URBAN FORM AND ACTIVITY-TRAVEL PATTERNS
AN ACTIVITY-BASED APPROACH TO TRAVEL IN A SPATIAL CONTEXT

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de Rector Magnificus, prof.dr. R.A. van Santen, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen op 23 januari 2002 om 16.00 uur

door

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geboren te Weert
Urban planning and design, to me, are fascinating fields of work. They are present anytime and anywhere, they shape the world we live in and offer us a land of opportunities (and some constraints). They combine both functional and aesthetical considerations and, given the expected life span of the product, always require a sustainable approach. The aesthetics of urban design I like to experience in my leisure time. I can really enjoy walking through a beautiful old city, a new residential development, a spacious square, or a compact mixed use centre full of people. My professional focus in urban planning, however, is more on the functional side. How do people cope with their spatial environment? How does it influence people's options and choices? Through the years, the way people travel in a spatial context has become the main subject of my interest. In 1995, this interest resulted in the start of a PhD project.

Doing a PhD is a job that takes you through ups and downs, through periods of confidence and times of doubt, wondering whether you will ever finish. In the last six years, many people have stood by me and every single one of them has contributed in some way or another to the result you see before you.

First of all I would like to thank Harry Timmermans for giving me the opportunity to develop my own research proposal. I very much appreciate the confidence he placed in me, the freedom I was given to develop the project and the support he gave me through the years. Without his encouragement and advice, there would be no thesis for which to write a preface. I am also very grateful to my second advisor Kay Axhausen. His careful and accurate review of the manuscript resulted in insightful and useful comments that have enhanced the quality of my work. His contribution is greatly appreciated. Furthermore, I would like to express my gratitude to Aloys Borgers. From the very beginning he has been an important support. He was always there to answer my questions, to discuss problems and to help me in choosing directions during the process. He has made valuable contributions to my work.

The urban planning group has provided a wonderful environment for doing my PhD. They offered both social, psychological and scientific support. The amicable atmosphere,
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Daniëlle Snellen
November 2001
TABLE OF CONTENTS

PREFACE .................................................................................................................. i

TABLE OF CONTENTS ......................................................................................... iii

LIST OF TABLES ..................................................................................................... vii

LIST OF FIGURES .................................................................................................... ix

1 | INTRODUCTION ................................................................................................. 1
  1.1 Background ........................................................................................................ 1
  1.2 Aims, Objectives and Basic Approach ............................................................. 2
  1.3 Organisation of the Thesis .................................................................................. 3

2 | DUTCH POLICY BACKGROUND ....................................................................... 5
  2.1 Introduction ........................................................................................................ 5
  2.2 The Mobility Issue ............................................................................................. 5
  2.3 National Spatial Mobility Policy ...................................................................... 8
     2.3.1 Mobility Policies from a Spatial Planning Perspective 1960-1990 .......... 8
     2.3.2 Spatial Policies from a Transportation Planning Perspective 1979-1995 .... 11
  2.3.3 Developments in Dutch Spatial Mobility Policy ....................................... 15
  2.4 Spatial Policy and Mobility on the Local Scale .............................................. 17
     2.4.1 Elaboration of the Second Transport Structure Scheme for the City Level .................................................................................................................. 17
     2.4.2 Instrument for Measuring Local Traffic Performance ......................... 19
  2.5 Conclusions ....................................................................................................... 19
| 5.5 | Independent Variables ......................................................... 76 |
| 5.5.1 | Variables Describing the Spatial Context .................................. 76 |
| 5.5.2 | Socioeconomic Variables ..................................................... 82 |
| 5.6 | Summary and Conclusions ....................................................... 83 |
| 6 | TRAVEL FOR FREQUENT ACTIVITIES ........................................ 84 |
| 6.1 | Introduction ............................................................................. 84 |
| 6.2 | General Description of the Data ............................................... 85 |
| 6.2.1 | Trips for Grocery Shopping ....................................................... 86 |
| 6.2.2 | Trips for Non-Grocery Shopping ................................................. 87 |
| 6.2.3 | Trips for Recurring Leisure Activities ...................................... 88 |
| 6.2.4 | Home-to-Work Trips .................................................................. 89 |
| 6.3 | The Multilevel Model: Model Estimation and Testing .................. 90 |
| 6.4 | Multilevel Models of Trip Characteristics .................................. 92 |
| 6.4.1 | Model Performance ................................................................. 94 |
| 6.4.2 | Discussion of the Results of the Multilevel Analyses .................. 97 |
| 6.5 | Summary and Conclusions ....................................................... 105 |
| 7 | ACTIVITY-TRAVEL PATTERNS .................................................. 110 |
| 7.1 | Introduction ............................................................................. 110 |
| 7.2 | Characteristics of Activity-Travel Patterns ............................... 111 |
| 7.3 | General Description of Activity Pattern Indicators ..................... 113 |
| 7.4 | Multilevel Models of Activity-Travel Diary Data ......................... 116 |
| 7.4.1 | Model Estimation and Performance ............................................ 117 |
| 7.4.2 | Results of Multilevel Models .................................................... 118 |
| 7.5 | Summary and Conclusions ....................................................... 122 |
| 8 | CONCLUSIONS AND DISCUSSION ............................................. 128 |
| 8.1 | Introduction ............................................................................. 128 |
| 8.2 | Short Summary of the Study ....................................................... 129 |
| 8.3 | Discussion of the Study ............................................................ 131 |
| 8.4 | Recommendations for Planning and Policy .................................. 132 |
| REFERENCES ............................................................................. 134 |
LIST OF TABLES

table 2.1 linking A, B and C locations to mobility profiles ................. 11

table 5.1 matrix for location choice ........................................... 58

table 5.2 neighbourhoods chosen for data collection ...................... 59

table 5.3 associations between neighbourhood characteristics .......... 61

table 5.4 list of pre-coded activities ........................................... 63

table 5.5 response rates by city of those willing to participate after initial contact .................................................. 65


table 5.6 probit estimates of city characteristics ........................... 65

table 5.7 response rates by neighbourhood of those willing to participate after initial contact ........................................... 66

table 5.8 probit estimates of neighbourhood characteristics ................ 66

table 5.9 associations between neighbourhood characteristics and socioeconomic characteristics ...................................... 68


table 5.10 percentage inconsistencies in activity diaries by city .......... 69

table 5.11a inconsistencies in activity diaries by neighbourhood ........ 70

table 5.11b inconsistencies in activity diaries by neighbourhood (continued) .................................................. 71


table 5.12 regression of errors by city ......................................... 72

table 5.13 regression of errors by socioeconomic indicators city ........ 72

table 5.14 regression of errors by neighbourhoods .......................... 73

table 5.15 regression of errors by socioeconomic indicators neighbourhood .... 74

table 5.16 multi level analysis of diary inconsistencies ..................... 75


table 6.1 model performance ....................................................... 95

table 6.2 significant effects of the independent variables on the number of kilometres travelled for grocery shopping ......................... 98


table 6.3 significant effects of the independent variables on the number of trips for grocery shopping ........................................... 99


table 6.4 significant effects of the independent variables on the number of kilometres travelled for non-grocery shopping ....................... 100
table 6.5  significant effects of the independent variables on the number of trips for non-grocery shopping ........................................... 102

table 6.6  significant effects of the independent variables on the number of kilometres travelled for recurring leisure ........................................ 103

table 6.7  significant effects of the independent variables on the number of trips for recurring leisure ............................................... 103

table 6.8  significant effects of the independent variables on the number of home-to-work kilometres ................................................ 104

table 6.9  significant effects of the independent variables on the number of home-to-work trips .................................................... 104

table 6.10 summary of results ......................................... 107

table 7.1  model performance ............................................ 117

table 7.2  significant effects of the independent variables on the total number of trips and tours and the trip/tour ratio ........................................ 118

table 7.3  significant effects of the independent variables on the number of trips and tours and the trip/tour ratio on weekdays .............. 119

table 7.4  significant effects of the independent variables on the total travel time and distance ................................................... 120

table 7.5  significant parameters travel time and distance on weekdays .................................... 122

table 7.6  summary of results ......................................... 126
LIST OF FIGURES

figure 2.1  distance travelled per person per day ......................... 6
figure 2.2  person kilometres travelled .................................. 7
figure 2.3  strategies and themes Second Transport Structure Scheme .......... 12
figure 2.4  desired urban form principles ................................. 13

figure 4.1  conceptual framework ........................................... 44
figure 5.1  urban shapes .......................................................... 55
figure 5.2  elementary transportation networks ............................. 57
figure 5.3  example of activity recording form .............................. 62
figure 5.4  urban shapes ......................................................... 78
figure 5.5  transportation networks city .................................... 78
figure 5.6  transportation networks neighbourhood ........................ 79
figure 5.7  local street network types ........................................ 79
figure 5.8  location of the Randstad Holland ............................... 79

figure 7.1  activity patterns by time of day ................................. 112
figure 7.2  tour distances ....................................................... 113
figure 7.3  transport mode or mode chain for tour ........................ 113
1 | INTRODUCTION

1.1 Background

In the last decade, national and local governments in the Netherlands have started the implementation of the so-called VINEX-policy to accommodate the expected housing needs in the decades ahead. As a result of this policy, vast building sites are being developed. The planning and design of these areas involve far-reaching decisions with respect to the spatial structure of the new neighbourhoods and districts and their position in the existing built environment. The design of the areas is supposed to meet national goals regarding sustainability and a reduction of car use. However, it is not always clear whether the new areas indeed do meet these policy goals, formulated by the Dutch government. That is, there is a lack of empirical knowledge whether particular urban form decisions have the impact they are expected to have.

In the Fourth Report on Spatial Planning Extra (also known as the VINEX-report), the government expressed a growing concern about the environmental and economic consequences of the growth in car mobility. The report aimed at improving local living conditions and reducing car mobility in cities and urban regions. The concept of the compact city was introduced as the main line of policy to achieve these goals. A mutual proximity of urban functions such as housing, jobs and services was prioritised over accessibility in pursuit of a more sustainable environment and a reduction of the growth of car mobility.

