-the-art and the future direction of this work in section 11.3, we first speculate on some wider implications of the activity framework which might be developed in the future — once it has become more established as a level or approach within transportation planning.

11.2 Potential Wider Applications

In its most general form, the activity approach provides a means of representing and studying most aspects of human behaviour, and as such could — and indeed has — been used to look at many issues other than household travel behaviour. U.K. television companies, for example, have found the activity diary to be a useful instrument for obtaining information about potential audiences and competing activities (e.g. A.T.V., 1970; B.B.C., 1975), and the B.B.C. are planning a new survey for 1983. There is also scope for undertaking studies incorporating activity-based concepts to look at the probable impact of a whole range of new forms of telecommunications and electronic gadgetry on daily life.
Similarly, there is scope for using activity concepts in studies of building design. The Buchanan Report (Ministry of Transport 1963) characterised the urban environment as a series of rooms and corridors, which suggests, by analogy, that some of the concepts could be applied at the intra-building level. There have indeed been suggestions that HATS might be used to investigate building layout and organisational administration, and over 20 years ago activity studies were used to help establish housing space standards (Department of the Environment, 1961); this approach was also an important feature in the production of a series of design guides (MTP Construction, 1974). This opens up the interesting possibility of working at the interface: an examination of the role of house design and provision of in-door facilities in influencing the use made of the external environment, and the requirements which people place on it.

In this section we speculate on other possible wider uses of an activity approach, looking in particular at four areas: labour problems in the transport supply industries, energy use outside transport, land use and transport and the use of an activity framework as a basis for inter-sectoral planning.*

*The last two issues also involve questions of long-term adaptation and structural-level decisions which are outside the scope of this thesis.
bus driver attitudes to schedules and working conditions in London (Bottom and Jones 1982). A very wide range of survey instruments were used in this study, including socio-demographic questionnaires, attitudinal questionnaires based on the use of rating and ranking procedures, and a number of trade-off techniques. In order to investigate the complexities of shift work, however, and its impact on family life, it was found helpful to develop display procedures using activity-based concepts, by adapting the HATS equipment described in Appendix II.

Examples of display boards that were used are shown in Figures 11.1 a/b; different types of shift were identified, as well as the pattern of working over the week. Drivers were invited to comment on the structure of the shifts, the weighting of the payments made for unsocial hours and spreadover duties, and the impact of different shifts on their personal and family life (by asking them how they fit in specific activities, such as shopping or social visits). Using this approach it was possible to explore issues such as the length of the meal relief, where it should be located within the duty, problems encountered when switching from one duty to another, etc. — in a more detailed way than using structured questionnaires or open-ended interviews.

This was only a small pre-pilot exercise, and the approach could be developed considerably further, but it did highlight a number of the problems which bus drivers face and enabled suggestions to be made as to how they might be overcome, and so reduce the negative features of the job.

Energy Use Outside Transport

Research into energy use and fuel consumption tends to emphasise the technological aspects of the subject, often focusing on the
Figure 11.1: Display Boards Developed to Examine Driver Attitudes to Patterns of Shift Work

(a) The duties worked by one driver over a seven day period:

(b) One Driver's Judgement on the Appropriate Allocation of Pay to Duties:

characteristics of a particular fuel or the energy inputs to a specific sector, while paying little attention to the behavioural aspects. In the electricity supply industry, for example, there are at present great technical efforts going into methods of 'peak-shaving' using such forms of energy storage as large fly-wheels, or reservoirs of water pumped uphill when demand is low and then used to run hydro-electric turbines at peak periods; it is quite possible that the same effect could be achieved by minor changes in behaviour patterns. One study of domestic gas consumption found wide variations in the level of consumption in adjacent dwellings of identical design that could only be attributed to differences in the behaviour patterns of the occupants (Grot and Socolow, 1974).

The activity framework provides a useful basis from which to explore household fuel consumption, since it deals with the activities which consume fuel and, through the understanding it provides of secondary impacts, is able to trace through the full energy ramifications of a change in behaviour. Indeed, looked at in terms of household activity patterns, any change in energy use associated with a reduction (or increase) in time devoted to one kind of activity must lead to a corresponding change in the energy expended on other activities for which time allocation is increased (or decreased) to compensate. Further, in many cases fuel consumption will also be sensitive to the timing of the activity, as this affects the amount of heating, lighting or air conditioning required.

Thus, even if an energy conservation policy introduced by a transport department appeared to be successful in travel terms, it may lead to significant secondary effects that in most cases will counter the objectives of the policy — and in extreme circumstances may mean that a measure designed to reduce fuel consumption may actually lead to an overall net increase in consumption across the economy.
Land Use and Transport

The activity-based work reported in this thesis can help to improve our understanding of the relationships between land use and transport, in a number of respects. The emphasis on timing, for example, enables the practitioner to consider the effects of revised opening hours of shops, etc., on the pattern of travel; similarly, it is possible to make deductions about the pressures on the urban spatial structure from knowledge of daily activity preferences and constraints. Holzapfel (1982), for example, argues that (p. 18) 'goods with a high consumption frequency must be offered near principal activity locations' (notably home and work), because the tight space-time prisms of workers limit the places at which they can shop.'

Although the emphasis in this report has been on the relationships between activity needs, constraints and demand for travel, the approach also provides detailed information on the demand for land use facilities — since it deals with all daily activities, not just trips. Thus, any change in the pattern of travel is usually associated with a change in the timing, location or duration of activity participation, and hence the patronage of land uses. Further, although transport policy may not affect significantly the overall level or allocation of consumer expenditure in an urban area, it can affect the more detailed pattern of that expenditure (both spatially and among competing types of goods and activities), and could have important spatial repercussions in the longer term.*

In the wider planning literature there is a considerable body of work on activities and land use patterns, and many of the earlier conceptual developments reviewed in Appendix I were made in this context.

*There is evidence that during the 1973/74 petrol shortages people switched to in-home activities as a result of the increased difficulty and cost of travel (see section 4.3); this might have had serious land use consequences if this pattern had been maintained for a considerable period of time.
Figure 11.2, for example, shows a conceptualisation of urban development after Chapin and Weiss (1968). In his own work, Chapin has emphasised the activity-land use link, but clearly there is scope for integrating the two aspects of planning, which he sees as the ultimate aim (Chapin, 1965, p. 245):

The objective is to be able to identify specific recurrent behaviour patterns which will enable the planner to make analysis of space use and travel and develop an integrated set of proposals for land use and transportation set forth in the comprehensive plan.

This is clearly still some way off, but it does at least open up the possibility of planning land use and transport in an integrated way, using common techniques for data collection, analysis, modelling and evaluation. At present, the coordination between these two areas of planning is often very weak. Rees and Wragg (1974, p. 6), for example, point to problems with regard to the location of health facilities:

An example of the gulf between transport planning and other planning fields is the centralisation of health facilities in major centres. Undoubtedly this improves the range and expertise of medical services available to the population, but it does make it more difficult for a large proportion of the population to gain easy access to hospitals. It is doubtful whether any serious discussion took place over the transport implications of central medical services.

The activity work suggests one avenue that might be explored to avoid problems such as this reoccurring in the future.

A Framework For Inter-Sectoral Planning

Practical problems of integration are also found in areas other than the relationship between transport and land use. Several Structure Plans, for example, have been criticised for the way in which the various subject areas have been analysed (Departments of the Environment and Transport, 1979, p. 6):
Figure 11.2: A Conceptualisation of the Urban Development Process

VALUES  BEHAVIOUR  LOCATION

PATTERNS

Source: Chapin and Weiss (1968), Figure 5.
Many structure plans have been divided into separate subject areas — shopping, transport, employment, etc. — and each one analysed independently of the others. Aims and objectives are defined, data is collected, alternatives are identified and evaluated before a final policy for each subject area is settled. But although key issues dominate some subjects the impact of actions in one subject area on events in another is seldom considered explicitly.

More speculatively, it is possible to conceive of the activity based concepts contributing to a general planning framework for use in various government departments. The sharing of a common set of concepts and survey data would generally aid communication between planning agencies, and could provide a basis for coordinated policy making and in the longer term lead to a basic administrative reorganisation.

Macmurray (1971) sees the concept of the activity as lying at the centre of a general structural model of the process shaping environmental characteristics (including the social and economic systems, etc.). Recently the integrative role which the concept of activity can play has been demonstrated by Barras, who describes the use of activity analysis (defined more broadly than in this thesis) to derive a resource allocation framework for strategic planning (Barras, 1978, p. 298) which could:

... encompass an integrated analysis of the behaviour of a local system ... By applying this theoretical approach, an urban or sub-regional system can be characterised as a system of inter-related 'activities', such as residential, manufacturing, service and local government activity, each producing and consuming one or more of a set of 'commodities' such as land, labour, floorspace and finance. These commodities, or resources are the basic physical entities of the system, and it is through their production and consumption, interpreted in the widest possible sense, that the different activities are inter-related.

His framework was designed to relate projected activity levels to a resource base, and to provide a consistency in policy formulation and resource allocation between different sectors of government. In the
process it begins to describe the inputs and outputs of the activity sub-systems in some detail, and provides a means of dealing with some aspects of the functioning of sub-systems at an aggregate level.

The types of activity-related concepts developed in this thesis might be used to extend this analysis in two respects:

(a) Through an incorporation of household demands for the outputs of various activity sub-systems at a finer level, which would enable travel patterns to be considered more explicitly.

(b) By the selective incorporation of a time of day factor. It would be inappropriate to simulate behaviour at the levels of detail used in the pattern-based models outlined in section 10.3, but some account should be taken of the constraints imposed on systems operation by the temporal dimension.

An example of how the latter might be achieved is provided by Ellegard, Hagerstrand and Lenntorp (1977), who develop alternative sketch scenarios for the future development of Nordic urban settlements using the notion of behaviour patterns within a closed 24 hour system (see Appendix I).

11.3 Conclusions and Recommendations

The development of a new approach to urban transportation planning is an unusually ambitious topic for a thesis, and clearly not an objective that could be achieved by one person, or within a few years. I have therefore made considerable reference to the work of others in the field, particularly in Part Three (dealing with applications), and have attempted to define clearly my own contribution in this new area of work. The subject matter is also unusual in that the thesis can reach no firm conclusion, other than to say that the activity approach set out here appears to represent a promising area of work which, in time,
could come to be accepted by the transportation planning community at large as an established part of the analyst's armoury of concepts and techniques. Certainly the early applications are very encouraging in this respect.

The activity work appears to provide a framework within which many of the unresolved methodological problems of the seventies can be tackled (e.g. complex travel patterns, secondary impacts, choice set definition), as well as some of the policy issues that have arisen in recent years. The major areas of weakness lie in the omission of cost aspects, associated with a lack of understanding of the way in which cost affects the scheduling of daily behaviour and adaptation to change, and in the treatment of project evaluation in an activity context. The latter requires further exploration of the relationships between the subjective and objective measures of impact, and the development of an explicit social framework for evaluation. Future work should also place greater emphasis on the supply aspects of behaviour and on the contribution of psychological factors.

At a practical level, we can envisage a role for the activity approach as providing methods for the analysis of complex travel behaviour and for dealing with broader questions of the role of transport in society. To what extent this occurs depends, however, not only on success in the development of practical, activity based planning methods, but also on the attitudes of government and the academic community.

The establishment in the U.K. of formal urban transportation planning in the sixties was strongly encouraged by the requirement of government that prescribed analytical procedures should be used to forecast demand and evaluate schemes, in order to obtain funding for large road projects — and accounts for the uniformity of the work carried out by local authorities until at least the mid-seventies.* The present lack

---

*This uniformity of approach was a mixed blessing in that, although it
of government direction in urban planning — as opposed, say, to trunk road appraisal — has resulted in a much greater diversity of methodological approaches to transportation planning. This may make it easier for some authorities to experiment with activity-based procedures, but makes it much less likely that they will be adopted universally.

In order to take full advantage of the activity approach, the analyst needs to take a broader view of travel than is conventionally adopted, and to assimilate a number of new concepts and acquire new technical skills. He might use unstructured interviews to identify the problem context, gaming simulation to explore the probable range of responses, from which he could make a judgement about the type of model and measures to use in the formal evaluation of the project. It is thus particularly encouraging, in terms of the longer term application of the approach, that aspects of this work have already been incorporated into many of the graduate and undergraduate courses in transport in the U.K. and abroad.

As the activity-based work moves towards practical application in transportation planning, there are a number of dangers associated with the transition from theory to application, which were faced by disaggregate modellers during the seventies. Three, in particular, were identified by a workshop at the Fourth International Conference on Behavioural Travel Modelling, held in Germany in 1979 (Jones 1981):

(i) People may not assimilate the activity work fully, and so discredit it through misapplication or misinformation.

(ii) Some researchers have been under pressure to apply activity-

encouraged high technical standards, it also discouraged innovatory work based on different approaches; many of the ideas in Mitchell and Rapkin (1954), for example, about the nature of complex travel and the importance of motivation were excluded from main-stream planning practice for over 20 years, in part because of the specifications laid down by Government.
related techniques, with very limited resources, before they have been developed fully or validated adequately.

(iii) There is a danger of practitioners seeing any new approach as a potential panacea, and later becoming disillusioned with the products of the work.

Recommendations

In order to avoid these dangers and ensure the further development and appropriate use of the activity-based work in transportation planning, the following recommendations are made:

(a) A number of carefully conducted and well-documented case studies should be carried out to show how the activity work can be applied in specific planning contexts.

(b) Further theoretical work should be undertaken, to enhance and extend the framework set out in Part Two, in at least four ways:

- the incorporation of cost factors
- closer integration with psychological and sociological theory
- work on social evaluation, and the links between objective and subjective measures of change
- more detailed analysis of supply characteristics and of the relationships between demand and supply.