The concept of the compact city is augmented by a detailed location policy for businesses and institutions. The main goal of these policies is to locate new residential areas, new centres of employment and new facilities within the existing urban area and in close proximity to the public transport system to stimulate the use of public transport, thereby reducing car use. In addition, mixed land use is stimulated. Most of the suggested policies apply to the level of the city or city region. Very few policy measures have been
suggested at the city district or neighbourhood level. The relevant policy documents emanating from the national government include only a few guidelines about instruments and concepts that can be used at the lower scale levels to reduce the growth in car mobility. Despite this lack of attention for the lower scale levels in the official policy documents, urban form characteristics at the level of the neighbourhood and the city district may be expected to influence mobility. Many municipalities realise this and, inspired by higher level policies, include measures for mobility growth reduction and mobility management in their standard local spatial plans, and more recently, in local transport plans. Often these measures are translations of higher level measures, such as higher densities, mixing of functions on the level of the city district or neighbourhood and the provision of ‘good’ facilities for cycling and public transport. More specific urban form characteristics, such as urban shapes and transportation network types at different scale levels are, in general, not part of spatial policies and plans as measures to influence mobility. The attempts made by local governments to develop their own local spatial mobility policy are laudable. It would, however, be better if more systematic and underpinned information was available on the relationship between urban form and mobility on this level. Recently, this necessity was recognised by the Council for Housing, Spatial Planning and the Environment (HSPE-council - VROM raad). In an advise to the Minister of Housing, Spatial Planning and the Environment (HSPE), published in 1999 [HSPE-council, 1999], they identified the potential positive effects of measures on the lower scale levels and proposed a shift of focus towards planning and design and a more area-specific approach.

1.2 Aims, Objectives and Basic Approach

This thesis is motivated by the professional belief that planning and design decisions regarding lower scale levels may potentially contribute to a reduction of car mobility. In the literature and in practice, it is a commonly held belief that different urban shapes and transportation networks will induce different activity-travel patterns. Dutch spatial mobility policies and plans, especially formulated at the level of the neighbourhood, city district and city, are either explicitly or implicitly based on a number of largely untested assumptions. Although a vast amount of literature on the relationship between urban form and travel patterns has been published in the last decade, there are several reasons why their relevance is limited. First, most studies are from a non-Dutch or even non-European origin, raising the issue of spatial transferability of research findings. Given
the differences between the Netherlands and other, especially non-European, countries in size, the spatial and cultural organisation of cities, and the relative absence of the bicycle in many other countries, further empirical investigation whether the results obtained in non-Dutch countries can be generalised to the Netherlands is required. Secondly, the existing studies show some serious potential methodological flaws. As Kitamura et al [1997] have argued “Is the observed association between travel and land use real, or is it an artifact of the association between land use and the multitude of demographic, socioeconomic, and transportation supply characteristics, which also are associated with travel?*

The aim of this thesis is therefore to empirically test the implicit or explicit car mobility reduction claims, underlying current Dutch mobility and land use policies. In particular, the objective is to examine whether a relationship between urban form and travel patterns exists in the Netherlands, and to explore the nature and strength of this relationship. The focus in this study will be on the neighbourhood/city district and the city. The urban form characteristics examined in this study include the morphology (urban shape) and transportation network types of the city and the neighbourhood, the relative location of neighbourhoods, the availability of facilities, and the density of the city and neighbourhoods.

In line with recent conceptualisations in transportation research, travel and mobility patterns are viewed in the context of activity-travel patterns (see e.g., Ettema and Timmermans, 1997). Travel demand is derived from the activities that individuals and households need or wish to conduct. The urban environment offers opportunities to pursue these activities, but at the same time may constrain the conduct of activities. Hence, to better understand the complex and possibly indirect nature between urban form characteristics and activity-travel patterns, an activity-based approach was followed as it better allows disentangling the impact of various factors, including urban form, on mobility patterns.

1.3 Organisation of the Thesis

This thesis describes the results of an extensive study into the relationship between urban form characteristics of neighbourhoods and cities and activity-travel patterns in a Dutch context. The activity-based approach was adopted for this study. The design of
the study and its results are reported in 8 chapters. The next two chapters deal with current planning practice and existing knowledge concerning the relationship between urban form and activity-travel patterns. Chapter 2 discusses past, present and future spatial mobility policies in the Netherlands and derives the principles underlying these policies. Chapter 3 outlines the literature on the relationship between urban form and activity-travel patterns and derives potentially influential urban form characteristics. Chapter 4 presents the research design of this project. It elaborates the activity-based approach and discusses the conceptual framework underlying the study. Chapter 5 presents the operational decisions, underlying the data collection and the selection of explanatory variables. This is followed by a discussion of the process of data collection in more detail. The choice of cities and neighbourhoods, the design of the questionnaire that was administered, and the response that followed will be discussed. Furthermore, the explanatory variables selected to operationalise the concept of urban form will be outlined. The data include both characteristics of frequently made trips for specific purposes (work, shopping, etcetera) and a full two day activity-travel diary. Chapters 6 and 7 present the results of the data analysis. Chapter 6 deals with the analyses of a number of frequently made trips, while chapter 7 discusses the results of analyses of travel data from complete activity-travel diaries. Finally, in chapter 8, the major findings of this thesis will be summarised and discussed.
2 | DUTCH POLICY BACKGROUND

2.1 Introduction

As indicated in the previous chapter, Dutch physical and transportation planning practice is characterised by a plethora of concepts, rules, regulations and instruments aimed at reducing the growth in car mobility. These instruments differ in terms of detail, actor, scale, and nature. In order to position the current study, this chapter discusses its policy background. In particular, it provides an overview of the various relevant policies. First, the mobility issue is discussed. This is followed by a summary of the various spatial and transportation planning policies at the national, regional and local levels of administration.

2.2 The Mobility Issue

The ability to move around is a key asset of our modern society. It enables individuals to participate in activities, to earn a living, to supply their basic needs, to relax and recreate, and to develop and maintain social bonds. It is also crucial for economic development, exchange of knowledge, experience and culture. We cannot survive without travel and transport in this day and age. But there are also significant negative effects of mobility that manifest themselves on different scales [HSPE-council, 1999]. On the international scale, reduced environmental quality and related issues such as global warming and acidification caused by emissions of CO$_2$, NO, and SO$_x$ are causes for concern. The contribution of the transport sector to the emission of these substances depends on the total number of kilometres travelled by motorised modes, while the location where these emissions take place is not important at this scale level. On a lower scale, an increase in mobility results in an increasing threat to the quality of life. It also reduces accessibility, defined as the ease of reaching a particular destination. Local living conditions suffer increasingly from effects such as unsafety, noise, local pollution from...
harmful emissions, traffic jams, space claims for transport, visual pollution, etcetera. Likewise, increasing traffic jams in and around cities reduce accessibility. Many of the transport and spatial planning policies aim at reducing these negative effects of travel and mobility. These policies will be discussed in the sections below. First, however, the scope of the problem will be explored.

The traffic volume depends on three factors: the number of people that wish to travel, the number of trips per person and the distance travelled per trip [AVV, 1997]. In the latter half of the 20th century, all three factors increased. The number of people that are potential travellers increased by 58% between 1950 and 2000 from a little over 10 million to almost 16 million. The number of trips per person grew from 3.58 in 1986 to 3.69 in 1996 [CBS, 1997]. The distance per trip also increased. Consequently, the number of kilometres travelled per person per day increased by 11% from 34.2 in 1986 to 38.1 in 1996 [CBS, 2000]. This increase can be attributed totally to motorised and public transport, while the use of non-motorised transport has remained approximately constant (figure 2.1). The combination of an increasing population and an increasing

![Figure 2.1: Distance travelled per person per day (CBS Statline, 2000)](image-url)
distance travelled per person per day, has resulted in a higher total number of person kilometres travelled (30%). Figure 2.2 portrays this increase in person kilometres travelled in the Netherlands between 1986 and 1996.

The effects described above are the result of a number of sociodemographic and socioeconomic factors that will also influence the development of mobility in the decades to come. First and foremost, the increase is the result of population growth. This growth is largely due to the postwar baby boom generation (born between 1945 and 1965), which does not only constitute a large group but is also a group in which car and driver’s license possession is high among both men and women. Members of this group, who are the elderly people of the future, are highly mobile. Immigration, which remains high, has been a second major contributing factor to the population growth in the Netherlands. However, on average, immigrants have a lower mobility than the autochthonous Dutch population. Apart from this population growth, several socioeconomic factors have contributed to the increase in mobility. The growing economy, accompanied by a 35% increase in household incomes and car ownership between 1983 and 1998 [CBS, 2000], is an important factor. Furthermore, the country
has seen a, still ongoing, increase in participation of women in the workforce and a strong increase in the number of households (stronger than the population growth).

For the future, a growth of mobility is expected, although not as strong as in the previous decades. Whereas the 1983-1997 period showed an increase in person kilometres travelled of 30% [CBS, 2000], a growth of 14-30% is now expected until 2030 [HSPE-council, 1999]. This growth will mainly be the result of an increase in the number of households and the rise of (second) car ownership. Car ownership per individual is expected to grow by 29-46% (to 470-530 cars per 1000 inhabitants) until 2020 [HSPE council, 1999].

This growth of (motorised) mobility in the past decades, the modal shift that can be witnessed and the expectations for the future have induced several governmental bodies to develop mobility reduction policies. Many of these policies involve spatial initiatives and plans. In the following two sections, these spatial mobility policies both at the national and the regional/local level, will discussed.

2.3 National Spatial Mobility Policy

Through the years of spatial planning in the Netherlands, transportation and mobility issues have played an important role. Vice versa, spatial issues have always played a role in transportation policy. The relevant policy documents on spatial and transportation planning are summarised and discussed in this section. More specifically, first the planning instruments that apply to the national and regional levels will be discussed. Next, general guidelines for local level planning that can be derived from the relevant policy documents will be identified.

2.3.1 Mobility Policies from a Spatial Planning Perspective 1960-1990

To better understand current mobility policies from the perspective of spatial planning, one should start with the Third Report on Spatial Planning (Derde Nota Ruimtelijke Ordening), which was published by the Ministry of Housing and Spatial Planning in three parts over a period of 6 years in the 1970’s. Under the influence of the report of the Club of Rome (The Limits to Growth) and the oil crisis of the early seventies, the reduction of mobility was identified as one of the goals of spatial policy:
“As yet, a limitation of the growth of the number of person kilometres, balanced to place, time and mode, appears to be the best choice. In particular, the ‘environmental friendly’ transport modes such as walking and cycling and, to some extent, public transport, need to be promoted. Limitation should chiefly be imposed on motorised transport.”

[Ministry of HSP, 1973]

The spatial mobility policy in the Third Report was based on four key elements: (1) location of new developments in existing urban regions, (2) good public transport connections for new developments, (3) mixed housing, employment and services on the scale of the urban region and (4) location of employment in the immediate proximity of railway stations. These key elements were to result in shorter travel distances, and an increase in the use of public transport and non-motorised transport modes like the bicycle. The label ‘compact city’ was chosen to communicate this line of reasoning.

In 1985, the Structure Sketch for Urban Areas (Structuurschets voor de Stedelijke Gebieden) [Ministry of HSPE, 1985] was published, translating the general national spatial policy into more specific plans and policies for the coming decade. The essence of the spatial mobility policy, however, had not changed, as illustrated by the following quote:

“The mobility growth within the urban regions is to be reduced and, in order to reduce the hindrance of mobility, the transport modes are to be influenced by:

- location of new developments within bicycle range of the urban centre and, if not possible, provision of good public transport to secure acceptable travel times;
- location of new employment preferably in the immediate proximity of railway stations;
- no unnecessary growth of trip distances by better mutual tuning and integration of housing, employment and services on all scales;
- promotion of the use of the bicycle, improvement of public transport in the urban region and, as a consequence, promotion of selective use of the car;
- a (re)location, design and management of the transportation infrastructure and a design and management of the urban area aimed at a reduction of hindrance from traffic.”

[Ministry of HSPE, 1985]
The Fourth Report on Spatial Planning (Vierde Nota Ruimtelijke Ordening), published in 1988 [Ministry of HSPE, 1988], followed by the Fourth Report Extra (Vierde Nota Ruimtelijke Ordening Extra) [Ministry of HSPE, 1990], replaced all previous national policy documents. The consequences of the considerable mobility growth of the years before, both with respect to the environment and to accessibility, were strong motives to further articulate spatial mobility policies. Clearly influenced by the Brundtland Committee report ‘Our Common Future’ [WCED, 1987], the Fourth Report (Extra) showed growing concern over the environmental and economic consequences of car mobility growth. The report aimed at improving local living conditions and reducing car mobility in the cities and urban regions. It prioritised mutual proximity of urban functions (e.g., housing, employment, services) over accessibility. This focus on mutual proximity is a crucial element of the Fourth Report Extra. The first priority is on the development of inner city locations, followed by locations on the edge of existing urban areas. Only when these options have run out, other locations should be considered.

“If at all possible, the government wants to prevent development of locations at a distance of existing urban centres, even when these are located close to a railway line.”

[Ministry of HSPE, 1990]

A further focus in the Fourth Report and the Fourth Report Extra concerned the location of activities (offices, firms, industries, organisations, etcetera). The ABC-location policy was introduced as a specific measure to stimulate the location of activities involving a large number of jobs or visitors in the immediate proximity of railway stations. The ABC-policy [Ministry of HSPE, et al., 1990] categorises locations in terms of an accessibility profile. A-locations are public transport oriented. An inter-city railway station is available, and the location is also reasonably accessible by car. Limited parking space is provided at these locations. B-locations have a little of both. They have a railway station and are well accessible by car. Finally, C-locations are car-oriented, located on the main road network and, in general, have no or limited public transport access. Similarly, activities are categorised according to their mobility profile. A certain mobility profile is assigned to an activity based on its employee density, car-dependency, visitor-intensity and road accessibility needs for freight. Table 2.1 gives an overview of the linking between accessibility profiles of locations and mobility profiles of activities.
table 2.1  linking A, B and C locations to mobility profiles

<table>
<thead>
<tr>
<th></th>
<th>A-location</th>
<th>B-location</th>
<th>C-location</th>
</tr>
</thead>
<tbody>
<tr>
<td>employee density</td>
<td>high: less than 40 m² per</td>
<td>moderate: between 40 and 100 m²</td>
<td>low: over 100 m² per employee</td>
</tr>
<tr>
<td>(number of m² per</td>
<td>per employee</td>
<td>per employee</td>
<td>employee</td>
</tr>
<tr>
<td>employee)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>car-dependency</td>
<td>less than 20% of employees</td>
<td>20-30% of employees is car-</td>
<td>over 30% of employees is car-</td>
</tr>
<tr>
<td></td>
<td>is car-dependent</td>
<td>dependent</td>
<td>dependent</td>
</tr>
<tr>
<td>visitor-intensity</td>
<td>daily stream of visitors</td>
<td>regular contact with customers or</td>
<td>hardly ever or occasional visitors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>business contacts</td>
<td></td>
</tr>
<tr>
<td>road accessibility</td>
<td>hardly important</td>
<td>possibly important</td>
<td>important</td>
</tr>
<tr>
<td>needs for freight</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Basically, national policies were focussed on the reduction of travel distances and promotion of public transport and non-motorised transport modes. The basic elements (new developments in existing urban regions, good public transport, mixed development and location policy) all aim at reducing travel distances and/or influencing mode choice towards non-motorised and public transport.

2.3.2 Spatial Policies from a Transportation Planning Perspective 1979-1995

In 1979, the Ministry of Transport, Public Works and Water Management (TPWWM), in cooperation with the Ministry of HSPE, published a Transport Structure Scheme (Structuurschema Verkeer & Vervoer - SVV) [Ministry of TPWWM, 1979]. The main goal of the policies presented in this document was to meet the demand for transport of individuals and goods in such a way that, on balance, it contributes positively to the welfare of society. The role for spatial planning in this document was to reduce the need for travel through adequate coordination and integration of areas for housing, jobs and services. Furthermore, the policy focussed, among other things, on the development of ring roads around towns and cities to reduce the inconvenience of through traffic in the built up area, the improvement and further development of bicycle and foot paths, and the discouragement of motorised traffic in residential areas.
In 1990, the Ministry of TPWWM, again in cooperation with the Ministry of HSPE, published the Second Transport Structure Scheme (Tweede Structuurschema Verkeer & Vervoer - SVVII) [Ministry of TPWWM, 1990], replacing the document that was published in 1979. The main problems the scheme attempted to tackle were the negative effects of increased (motorised) mobility and reduced accessibility on the economy, the environment and road safety. The document took the sustainable society, in the definition of the Brundtland committee [WCED, 1987] as a point of departure for formulating the new policies. Five strategies and four main themes were identified to improve living conditions and address the issue of accessibility. Figure 2.3 gives an overview of these solution strategies and policy themes. The theme ‘guiding mobility’ includes several spatial elements: spatial design, redevelopment of urban areas and parking. The policy statements concerned with spatial design focussed on the concentration of housing, workplaces, recreational facilities and other facilities according to the principles of the ABC-policy and in close connection to good quality public transport, reduced road traffic congestion, improved safety and reduced costs.
transport lines. The ABC-policy also includes parking policy. The policy on redevelopment discouraged the (unnecessary) use of the car. Urban areas should have a coarse network for cars, dividing the area into districts and neighbourhoods between which direct connections are available for walking, cycling and public transport, but not for cars.

Five years after the Second Structure Scheme, the Ministry of TPWWM published a report stating their specific vision on the relationship between urbanisation and mobility [Ministry of TPWWM, 1995]. The document focussed mainly on location choice in relation to infrastructure and transport services, and also looked at basic land use principles for these locations. It attempted to answer the question which locations are most favourable in order to secure affordable accessibility and quality of living conditions. The vision stated that short distances between new locations and the existing built up areas and connection to the public transport network positively influence mobility in the sense that such short distances will stimulate the use of non-motorised transport and result in shorter travel distances. Furthermore, the report discussed the effects of three other dimensions of urbanisation, (i) orientation on one or more urban centres, (ii) degree of concentration, and (iii) degree of mixed land use. It concluded that new residential developments should mainly be located in existing urban regions. Locations within or with direct connections to the city or town, with easy access to existing public transport, are preferred. This would reduce travel distances and therefore reduce the use of the car, increase the use of public transport and improve accessibility. If these locations are no longer available, alternative locations along public transport axes between the urban regions are preferred. The orientation on more than one urban centre should lead to a more balanced pressure on the infrastructure network and therefore to improved accessibility. The land use at the new locations should be mixed, combining housing, jobs and services. This mixed land use can be realised at the location itself (in case of large developments), or by locating smaller new developments close to existing ones with other functions. It is assumed that mixed land use reduces travel distances and thus car use. It is also assumed to improve accessibility. Furthermore, compactness is considered an important feature. This can be achieved with smaller developments in or close to existing urban areas or, if necessary, by larger developments further away. Compact development again reduces distances and consequently motorised mobility. Figure 2.4 visualises the preferred urbanisation principles.
### Do’s

- Separating
- Concentration
- Public transport connected
- In or near to existing urban area
- One or more centre oriented locations

### Don't's

- Mixing
- Deconcentration
- Not connected
- Away from existing urban area
- One centre oriented locations

*figure 2.4  desired urban form principles [Verroen, 1995]*
2.3.3 Developments in Dutch Spatial Mobility Policy

Both the Ministry of Housing, Spatial Planning and the Environment and the Ministry of Transport, Public Works and Water Management are working on new policy documents to update and replace the existing Fourth Report Extra and the Second Transport Structure Scheme. In 1999, the Ministry of HSPE published the Start Memorandum Spatial Planning (Startnota Ruimtelijke Ordening) [Ministry of HSPE, 1999], a preparatory document for the Fifth Report on Spatial Planning (Vijfde Nota Ruimtelijke Ordening). In the same year, the Ministry of TPWWM published the Transport Perspectives Memorandum (Perspectievennota) [Ministry of TPWWM, 1999], in preparation of the National Traffic and Transportation Plan (Nationaal Verkeer en Vervoerplan). Both documents mark a change in thinking about spatial mobility policy. More than in the previous reports and memorandums, the positive effects of mobility are recognised. Mobility is considered crucial for economic development and for the individual development of people. But it is also recognised that, without intervention, risks are taken with regard to accessibility, environmental quality and quality of living conditions. Mobility should be kept within a framework of quality of the living environment, nature and social justice.