(c) Empirical work should be undertaken, to identify aspects such as the key explanatory variables, the range of operation of model domains, and the extent to which data needs can be simplified without seriously distorting the analysis.

(d) A conscious effort should be made to continually educate planners and engineers to the developments taking place, through suitable seminars, courses, etc.
At the moment, however, although there are a growing number of instances of planning departments using activity approaches to tackle transport problems, a lot depends on the enthusiasm of individuals taking the ideas on board and applying them to a particular problem. In a sense, we may liken the technical transport planning procedures to the art of cookery. In the past professionals have tended to rely on set menus and pre-packaged meals that simply had to be cooked in a prescribed way. These are now proving inadequate, as customer requirements are changing and are becoming more diverse. What the activity approaches can offer are a range of recipes, and ingredients, but planners and engineers will have to emulate the judgement and imagination of a good chef if the full benefits of the approaches are to be realised.
APPENDICES
APPENDIX I: A REVIEW OF THE HUMAN ACTIVITY LITERATURE

Introduction

This Appendix reviews the non-transport literature on human activity studies, drawing primarily on work in economics, geography and planning. The review provides a background to the framework developed in Part Two and is quite detailed, because of the unfamiliarity of most of the transport research community with this wider literature. It is necessarily selective, however, and emphasises aspects of relevance to the work presented in this thesis. For more general overviews of the literature the reader is referred to Anderson (1971), Gutenschwager (1973), Ottensmann (1972), Thrift (1977a), Carlstein, Parkes and Thrift (1978) and Parkes and Thrift (1980). Transport-related studies are described in Chapter 8.

Most of the studies included in this review share a common concern with how people allocate their time among different activities, and several studies go further and examine the use of space as well. This information is usually collected using some form of written diary that asks what each respondent is doing, when (and where), and may also include questions about why or with whom each activity was carried out, to what benefit, or with what degree of choice. Studies vary considerably in the form and the level of detail with which they record activity, location and timing information; examples of two forms of activity diary are shown in Figure 1. A general review of diary techniques and their strengths and weaknesses is provided by Hedges (1974).

The literature dealing with human activities is very extensive and diffuse and could be classified in a number of ways (e.g. according to the purpose of the study, the techniques employed, or the scope of the investigation). This review is primarily concerned with the various characterisations and explanations of human behaviour, and so a simple classification has been adopted, based on the measure of behaviour used as the main unit of analysis. From the literature, four levels of analysis may be identified:
Figure 1. Different Activity Diary formats:

### (a) Free Format Diary
- TSU Activity-Travel Survey

<table>
<thead>
<tr>
<th>TIME OF START</th>
<th>ACTIVITY</th>
<th>DETAILS OF TRAVEL</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### (b) Semi-Fixed Format Diary
- Institute of Community Studies

<table>
<thead>
<tr>
<th>TIME</th>
<th>WHAT DID YOU DO?</th>
<th>TIME BEGAN</th>
<th>TIME ENDED</th>
<th>SAME ACTIVITY DONE AT SAME TIME AS YESTERDAY?</th>
<th>AT HOME</th>
<th>AT WORK</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(1) Activity events
(2) Activity duration and time allocation
(3) Activity timing and sequencing
(4) Activity structure and patterning

There have also been several formal attempts to model individual or household activity patterns, and these are briefly reviewed in a concluding section.

(1) Analysis of Activity Events

A variety of studies have attempted to account for people's participation in particular activities, either at an individual or an aggregate level. One common approach involves the use of multiple regression or similar techniques to relate, say, mean participation rates to socio-economic and locational characteristics (e.g. North West Sports Council, 1972); this is similar in style to certain trip rate models. In strong contrast are several qualitative studies, which try to identify the meaning behind activity participation (e.g. "I feel I am bring creative", Havinghurst, 1961, p.317), using a range of semi-structured or unstructured survey techniques. Good examples of the insights provided by this type of work are to be found in Young and Willmott (1973) and Rapoport and Rapoport (1975).

At a more theoretical level, activity participation has been explained from two perspectives: as a choice process, or as the outcome of constraints.

Choice-based Explanations

Chapin (1965) has proposed a simple model of activity choice based on the following mechanism:

\[
\text{MOTIVATION} \quad \rightarrow \quad \text{CHOICE} \quad \rightarrow \quad \text{ACTIVITY}
\]

The importance of motivation as an initiator of action is well established in psychology (Evans, 1975) and the links between motivation and activity choices have been studied at least as far back as Sorokin and Berger (1939), who asked respondents to indicate their motives for certain types of activity participation.

In a more recent exposition, Chapin (1974) explains activity choices as the outcome of two sets of factors: those which pre-
condition and those which predispose action. The former comprise role and background variables which constrain and shape requirements to varying degrees (e.g. age, health, role in household) and the latter cover various motivational and attitudinal characteristics associated with an activity. He identifies two broad groups of needs which may be satisfied by activity participation:

(i) Subsistence needs: "need for sleep, food, shelter, clothing, and health care". These are of a more compulsory nature and take precedence over type (ii).

(ii) Culturally, socially and individually defined needs: "felt needs for security, status, achievement, affection, and social contact; outlets for exercise of personal talents, ingenuity, prowess and skill; need for mental release, for example, the release of feelings of joy, fear, frustration, or alienation; and need for physical release, for example, physical exercise as well as rest and relaxation".

Chapin has concentrated on relatively discretionary activities in his empirical studies and so has laid more emphasis on the second group of needs.

The first group comprises basic physiological needs that are shared (to some degree) by every individual. The second covers a range of needs which may be ordered into a hierarchy of motivational levels of decreasing importance. Chapin and others commonly base this ordering on the work of Maslow (1970), who proposed the following classification of non-physiological needs (in decreasing order of priority):

(a) Safety, relating to the requirement of a predictable and orderly world.

(b) Affection, which govern friendships and interpersonal relations.

(c) Esteem, including needs for achievement, independence and prestige.

(d) Self-actualisation, which is met by the full exploitation of talents and potentialities.

Higher level needs are thought to be operative as determinants of behaviour only when lower level needs are reasonably well satisfied*.

* Variants have been proposed by other writers. Hartgen and Tanner (1971), for example, identify physical needs (food, shelter, air and sleep), social needs (education, recreation, religion) and psychological needs (self-confidence, power, competence).
The range of activities able to satisfy a need increases as we move up the hierarchy.

Little is known in detail about the relationship between need and activity, but Kew and Rapoport (1975) have depicted the association between leisure activities and the needs they satisfy as a three element process:

(1) Preoccupations, which are people's underlying absorptions, closely linked to that person's biological and socio-psychological development (and hence related to life cycle change).

(2) Interests, which represent a variety of ways in which basic preoccupations may be expressed and satisfied; although preoccupations are shared by everyone in a given phase of life, the ways in which they are translated into interests may vary widely.

(3) Activities, which are the specific sphere of action (e.g. driving, dancing, participating in or watching sports, attending clubs, etc.) through which interests of a more general nature are realised. Each interest may be realised through a number of different activities, and some activities may serve several interests.

This is somewhat analogous to the treatment of a travel mode as comprising a number of distinct attributes (speed, comfort, reliability, safety, etc.) rather than being an indivisible entity. Chapin (1968, p.82) has suggested how decisions are made in this multi-attribute space:

...the individual examines the activity alternatives available and consciously or unconsciously searches for an optimal combination of satisfactions, based on the sub-optimization of a particular set of basic motivations he possesses at a particular time, finally making his trade-offs based on the satisfaction levels anticipated from the particular set of motivations stressed in each combination. The output of this process is an activity choice.....

Possible research approaches are provided by Bowman (1975), who predicts the viewing of television programmes as a function of programme characteristics (using a regression model), and Baxter et al. (1977) who look at clusters of recreation activities which are substitutable and hence appear to satisfy similar needs.
Constraint-Based Explanations

In strong contrast to the work of Chapin are a series of Swedish studies carried out under the direction of Professor Hagerstrand, in the Department of Geography at Lund University. Instead of regarding behaviour patterns as the outcome of choices, Hagerstrand examines the extent to which actions arise from the operation of constraints in space and time. Some of his notions apply more properly to the study of activity sequences and will be considered below (see level 3); but he identifies three broad groups of constraint (Hagerstrand, 1970) which may help to account for individual activity occurrences. These are:

1. 'Capability' constraints: "those which limit the activities of the individual, because of his biological construction and/or the tools he can command". An individual is thus committed to devoting time to certain activities, such as sleep, and is limited, for example, in the destinations he can reach by the modes of travel available.

2. 'Coupling' constraints: "These define where, when, and for how long, the individual has to join other individuals, tools, and materials in order to produce, consume, and transact". Fixed times and locations of work and school are examples of coupling constraints.

3. 'Domain' or 'authority' constraints: these refer to limitations and controls on access to facilities in space and time, which may only become accessible "upon invitation or after some kind of payment, ceremony or fight". A study of authority constraints in the leisure field is provided by Emmett (1971).

Individual actions are largely determined by interactions between these three types of constraint (and with the preceding activities in a sequence – see below). The basic elements of Hagerstrand's conceptualisation of behaviour are set out in Hagerstrand (1970), and useful reviews are provided by Pred (1973) and Thrift (1977a).

The Approaches Compared

The contrasting approaches adopted by Hagerstrand and Chapin largely reflect their interests in different aspects of behaviour. Hagerstrand is trying to develop a general geographical scheme for understanding behaviour at all levels, and in the context of human behaviour is interested in examining the operation of constraints, so that planners can relax them and maximise choice; whereas Chapin is
directly interested in people's choices and preferences, so that as a planner he can provide facilities for the satisfaction of needs and wants. Hagerstrand is thus more interested in 'obligatory' actions and Chapin in 'discretionary' ones.

Although there is a clear conceptual distinction between choice and constraint, it is often difficult to demarcate the two in practice. In a very fundamental way, for example, needs are themselves constraints which condition and control behaviour. In addition, certain everyday constraints may be altered on a longer term basis (see level 4), when, for example, households change their residential location. Shapcott and Steadman (1978) have stressed the social nature of many constraints (e.g. shop opening hours) and the ability of society to alter these if they become irksome*.

Hagerstrand's constraints approach defines necessary, but not sufficient conditions for behaviour; it provides a context for examining to what extent people are able to exercise choice on a daily basis. Chapin (1974) now recognises the importance of supply constraints more explicitly in his conceptualisation of behaviour, and conceives of actions resulting from the combined effect of the propensity to engage in an activity and the opportunity to engage in that activity. It is thus probably most productive to combine the two approaches and to view activity 'choice' as a process for satisfying a need or set of needs, subject to a set of subjective and objective constraints - although as we shall see, there are good reasons for believing that activity choices are not made independently of one another.

(2) Activity Duration and Time Allocation

The first level of complexity, beyond simply recording the existence of an activity event, involves a measure of the duration of an activity episode. Since people have a limited time at their disposal, it now becomes possible to compare time allocation between activities and to start examining interactions and trade-offs between activity choices.

* They use the analogy of a language, which prescribes constraints and opportunities for communication, but which itself is subject to modification when enough individuals change the rules.
'Time-Budget' Studies

Time budgets account for total time use over a given period, by recording the mean time spent on each of a set of activities. One of the first documented use of this statistical technique was in a study of Moscow workers by Strumlin in 1924. The Eastern Block countries have retained a primary interest in working time and production-oriented activities in their subsequent studies, but in the West the emphasis has been more on consumption and the use of leisure time (e.g. Lundberg et al, 1934; Salaman, 1974). Here the main academic interest in time budgets has come from sociology and anthropology, although there have also been studies by special interest groups, such as radio and television companies (e.g. BBC, 1975; A.T.V., 1970). A general review of American Sociological studies of leisure time use carried out between 1945 and 1965 may be found in Mayersohn (1969).

Sociological and anthropological investigators have used time budget measures as a means of describing social conditions in an area, and as a basis for quantitative comparisons between areas, or through time. Sahlin's (1972), for example, used the technique as part of a study of the economies of 'primitive' societies and Meier (1959) has used it as a measure of the quality of human life. During the 1960's a serious attempt was made to compare living conditions in a number of countries by carrying out a multinational time budget study, using standardised questionnaires and sampling procedures. The findings are reported in Szalai (1972) and show a high degree of similarity in average time budgets between countries. An apparent constancy in travel time budgets has also been widely reported, and it seems that this temporal stability exists across the full range of human behaviour.

Other writers have explored time budget stability over time. Robinson (1969), for example, compared American time budget statistics for 1934 and 1965/6 and was able to identify some changes due to social and technological developments (notably the impact of television on leisure habits), although time budgets for broadly grouped activities remained more stable. More recently Shapcott and Steadman (1978) have compared British data for 1961 and 1973 and also report a general stability between broad groups of activity, despite a 30% increase in real incomes over this period.
Empirical Models of Time Use

The simplest form of model deals with time spent on one activity, independently of the time allocated to others. In a study of working class couples, for example, Cullen and Phelps (1975) relate the mean time allocated to an activity to various socio-economic characteristics of the participants. An example of their regression equations is given below:

Domestic work time (minutes) = 470 - 420 (male) - 201 (working wife)
\[ (t = 13.2) \quad (t = 6.0) \]

\[ R^2 = 67.4\% \quad F \text{ ratio} = 100 \]

This simple but effective model allows simultaneously for the type of person and (in proxi fashion) for the amount of time committed to compulsory work activity. Robinson (1977) documents a more detailed study of the use of time, which confirms the overriding importance of sex and employment status as explanatory variables. Bain (1976) adopts a conceptually similar approach, but uses Tobit probability techniques to model activity duration as a choice process (i.e. time allocated to a particular activity may vary between individuals, from zero to a defined maximum); he employs both socio-economic characteristics and the time allocated to certain other activities as explanatory variables. Again, however, time allocation is estimated separately for each activity.