In 1999, the Council for Housing, Spatial Planning and the Environment (HSPE-Council) was asked by the Minister of Housing, Spatial Planning and the Environment to give advise on the spatial consequences of the Perspectives Memorandum, in view of the upcoming Fifth Report on Spatial Planning. The Council’s advise [HSPE-Council, 1999] included a critical review of the merits of the current spatial mobility policy. Basically, the official policies until 1999 have focussed on inducing modal shift away from the car to walking, cycling and public transport and on lowering the volume by reducing travel demand through appropriate location policies. The Council proposed a new policy strategy which asks for the development of specific policies to address the negative effects of (motorised) mobility: (a) total emission of harmful substances, (b) problems related to the quality of living conditions and (c) accessibility problems. The recommendations for spatial mobility policies in the future included the following [HSPE-Council, 1999]:

- reversing the way we think about transport systems in spatial planning policy; the focus should not be on adjusting the spatial structure, but on adjusting the
transport system; a strong coherence in content between the Fifth Report and the National Traffic and Transportation Plan is important;

- attention to planning and design, and an area-specific approach, in order to preserve and restore urban quality, quality of living conditions and accessibility;
- providing well-planned connections for cycling and public transport;
- reducing through-traffic in residential areas;
- bundling of traffic flows between cities;
- reducing car use in neighbourhoods to obtain more liveable conditions by arranging proximity of services and a designated parking policy;
- providing public transport to new areas in an early stage of development;
- revising the ABC location policy, in particular for A and B locations.

Recently, both ministries have published their policy intentions, as a first step in the process of establishing the Fifth Report on Spatial Planning and the National Traffic and Transportation Plan. These documents sustain the change in thinking about mobility and the opportunities for spatial planning to contribute to the reduction of (the negative effects of) mobility. In the evaluation of previous policies the Fifth Report policy intention states the following on the effects of spatial mobility policy in the past:

> "Even where urban form goals were reached, the effect on transportation was small. ... Mobility develops under the influence of factors that cannot be affected by urban planning and the effects of which are much greater."

[Ministry of HSPE, 2001]

However, the proposed spatial policy is not all that different from previous policies. There still is a priority for compact cities, intensive and economical use of space and mixing of land uses. Yet, the argumentation for the policy is no longer found in reduction of (motorised) mobility and the attainment of a modal shift, but in achieving a high quality environment. The most notable policy change is the step from urban regions to urban networks as a leading principle to accommodate future spatial developments. Urban networks are defined as strongly urbanised zones consisting of well connected compact cities and towns of different sizes, each with their own character and profile, separated by green, open areas. These networks have to meet with the observed change of society into a network society in which people and businesses are no longer oriented towards one city or town, but towards multiple urban centres. Between these centres a wide variety of activity patterns develops and the urban network is to accommodate these patterns in order to prevent urban sprawl. Finally, although the
potential of urban planning to help reduce mobility has been given up on, possibly under the influence of the advice of the HSPE council, the policy intention still aims at a local modal shift toward more sustainable modes by means of urban design.

The policy intention for the National Traffic and Transportation Plan, published in 2000 [Ministry of TPWWM, 2000] holds similar views on the relationship between urban planning/urban form and travel and transportation. The focus is no longer on the reduction of mobility, but on mobility management. In other words, on finding ways to accommodate the need for travel and transportation while reducing their negative impacts, such as pollution and unsafety. The role of urban planning and design is to contribute to a more efficient use of infrastructure and to attain better accessibility and mode choice. Locations that are visited on a daily or almost daily basis should be located in walking or cycling distance, while new residential or work locations should be developed near nodes of road and public transport infrastructure.

2.4 Spatial Policy and Mobility on the Local Scale

The previous section has shown that the national planning and transport authorities to date have paid ample attention to spatial mobility policy. Although some policy concepts, guidelines and instruments have immediate implications for regional policy, such policies can only be effective if appropriate action is taken at the local level. The aim of this section is not to discuss such local plans in any level of detail. Too often, they provide a specific solution to a specific local problem. The focus of the next section will be on more general principles and instruments that have been suggested for local planning initiatives.

2.4.1 Elaboration of the Second Transport Structure Scheme for the City Level

Prevailing national policy documents only provide some general guidelines for local transport policy. In the years immediately following the Second Transport Structure Scheme, the Ministry of TPWWM installed a working group to elaborate the local implementation of the national policy. The project intended to explore the possibilities for medium-sized cities in the Netherlands to contribute to the reduction of mobility. The main objective was to create “a liveable and accessible city, pleasant to be in and attractive for the establishment of economic and other activities” [Ministry of TPWWM
Urban Form and Activity-Travel Patterns

and Heidemij Advies, 1993]. Sub-goals concerned the reduction of hindrance and danger, the reduction of the need to use motorised transport, improvement of conditions for walking and cycling, improvement of public transport, discouragement of the use of motorised transport and more efficient use of existing roads and parking capacity. The projects resulted in a report, describing an exercise of improving an existing city, based on the principles of the Second Transport Structure Scheme. Guidelines were given at the level of the region, the city and the neighbourhood. Provinces and municipalities could use these guidelines when formulating their specific policies.

The following recommendations were made for regional plans: i) improvement of the connection between the bicycle and public transport by provision of excellent storage facilities at train and bus stations, ii) direct, safe and comfortable bicycle connections between towns and villages within a 10 kilometre radius, iii) strong improvement of regional public transport and iv) provision of park-and-ride facilities in the periphery of cities. At the city level, the following recommendations were made: i) development of an integral traffic and transportation plan in which accessibility of activities in liveable conditions plays an important role, ii) emphasis on direct and safe connections for non-motorised transport, iii) stimulation of the idea to view the city as a ‘place to be’ (with the exception of a few main traffic connections), iv) establishment of direct, safe bicycle connections to all public transport nodes and to concentrations of jobs, shops and/or facilities, v) good storage facilities for bicycles at public transport nodes and at concentrations of jobs, shops and/or facilities, vi) a public transport network that is as straight and direct as possible to avoid detours, vii) development of park-and-ride facilities in the periphery of the city, viii) concentration of motorised traffic on a limited number of roads, ix) banning through-traffic from particular residential areas using circulation and design measures, x) a sharpening of parking policy and xi) the concentration of parking at suitable locations. Finally, some recommendations were formulated for the neighbourhood level: i) evaluation and, if necessary, revision of traffic circulation and design in neighbourhoods, ii) straitening of bus lines to avoid detours, iii) realisation of public transport nodes in new building sites, located at a considerable distance from important destinations in the city, iv) additional public transport for disabled persons, v) more space for non-motorised transport, vi) the creation of low-traffic inner cities, vii) the creation of parking facilities in the periphery of the inner city and viii) the formulation of parking policies for neighbourhoods, if necessary.
2.4.2 Instrument for Measuring Local Traffic Performance

In 1997, the NOVEM (Dutch Organisation for Energy and Environment) published a report on energy conservation in transportation through urban planning and design [Janse, 1997]. In this report, rather favourable conclusions were drawn regarding the potential for energy conservation when the ‘right’ choices are made in urban planning and design. As a follow-up, the NOVEM, commissioned by the Ministry of Economic Affairs, developed an instrument which calculates the energy use for transportation per household for a certain area. This instrument, named “VerkeersPrestatie op Locatie” (Local Traffic Performance - LTP), can be used to serve several goals. First, it can be used as a steering instrument, for instance to set ambitions for new developments. Secondly, it can be used to assess the energy consumption of plan alternatives. Finally, the instrument can in principle be used as a aid in the design process of new plans.

The LTP-instrument is based on the assumption that people choose the transport mode with the lowest resistance, taking into consideration travel time, travel costs, reliability and comfort [NOVEM/Ministry of EA, 1999]. Planning and design should therefore be aimed at making sure that the transport mode that is best from an energy point of view is also the mode with the lowest resistance. From an energy point of view, walking is the optimal mode for areas of approximately 1,000 x 1,000 metres. Thus, on this scale, planning and design should give priority to the pedestrian. On a scale up to 4,000 x 4,000 metres, the bicycle is the optimal mode and should therefore be prioritised, while on larger scales, public transport and the car are the best. These principles lead to a bottom-up approach for urban planning and design, assigning space to the pedestrian first, then to the bicycle, and finally to public transport and the car.

2.5 Conclusions

The Dutch government and planning institutions have been pursuing spatial mobility policies for almost 30 years now. During most of these 30 years, the main goals underlying this policy have hardly changed. Reduction of travel distances and promotion of alternative transport modes have been the key issues and several policies have been proposed and refined to achieve these goals. Basically, these policies can be divided into two categories: policies that aim at controlling the location of activities and policies that aim at improving connections between activities by different transport modes (multi-
modal transport systems). Although the faith in the potential contribution of spatial policies to mobility reduction appears to lessen, the review of the Dutch policy literature provides evidence of a consistent view on how to influence mobility through location and transport policies. Many of the proposed measures concern the urban form for regions and cities. It appears that Dutch policy makers are still rather convinced of the effectiveness of the manipulation of urban form for achieving a modal shift towards more sustainable transport modes, given the fact that the same (types of) measures keep reappearing in policy documents. However, the argumentation for the suggested measures is rather weak, based more on reasoning than on empirical evidence. Hence, it is questionable whether the measures taken to date have been effective in reducing the mobility growth, and whether they will be in the future. Most of the suggested policies are, either explicitly or implicitly, based on the assumption that activity-travel patterns of individuals and households are strongly influenced by urban forms characteristics.

In the next chapter, we will critically review the literature on the relationship between urban form and mobility in order to assess the empirical foundation of the formulated policies.
3 | TRAVEL AND ITS SPATIAL CONTEXT

3.1 Introduction

In the previous chapter, the policy background for this thesis was discussed. An examination of Dutch spatial and transport policies indicated that these policies involve two major goals: a reduction of travel distances and the promotion of the use of alternative transport modes. Urban planners and designers seem to believe that the right urban form can contribute to achieving these goals.