Other studies have examined time spent on several activities simultaneously. Robinson (1977), for example, shows that a one hour increase in working time is associated with an 0.6 hr decline in 'free time' and an 0.4 hr reduction in personal and domestic activities. Similarly, higher television watching is associated with a reduction in social and cultural activities.

If all activities are examined simultaneously the analysis becomes more complicated, but this does have the advantage that the time budgets form a closed system over a defined period of time, since more time on one activity can only be gained at the expense of less time on another. Shapcott and Wilson (1976) used this property to examine associations between activities. In general one would expect negative correlations between activities and by assuming maximum independence between activities it is possible to compute a theoretical correlation matrix and compare it with the
observed matrix. The residuals then give an indication of the activities that are more (or less) closely related than one would expect, a priori, over the day. They found stronger than expected negative correlations between sleep and domestic or paid work activities, and positive correlations between paid work and travel time, and between sleep and personal hygiene or private leisure.

Theories of Time Allocation

Although time has long been recognised by economists as a component of the labour input to the production of goods and services in the monetary sector of the economy, time allocation and the use of non-work time have been of relatively recent interest. Carlstein and Thrift (1978) argue that interest in theories of time allocation have been associated with the growth of leisure time and associated industries, and a post-war switch from the subsistence to the monitorized sector in areas such as child care and health care activities. They provide an interpretative review of the time allocation literature in the context of human activity research to which the reader is referred for a detailed review of this work. Some of the main developments are summarised below.

One of the first writers to attempt a formal theory of time allocation was Becker (1965), who argued that households should be seen as producers as well as consumers. Household members combine inputs of market goods and time, to produce a range of basic commodities (e.g. participating in activities such as seeing a play) for their own use, in accordance with the cost-minimization rules of the traditional theory of the firm. Commodities are produced in quantities which maximise a utility function of the commodity set, subject to 'prices' (i.e. market prices and time) and constraints on overall income and time. Becker sees non-work time — beyond a certain amount required for sleep, eating and physical well-being — as a source of foregone earnings and so views time and money as being interchangeable. This enables him to define an overall budget constraint referred to as the "full income", which represents the maximim earning potential of an individual at a given point in time. Utility is thus measured in terms of the opportunity cost of time that could have been spent in production but Becker acknowledges that this will vary over time and by type of commodity, since:
(i) There are fewer opportunities to earn money at certain times of day or on certain days of the week.

(ii) The opportunity cost will be lower for essential activities which contribute to the 'efficiency' of the individual (e.g. sleep).

Household production functions are adjusted to provide commodities in the quantity and of a quality required by the household, subject to budget and other constraints. The link between production and consumption is provided by a reformulation of consumer theory proposed by Lancaster (1966), who argued that consumers derive satisfaction from the attributes of commodities rather than from the commodities themselves. Thus, changes in preferences or constraints may lead both to a change in the pattern of consumption and in the quality of commodities consumed. Becker distinguishes in particular between 'goods-intensive' and 'time-intensive' activities.

As wage rates rise, time becomes more valuable relative to goods, so that consumers tend to modify their production functions; they adjust the attribute mix of existing commodities, by conserving time and becoming more lavish with goods inputs (e.g. making greater use of convenience foods rather than preparing the meals themselves), as well as generally shifting their consumption patterns away from time-intensive to goods-intensive pursuits. This point has been developed by Linder (1970) in his book on the "Harried Leisure Class", which uses these and other arguments to account for the apparent paradox that, as wage rates rise and working time falls (through increased productivity), leisure time also appears to be becoming more scarce.

Becker also argues that decisions about time allocation between market and consumption goods take place at the household level, and in a subsequent book (Ghez and Becker, 1975), the authors examine changes in the allocation of time over the life cycle. Here, education is added to the previous activities of work and consumption, as an investment in 'human capital'; given the long time scale, account is also taken of interest rates on capital, time preferences with regard to consumption, a function for the depreciation of goods, and a savings function. A similar extension to cover the life span of a household has been proposed by Cohen and Stafford (1974).
One of the main criticisms of Becker's work by fellow economists has been his assumption that the marginal rate of substitution of income for leisure is equivalent to the wage rate, on the basis that people are able to substitute freely between work and non-work activities, up to the limit of their full income. De Serpa (1971) and Evans (1972) have both argued that time and money budgets cannot be interchanged in this way, because of constraints on activity duration and the varying utilities people ascribe to different activities.

De Serpa adds to Becker's formulation by stating (p.828) that:

The decision to consume a specified amount of any commodity requires that some minimum amount of time be allocated to it, but the individual may spend more time on that activity if he so wishes.

Where a binding technological, physical or institutional constraint applies to the duration of activity participation, then the marginal rate of substitution between two goods will no longer be equal to their price ratios - and de Serpa argues that we should therefore distinguish between the value of time as a commodity and as a resource.

Evans also argues that there is a fundamental difference between the value of a relaxation in a time constraint - leading in this case to an overall increase in the available time budget - and the value of time used in a specific activity. He summarises his argument (p.2) as follows:

...... the value to the consumer of an increase in the total time available must be distinguished from the value which he places on his time in any particular use. The latter is the price at which the consumer is willing to sell his time and this price will vary with the use to which his time must be put; for example, the rate of pay required by any individual varies with the type of work which must be done. The former is the consumer's valuation of a relaxation of the constraint on his behaviour caused by the limit in the time he has available.

Evans uses the latter argument to explain why travel time valuation varies according to the method of travel used.

Questions concerning the economics of time are reviewed in detail in Sharp (1981). Economists have developed the broad outline of a theory of time allocation which, if extended to include timing (see level 3) as well as time constraints, could provide an important basis for examining the scheduling of daily behaviour.
Measures of Activity 'Elasticity'

One important way in which the economic work can contribute to human activity studies is through the examination of adjustments in time allocation between activities at the margin — for example, what do people do if work hours decrease, or commuting time increases?

A number of writers have examined the 'elasticity' of activities in an empirical context, commonly in studies of the effects of a reduction in working hours (e.g. see Robinson, 1977). Usually, however, the definition used has differed from that familiar to the economist, and has instead been applied to a measure of dispersion of activity durations within a population, about the mean value. Parkes (1974), for example, uses a measure based on the standard deviation of the duration of activity participation, divided by the mean, and multiplied by 100 to express the value as a percentage. This gives some indication of the fixity and flexibility in activity duration, but does not directly provide a means of forecasting adjustments in allocation in response to changed conditions.

True elasticity measures are difficult to obtain — particularly if account is taken of the inhibiting effects of timing constraints and thresholds on the process of adjustment. One promising possibility is to use a gaming approach developed by Chapin (1965, 1974) to obtain such measures.

Chapin's 'Trade Stamp Game' is designed to examine how people would make use of increased leisure time and incorporates three key elements:

(i) a limited time budget
(ii) trade-offs between different leisure activities
(iii) simplified (but realistic) assumptions about the duration of activities and the times of day during which they are available.

Respondents first indicate how their leisure time is allocated at present and then adjust time allocations to take account of an increase (or decrease) in available free time. The game is based on a seven day time allocation and it is possible to allow for activities which are undertaken on a less frequent basis. It does not take explicit account of timing constraints; but it is probably reasonable as a first approximation to assume that
participants make choices on the assumption that these are not binding, so enabling measures of elasticity to be obtained. So far, however, the technique does not appear to have been used in this way.

(3) Activity Timing and Sequencing

Time allocation studies concern themselves with the duration of activities, but not their timing. If models based on these concepts are used for forecasting, there is a danger that the predicted time allocations might require people to carry out activities at a time when the facilities are closed, or in a sequence which is infeasible. The introduction of timing (and indirectly space) adds new dimensions to the understanding of behaviour and enables a more complete exploration of opportunities and constraints. As in the preceding section, it is possible to some extent to differentiate between studies which examine the timing of only one activity and those which look at how the timings of activities are linked - and hence investigate the sequence of behaviour.

The Timing of Activities

Information on the timing of activities can be presented in the form of histograms, indicating the number (or proportion) of people participating in a particular activity, by time of day; examples are provided in Bullock et al (1974). The cyclical nature of activity participation through the day has encouraged some writers to search for empirical regularities; Cullen and Phelps (1975), for example, used harmonic regression analysis to produce a smoothed out envelope of each distribution, with some success. It is also possible to retain the advantages of the time allocation models (i.e. a closed system and time trade-offs) by superimposing the frequency distributions of participation by time of day, for a range of activities, so that they sum to the sample size (or 100%). Examples of data presented in this form may be found in Szalai (1972), Chapin (1974) and BBC (1965).

In a review of the nature of time, Thrift (1977b) identifies three aspects that influence the temporal distribution of activities: biological, psychological and socio-ecological time. Like all living organisms, man has a system of biological 'internal clocks' which regulate and control many aspects of his behaviour (Luce 1973).
Most rhythms tend to conform to a 24 hour cycle and are termed 'circadian', although some operate over longer periods (e.g. the menstrual cycle and ageing itself). The circadian rhythms peak at different times; for example, most people tend to feel tired about 2pm and their efficiency curves then rise again and peak in mid-afternoon, while body temperature is at its lowest between 1am and 7am. Thrift (1977b) concludes that "much daily variation in activity and attention to activity is a product of biological rhythm" and Lynch (1972) has suggested that "as we learn more about the inherent rhythms of the body (sleep, excretion, eating, attention, mood), we may find that we should rearrange established timings to achieve a better fit".

Psychological time is time as perceived by the individual. This experiential time may differ considerably from the objective measures of time, but in modern society there are strong pressures on individuals to align clock time and psychological time. Inability to do so may lead to mental disturbance and Thrift concludes that "man's answer to the press of time appears to be routinization of the daily round".

He defines socio-ecological time as "the temporal organisation of society as mediated by the basic constraints on home life (be these biological, environmental, or whatever)", which is measured using the control mechanisms of the clock and the calendar. The timing of behaviour may thus be viewed as an interaction between various motivations expressed in biological time and the availability of services and facilities in socio-ecological time, as mediated by the experience of behaviour in psychological time.

As we better understand the dimensions of time, the distribution and sequencing of observed activities make greater sense. Maw (1972), for example, analysed the time devoted to broadly defined groups of 'essential' and 'optional' activities through the day and detected three superimposed trends:

(1) Optional activities progressively replace essential activities through the day, until bedtime.

(2) Leisure activities increase through three plateaux, at about 10am, 3pm and 8pm. Such times fall between meals, sleep and various cultural commitments (e.g. work).

(3) Highly committed activities occur in three waves, with peaks at noon, 5pm and 10pm; these correspond with basic needs such
as eating and personal care activities.
Similar findings were reported by Cullen, using a time series
analysis, who found that the basic work - sleep and eating -
eating cycles were of overriding importance in determining the timing
of activities through the day. He also observed that "the waking day
begins to break up into something more gregarious after mid-day"
and that "the variety, speed and complexity of behaviour must be at
its highest from mid-morning to mid-afternoon"(Cullen and Godson, 1972).

Activity Sequencing

There is also evidence that biological and psychological factors
influence the sequence of activities; for example, the tendency to
follow sleep with personal care and eating activities. Chapin and
Hightower (1966) and Cullen (1972) have observed that periods of
high and low activity tend to oscillate, the former being associated
with committed, high priority activities and the latter with
passive, uncommitted, low priority ones. Maw identifies a three-
phase sequence through the day:

COMMITMENTS → ACTIVE PURSUITS → SOCIAL OR PASSIVE ACTIVITIES

and illustrates its operation (Maw, 1969, p. 925):

This sequence is evident on a normal Saturday, when shopping
reaches a peak in the morning (except in those areas where a
high proportion of the population is at work), the afternoon
is the traditional time for sport, and in the evening people
pursue more social or passive activities, like going to parties,
dancing or watching television.

Chapin (1968) also views activity sequences as being made up of
successive motivation - choice - activity decisions, but does not
clearly specify how the types of need vary by time of day. The
apparent sequential linkages between certain activities has
encouraged attempts to describe activity sequence using transition
probabilities and to model activity patterns using Markov chain
models (see later section).

The ways in which people use facilities and spaces at different
times of day clearly has its aggregate counterpart in terms of the
way urban spaces are used; for example, contrast the congestion in
the Central Business District during the day with its virtual
abandonment at night. Using standard factorial ecology procedures, but based on space-time instead of the traditional spatial units, Taylor and Parkes (1975) are able to differentiate between areas according to their temporal regimes. Other work in progress is looking at the city wide effects of biological and psychological rhythms in terms of the distribution of 'stress signals'; this involves mapping violations of public order, or the use of ambulance or Samaritan services, in space and time (Parkes and Thrift, 1980).

'Time Geography'

Probably the most comprehensive and successful examination of activity sequences in a theoretical context has been made by Hagerstrand and co-workers, using what has come to be known as the 'Time Geography' approach. Their work is based around a technique for continuously mapping behaviour (or the existence of objects) through time and across space. It is properly represented in a three dimensional 'space' using two horizontal axes for areal location and a vertical one for time - like a series of maps stacked one upon another, each representing a person's or object's spatial location at successive moments in time - though it is often simplified to a horizontal distance axis and a vertical time axis, as in Figure 2.

Figure 2a shows the simplified time-geographic representation of a part of one person's day. An individual's behaviour can be mapped as a path through time; this is either stationary in space and associated with a location (or station), or represents movement between stations (i.e. travel). The former is represented by a vertical section of the path and the latter by an angled path, reflecting the fact that the individual is simultaneously moving through time and space. The mapping concept is quite simple and readily intelligible, yet it is extremely powerful, and has a certain deductive logic due to the fact that it provides a continuous representation of behaviour.