The goal of this chapter is to review the literature and assess the theoretical and empirical support for such a claim. In particular, the wide range of articles, papers and books about the relationship between characteristics of urban form and travel behaviour that has been published during the last two decades will be discussed. In doing so, a distinction will be made between theoretical studies, simulation studies and empirical evidence. This distinction is important for the following reasons. Theoretical studies may be relevant for policy development because specific policies can be linked to more general theoretical concepts and constructs. Simulation studies have the advantage that the link between urban form and travel behaviour can be examined in principle. The validity of the results of simulation studies, however, depends on the validity of the model assumptions. The real world might be quite different from the simulated world. In that sense, empirical studies can provide the only true support, but even empirical studies should not be taken for granted as their results might be an artifact of poor methodology, a specific sample or study area, etcetera. The conditions leading to specific conclusions for a particular sample in a particular study area do not necessarily generalise to the Dutch context.

Thus, in the present chapter we will systematically assess the relevant literature. Differences in scale will be identified. The chapter is organised as follows. Sections 3.2, 3.3 and 3.4 deal with theoretical discussions, model simulations and empirical studies.
respectively. Each section first discusses the type of study and then reviews the available literature, making (where relevant) a distinction between the national, regional and local scale. In the final section, the results most relevant to the present thesis are outlined and conclusions are drawn.

3.2 Theoretical Discussions

Theories on the relationship between urban form and travel patterns are mainly based on the notion that travel is the result of people’s desire to engage in activities. Since activity locations are spatially distributed over a larger area, these activities cannot all be performed at the same location. The result is travel.

Theoretical reflections on the potential effects of urban form typically concern the spatial distribution of important activity locations such as residences, jobs and shops. Shortening distances between these types of locations is often presented as a means to decrease mobility growth. A typical representative of this line of reasoning is The New Urbanism (TNU) movement. This movement, based in the late 1980s, ‘seeks to reintegrate the components of modern life - housing, workplace, shopping, and recreation - into compact, pedestrian-friendly, mixed use neighbourhoods, linked by transit and set in a larger regional open space framework’ [CNU, 2000a]. Developments should be pedestrian-friendly in size (neighbourhoods no larger than 400 metres from centre to edge), in layout (interconnected networks) and in urban design (coherent blocks fronted with building entrances instead of parking lots). A mix of activities in proximity of each other and a spectrum of housing options in each neighbourhood should enable interactions within a close range of one’s home. These, and other, (design) principles of The New Urbanism have been published by the Congress for the New Urbanism in their charter [CNU, 2000b].

With regard to land use and transport issues the following items can be found in this charter:

‘... neighbourhoods should be diverse in use and population; communities should be designed for the pedestrian and transit as well as the car; cities and towns should be shaped by physically well defined and universally accessible public spaces and community institutions ...’
The physical organization of the region should be supported by a framework of transportation alternatives. Transit, pedestrian, and bicycle systems should maximise access and mobility throughout the region while reducing dependence upon the automobile.

Neighbourhoods should be compact, pedestrian-friendly and mixed-use. Districts generally emphasise a special, single use, and should follow the principles of neighbourhood design when possible. Corridors are regional connectors of neighbourhoods and districts; they range from boulevards and rail lines to rivers and parkways.

Many activities of daily living should occur within walking distance, allowing independence to those who do not drive, especially the elderly and the young. Interconnected networks of streets should be designed to encourage walking, reduce the number and length of automobile trips, and conserve energy.

Appropriate building densities and land uses should be within walking distance of transit stops, permitting public transit to become a viable alternative to the automobile.

Concentrations of civic, institutional, and commercial activity should be embedded in neighbourhoods and districts, not isolated in remote, single-use complexes. Schools should be sized and located to enable children to walk or bicycle to them.

In the contemporary metropolis, development must adequately accommodate automobiles. It should do so in ways that respect the pedestrian and the form of public space.

Streets and squares should be safe, comfortable, and interesting to the pedestrian. Properly configured, they encourage walking ...

The basic theory behind most of these recommendations is that when facilities and services are located within close proximity of homes, they will be chosen as destinations for activity participation. Combined with a pleasant and interesting environment for pedestrians, and accessible transit facilities, this should lead to reduced car use.
Several publications reflect on the TNU and, comparable, neo-traditional design (NTD) principles for urban design and their transport consequences. Gibson [1997], for example, focussed his discussion on the expected advantages of TNU with regard to transport. He argued that mixed use districts (with a minimum of two primary uses), a relatively high residential density, and a scale of districts that caters for pedestrian access to daily needs, ‘(almost) automatically reduces the demand for car trips’. Crane [1996a] also theorised on the claims that NTD-advocates make with regard to the influence of urban form on travel behaviour, especially at the neighbourhood level. His discourse on the subject is fairly critical and questions the correctness of their claims. Although he agreed that NTD improves the accessibility of neighbourhoods (similar to Gibson), he argued that this also decreases the costs for travel (in both time and money) for all transportation modes. This will most likely lead to an increase in the number of trips people make. Hence, he concluded that the claim of a reduction of (motorised) mobility cannot be substantiated.

Logically, both lines of reasoning seem plausible. The critical question here is how individuals and households organise their daily activity-travel patterns within the opportunities and constraints set by their immediate and larger urban environment. This is not a theoretical, but an empirical question. Model simulations and empirical analysis can be used to disentangle this complex relationship. These types of studies will be summarised in the next two sections.

3.3 Model Simulations

Simulation studies can provide us with interesting information on the relationship between urban form and travel behaviour. More specifically, simulation allows one to create a particular urban environment and to investigate how some assumed relationship between this environment and human behaviour, typically captured by some model, will result in aggregate travel patterns. Such studies have been conducted at the regional and at the local level.

An interesting model simulation study at the regional level has been conducted by Verroen, et al [1995]. This study explored the potential mobility effects of different urbanisation scenarios in The Netherlands. Scenarios were built based on variations in several aspects of urban form, e.g. mono-functional or mixed land use, mono-centric or
poly-centric orientation and concentration or deconcentration. Using existing
transportation models, the mobility effects of different scenarios were estimated. It was
concluded that a concentrated development of poly-centric oriented, mixed land use,
urban areas would yield the best results. Interestingly, the compact city concept, at the
time of the study the urbanisation policy in the Netherlands, did not come out as the best
scenario. However, it should be noted that the differences between scenarios were small.

Whereas Verroen et al’s study analysed hypothetical urban scenarios, the study
conducted by Giuliano and Small [1993] looked at real urban situations. Necessary travel
in an urban region was estimated using a transportation model. The model determined
the commuting pattern that would minimise average commuting time or distance, given
the actual spatial distribution of jobs and housing locations. The results were compared
to actual travel. Giuliano and Small found a large discrepancy between actual and
necessary travel. Variations in required commuting across job locations only weakly
explained variations in actual commuting. They concluded that little effect can be
expected from measures that aim to improve the jobs-housing balance in an area.

Two other studies focussed on the effects of neo-traditional design as opposed to
conventional urban design. Neo-traditional design can be generalised as an attempt to
go back to development patterns from pre World War II traditional communities. These
designs are based on mixed land uses, a highly interconnected street network and a
street design that accommodates pedestrians and cyclists as well as motorists.
Conventional urban design is used to describe a broad range of designs of mainly post-
war neighbourhoods. These neighbourhoods are characterised by segregated land uses,
hierarchical street networks and an extensive use of cul-de-sacs. McNally and Ryan
[1993] used conventional transportation planning models to evaluate the differences in
performance of two hypothetical street networks, representing a neo-traditional and a
conventional suburban community. All aspects of the modelled communities were held
constant, except for the actual configuration of the networks. The model simulated the
total vehicle miles travelled, average trip lengths, and congestion on links and
intersections. The results of the exercise showed that equivalent levels of activity (given
the land uses in the communities) can produce greater congestion and longer average
trip lengths in conventional network structures and that neo-traditional designs can
improve system performance.
In another study, Crane [1996b] criticised the fact that modelling exercises looking at the relationship between urban form and travel, such as the one discussed above, assume that trip generation is the same in different types of neighbourhoods. He therefore presented results from a modelling exercise concerning the potential effects of Neo-Traditional Design (NTD) principles that included trip generation. More specifically, he assumed that, given a certain amount of money and time to spend on travel, changes in the urban setting and in the supply of transportation can change people’s choice behaviour. Crane formalised the choice of the number of trips by each mode as a constrained maximisation problem. The objective is to maximise the benefit of travel by mode, given the budget limitations in time and money. Using the method of comparative statistics, the potential effects of three design elements commonly assumed to have transportation benefits were simulated. These were grid street patterns, traffic calming measures and mixed land uses at higher densities. The analyses led to some notable conclusions. For the three tested measures, it was not always clear whether they will increase or decrease the number of car trips, the total distance travelled and the modal split. Traffic calming measures are most likely to reduce trips, vehicle miles travelled (VMT) and the use of the car in most circumstances. However, grid patterns, mixed land use and higher densities can, depending on the circumstances, both increase or decrease these travel indicators.

When assessing these findings, one should keep in mind that the results are directly derived from models, which are built on assumptions on how the real world works. According to Næss [1995], this holds a great danger of circularity in the reasoning. Furthermore, models (over)simplify reality, both as far as human behaviour is concerned and in terms of the hypothetical situation being tested. For example, the models used for these simulations are often based on the traditional, aggregate 4-step transportation demand model. Although this type of model is still generally used in transportation planning, its drawbacks are well known. Aggregating results over zones leads to incorrect estimations of total travel, especially for non-motorised travel, since travel within zones is (normally) not taken into account. Furthermore, by considering each step in the model (trip generation, trip distribution, mode choice and route choice) as an isolated decision, the interactions between these decisions are not accounted for. Thus, the validity of the results of the simulations ultimately depend on the validity of the underlying assumptions regarding activity-travel patterns. In the next section, we will therefore summarise the outcomes of empirical studies into the relationship between urban form and activity-travel patterns.
3.4 Empirical Studies

Within the group of empirical studies, a distinction can be made between comparative studies (mainly case studies) and analytical studies. Comparative studies into the relationship between urban form and travel behaviour typically compare two or more regions, cities or neighbourhoods on a number of aspects. Statistical analyses in this type of study are often limited to simple analyses such as Chi-square analysis and analysis of variance. In contrast, analytical studies typically apply more advanced statistical analyses to discover the relationships, if any, between aspects of urban form and travel characteristics.

A wide range of articles and papers is available. However, these mainly originate from the US, complemented with studies from Britain, Scandinavia and South America. Furthermore, many of these studies do not control for socioeconomic and demographic factors. From studies that do control for these variables, contradictory conclusions have been drawn on the relative influence of spatial versus non-spatial variables. For instance, Boarnet and Sarmiento [1998] concluded from a study in Southern California that there is no evidence that land use variables influence travel behaviour, Hanson [1982] found that sociodemographic variables outweigh spatial variables, while Kitamura et al [1997] and Sun et al [1998] found, based on the Portland travel survey, that spatial factors do explain some variation in travel behaviour and travel patterns. Næss [1993], and Næss et al [1996] concluded in their studies of Scandinavian towns that the effects of spatial factors outweigh the effects of socioeconomic variables. Finally, a Dutch study showed some interesting findings on the relationship between spatial structure and travel patterns. MuConsult [2000] found that only 40% of the variance in number of trips can be accounted for by the selected characteristics of the spatial environment, the household and the individual. The explained proportion of variance in number of trips is lower for non-motorised and public transport trips than for motorised trips. Furthermore, the explained proportion of variance is higher for certain types of trips, such as grocery shopping and home-to-work trips and lower for social and recreational trips.

A summary of the studies described in this section is found in appendix 1. For each study, a few important characteristics are recorded. These include the method of analysis that was applied, the source and type of data used and whether or not the study controlled for socioeconomic variables. The table also shortly summarises the main findings with regard to the influence of spatial variables on travel behaviour.
3.4.1 The Region as the Unit of Observation

At the regional level comparative and analytical empirical studies are available from both US and European authors. The best known, and probably the most criticised study, at this level is from Newman and Kenworthy [1989]. Comparing metropolitan regions in Europe, Asia, Australia and America, they found that gasoline consumption decreased with increasing density. Although they were highly criticised for not controlling for income and gasoline prices, and for questionable reliability of their data, this study has been the point of departure for many to follow.

Handy [1993] published a comparative study of non-work travel in the San Francisco Bay Area (divided into 550 zones). For each zone the local and regional accessibility was calculated. These accessibility measures were based on an exponential form of the gravity model. Local accessibility is dependent on close proximity to locally oriented centres of activity, whereas regional accessibility is dependent on good transportation links to large regionally oriented concentrations of activity. Correlations were calculated between the measures of accessibility and average shopping distance and average shopping kilometres travelled. Handy concluded that although mixed land use development does not reduce mobility, it does influence mode choice for shopping trips in a positive way towards more non-motorised travel.

A comparative study from Schimek [1996] compared the urban regions of Toronto and Boston. Based on differences in urban structure and travel patterns in both cities and their regions, he concluded that higher densities, greater concentration of jobs and better public transport facilities in Toronto’s urban region explain this region’s higher transit use and lower car use. However, these conclusions are drawn mainly based on a descriptive analysis without hypothesis testing and controlling for socioeconomic factors.

Gordon [1997] started his article with a critical discussion of the theories on the relationship between urban form and travel behaviour, also referring to the Newman and Kenworthy study. He argued that the relationships found, especially in studies not controlling for socioeconomic factors, form an inadequate basis for policy making. By analysing three existing data sets (Newman and Kenworthy’s data set, National Travel Survey records of travel behaviour in 1,300 areas across Britain and a travel-to-work survey in 193 English functional urban regions) he set out to substantiate his doubts on
the positive effects of compactness. Regression analysis of the Newman and Kenworthy data set indicated that density, fuel price and GDP per head together explain more than 90% of variation in energy use. Analyses of the NTS data set showed that approximately 1/3 of variation in energy use is explained by variables describing size, density and accessibility and another 1/3 is explained by socioeconomic variables. The analyses of the third data set yielded limited results, indicating a relationship between workplace density and modal split. Despite his initial doubts, his multivariate regression analyses showed that both spatial factors like density (jobs and residents), urban size, mixing of functions, accessibility of facilities, and socioeconomic factors like income, economic group, fuel prices, gender and working hours, are important with regard to both mode choice and energy use. He concluded that apparently settlement planning does play a role in reducing energy use for travel, but that ‘compactness as a general prescription’ is not the simple answer to the question.

Miller and Ibrahim [1998] concluded from their study in, again, the Toronto region (divided into 1404 zones) that density should be considered an intermediate, and not so much a causal, variable. They stated that centralising developments in the city centre and subcentres is most important and that working towards a better jobs-housing balance by mixing urban functions has not been proven to be an effective policy. Conclusions were based on an analysis of aggregated data. The average commuting distance in a zone was regressed against variables describing the distance to job locations, the job density in and around the home zone and the population density in the home zone ($R^2 = 0.45$).

Schimek, Miller and Ibrahim and Handy did not control for socioeconomic and/or demographic factors in the studies discussed above. Since factors like car ownership, income, household type etcetera are expected to influence travel behaviour, studies that do control for these types of factors are much more interesting. Mogridge [1985] compared the London and Paris regions. Population density, mean household income, car ownership, median daily travel time per traveller and energy consumption were set out against the distance to the city centre. From these comparisons, Mogridge concluded that car ownership is more important than residential density or public transport provision. Although this study is interesting, it applied a rather simple methodology.

Næss [1993] studied 15 Swedish urban regions, using more advanced techniques. Travel was represented by energy use data from public transport companies and fuel sales. Explanatory variables were urban area densities, average income and population size, a
concentration index for the home location of each inhabitant and the degree of urbanisation. Bivariate analysis showed that the energy consumption per capita correlates most strongly with the concentration index. Higher centralisation goes with higher energy consumption, which is against expectations. A correlation was also found with density. Multiple regression analysis indicated that 39% of the variation in energy consumption can be explained by variation in population density, concentration index and degree of urbanisation.

A similar study, focusing more on the characteristics of job locations, was published by Næss and Sandberg [1996]. They studied commuting trips of six companies in Greater Oslo and found that both the modal split and the energy use for journeys to work are, to a high extent, influenced by the geographical location of the workplace. Employees of workplaces in peripheral, low density parts of the region are far more frequent car drivers and use considerably more energy for journeys to work than employees of workplaces located in the central high-density areas. Conclusions are based on regression analysis controlling for a number of socioeconomic variables. The explanatory power of the model for modal split was 50% and for the energy use model 16%.

3.4.2 The City as the Unit of Observation

At the level of the city, findings are often complementary to the studies discussed above. Næss [1993] investigated the relationship between population density and energy use for transport in 97 Swedish towns. Energy use was based on fuel and electricity consumption figures. He found that 19% of variation in energy use is explained by population density. Although energy consumption does seem to be related to income levels, this relationship is not significant. Similarly, no effects were found from total population size, percentage of population living in rural areas and percentage of population living in the city centre.

Frank and Pivo [1994] looked at the effects of land use mix, especially on mode choice for home-to-work and shopping trips. Data on household travel behaviour was obtained from the Puget Sound Transportation Panel. Explanatory variables included gross population and employment density and land use mix (based on an entropy index) and control variables included, among others, household type (defined in life-cycle stages), employment status and car ownership. The analyses, Pearson correlations, cross tabulations and multivariate regression (R² between .14 and .43), affirmed the
relationship found in other studies that land use mix influences car use (correlation coefficient: -0.13) and use of other modes (correlation coefficients: for transit +0.15 and for walking +0.21) in a positive way for home-to-work trips. They also found that both types of density have similar positive effects. Interesting is their finding that the relationship between mode choice and employment density is not linear, but that there are two thresholds along a continuum at which a modal shift occurs from motorised transport to transit and non-motorised transport.

Banister, Watson and Wood [1996] presented an analysis of energy use for transport. Analysis was done through contingency tables and correlation analysis, which identified bivariate relationships. Stepwise regression was used to explain the measure of energy use. The study consisted of 5 case studies in 4 British and 1 Dutch cities and controlled for demographic and socioeconomic factors such as employment, car ownership, socioeconomic status, age, housing tenure, housing type and household composition. The physical environment was described by density, percentage of open space, size of the city, compactness (length to width ratio) and population. From their study they concluded that mixed land use and concepts of self containment are important, but that they only have the desired effect when the balance is not merely quantitative (e.g. number of jobs) but also qualitative (e.g. types of jobs). They also found that car ownership, employment and socioeconomic group, are important non-spatial factors, while density, open space and size of the urban area are the key spatial variables influencing energy use for transport.

Næss et al [1996] studied the relationship between urban form characteristics and energy use for transport in 22 Nordic towns. They applied multivariate regression analysis to a set of urban form characteristics (including, among others, population size and density, geometric shape of the town, population concentration index, supply of roads and public transport) and socioeconomic variables (income, education level, car ownership, frequency of extra-urban commuting, composition of trades etcetera). Results showed that five variables account for 74% of the variation in energy use (fuel and electricity consumption for travel), two of which describe elements of urban form: population density and concentration index.
3.4.3 The Neighbourhood as the Unit of Observation

Finally, several authors looked at functional and design characteristics of neighbourhoods and their relationship with travel behaviour and travel patterns. Many of the findings in empirical studies at this level are in line with findings at higher levels. First a set of comparative studies is discussed. These studies often look at the differences between neo-traditional transit-oriented neighbourhoods and standard suburban car-oriented neighbourhoods. This is followed by studies that are more of an analytical nature, focussing on the effects of different characteristics of the spatial environment instead of the neighbourhood type as a whole.

Ewing et al [1994] published a comparative study of six neighbourhoods in Florida. The study analysed travel data from a diary based survey. The neighbourhoods were described using a number of land use characteristics: density (residential and employment), jobs/housing ratio, percentage of multifamily dwellings and accessibility indices for work trips and non-home-based trips. Socioeconomic factors were controlled for by including respondents of similar incomes in each neighbourhood. Analysis of variance was performed and significant variations in work-related travel time, non-work related travel time and total travel time were found. Comparing this with the characteristics of the six neighbourhoods, the authors concluded that density and land use mix are the main factors reducing motorised transport.