Using this representation, behaviour is constrained by the following factors:
(a) People are usually only able to participate in one primary activity at a time.
(b) A person can only be in one place at a particular time.
(c) Every activity has a duration and so consumes a certain amount
(a) Time-Space Trajectory

(b) Coupling Constraints

Figure 2: Some Basic Concepts in Time Geography
(After Hagerstrand, 1970)
(d) Movement between stations takes time, which is inversely related to the speed of travel (see below).

The capability, coupling and authority constraints that were referred to previously as factors influencing the selection of an activity event (level 1) were in fact conceived within the time-geographic framework as operating to influence the sequence of activities. Figure 2b, for example, illustrates how various coupling constraints can predetermine an activity sequence, and a substantial proportion of a person's daily path. The individual depicted in this example has to meet colleagues at his work station for the working day and then return to his home station in time to share an evening meal with other household members. Further examples may be found in Thrift (1977a) and Matzner et al (1976).

In the travel context, one of the most important of Hagerstrand's concepts is that of the space-time 'prism'; this is a form of capability constraint which limits the physical reach of an individual during a period of uncommitted time, due to the fact that it takes time for the individual to move through space.

Figure 3a illustrates the basic concept. Assume an individual is committed to being at station 1q (say home) until time t1, and that he has to be at 1l by time t2. He thus has uncommitted time from t1 to t2, but the use he can make of it depends on the speed with which he can travel from 1q to 1l. On foot it may take (t2 - t1), leaving him no time for any other activity; but the use of faster modes enables the traveller to reach an enlarged area of space and within this envelope he may trade-off the extra distance (and hence time) of reaching destinations off his direct route (dx), against the time he has available to spend there (ty). Space-time prisms thus define the range of possible opportunities.

This example over-simplifies the individual's options, since it assumes that space is isotropic and that stations are ubiquitous. In practice, there are a limited number of stations at which an individual can undertake a desired activity, which may or may not be open at that time of day; there is probably also a minimum duration needed for the activity, so that stations at the apex of the prism are effectively excluded.
(a) Effect of Different Modes

Traffic Modes:
- Walk
- Car
- Cycle

(After Hagerstrand, 1970)

(b) Introduction of Station Constraints

(Equal = minimum station time)

(Modified from Thrift, 1977a)

Figure 3: The Concept of the Space-Time 'Prism'
Some options are defined in Figure 3b. Option (a) is excluded because the minimum duration criterion cannot be met and the individual has a choice between (b), (c) and (d); if he chooses (b) he cannot also reach (c) and (d), but by choosing (c) he could also reach (d), if he wished. For an individual travelling by car or cycle, this gives some indication of the options that might be available, but if public transport is used options are further constrained by the fact that services run at particular times.

An individual's day can therefore be viewed as a path with certain fixed sections (e.g. due to the space-time fixity of sleep and work or school activities) and other more flexible sections, bounded absolutely by prisms of different size and shape. This representation stresses the way in which one activity 'choice' restricts subsequent activity options. The time geographic framework is thus able to define in objective terms a 'corridor' of space-time opportunity through the day, but does not primarily concern itself with the actual path that is chosen.

Conclusion

Hagerstrand's conception of constraints is avowedly 'physicalistic', since he is concerned with delimiting objective constraints on daily behaviour, as they influence opportunities for interaction in time and space. Other writers, such as Cullen (1972), have criticised this approach and argue that behaviour is as much limited by subjective constraints as by objective ones — and objective and subjective notions of space and time may differ markedly. The subjective spatio-temporal world has recently become of growing interest to geographers. Buttimer (1976), for example, has examined the concept of 'lifeworld' ("the culturally defined spatio-temporal setting, or horizon of daily life") and Rose (1977) has considered how experiential time might be incorporated in Hagerstrand's framework.

This omission is not really a serious problem from Hagerstrand's viewpoint, since he is primarily interested in helping the planner to find ways of reducing physical constraint and so maximise freedom of action. It is something of a limitation however, in the context of understanding behaviour.
(4) Activity Structure and Patterning

When attention switches from path options to observed activity patterns it is appropriate to adopt a rather different conceptualisation of daily behaviour, one which takes account of the activity as a separate element. Hemmens (1970) suggested a triangular relationship between activity, space and time (both timing and duration), and Bullock et al (1974) have adapted this to define options and constraints in the form of a three-dimensional matrix. Used for aggregate analysis, the daily activity patterns of a population may be described as a distribution across the cells of the matrix, with each cell indicating the number of people engaged in a particular activity, at a given location and specific time of day. Constraints may be represented by the fact that certain cells are not available; for example, many locations and time slots are not available for shopping. This conceptualisation makes explicit the activity dimension implicit in much of Hagerstrand's work, and the notion of cells instead of paths leads to an emphasis on pattern rather than sequence. However, like the time geography work, it delimits objective constraints but does not directly account for behaviour.

Choice in the Context of Pattern Constraints

Ray Maw and colleagues at the Built Environment Research Group (Polytechnic of Central London) have conducted some very detailed research into the demand for recreation in the context of daily activity patterns, which has not been widely recorded in the human activity literature; a summary of their conceptual work is provided in Maw and Cosgrove (1972). Participation in a particular leisure activity is seen to result from a decision process that embodies a number of filters. These define both constraints and alternative options that are either objective or subjective in nature. The framework is presented in the form of an operational model of leisure demand, but this has been redrawn in Figure 4 to represent the implied decision making structure, at the individual level.

As can be seen from this figure, the modified framework is in two stages; the first part determines the type of activity which a person would wish to participate in and this is then matched against the available supply of activity facilities. The preferred type of activity depends on the amount of time, money and energy the
Figure 4: The Context and Components of Leisure Activity Decisions

Based on Maw and Cosgrove (1972)
individual has available (and bearing in mind the tendency to pursue more passive pursuits into the evening), on his 'influence' (e.g. whether eligible to join certain clubs), and on the timing of his uncommitted time. Given a predisposition for participation in a certain type of activity, the likelihood of visiting an appropriate facility depends on:

(i) weather conditions
(ii) the time and cost of travel involved
(iii) the person knowing about the existence of the facility, and
(iv) his evaluation of its attractiveness.

As outlined the framework relates to individual activity decisions, but it is mentioned here rather than earlier because it is firmly set in the context of a routinized activity pattern. The notion of uncommitted time blocks (of specified timing and duration) is a central feature and the decision framework illustrates some of the dimensions of behaviour that are missing from Hagerstrand's representation of behaviour*. Maw's work is significant, both for its inclusion of objective and subjective constraints (e.g. levels of awareness) and because he views leisure behaviour as the result of choices in the context of constraints.

The Structure of Daily Behaviour

Cullen has adopted a similar approach, but takes it further by examining complete patterns of daily behaviour and the ways in which these are shaped by the perceived nature of commitment and choice through the day. In addition to collecting information about the location and timing of activities, Cullen has been concerned to establish how much choice the individual had when engaging in each activity (e.g. could it have been done at another time, or in another place?), and to what extent the activity was a routine event, or in some way specially planned, or perhaps spontaneous. From work on student activity patterns he was able to identify a clear structure to the day (Cullen and Godson, 1972, p.8):

---

* This depth of understanding is partly gained at the expense of breadth, however, since the framework requires that large sections of the daily activity pattern are fixed and given.
Activities to which the individual is strongly committed and which are both space and time fixed, or just time fixed, tend to act as pegs around which the ordering of other activities is arranged and shuffled according to their flexibility ratings. Any periods of the day which are left free after this process are either scheduled in a later, shorter planning period, or are ultimately occupied by 'spur of the moment' activities or 'doing nothing'.

The idea of a set of fixed events around which the day is structured has been taken up by other writers and is apparent, for example, in the concept of 'markers' proposed by Parkes and Thrift (1975).

Cullen's university sample comprised mainly young, single persons who (not surprisingly) had a level of daily activity commitment which was considerably less than the average person's. This was apparent from a subsequent study of working class couples living in a Hackney housing estate (Cullen and Phelps, 1975); here 78% of waking weekday was regarded as 'routine', compared with 35% for the University sample, and only 4% classified as 'filling in time' (as opposed to 23% for the latter group). The pegs or markers dominated the days of the working class couples to such an extent that many people were left with very little choice about their behaviour, on a day-to-day basis. Even in the case of leisure activity, only about 40% of the occurrences were reported as being flexible with regard to the choice of activity and only 13% offered a choice of location. For employed men and women the peak time for spur of the moment and time filling activities was mid-evening, but for housewives it occurred in the late afternoon - a slack period before the routine of the evening meal and associated domestic activities.

For the typical working class couple, therefore, the structure of their daily behaviour is (Cullen and Phelps, 1975, pp.71/2):

...one of a dominant and inflexible pattern of routine domestic and paid work, punctuated by equally inflexible and equally routine meals and personal chores. More flexible punctuations include spur of the moment shopping trips, and the whole pattern relaxes considerably, though by no means entirely, as the evening is given over to social and leisure pursuits, sometimes routine, sometimes deliberately arranged and sometimes just filling in time.

* This ranged from 70% of waking hours for housewives, to 82% for working men. These figures exclude travel time.
Aubertin (1973) also studied a sample of married couples and found a similar pattern of commitment through the day. Using a simple four-fold activity classification she was able to identify a generalised weekday pattern of behaviour, based on the dominant activity at each time of day. This is illustrated in Figure 5. It appears that, rather than being the result of external space-time constraints, much of the routine in a person's life may be attributed to a commitment to joint activities with other household members, or with friends or colleagues. Aubertin found that, on average, about two hours of the normal couple's waking day is spent in overtly joint activities - but this takes no account of any child-care commitments.

Shapcott and Steadman (1977) carried out a detailed study of the changes in employees' activity patterns brought about by the introduction of flexible work hours at a government establishment in Reading. Despite a general enthusiasm for the freedom of action which the scheme allowed, they found that many employees did not alter their arrival or departure times; for example, only one third changed their habitual time of arrival in the morning. The authors recognise that this may partly reflect entrenched habits and psychological inertia - even six months after the scheme's introduction - but they conclude that an important factor appeared to be the inability to change arrangements set up around their old working hours (such as domestic arrangements or lift sharing), which the introduction of flexi-hours did nothing to remove. For many, the space-time fixity of the evening meal is as strong a constraint as those imposed by work or educational institutions.

**Longer Term Choice Options**

An important result of the work on the structure of household activity patterns is the attention it focuses on the nature of constraints. There is a need to distinguish between everyday behaviour, which is highly routinized and constrained, and longer term decisions which provide occasional choice situations that may substantially alter daily behaviour; for example, a change of residential or work location, the decision to start a family, or perhaps the acquisition of the household's first car. Added to this are the long term choices made by society, in terms of legislation on opening hours, observance of various customs, etc. (Shapcott
Figure 5: The Structure of Daily Behaviour

(Married couples, Monday-Friday)

ST = Sleep Time (excluding naps and dozing)

CNWT = Committed Non-Working Time (including: eating and meal preparation, personal care, child and family care, household duties)

WT = Working Time (activity in connection with paid employment, including time spent travelling to/from work)

FT = Free Time (personal interest and other activities, including sports and games, passive leisure, etc)

Source: Aubertin (1973)
and Steadman, 1978).

For example, the increasing tendency for shops to stay open in
the evening reflects the changed shopping requirements of the
growing number of working wives, and the greater need for a car
(often only available outside husbands' working hours) to transport
bulk purchases from the larger supermarkets.

Cullen (1978) has characterised the relationship between short
term constraint and long term choice as a cyclical process; this
is reproduced in Figure 6. An individual's (or household's)
situation, or socio-spatial context, is the result of life
situations and occasional life choices. Once this situation alters,
daily behaviour is adapted in some way and quickly becomes
routinized into a new activity pattern. In following this daily
pattern the individual gains experience about his pattern of living
and about possible alternatives; this information influences and
may indeed precipitate a subsequent life choice, which again
alters the individual's situation and leads to a new daily activity
pattern ..... and the cycle repeats. The validity of this
conceptualisation has been confirmed by Michelson (1977), who
carried out a longitudinal diary survey of residential relocation
and found a conscious realisation of the implications of this type
of decision for daily behaviour.

Conclusion

Writers have used three different techniques to explore the
degree of flexibility and the nature of commitment in the structure
of people's daily lives:

(i) asking them directly to rate each activity (Cullen et al)
(ii) monitoring response to a policy change (Shapcott and
    Steadman), and
(iii) comparing the activity patterns of different groups, such
    as shift and regular workers (Aubertin).

Each has confirmed the importance of routine in daily life and the
need to view behaviour as a pattern of events, interlinked in space
and time with the behaviour of others.

This necessitates a two-directional view of the time dimension,
with people planning events around fixed points in their day.
Parkes and Thrift (1975) have used the phrase the 'accordion effect'
to describe the changes in behaviour which may result from an
Figure 6: Interrelationships Between Short and Long Term Behaviour
(Source: Cullen, 1978, page 32)
abnormal event (e.g. the need to stay late at work), because of the way in which this may involve revisions to the activity pattern before as well as after the event.

Although this backwash effect is indirectly represented in Hagerstrand's conceptualisation of behaviour (in that the specification of choices inside a space-time prism depends on a knowledge of the next space-time commitment), it is more difficult to conceive of a restructuring of behaviour when dealing with the concept of an unbroken life path. The latter may be a useful description of observed behaviour, but it seems more satisfactory to explain behaviour in terms of the scheduling of activity blocks in space and time.

Modelling Activity Patterns

This review concludes with a brief examination of attempts to model activity patterns, drawing on concepts introduced at each of the four levels described above. The models are grouped under three headings: simulation of individual activity choices, the representation of aggregate activity patterns, and the modelling of behaviour options. A more detailed review of space-time models is provided in Bennett and Haining (1976).

Simulation of Individual Activity Choices

The 'motivation - choice - activity' conceptualisation of activity participation proposed by Chapin encourages the view that each activity decision is taken independently of others and that daily activity patterns result from a series of such separate decisions. As we have seen, this is an unrealistic viewpoint in most cases, but it does make for simple model structures, based on a repetitive decision making process, often using Markov Chain models.

Hemmens (1966) describes an early attempt to simulate urban activity sequences using transportation study data from Buffalo, New York. He derived probabilities of transition between successive activities and attempted to develop a two-stage Markov model which...
would first simulate the type and timing of each activity and then its location. He was unable to develop a satisfactory model and, after reviewing a number of other unsuccessful attempts, concluded that "the problems of conceptual structure, model structure and data requirements.....(indicate that).....the proposed use of the semi-Markov process for simulation of urban activities is not warranted". This has not deterred other attempts, however, and this form of model is still popular among many researchers who attempt to model travel and/or activity sequences.

Brail (1969) describes a more sophisticated activity choice model, subsequently developed at the same centre where Hemmens carried out his work. Brail's model simulates an individual's sequence of daily activities, from waking till sleeping, by a series of successive activity choices. The model determines activity choice, location choice, travel time and activity duration by sampling from the appropriate discrete or continuous probability distribution. After a set of choices has been made, a distribution of retiring times is sampled before proceeding to the next set of non-sleep choices. Probability distributions vary by person type and time of day, but the model was never fully tested using a sample of the population.

Stephens (1976) has developed and tested an activity pattern model which uses a similar type of simulation technique, but which differs markedly from Brail's work in that it is explicitly based on Cullen's notion of pegs around which the day is structured. The model was developed using a sample of university students and staff and is based on a 15 minute time interval. Instead of operating in a simple sequential fashion, it starts with the pegged times as given; it then searches for various other fixes in the day and finally fills in the rest of the day in sequence with less committed activity, using transition probabilities of linkage coefficients between successive activities. The model records the type of activity that is selected and its timing, duration and location, and has a forward search facility to ensure that a proposed activity does not encroach into 'pegged' time.

Despite its apparent sophistication, Stephen's model was unable to replicate existing behaviour very satisfactorily - except around the pegs which formed an input to the model - and he concludes that it would have been better if he had included some objective space-time constraints, instead of relying completely on the subjective assessments of fixity or flexibility. In part, however, it also
reflects the logic built into the model, since it appears from his
description that pegs are time-fixed, but that the type and location
of the activity associated with them are sampled probabilistically.
This misrepresents the nature of a peg and it is not surprising that
Stephens experienced problems.
Even if this model had been successful, however, simulation models
which are built up entirely from empirically derived probability
distributions appear of little value to policy makers, since there is
no way of know how such distributions might be affected by a policy
change. For example, would the distribution of shopping times (both
timing and duration) be affected by revisions to work hours? A priori,
one would anticipate that they might, but there is no obvious way of
taking account of this in the model. Similar problems arise when
modellers attempt to use Markov chain processes for forecasting
purposes.

Representation of Aggregate Activity Patterns

A more successful approach to modelling daily activity patterns
- again, based on a student sample - has been developed at the Martin
Centre in Cambridge, using entropy maximisation procedures to generate
the most likely distribution of people among activities and locations
through the day*. The work is described in Tomlinson et al (1973).
The model is based on the cellular concept of options and constraints
(i.e. activity/time/location combinations) described earlier in this
appendix and the main inputs include:
(a) mean daily time allocation for each of 12 activity groups,
    including travel (summing to 24 hours);
(b) locations at which each activity could be undertaken;
(c) timing restrictions on activities at different locations;
(d) information about travel times between locations;
(e) distributions of time devoted to sleep and formal lectures.
A comparison of predicted and actual time allocation to activities
for successive 15 minute time periods showed a reasonably good
agreement between the two although, because the model assumes

* The project began by developing a simulation model (Bullock et al,
1972), but this was subsequently replaced by the entropy formulation
because it is computationally more convenient and makes fewer
assumptions about behaviour.
independence between successive activities, it was unable to 
replicate certain strong associations such as those between sleep 
and personal care activities. A mechanism was subsequently proposed 
to handle this problem.

In developing the model there was "...no attempt to examine the 
patterns of activities from the standpoint of the individual as a 
decision maker and no concern with the reasons for which the 
individuals choose to behave in certain ways" (Tomlinson, et al, 
1973, p.232); yet the model performed surprisingly well given that 
constraints on students are known to be less than those on the 
population as a whole. From the policymaker's viewpoint the model 
has a number of attractive features, since it requires objective 
data which can be easily provided (e.g. opening hours of shops); 
it is probably a reasonable approximation to assume that mean daily 
time budgets remain stable, although it is likely that the timing and 
duration of activity episodes would vary. Conceptually the model 
also has appeal because it is concerned with structure not sequence 
and so is able to handle basic rearrangements to daily activity 
patterns.

The Cambridge work led to a belief that if an entropy model of 
student activity could be developed successfully, then it should be 
possible - perhaps easier - to develop models for other population 
groups with more heavily constrained lives. In the event this effort 
has not proved successful, because of the greater variability in 
person and environmental characteristics among non-student groups 
and because of the stronger linkages among other kinds of 
individual. Students effectively operate as one-person households 
and so there is no need to consider the complex chauffeuring and 
other domestic arrangements that occur in other types of household. 
Thrift (1977b) describes this as the modeller's 'time-space budget 
paradox' and argues that it makes successful aggregate modelling 
almost impossible.

Modelling Behaviour Options

One response to this problem is to examine what people could 
do, rather than attempt to predict what they will do. Using the 
notion of the space-time prism Lenntorp (1976), a member of 
Hagerstrand's group, has developed a detailed simulation model 
which avoids the pitfalls of aggregation and revealed preference by
looking at the path options faced by representative individuals living in different areas. A summary of the model is provided in Thrift (1977 a).

Known as 'PESASP', Lenntorp's model explores the impact of a change in transport network (e.g. revised bus schedules) or land use facilities on the number of ways in which an individual can achieve a given 'activity program'. Three types of input are necessary:

(a) the relevant activity program, specifying which activity has to be fitted in between fixed activities in space-time (e.g. visiting a shop for t minutes en route from work to home);
(b) details of the land use pattern, recorded in space-time (locations and opening hours);
(c) details of the transport network in space-time (actual road network and bus schedules).

The flow chart from an early version of the model is reproduced in Figure 7. The model systematically works through the list of activities in the activity program, examining all feasible destination stations for the set of available modes, and taking account of appropriate space, duration and timing constraints. An example of the types of output which can be provided by the model are shown in Figure 8, based on access to post offices from a given set of dwellings and workplaces. Note how the four modes differ markedly in the extent to which they enable flexibility in individual activity patterns, and the importance of flexible working time as a means of reducing time-space constraints on behaviour.

Although the model does not forecast actual behaviour, it does have a useful policy role in that it is able to demonstrate how, for example, small timing or frequency adjustments can significantly affect the individual's set of opportunities in space and time. The studies documented to date are based on activity programs comprising only short sequences of activities, but the approach is capable of extension to longer periods of time and this work is currently underway.

An alternative means of avoiding the time-space budget paradox is to sketch out some broad constraints on aggregate patterns of behaviour, using some of the deductive properties of the space-time framework. This has been done by Hagerstrand and his associates in a study of alternative futures for Swedish society (Ellegard et al,
Program evaluating the set of alternative sample paths version one 1969

PESASP

Start

Read data on environment

Read list of coefficients

Read datagroups on action lists

Permuting routine determination of action sequence

Print head of result table

Take one couple of fixed stations (FS)

Take one mode of travel

Take one action list

Last sequence processed

No

Yes

Last couple of 'FS' processed

Yes

Last mode of travel processed

Yes

Last action list processed

Yes

End

(First action)

Evaluate duration of the first action

Search routine evaluate set of possible stations for the 2nd action

Transport routine move individual to a station belonging to the first set

Conflict with restrictions in the action list or in access to the station

Yes

No

Yes

No

Yes

No

(Second action)

Evaluate duration of the second action

Search routine evaluate set of possible stations for the 3rd action

Transport routine move individual to a station belonging to the second set

Conflict with restrictions in the action list or in access to the station

Yes

No

Yes

No

Dept. of Geography/Lund Sweden

B. Lenntorp

Figure 7: Flow Chart from an Early Version of the PESASP Model

(Source: Parkes and Thrift, 1980, Figure 6.13)
Number of alternative possibilities of performing a specific activity programme under given conditions

The postulated activity programme is as follows: An individual is to leave his station of residence and commute to work and back home again. During the trip to work or homeward journey, for which he has one hour each at his disposal, he has to visit a post office (cf. Figure 2). From every given station of residence the programme can be carried out in a maximum of 108 different ways (which are the combinations of different work places and post offices and sequences). The possibilities of performing the programme in a medium-sized city has been simulated with regard to various modes of travel.

The figure shows, for example, that a person travelling by bus in the observed public transport system has, from more than 30 per cent of the dwelling stations, a set of alternatives of about 14 per cent of the total number and that 70 per cent of the dwelling stations have a set of alternatives comprising less than 45 per cent of the total number of possible alternatives. Flexible working hours imply that the individual can start working within a half-hour interval, while the duration of work is unaffected.

Figure 8: Example of the Output from a PESASP Study

(Source: Lenntorp, 1978, Figure 3)
1977). Their model is based on the notion of aggregate patterns rather than individual paths and uses time blocks as the unit of account. It works with a closed system of individuals and time (24-hour day) and examines how daily travel patterns are affected by changes in the distribution of time allocation to activities.

The scenario forecasting process is carried out in six stages which are summarised in Figure 9. Having identified the region and time interval to be examined (S1), the total time available to the population can then be determined (S2). Revised aggregate time budgets can then be prepared for major types of activity and different groups of the population (S3), taking account of the likely impacts of technological and social change. Assumptions are then made about the temporal distribution of the aggregate time allocations through the day (S4), for both demand and supply aspects. In stage five (S5) the demand for and supply of time for specific activities are allocated among the population in the region. Further assumptions are next made about the future structure of travel patterns (for example, a decrease in the number of stops on Work-Home journeys, because of increased leisure time and looser space-time constraints), and it is then possible to forecast the number of journeys between stations, by time of day (S6). Finally, the implications of alternative futures are illustrated for different typical households, to show the effects of the scenarios on individuals living in the various societies.

This procedure makes some use of the obvious reciprocity between travel and place-fixed activities. However, it is only incorporated in the crudest way and all the factors which influence travel patterns appear to be 'assumed' rather than deduced from the model. For example, one scenario states that:

10 per cent of all journeys between home and work include a visit to some other place. In 1970 the corresponding figure was 26%. The decline will be due to increased leisure being partly applied to these visits apart from journeys between home and work.

It does not appear that this has been based on any detailed consideration of activity pattern re-scheduling and indeed the model does not attempt to estimate the increases in non-work, home-based journeys. It seems as though the travel 'forecasts' are largely based on the travel assumptions input to the procedure and the activity pattern is only used to provide a crude indication of timing. This is unfortunate as it hardly taps the potential of the human activity approach.
Figure 9: Main Stages of the Scenario Forecasting Model

Source: Ellegard, Hagerstrand and Lenntorp (1975), Figure 2.1.
APPENDIX II: THE HOUSEHOLD ACTIVITY-TRAVEL SIMULATOR — DISPLAY

EQUIPMENT AND APPLICATIONS OF THIS TECHNIQUE

Reference has been made at several places in this thesis to the 'HATS' technique, a gaming simulation procedure used in an exploratory context to examine the processes of household adjustment to changing conditions. Examples of the policy and methodological implications of findings from HATS studies were given in sections 9.2 and 9.3, respectively, and a detailed case study was presented in section 6.4.

An outline of the survey procedures was provided in section 9.2, together with an assessment of the role and performance of the technique. This appendix contains additional background information, first describing the display equipment in detail and then discussing ways in which HATS has or might be used within transportation planning. Much of the material is taken from the HATS Educational Manual (Jones, 1982c), and Jones, Dix, Clarke and Heggie (1983).

The Display Equipment

The HATS equipment is shown schematically in Figure 1; it comprises a set of display boards (one for each household member) and a box containing component pieces. Each board has two parts (see Figure 1A): a lower one on which the temporal pattern of activities can be represented, together with a crude spatial distinction between home, non-home and travel activities; and an upper portion on which more detailed spatial information can be recorded (land use, travel facilities, etc.) using some form of printed, sketch or 'mental' map. A completed display board was shown in Figure 9.1.

The lower part of each board comprises four parallel, equally-spaced horizontal raised strips on which time scales are marked out in intervals, usually with 5 or 15 minutes as the basic unit. They delimit three grooved sections in which are recorded the activities undertaken. The bottom section is used to record in-home activities, the top one is reserved for away-from-home activities and the middle section is for travel. The boards usually cover an 18 or 24 hour day, but the equipment can be used to handle a longer period of time, such as two days or one week (e.g. see Figure 11.1). In some applications the boards incorporate additional stacking areas above and below the outermost sections, as shown in Figure 2; these provide a means of storing blocks to be
Figure 1: HATS Display Equipment

A) DISPLAY BOARD

MAP
or other form of spatial representation

<table>
<thead>
<tr>
<th>Non home activities</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>Time scales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Home activities |  |  |  |  |  |  |  |

B) COMPONENTS BOX

ACTIVITIES (by colour)

<table>
<thead>
<tr>
<th>Duration</th>
<th>Sleep</th>
<th>Work</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td></td>
<td></td>
<td>5 min</td>
</tr>
<tr>
<td>10 min</td>
<td></td>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>2 hours</td>
<td></td>
<td></td>
<td>2 hours</td>
</tr>
</tbody>
</table>

LOCATION MARKERS
included in a pattern, or of examining 'spillover' effects on to other days, while retaining the basic 24 hour framework.