Friedman et al [1994] analysed data from the 1980 San Francisco Home Interview Surveys. They compared trip generation in standard suburban and traditional communities. Standard suburban communities have mainly been developed since the early 1950's, have segregated land uses, minimal pedestrian access between different land uses, a well-defined hierarchy of roads, concentrated area access via major arterial roads and relatively little transit service. Traditional communities have mostly been developed before World War II, have a mixed use downtown commercial district with on-street parking, an interconnecting street grid and close proximity between land uses. Neighbourhoods were matched on similarity in income and housing prices. Trip generation (total, per mode and per trip purpose) was compared for both neighbourhood types and this revealed differences in travel behaviour. Higher total trip rates and car trip rates were found among residents of standard suburban neighbourhoods. The authors urge for caution in interpretation of the results, since quite some socioeconomic differences were present despite the attempt to match neighbourhoods.
Scott Rutherford et al [1996] studied data from two travel diaries in the Seattle area. The study included 4 neighbourhoods and a large number of socioeconomic variables such as age, income, sex and household type. No statistical analysis were performed, just comparisons of travel behaviour indicators for each of the neighbourhoods were made. They concluded that mixed land use appears to be linked to fewer miles travelled. A later study from McCormack et al [2001] elaborated on the previous one. In this study, they compared travel data from travel diaries from 3 Seattle region neighbourhoods with neo-traditional characteristics (mixed land use) with data collected throughout the region. Using ANOVA they concluded that residents of the mixed land use neighbourhoods travelled less miles than those in adjacent areas. The contrast in mileage was even greater when comparing with residents of suburban areas. However, no differences were found for travel time. Travel time did differ across the types of neighbourhoods, but this effect was attributed to socioeconomic characteristics.

Handy [1996] conducted a case study of four neighbourhoods in the San Francisco Bay Area. Neighbourhood selection was made stepwise. First, two areas were selected based on the location in the region and accessibility to regional centres of retail activity. Within each area a traditional (interconnected grid pattern, turn of the century) and a modern (curvilinear streets and cul-de-sacs, post World War II) neighbourhood were selected. Neighbourhoods were similar on socioeconomic characteristics, although differences remained. Densities also differed across neighbourhoods. Several characteristics of travel behaviour were compared. Significant differences between the neighbourhoods were found in supermarket trip patterns with regard to average travel time, average frequency, percentage of walking trips, average number of visits last month and average frequency of convenience store trips. With regard to walking trips for shopping, significant differences were found for average frequency of walking trips and percentage of walking trips. Comparison of regional shopping trips revealed significant differences in the average frequency, the average number of visits last month and average travel time. An ANOVA of trip frequency by destination and mode showed more variation across case study areas than across household types for most of the trip characteristics. Handy concluded that better accessibility (shorter distances to activities, similar range of potential destinations) leads to shorter average trips. However, when higher accessibility also includes more variation in potential destinations, average trips are longer. Better accessibility is also related to higher trip frequencies and a larger number of walking trips.
Urban Form and Activity-Travel Patterns

Cervero [1996] studied differences in travel behaviour between transit and car-oriented neighbourhoods in the San Francisco Bay Area. A matched pair analysis was conducted, matching neighbourhoods on income, transit service and topography, choosing pairs of neighbourhoods that were no more than 4 miles apart. Transit neighbourhoods were originally built along a streetcar line or a rail station, date from before WWII and have primarily gridded street patterns. Car neighbourhoods date from after WWII, have primarily random street patterns and were built without regard to transit facilities. From the paired comparisons it was found that transit neighbourhoods tend to show more trips, a higher proportion of walk/cycle trips, higher transit modal split and a higher walk/cycle modal split. The study also reports the results of a regression analysis of the aggregate data, with the percentage of work trips by transit as the dependent variable. It was found that the percentage increases with higher residential density and better transit facilities in the neighbourhood and the interaction term of both, and decreases with household income ($R^2 = 46\%$). Cervero concluded that although car use is dominant in all neighbourhoods, it is less dominant in transit-oriented neighbourhoods.

Nasar [1997] compared two neighbourhoods in a study into the effects of neo-traditional land use on car dependency (car use for trips of different purposes). Significant differences in car dependency were found between the neo-traditional neighbourhood (high land use diversity) and the suburban neighbourhood (low land use diversity) for grocery shopping trips, other shopping trips, library trips and total number of trips. Note that differences, although significant, were small. No differences were found for trips to the post-office, the park and friends. Nasar also looked at interaction with demographic characteristics and concluded that effects were stronger for older people, women, unmarried people and households without children. However, these conclusions are not based on multivariate analyses.

Florez [1998] collected data on travel behaviour, socioeconomic characteristics and residential satisfaction in three neighbourhoods in Caracas. The selected neighbourhoods were similar in building characteristics (housing in blocks) and income (middle income), but differed in street networks (connectivity) and land use mix. They also differed in age. Two neighbourhoods had a traditional street pattern, one neighbourhood a clustered pattern (cul de sacs). A random sample of 60 respondents per neighbourhood was taken. Travel characteristics (trips, travel time, modal split and destination choice) and socioeconomic characteristics of each of the neighbourhoods were compared. No multivariate analyses were performed. The results indicated that
Development patterns are linked to travel behaviour. Traditional patterns are associated with lower car use, more transit trips and lower travel times.

In general, these studies comparing (neo-)traditional, transit-oriented neighbourhoods with standard suburban neighbourhoods reach similar conclusions. Transit-oriented neighbourhoods have lower numbers and shares of car trips and higher numbers and shares of public transport trips. However, it should be noted that these studies are mainly of a comparative nature and controlling for socioeconomic variables is often absent or based on pairs of comparable neighbourhoods. The vast majority of these studies lack a rigorous analysis.

Hanson [1982] studied data from the Uppsala travel diary. She performed a number of multivariate stepwise regression analyses for workers and non-workers, attempting to link travel behaviour characteristics to both spatial and sociodemographic variables. Main spatial variables included in the study describe the number of activity sites within 1 or 4 kilometres from the home or work location. The number of trips for both workers and non-workers was influenced by the number of activity sites within 1 kilometre from home ($R^2$ respectively 14% and 31%). The average distance from home to the visited location depended for workers on the number of activity sites within both 1 and 4 kilometres from home and within 1 kilometre from work ($R^2$=43%). For non-workers only the number of activity sites within 1 and 4 kilometre from home were of significant influence ($R^2$=39%). The number of shopping stops for workers was significantly related to the number of activity sites within 1 kilometre from work ($R^2$=20%). For non-workers no spatial variables were of significant influence ($R^2$=28%). The number of social stops was not influenced by spatial variables for both workers and non-workers ($R^2$ respectively 30% and 10%). Finally, the number of work stops (for workers only) was influenced by the number of activity sites within 1 kilometre from home ($R^2$=28%). All models also included one or more socioeconomic variables, except for the non-workers model for the average distance from home to the visited location. From the results the author concluded that sociodemographic variables outweigh spatial variables, yet the influence of spatial patterns should not be overlooked.

Cervero [1988] presented the results of a study into the effect of land use mix on job locations on travel behaviour. The study included 57 of the largest suburban centres in the US and used variables measuring size, density, land use composition and price and supply of transport services (transit, roads, parking etcetera). Stepwise regression
analysis was performed on mode shares for work trips. The $R^2$ of the four models (drive alone, drive alone minus regional drive alone, ride sharing and walk/bicycle) varied between 37% and 66%. The performance of the walk/bicycle model was best. The results show that single use office settings induce solo commuting, while more varied work environments generally encourage ride sharing, walking and cycling, particularly when consumer retail services are available.

The study published by Cervero and Gorham [1995] compared commuting characteristics of transit-oriented and car-oriented neighbourhoods in the San Francisco Bay Area and in Southern California. In contrast to most of the studies of this type discussed above, this study applied regression analysis to the data, adding value to its results and conclusions. Transit-oriented neighbourhoods were developed mainly before 1945 and characterised by higher densities and more gridded street patterns. Car-oriented neighbourhoods were developed after 1945 and have primarily random street patterns and no regard for transit. Neighbourhoods were matched in terms of income and transit service intensity and were located no more than 4 miles apart in order to keep topographical characteristics comparable. Regression analysis was applied using only the Los Angeles County data (1636 cases). The dependent variable was the percentage of work trips by transit ($R^2$=55%). Small, yet significant, effects were found for density, household income, neighbourhood type and the interaction between density and neighbourhood type.

Næss et al [1995] studied 30 residential areas in Greater Oslo. These neighbourhoods cover differences as to physical design and location, including dwelling types, population density, distance to downtown Oslo, distance to local centres and distribution of population over districts of Oslo. Within each neighbourhood, households were selected randomly. The study included data from 329 households (875 individuals), which is a response rate of 55%. Travel behaviour and socioeconomic data were collected through a questionnaire survey. Geographical data was obtained from maps, technical visits and public administration bodies. The study included two composite spatial variables. The local service accessibility index was computed based on the individual distances from each household’s dwelling to the nearest primary school, secondary school, kindergarten, grocery shop and post office. A similar index was computed for public transport accessibility. Multivariate regression analysis was performed for several dependent variables. Regression analysis of total travel distance ($R^2$=37%) revealed significant effects of the distance to downtown Oslo (direction of effect +), the number
of cars per adult household member (+), the number of children in household (-) and local service accessibility (-). Public transport accessibility (+) was significant only at the 0.1 level. Regression analysis of distance modal share public transport (R²=58%) revealed significant effects of the number of cars per adult household member (-), residential density (+) and the proportion of women in household (+). Regression analysis of energy use for local transport (R²=41%) revealed significant effects of the number of cars per adult household member (+), the number of children in household (-), the distance to downtown Oslo (+) and local service accessibility (-). Path analysis was performed on the data to identify indirect effects of variables. Density was found to influence local service accessibility and also car ownership. The latter effect was independent from other household characteristics associated with density. Higher incomes were found to affect car ownership. Total causal effects showed that energy use increases with distance to downtown Oslo, income and area per capita in local community, and decreases with residential density, local service accessibility, number of children in household and average age of adult household members.

In a Dutch study [Konings, et al, 1996] into the effects of density and location type (rural, suburban or urban) on home-to-work travel, 909 recently moved households in new development locations were studied. The study included four groups of explanatory variables: socioeconomic characteristics (income, hours work, car ownership), household composition, housing situation and spatial characteristics (degree of urbanisation, housing density, distance to public transport services and home-to-work distance). A multivariate regression analysis was conducted with the number of home-to-work kilometres by car per household as the dependent variable. The best model obtained had a R² of 18% and included the following significant explanatory variables: car ownership, household type, number of earners in household and housing tenure. No effect of any of the spatial characteristics was found. Comparative analysis of the locations in the study led to the conclusion that the use of public transport increases with density. Suburban and urban locations with medium density showed the highest use of public transport, while rural, medium density locations showed the highest figures of bicycle use. The use of the car decreases with density, but is independent of location type.