The pieces used to build up a picture of daily behaviour patterns are housed in a separate components display box (represented schematically in Figure 1B). They are of two main types: activity blocks (including travel) and location markers. All activities other than travel are grouped under about ten headings for display purposes and are colour coded (e.g. work is red, shopping is green). Travel blocks are coloured brown and are reserved for the central grooved section. In some studies waiting time is distinguished from travel time. The pieces are rectangular in shape and are fitted into the appropriate grooved section on the board from the starting time of the activity until its completion. Each activity is available in a number of lengths to allow for different activity durations and non-standard time periods can be recorded by using two or more pieces (e.g. \( \frac{1}{2} \) hours = 1 hr + \( \frac{1}{2} \) hr).

The temporal representation of a person's day thus comprises a succession of non-overlapping coloured blocks which are slotted into one of three grooved sections. If a person spends the whole day at home the activity-travel pattern is fully represented by pieces forming a continuous sequence using the bottom grooved section only. When the person travels away from home, however (thus involving the other two sections), further information is added to the display board to indicate the location of activities and the modes used and routes followed while travelling.

Location, mode and route information is recorded on a detachable map, or some form of spatial representation, which covers the upper part of each board. The precise form of representation may vary according to the study; for example a local large scale map may be used, or a more general sketch map and in some applications it may be appropriate to record a person's own 'mental' map. The locations of all activities undertaken are recorded using markers which correspond in colour to the activity colour codes. All in-home activities are represented by a single marker but the location of each away-from-home activity (i.e. those which are recorded in the upper grooved section) is shown separately. Travel routes which link the activity locations are indicated on the map and the mode of transport used is recorded alongside.

The T.S.U. version of the HATS equipment is designed for use as a field survey instrument and is therefore of fairly robust construction. The boards are made of plywood sheet, edged with a plastic strip and
Figure 2: Use of a Stacking Area to Help Plan In-Home Activities

Source: Jones (1983c), Figure C.5c.
covered with thin tinplate (as all components are magnetic). The time scales are printed on a base sheet and the raised strips formed from transparent perspex sheet, kept in place by six retaining screws. The components boxes were vacuum formed using white plastic sheeting. The location markers are small, appropriately coloured circular magnets and the rectangular activity blocks are either purpose-made ceramic markers (for the small sizes) or painted blocks of hardwood or plastic, covered on one side with an adhesive magnetic rubber strip. The blocks are 2 cm in height and constructed to a scale of 2 cm = 1 hour.

Although it is very robust, the resulting equipment is very expensive to produce and rather heavy. There are various ways in which the equipment could be simplified for educational use, and constructed from materials that are readily available; suggestions are provided in Jones (1982c).

Uses of the Technique

The HATS technique has been used in four major studies of household adaptation, up to the end of 1982; these comprised:

(a) School hour changes in Burford, West Oxfordshire (described in section 6.4).

(b) Bus service cutbacks in rural areas.

(c) Bus service improvements in Basildon new town.

(d) Alternative strategies for improving public transport services in a growing sector of Reading.

Results from each of these studies were cited in Chapter 9, and elsewhere. The first study was undertaken specifically for research purposes, to explore household adaptation, while the other three studies had more of a policy orientation and were, to varying degrees, supported by outside funds and involved collaboration with consultants and local authority staff. The technique has also become an established component of several transport courses, as described in section 9.5.

In a research context, HATS has proved to be a very effective device for examining patterns of adaptation, including the operation of thresholds and the re-structuring of behaviour (see sections 6.2 and 6.4), because of the form of display it uses and the dynamic, interactive nature of the interview (as discussed in section 9.2). Experience has shown that HATS works particularly well with the larger
households comprising adults and children. Such families are affected by a wide range of changes because of the variations in the ages and occupations of their members, and they often adapt in complex ways because of the nature of the constraints and linkages that affect them. These groups are often difficult to study using more conventional interview procedures.

HATS was first presented to an audience of practicing engineers, planners and consultants at a PTRC conference in July 1976 (Jones, 1976), where it received a very mixed reception. Most people were simply puzzled by the idea of using a gaming simulation approach in a policy context, and some people regarded it as an academic joke. Since then attitudes have changed to a remarkable degree towards the use of unconventional techniques — and the pendulum has swung to the point where some now mistakenly see them as a panacea for their problems.

Despite this caveat, the potential for using exploratory research methods in a policy context is very considerable. Table 1 suggests a wide range of ways in which gaming simulation techniques like HATS might be used as a policy aid: in addition to the more conventional forecasting role, possibilities range from problem identification through to product marketing. Some examples of practical applications were described in sections 9.3 and 9.4, including applications of similar techniques developed by other writers.

It seems likely that HATS will be of most value in policy terms when used in conjunction with other techniques, either in advance of, or alongside, more conventional procedures. HATS interviews provide detailed high quality data from relatively small numbers of households and it is advantageous to use the information in conjunction with other available sources (e.g. census data or transportation study data) in order to arrive at a balanced and comprehensive policy assessment. In practice some staff have found it difficult to combine the two forms of data — particularly where reliance is placed on standard statistical packages — but the development of techniques for activity analysis (described in section 10.1), together with improved training, are likely to overcome these problems in time.
Table 1
Potential Uses of HATS as a Policy Aid

- **Problem identification**: identification and clarification of problems faced by groups of the population, and the options open to them.

- **Policy generation**: better understanding of problems suggests ways in which they might be resolved — some of which are not immediately apparent to the professional.

- **Policy screening**: HATS provides a means of rapidly checking the feasibility and likely range of effects of a set of policy options.

- **Policy impacts**: more formal use of HATS to identify specific direct and secondary impacts of policies.

- **Pre-pilot technique**: to help identify key factors to be incorporated in a structured questionnaire survey, and how they should be represented.

- **Monitoring**: as a component in a monitoring exercise, to establish what effects a policy is having, and why.

- **Model selection**: knowledge of likely response patterns provides a guide for the selection of a model with an appropriate structure.

- **Forecasting**: where household responses are likely to be very complex, and not capable of formal modelling, HATS can provide approximate forecasts.

- **Evaluation**: HATS provides quantitative measures of impact and qualitative information about household reaction to policy measures.

- **Policy communication**: HATS has been used to explain policy ramifications to politicians, using a case study approach.

- **Policy interaction**: illustrates the joint effects on families of policies that are being implemented independently by a number of government agencies.

- **Public participation**: as a means of communicating policy options to the public and inviting their response.

- **Marketing**: HATS provides insights which may be used in a commercial marketing exercise (e.g. stress benefits of new transit scheme, as perceived by some families).

Source: Jones (1982c), Table III.2
APPENDIX III: A HYBRID SIMULATION/CHOICE ACTIVITY-TRAVEL MODEL

Introduction

Developed by the writer, the model simulates the activity-travel decisions of population groups in an urban area, and determines the use made of various activity and travel facilities throughout the day. Models of this type were described in section 10.3, where they were termed hybrid because they combine elements of 'event' and 'pattern' level models.

This Appendix describes the general form and operation of the model, illustrates the types of input data it requires and the outputs it can provide, and concludes with a listing of one version of the model.

Model Operation

Figure 1 illustrates the main components and stages of operation of the model. Five sub-models can be identified:

I Control Program

This controls the overall sequence of the model's operations, ensuring that all time periods, activity groups, person types and residential zones are considered in the appropriate order. It also stores information on the allocation of people to activities in zones and to modes along corridors, by time of day and provides this information as an output at the end of the model run.

II Activity-Demand Model

At the start of each time period this component provides details of the number of persons of a given type, living in each zone, who are about to select from a particular group of activities of specified duration(s). This information is derived from a knowledge of the population characteristics of each zone and a set of activity profiles which specify the broad pattern of activity demand for a population group through the day. The model compares the anticipated activity demand patterns with the committed behaviour from preceding time periods, and by subtracting the latter from the former obtains the numbers of people ready to begin each activity group. The distribution, duration and timing of the activity episodes are calculated and compared with time commitments to each activity
Figure 1: Operation of the Activity-Travel Model

KEY

T = Time Period  AG = Activity Group  PT = Person Type  HM = Home Zone  ACT = Activity

UPPER CASE Operations = Exogenous Inputs
group in future time periods, and adjusted accordingly.

This version of the model works with five activity groups: sleep, personal care/domestic in-home activities, work/educational activities (assumed to be non home-based), shopping/service activities outside the home, and leisure activities (both in-home and out-of-home). Although the time spent on the home-centred sleep and personal care/domestic activity groups is regarded as a fixed input and is not simulated in the model, 'leisure' time is computed as the residue of time not spent on other activities during each time period and so the former do influence the performance of the model. Information on work/education activity and travel patterns is also provided exogenously; however, this is an important factor because it limits car availability for other trip purposes. The activity groups which are fully simulated in the model are the non-home shopping and service activities and the complete set of leisure activities (both home and non-home).

III Choice Set Definition Model

This model determines the feasible set of activity and transport facility options for general shopping/services and leisure activities, and may also recognise more specific activities within an activity group (this is otherwise done implicitly via the different types of activity facility available in different zones). In the case of the leisure activity group, home is normally considered to be one locational option.

In the version shown in Figure 1, the model begins with the objective set of activity facilities (identified at a zonal level) that are open for use during the current time period and remain open long enough for the appropriate activity to be undertaken. A spatial perception filter is then applied (which allows for the restricted spatial knowledge of opportunities) to produce a smaller perceived choice set, unique to each residential zone and population group. Zonal attraction values and inter-zonal travel times and costs by available modes from the residential zone to and from the feasible destination zones are computed or retrieved: both may vary by time of day and for convenience a mean value is taken across the relevant time periods.

If the return journey is not feasible by a particular mode (e.g. due to non-availability of a return bus service at the appropriate time) the option is removed. Further destination/mode options may
be excluded at this stage if access time (or possibly cost) exceeds a given level defined as appropriate to the kind of activity. The output from this model is in the form of a set of feasible activity- and transport-facility options, which are valid both for the current time period and far enough ahead for the activities to be completed once begun.

**IV Car Availability Model**

As well as accounting for the complete space-time allocation of the total residential population, the control program also keeps a check on the number of residents' cars from each zone that are in use during each time period. From a knowledge of the car ownership in each zone the model calculates the unused stock of vehicles at the start of a time period. Given information on the probability of person types in each zone holding a driving licence, it is possible to estimate how many potential travellers have a car available and to stratify decision takers on this basis in the choice model. As the model is not interactive between population groups, it is necessary to assign priorities on the use of a car (e.g. work trips over non-work trips; trips by men having priority over trips by women, etc.).

**V Choice Model**

This model allocates people among the choice options identified in the Choice Set Definition model. Choice allocations are made separately for each person type, by zone, during each time period and for each activity group. Car owners are considered first and allocated between car and bus modes according to their relative (dis)utility. Car passengers are assumed to be a fixed proportion of car drivers (though factors vary by trip purpose), and the remaining residents are allocated to destinations accessible by bus.

There is clearly considerable scope for varying the complexity of this submodel - as there is with most other components of the model. The version listed in Tables 1 and 2 (at the end of the Appendix) uses a simple form of model, in which net attraction measures are calculated for all options (e.g. destination attraction minus travel cost) and persons are allocated to options in proportion to these measures. This could be replaced by a more sophisticated logit or probit model formulation.
Simple Example

The example is similar to that used in Figure 10.9, which illustrated the effects on the utilization of land use and transport facilities by one group of people of a reduction in evening bus service from the suburbs to the town centre and an earlier curtailment of the service.

The types of model input and output are shown in Figure 2, together with the assumptions used in the model about the duration of activity episodes, etc. Table 1 lists the model inputs and the resulting outputs from two runs of the model. The basic figures show the activity-travel patterns associated with a high level of bus service in the evening and the figures in parenthesis show the effects of a reduction in service. This leads to a very slight increase in travel by car, but the main effect is to transfer some leisure activities from the town centre to the suburbs and to increase the number of people staying at home in the evening.

A listing of one version of the computer program used to develop a three-zone example is provided in Table 2.

Discussion

The Activity-Travel Model represents a simple attempt to develop an aggregate model of activity and travel behaviour that takes detailed account of the temporal dimension and is able to show the interrelationships between use of travel and activity facilities in an urban area. It demonstrates, for example, how changes in work hours affect the demand for travel, or how bus service reductions alter the patterns of use of activity facilities.

The implied decision-making sequence contained in the choice model is illustrated in Figure 3; a number of factors are considered by the model, but it deals with activity-travel choices at the 'event' level. Decisions are made independently of other people and other activities - except that commitments to obligatory activities are modelled as constraints - and all trips are assumed to be home-based.

One important simplification in the handling of activity patterns is the use of input activity profiles to represent the pattern of demand. The assumption behind their use is that, by choosing sufficiently aggregated activity groups, there will be little time-trading between the groups, and so time allocations will be independent of local supply conditions. The availability of facilities
Figure 2

Model Assumptions and Data Requirements

Simple Example

Data Inputs:

NOSOCC: Number of People x Activity Type x Time of Day (Sleep, Personal/Domestic at home, Work/School, Shopping/Services, Leisure)
TRCOST: Inter-zonal travel costs x Mode x Time of Day (Public transport, Car)
FACATT: Attraction of Activity Facilities x Zone x Time of Day
FACAV: Availability of Activity Facilities x Zone x Time of Day
CAROWN: Number of Cars Owned x Person Type x Zone
LINK: Inter-zonal Work Trips x Mode x Time of Day
PERCEP: Spatial Perception of Areas of the Town

Model Assumptions:

Activity Durations:

Local Shopping: 1 hour (80% of shopping episodes)
Central Shopping: 2 hours (20% of episodes)
Leisure, Non-home: 2 hours
Leisure, In-home: 1 hour

Vehicle Occupancy:

Work trips: 1.2
Shopping trips: 1.5
Leisure trips: 1.8

Probability of Owning Driving Licence: 0.5

Model Outputs:

CONSMP: Number of People x Activity x Zone x Time Period
CRFREE: Number of Cars Available x Person Type x Zone
LHOMEx: Number of People engaging in Leisure Activity outside the home
LHOMEx: Number of People engaging in Leisure in-home
LINK: Inter-zonal trips x Mode x Time of Day (Public transport, Car driver, Car passenger)
Figure 3: Implied Decision-Making Sequence in the Activity-Travel Model

For a given: Time of day, person type, residential zone

1. Establish Demand for Activities:

2. Determine Set of Perceived Destinations for Activity A₁:

3. Determine Feasible Means of Access:

4. Evaluate Activity and Travel Facilities; Determine Net Attractions:

5. Forecast Resulting Patterns of Activity and Travel Consumption:

. . . . . . REPEAT FOR A₂, A₃.
might affect how leisure time was spent, for example, but not how much time was spent on leisure activities overall. There is some support for this view in the review in Appendix I but the degree of independence between demand and supply is clearly more limited when stratified by time periods; shopping can only be undertaken during shopping hours. In view of this limitation it would clearly be more satisfactory to take the daily time budget as the stable input and use a time-allocation model to derive the activity profiles, perhaps based on the entropy modelling approach adopted by Tomlinson et al (1973).

The main features of the model are its ability to handle car availability (at an aggregate level) and its sensitivity to a number of changes in supply conditions, by time of day. Elasticity in trip generation is dealt with in two ways. In the case of leisure activities there is an explicit trade-off between in-home and out-of-home activities, as there is a clear relationship between trip frequency and the supply of activity and transport facilities. There is also the possibility for a more restricted sensitivity in the case of shopping/service activities (which would also apply to leisure). If residents carry out activities locally less time will be spent in travel, which provides a slight increase in aggregate time for future occurrences of the activity; this sensitivity could be increased if time spent at the destination were (inversely) related to the travel time. There would thus be a choice between many short duration episodes and trips or fewer longer ones, as is observed for example in shopping travel.

Although the model is unable to take account of many of the processes of adaptation operating at the micro level, it could prove useful as an educational tool for illustrating some of the consequences of the interdependencies of behaviour in time and space at the city-wide level.
Table 1: Activity-Travel Model - Sample Inputs and Outputs

<table>
<thead>
<tr>
<th>FACATT:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H1</td>
<td>H2</td>
<td>Suburb 1</td>
<td>Suburb 2</td>
<td>Town</td>
<td>Suburb 1</td>
<td>Suburb 2</td>
<td>Town</td>
<td>Suburb 1</td>
<td>Suburb 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buses</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Shoppers</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FACADV</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOSOCC:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></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>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRCOST:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>70</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

KEY: H1 = Residences in Suburbs 1  H2 = Residences in Suburbs 2  ( ) = Effects of Bus Cutbacks
<table>
<thead>
<tr>
<th>Time</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>9am</td>
<td>45</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>10am</td>
<td>74</td>
<td>101</td>
<td>101</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>60</td>
</tr>
<tr>
<td>12pm</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>4pm</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>6pm</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

**Table 1 (continued)**

**CONSM**

<table>
<thead>
<tr>
<th>Time</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>9am</td>
<td>45</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>10am</td>
<td>74</td>
<td>101</td>
<td>101</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>60</td>
</tr>
<tr>
<td>12pm</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>4pm</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>6pm</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

**LINK (Sample Route)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>6am</td>
<td>20</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>9am</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>10am</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>12pm</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>2pm</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>4pm</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>6pm</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 1 (continued)**
Table 2:

Activity-Travel Model:
Listing of Computer Program

C ACTIVITY-TRAVEL MODEL
C WITHOUT ROUTE CHOICE OR MINIMUM PATH SUBROUTINE
COMMON COMOCC(3,2,2), PERCAV(18,2,3,2), TRCOST(18,2,2,3), NOSOCC
1(11,2), FACAV(18,2,3), FACAT(2,5,2), PCOCC(18,5), LU13(18,3), LW31,
2(18,3), LW23(18,3), CRFREE(18,2), PERCEP(2,3), NSTART(2,2),
3RESPOP(2), CAROUN(2), DSTRB(2), T, TP, AG, ACT, DEST, HOME, ZONES, MODE,
4METHOD
REAL TRCOST, FACATT
INTEGER COMOCC, PERCAV, NOSOCC, FACAV, PCOCC, LU13, LW31, LW23, LW32,
1 CONTINUE, PERCEP, NSTART, RESPOP, CAROUN, DSTRB, T, TP, AG, ACT, DEST, HOME,
2 ZONES, MODE, METHOD
CALL DATA
CALL PRELIM

C THE SIMULATION MECHANISM OF THE ACTIVITY DEMAND SUBMODEL
T = 1
TP = 0
DO 111 M = 1,3
DO 111 ACT = 1,2
DO 111 HOME = 1,2
111 COMOCC(M,ACT,HOM) = 0
AG = 3
HOME = 1
102 IF (AG.EQ.3) GO TO 200
IF (NSTART(ACT,HOME).GT.0) GO TO (201,202),ACT
HOME = HOME + 1
AG = AG + 1
IF (AG.LE.5) GO TO 101
T = T + 1
IF (T.EQ.13) GO TO 104
IF (PERCAV(T,ACT,HOME).EQ.1.AND.PERCAV(T+1,ACT,HOME).EQ.1) GO TO 105
104 IF (PERCAV(T,ACT,HOME).EQ.0) GO TO 787
DSTRB(I) = (NSTART(ACT,HOME)*8)/10
DSTRB(2) = NSTART(ACT,HOME) - DSTRB(I)
COMOCC(2,ACT,HOME) = COMOCC(2,ACT,HOME) + DSTRB(2)
COMOCC(3,ACT,HOME) = COMOCC(3,ACT,HOME) + DSTRB(2)
2 CONTINUE
GO TO 100
200 CALL TRAVEL
GO TO 105

C THE CONSUMPTION OF SHOP/SERVICE ACTIVITIES IS CALCULATED
201 CALL (T, EQ.17) GO TO 104
IF (PERCAV(T,ACT,HOME).EQ.1.AND.PERCAV(T+1,ACT,HOME).EQ.1) GO TO 105
104 IF (PERCAV(T,ACT,HOME).EQ.0) GO TO 789
DSTRB(I) = NSTART(ACT,HOME)
DSTRB(2) = 0
GO TO 107
105 DSTRB(I) = (NSTART(ACT,HOME)*9)/10
DSTRB(2) = NSTART(ACT,HOME) - DSTRB(I)
J = COMOCC(2,ACT,HOME) + DSTRB(2)
IF (J.LE.0) GO TO 107
COMOCC(2,ACT,HOME) = COMOCC(2,ACT,HOME) - DSTRB(2)
DSTRB(I) = DSTRB(I) + J
DSTRB(2) = DSTRB(2) - J
GO TO 106
106 CALL TRAVEL
GO TO 105
202 CALL TRAVEL
GO TO 104
999 CALL OUTPUT
GO TO 555
780 K = T + 6
WRITE (6,2000) HOME, K
2000 FORMAT (1X,20H LOCAL SHOPS IN ZONE,I2,10H ARE CLOSED AT TIME,I2)
555 STOP
END

SUBROUTINE DATA
COMMON COMOCC(3,2,2), PERCAV(18,2,3,2), TRCOST(18,2,2,3), NOSOCC
1(11,2), FACAV(18,2,3), FACAT(2,5,2), PCOCC(18,5), LU13(18,3), LW31,
2(18,3), LW23(18,3), LW32(18,3), CRFREE(18,2), PERCEP(2,3), NSTART(2,2),
3RESPOP(2), CAROUN(2), DSTRB(2), T, TP, AG, ACT, DEST, HOME, ZONES, MODE,
Table 2 (cont.)

METHOD REAL TRCOST, FACATT
PERCavin, NOSOCC, FACAV, PCOCC, LU13, LU31, LU23, LU32,
1 CRFREE, PERCEP, NSTART, RESPOP, CAROWN, DSTRB, TP, AG, ACT, DEST, HOME,
2 ZONES, MODE, METHOD
READ (1, 1000) (PCOCC(T, AG), T=1, 18), AG=1, 5,
READ (1, 1000) (LU13(T, METHOD), T=1, 18), METHOD=1, 3,
READ (1, 1000) (LU31(T, METHOD), T=1, 18), METHOD=1, 3,
READ (1, 1000) (LU23(T, METHOD), T=1, 18), METHOD=1, 3,
READ (1, 1000) (LU32(T, METHOD), T=1, 18), METHOD=1, 3,
READ (1, 1000) (((TRCOST(T, HOME, HOME, DEST), T=1, 18), HOME=1, 2),
1000 CONTINUE
END
RETURN
END
SUBROUTINE PRELIM
COMMON COMOCC(3,2,2), PERCAV(18, 2, 3), TRCOST(18, 2, 3), NOSOCC
1 (13, 5), LU13(18, 3), LU31, LuZ3, LU32,
2 CRFREE(18, 2), PERCEP(18, 5), NSTART(2, 2),
3 RESPOP(2), CAROWN(2), DSTRB(2), TP, AG, ACT, DEST, HOME,
4 ZONES, MODE, METHOD
C THE PATTERN OF ACTIVITY DEMAND FOR EACH HOME ZONE IS CALCULATED
DO 1 T = 1, 18
DO 2 HOME = 1, 2
N = 0
DO 3 AG = 1, 4
NOSOCC(T, AG, HOME) = (PCOCC(T, AG) * RESPOP(HOME)) / 100
N = N + NOSOCC(T, AG, HOME)
CONTINUE
C CAR AVAILABILITY FOR NON-WORK JOURNEYS IS CALCULATED
C TRAVEL(1, HOME, HOME) = CRFREE(T, HOME)
C PERCEIVED AVAILABILITY OF FACILITIES IS CALCULATED
DO 10 T = 1, 18
DO 7 ACT = 1, 2
DO 3 DEST = 1, 3
DO 5 HOME = 1, 2
PERCEP(T, ACT, DEST, HOME) = FACAV(T, ACT, DEST) + PERCEP(HOME, DEST)
CONTINUE
END
SUBROUTINE TRAVEL
COMMON COMOCC, PERCAV, NOSOCC, FACAV, PCOCC, LU13, LU31, LUT3, LU32,
CRFREE, PERCEP, NSTART, RESPOP, CAROWN, DSTRB, TP, AG, ACT, DEST, HOME,
ZONES, MODE, METHOD
C THE PATTERN OF ACTIVITY DEMAND FOR EACH HOME ZONE IS CALCULATED
DO 1 T = 1, 18
DO 2 HOME = 1, 2
N = 0
DO 3 AG = 1, 4
NOSOCC(T, AG, HOME) = (PCOCC(T, AG) * RESPOP(HOME)) / 100
N = N + NOSOCC(T, AG, HOME)
CONTINUE
C CAR AVAILABILITY FOR NON-WORK JOURNEYS IS CALCULATED
C TRAVEL(T, HOME, HOME) = CRFREE(T, HOME)
C PERCEIVED AVAILABILITY OF FACILITIES IS CALCULATED
DO 10 T = 1, 18
DO 7 ACT = 1, 2
DO 3 DEST = 1, 3
DO 5 HOME = 1, 2
PERCEP(T, ACT, DEST, HOME) = FACAV(T, ACT, DEST) + PERCEP(HOME, DEST)
CONTINUE
END
Table 2 (cont.)

<table>
<thead>
<tr>
<th>Zones</th>
<th>Mode</th>
<th>Method</th>
<th>Consmp</th>
<th>Ls13</th>
<th>Ls31</th>
<th>Ls23</th>
<th>Ls21</th>
<th>Lr13</th>
<th>Lr31</th>
<th>Lr23</th>
<th>Lr21</th>
<th>Lhome</th>
<th>Lnhome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C Leisure Choices are Computed
C Net attraction values are calculated
3 DO 10 DEST = 1,3
   NETATB(DEST) = 0
   NETATC(DEST) = 0
   PRACTB(DEST) = 0
   IF (PERCAV(T,2,DEST,HOM) .LT. 0.0 .OR. PERCAV(T+1,2,DEST,HOM) .LT. 0.0) GO TO 10
   IF (NETATB(DEST) .LT. 0.0) GO TO 10
10 IF (NETATB(DEST) .LT. 0.0) GO TO 11
   NET = NETATB(DEST) + NETATC(DEST)
   PRACTB(DEST) = NET
   IF (NETATB(DEST) .EQ. 0.0) PRACTB(DEST) = 0.0
   GO TO 12
11 IF (NETATC(DEST) .LT. 0.0) GO TO 11
   NET = NETATB(DEST) + NETATC(DEST)
   PRACTC(DEST) = NET
   IF (NETATC(DEST) .EQ. 0.0) PRACTC(DEST) = 0.0
   GO TO 12
12 IF (NETATB(DEST) .LT. 0.0) GO TO 12
   NET = NETATB(DEST) + NETATC(DEST)
   PRACTB(DEST) = NET
   IF (NETATB(DEST) .EQ. 0.0) PRACTB(DEST) = 0.0
   GO TO 13
13 IF (NETATC(DEST) .LT. 0.0) GO TO 13
   NET = NETATB(DEST) + NETATC(DEST)
   PRACTC(DEST) = NET
   IF (NETATC(DEST) .EQ. 0.0) PRACTC(DEST) = 0.0
   GO TO 14
14 CONTINUE

C Numbers calculating each course of action are calculated
1 LL = NOSOCCT(1,1,HOM) + NOSOCCT(1,2,HOM) + NOSOCCT(1,3,HOM)
   COHOMCT(1,1,HOM)
Table 2 (cont.)

\[
\begin{align*}
XX &= LL \\
YY &= NSTART(2, HOME) \\
ZZ &= CRFREE(T, HOME) \\
\text{IF} (T.EQ.18) \text{ GO TO 51} \\
\text{IF} (\text{CRFREE}(T+1, HOME) .LE. CRFREE(T, HOME)) \quad ZZ = \text{CRFREE}(T+1, HOME) \\
51 \quad P &= YY + ZZ/XX \\
\text{NCARAV} &= \text{ROUND}(P) \\
N &= 0 \\
M &= 0 \\
\text{DO 15} \quad \text{DEST} = 1,3 \\
\text{NOSP}(\text{DEST}) &= 0 \\
\text{IF} (\text{PRACTC}(\text{DEST}), \text{EQ}, 0) \text{ GO TO 15} \\
U &= \text{NCARAV} \cdot \text{PRACT}(\text{DEST}) \\
\text{NOSC}(\text{DEST}) &= \text{ROUND}(U) \\
W &= \text{NOSC}(\text{DEST}) \cdot \text{PRCR}(\text{DEST}) \\
\text{JJ} &= \text{ROUND}(W) \\
\text{WW} &= JJ \cdot 0.8 \\
\text{NOSP}(\text{DEST}) &= \text{ROUND}(\text{WW}) \\
N &= N + \text{NOSC}(\text{DEST}) \\
M &= M + \text{NOSP}(\text{DEST}) \\
15 \quad \text{CONTINUE} \\
\text{NBSNY} &= \text{NSTART}(2, HOME) - \text{NCARAV} \\
NN &= 0 \\
\text{DO 16} \quad \text{DEST} = 1,3 \\
\text{NOSB}(\text{DEST}) &= 0 \\
\text{IF} (\text{PRACTB}(\text{DEST}), \text{EQ}, 0) \text{ GO TO 16} \\
E &= \text{NBSNY} \cdot \text{PRACTB}(\text{DEST}) \\
\text{NOSB}(\text{DEST}) &= \text{ROUND}(E) \\
N &= N + \text{NOSB}(\text{DEST}) \\
16 \quad \text{CONTINUE} \\
\text{TOTALS} \text{ ARE CHECKED AND ADJUSTED FOR T+1 DEMAND CONSTRAINT} \\
\text{IF} (T.EQ.18) \quad \text{IJ} &= 0 - (N + M + NN) \\
\text{IF} (T.EQ.18) \text{ GO TO 19} \\
\text{IJ} &= \text{NOSOCC}(T+1, AG, HOME) - (N + M + NN) \\
19 \quad \text{IF} (\text{IJ} \cdot GE \cdot 0) \text{ GO TO 20} \\
X &= \text{NOSOCC}(T+1, AG, HOME) \\
Y &= N + M + NN \\
G &= X/Y \\
N &= 0 \\
\text{DO 17} \quad \text{DEST} = 1,3 \\
Q &= \text{NOSC}(\text{DEST}) \cdot G \\
\text{NOSC}(\text{DEST}) &= \text{ROUND}(Q) \\
R &= \text{NOSP}(\text{DEST}) \cdot G \\
\text{NOSP}(\text{DEST}) &= \text{ROUND}(R) \\
N &= N + \text{NOSC}(\text{DEST}) \\
\text{IF} (\text{DEST}, \text{EQ}, 3) \text{ NOSOCC(DEST)} &= \text{NOSOCC}(T+1, AG, HOME) = N \\
\text{IF} (\text{DEST}, \text{EQ}, 3) \text{ GO TO 17} \\
C &= \text{NOSB}(\text{DEST}) \cdot G \\
\text{NOSB}(\text{DEST}) &= \text{ROUND}(C) \\
N &= N + \text{NOSB}(\text{DEST}) \\
17 \quad \text{CONTINUE} \\
\text{C OUTPUT VALUES ARE COMPUTED} \\
KK &= N \\
\text{DO 18} \quad \text{DEST} = 1,3 \\
K &= \text{NOSC}(\text{DEST}) + \text{NOSP}(\text{DEST}) + \text{NOSB}(\text{DEST}) \\
\text{CONSMP}(T, 3, DEST) &= \text{CONSMP}(T, 3, DEST) + K \\
\text{IF} (T.EQ.18) \text{ GO TO 18} \\
\text{CONSMP}(T+1, 3, DEST) &= \text{CONSMP}(T+1, 3, DEST) + K \\
18 \quad KK &= KK + K \\
\text{CONSMP}(2, AG, HOME) &= KK \\
A &= \text{NOSC}(3) \cdot \text{PRCR}(3) \\
\text{IF} (\text{HOME}, \text{EQ}, 2) \text{ GO TO 77} \\
\text{LR13}(T, 1) &= \text{ROUND}(A) \\
\text{LR13}(T, 2) &= \text{NOSP}(3) \\
\text{LR13}(T, 3) &= \text{NOSB}(3) + (\text{NOSC}(3) - \text{LR13}(T, 1)) \\
\text{IJ} &= \text{LR13}(T, 1) \\
\text{IF} (T.EQ.18) \text{ GO TO 21} \\
\text{LR31}(T+1, 1) &= \text{LR13}(T, 1) \\
\text{LR31}(T+1, 2) &= \text{LR13}(T, 2) \\
\text{LR31}(T+1, 3) &= \text{LR13}(T, 3) \\
B &= \text{NOSC}(2) \cdot \text{PRCR}(2) \\
\text{LR21}(T, 1) &= \text{LR13}(T, 1) + \text{ROUND}(B) \\
\text{LR21}(T, 2) &= \text{LR13}(T, 2) + \text{NOSP}(2) \\
\text{LR21}(T, 3) &= \text{LR13}(T, 3) + \text{NOSB}(2) + (\text{NOSC}(2) - \text{ROUND}(B)) \\
\text{LR21}(T+1, 1) &= \text{LR21}(T, 1) + \text{ROUND}(B) \\
\text{LR21}(T+1, 2) &= \text{LR21}(T, 2) + \text{NOSP}(2) \\
\text{LR21}(T+1, 3) &= \text{LR21}(T, 3) + \text{NOSB}(2) + (\text{NOSC}(2) - \text{ROUND}(B)) \\
\text{GO TO 22} \\
\text{LR23}(T, 1) &= \text{ROUND}(A) \\
\text{LR23}(T, 2) &= \text{NOSP}(3) \\
\text{LR23}(T, 3) &= \text{NOSB}(3) + (\text{NOSC}(3) - \text{LR23}(T, 1)) \\
\text{IJ} &= \text{LR23}(T, 1) \\
\text{IF} (T.EQ.18) \text{ GO TO 21} \\
\text{LR32}(T+1, 1) &= \text{LR23}(T, 1)
-439-

Table 2

(cont.)

LR32(T+1,2) a LR23(T,2)
LR32(T+1,3) 3 lr23(T, 3)
B a N0SC(1)*PRCR(1 )
L R 2 K T , 1 ) a LR21<T,1) + ROUND (B)
LR21(T,2) « LR21 (7,2) + N O S P d )
L R 2 K T f 3 ) 3 L R 2 K T , 3 ) + N O S B d ) • ( N O S C d >-R0lJND<B> >
LR12(T+1,1) 3 LR12<T+1»1)
+ ROUND(B)
LR12(T+1,2) s lR1 2 (T + 1 12) + N O S P d )
LR12(T+1,3) a |_R1 2 (T+1 , 3) + N O S B d ) + ( NOS C (1 )-ROUN D (B ) )
CRFREE<T+1,HOME>
A CRFREE<T+I.HOME)
- JJ
LHAME(T,HOME)
a NSTART(2.HOME)
- KK
LNHOME(T.HOflE) a C O L L O C C D ,2, HOME) + C O M O C C ( 2 ,
CRFREE(T.HOME)
A CRFREE(T.HOME)
- JJ
RETURN
END
SUBROUTINE
OUTPUT

2, H O M E )

COMMON COMOCC(3,2,2)»PERCAV(18,2,3,2),TRCOST(18,2,2, 3) .NOSOCC
1 (13,5.2),FACAv(1o,2/3),FACATT(2,5,2),PCOCC(18,5),LW13(18,3),LW31
2(13,3), LW23(13,3)iLU32d8,3) , CRFREE (1 8, 2) ,PER CEP(2,3) ,NSTART(2,2) ,
3RESPOP(2),CAROWN(2),DSrRB(2),T,TP,AG,ACT,DEST,HOME,ZONES,MODE,
4METH0D
COMMON / ZERO / CONSMp, LS1 3d3.3),LS31 (1 8.3) , LS 23 (1 8 3) , LS32 (1 8,3),
1LS12(13,3),LS21 (13,3) ,I.R13(18,3) ,LR31 (1 8, 3), LR23 (1 8, 3) , LR32 (1 8, 3) ,
2IR12(13,3),LR21(18,3),LHOME(18,2),LNHOME(18,2)
REAL
TRCOST,FACATT
INTEGER COMOCC,PERCAV,NOSOCC,FACAV,PCOCC,LW13,LVJ31,L«23,LW32,
1 CRFREE,PERCEP,NSTART,RESPOP,CAROWN,DSTRB,T,TP,AG,ACT,DEST,HOME,
ZONES,MODE,METHOD,
CONSMP(18,3,3),LS13,LS31,LS23,L3 32,LS1 2,LS21 » LR13,LR31 ,
LR23,LR32.LR12,UR21,LHOME,LNHOME
WRITE (2,2002)
s
WRITE (2,2003) (((NOSOCC(T,AG,HOME),Ta1,18),AGa1,5),HOME 1,2)
WRITE (2,2002)
URITE (2,2003) ((LHOME(T,HOME),T=1,18),HOM£a1,2)
WRITE (2,2002)
WRITE (2,2003)
. . . ((LNHOME(T,HOME),Ta1,18),HOMEa1,2)
WRITE (2,2002)
WRITE (2,2003) ((CRFREE(T,HOME),Ta1,18),HOMEsI,2)
WRITE (2, 2002)
WRITE (2,2004) ((((PERCAV(T,ACT,DEST,HOME),Ta1,18),DESTs1,3),
ACTal,2),HOMEa1,2)
URITE (2,2002)
WRITE (2,2003) (((CONSMP(T,N,DEST),Ta1,18),Ns1,3),DESTa1,3)
WRITE (2,2002)
WRITE (2,2003) ((LIJ13(T,METHOD) ,Ta1 ,18) METHODal,3)
WRITE (2,2003) ((LW31(T,METHOD),Ta1,18) METHODa1,3)
WRITE (2,2002)
WRITE (2,2003) (( L'J23(T,METHOD) ,T=1 ,1 8) METHODal,3)
URITE (2,2003) ((LU32(T,METHOD),Ta1,18) METHODal,3)
URITE (2,2002)
WRITE (2,2003) ((LS13(T,METHOD),Ta1,18) METHODal,3)
URITE (2,2003) ((LS31(T,METHOD),T=1,18) METHODal,3)
URITE (2,2002)
URITE (2,2003)
"
((LS23(T,METHOD),T=1,18) METHGDsl,3)
WRITE (2,
_.2003) ((LS52(T,METHOD),T=1,18) METHODal,3)
URITE (2,2002)
URITE (2,2003) ((LR13(T,METHOD),T=1,18) METHODal,3)
URITE (2,2003) ((LR31(T,METHOD),T=1,18) METHODal,3)
WRITE (2,2002)
URITE (2,2003) ((LR23(T,METHOD),T=1,18) METHODal,3)
WRITE (2,2003) ((LR32(T,METHOD),T=1,18) METHODal,3)
WRITE (2,2002)
WRITE (2,2003) ((LR12(T,METHOD),Ts1,18) METHODsl,3)
URITE (2,2003) ((LR21(T,METHOD),Ta1,18) METHODal,3)
WRITE (2,2002)
2002 FORMAT(1 HO)
2003 FORMAT(3X,1816)
2004 FORMAT (1 OX,1811,5x,1811,5X,1811)
RETURN
END
FUNCTION ROUNDCX)
I a X
Y a X-I
IF (Y.GT.0.499)
I a 1+1
ROUND s J
RETURN

END
BLOCK DATA
COMMON /ZER0/C0NSMP,LS13,LS31.LS23,LS32,LS12,LS21,LR13,LR31,
1LR23,LR32.LR12,LR21,LHOME,LNHOME
INTEGER CONSMP(18,3,3)/162+0/,LS13(18,3)/54+0/,LS31(18,3)/54+0/,
1 LS23(13,3)/54*0/» LS32(18,3)/54 + 0/,LS12(18,3)/54-0/,LS21(13,3)/54+0
2/,LRl3(18,3)/54+0/,LR31(13,3)/54*0/,LR23(18,3)/54+0/.LR32(18,3)
3/54*0/,LR12(13,3)/54+0/,LR21(18,3)/54+0/,LHOME(18,2)/30*0/,
4LNH0MEC13,2)/36+0/
END
FINISH


BIBLIOGRAPHY