Kitamura et al published a micro analysis study of land use and travel in 1997. The study included five neighbourhoods in the San Francisco Bay Area, that were carefully selected to represent extreme values in terms of land use and mixture, while income levels were kept around a medium level. Travel diaries were used to collect data on travel behaviour
of inhabitants and on their demographic and socioeconomic characteristics. Measures of mobility included number of trips (by travel mode) and fractions of trips by travel modes. Multivariate regression analysis was applied to the data to identify relationships between land use and travel behaviour. The explanatory power ($R^2$) of the best models for each of the dependent variables varied between 0.03 and 0.16. Significant effects were found for the following land use characteristics: residential density, public transit accessibility, mixed land use and the presence of side walks.

Cervero and Kockelman [1997] studied the relationship between travel behaviour and the 3 D’s (density, diversity and design). They used travel data, socioeconomic data and data on design features and land use from 50 sampled neighbourhoods. Density, diversity and design were defined using a large set of characteristics, also including some composite variables obtained by factor analysis. Multiple regression was applied, first building a base model with only socioeconomic control variables, then adding variables describing the built environment. Models were estimated for the total number of vehicle miles travelled (VMT) per household and the VMT for non-work trips per household. The final models were both significantly better than the base models, the $R^2$ for the total VMT model was 14% for the base model and 17% for the total model, whereas the $R^2$ for the non-work VMT model was 15% for the base model and 20% for the total model. The total VMT is negatively influenced by the accessibility index and positively by the proportion of rectangular neighbourhood blocks. The non-work VMT is negatively related to a factor of intensity (a composite variable describing density and the intensity of different functions), the proportion of parcels with vertical mixing and the percentage of four way intersections. It is positively related to the percentage of rectangular blocks. The authors conclude from the study that there is some degree of credibility to the new urbanism claims.

Sun et al [1998] studied travel behaviour in relation to land use and socioeconomic characteristics in the Portland area. Using data from the Portland activity-travel survey they modelled this relationship using multivariate regression analysis. Land use characteristics included density, land use balance (an entropy based index) and accessibility measures. Socioeconomic characteristics included household size and income, vehicle ownership, dwelling type and tenure, number of years in current home and number of phone lines in household. The best model for number of trips included only socioeconomic explanatory variables and had a $R^2$ of 0.68. The model for vehicle miles travelled (VMT) did include land use variables. Land use balance and accessibility
were significantly related to VMT, together with a set of socioeconomic variables. The explained proportion of variance of this model was 0.37.

Røe [1999] studied travel behaviour of residents of Oslo. Travel data was collected through a telephone survey of 400 respondents in 30 residential areas. Land use variables included the distance from home to work, from home to the city centre and constructed variables representing the distance to the nearest private services (nearest grocery shop, shopping centre, restaurant/café, post-office, cinema, doctor etcetera) and the nearest public services. Socioeconomic variables included the number of children under 18 years, the number of cars, gender and household income. Regression analysis showed that 26% of variation in travel distance can be explained by the distance from home to work, the distance from home to the city centre, the distance to private services and the number of children in the household. 9% of variation in travel time can be explained by the distance from home to work and the distance to private services. The included socioeconomic variables were not significantly related to travel time.

A Dutch study [MuConsult, 2000] focussed on micro-level characteristics of the spatial environment. Travel behaviour data was collected from 713 respondents, while data on the urban environment was based on observances from the pollsters. The variables included characteristics of the neighbourhood, the street and the individual dwelling, as well as socioeconomic characteristics of the individuals and households. Multivariate regression was applied to the total number of trips and kilometres and the number of trips and kilometres by transport mode. The models presented in the report are not the best models, but models including all variables studied. R² varied from 8% to 40%, with best performance from the models for total travel and car travel and worst performance for the walk models. The report also listed the differences in R² between models including only individual and household characteristics and models including all explanatory variables. It was found that including spatial characteristics in the models significantly improved the explanatory power for almost all the dependent variables (except kilometres by bicycle). The added value (increase of R²) of including spatial variables ranged from 4 to 15%. The results showed that street type (home zone or 30 km zone), density and the ‘walk and cycle friendliness’ of the neighbourhood are spatial factors influencing the number of kilometres travelled, while street type and the accessibility of shopping facilities influence the number of trips. Interestingly, dwelling type and the presence of a garden were also influencing factors.
Dumbaugh et al [2001] looked at mixed land use neighbourhoods in an attempt to model internal capture rates. They studied 22 mixed-use developments in South Florida, varying in location, size and degree of mixing. Trips were defined as internal when they did not cross the Traffic Analysis Zone (TAZ) borders. As independent variables density, jobs/housing balance, commercial jobs balance, an entropy measure, retail jobs/population balance and accessibility measures were introduced. Regression analysis with internal capture rate as a dependent variable resulted in a model explaining 47% of the variation in the rate. Significant effects were found for density, the commercial jobs balance and the jobs/housing balance. The researchers concluded that neighbourhoods are most successful in internalising trips if they have a higher density, provide a commercial element and have a balance of jobs that reflects the balance of the overall region. Remarkable in this study is that the size of the neighbourhood was not included as an independent variable in the regression, while this variable is likely related to the internal capture rate.

3.5 Conclusions and Discussion

This summary of the vast amount of literature on the influence of urban form characteristics on travel behaviour demonstrates the ambiguity on this issue. It is very difficult to draw general conclusions. There seems to be not much discussion on which factors are potentially important. On all scales and in all types of studies three major factors keep reappearing; density, land use mix and transit access are considered most important.

The basic theoretical ideas start with these factors. Given that travel is the derivative of activity participation, distances between activity locations should be reduced to reduce travel. Increasing density and land use mix are seen as the basic measures to achieve this. Furthermore, the theoretical discussions focus on increasing attractiveness of alternative travel modes such as walking, cycling and transit. Transit access and better design of the urban environment (interconnected networks and attractive streets) are proposed as measures. Nevertheless, some critical remarks can be made with regard to these theoretical discussions. Shortening distances between urban functions will offer people the opportunity to reduce their travel time and costs. However, this does not automatically mean that people will behave accordingly. Other factors can influence people’s destination choices, factors that are not under control of land use planners.
Furthermore, it remains to be seen what people do with the time and money they save in more efficient urban settings. It is very likely that (part of) it will be used for additional activities and travel.

Similar remarks can be made with regard to model simulations. From comparisons between simulation and reality it becomes evident that there is a considerable discrepancy between the two. Since most simulation models are based on theories on how travel decisions are made, the comparisons with reality show that these theories are not always correct. Keeping this in mind, simulation studies seem to indicate that land use mix can yield positive effects while the same holds for poly-centric regional development.

The results of the empirical studies vary substantially, ranging from no influence to significant influence. However, there seems to be some agreement on the factors that are of influence. Increased density, land use mix, concentration of jobs, increased transit access and a decentralised urbanisation pattern for the urban region yield best results with regard to decreasing (motorised) mobility. Unfortunately, most of the studies lack methodological rigour. The studies comparing pairs of neighbourhoods at best provide only indicative results. Moreover, many studies did not control for any differences in sociodemographic characteristics, implying that it remains unclear whether differences in mobility and car use should be attributed to characteristics of urban form or to differences in sociodemographic characteristics. Also, many studies relied on data sets that were originally collected for other purposes, implying that the researchers’ opportunities to perform any rigorous analysis were limited from the very beginning.

If we focus on the much smaller sub-set of studies that at least have attempted to avoid the typical methodological pitfalls, it seems fair to say that spatial factors at best play only a limited and certainly a minor role. Explained variances tend to be small, and as we will argue later, significance may be over-valued. But even if we take the most positive view, the question remains to what extent the predominantly American studies can be generalised to the Netherlands, a country with a larger and more intense urban planning and urban design tradition, as can be seen in the previous chapter. Given the differences in scale and spatial and cultural organisation of cities, combined with the fact that the bicycle is an almost absent transport mode in many other countries, there are some a priori reasons for questioning such generalisability. Further research into the specific Dutch situation is therefore required.
4 | RESEARCH DESIGN

4.1 Introduction

The aim of this thesis, as discussed in chapter 1 and motivated in the previous chapter, is to empirically test the often assumed relationship between urban form and activity-travel patterns. It will be examined whether particular urban forms are associated with less car mobility than others. If so, urban form characteristics can contribute to a reduction in the growth of motorised mobility. In the previous two chapters, Dutch policies and the academic literature concerned with the relationship between urban form and mobility were discussed. This discussion led to the conclusion that there is mixed evidence on this assumed relationship. It is unclear whether the available positive evidence, mostly obtained in the United States, can be generalised to the Dutch situation. Moreover, the majority of the existing studies are potentially flawed in that their methodology has been weak. Three methodological flaws are most common. First, only few studies have systematically tried to rigorously disentangle the influence of sociodemographic variables and properties of the urban environment and transportation system on activity-travel patterns. Often, there is a strong empirical relationship between sociodemographic variables and neighbourhood characteristics, implying that any correlation between mobility patterns and neighbourhood characteristics might be spurious. Secondly, researchers have apparently not realised that the use of different levels of aggregation (individual, neighbourhood, city) in the same analysis directly impacts the significance levels of the estimated regression coefficients, which may lead them to draw the wrong conclusions. Thirdly, many studies only look at trips for specific travel motives, such as work or shopping. Effects found on these types of trips do not shed light on the effects on total travel over all motives. As we have seen in the previous chapter, this may be a critical issue. Time savings for one motive may induce people to make other trips.
In this thesis, we will avoid these potential methodological flaws by using a quasi-experimental design approach and applying multilevel analysis, a technique that deals with different levels of observation. In section 4.3, the potential flaws that need to be avoided are discussed in more detail. This is followed by a discussion of the principles underlying the data collection. The types of urban form characteristics to be included in the study are discussed next. The chapter finishes with a short summary of the research approach. To provide the right context for the design of this research project, we will first outline its conceptual framework.

4.2 Conceptual Framework: An Activity-Based Approach

To the best of our knowledge, existing studies into the relationship between urban form and mobility have typically looked at specific trip purposes as opposed to comprehensive activity-travel patterns. While trip-specific analysis has its own relevancy, it is not necessarily the best approach if the overall goal of the analysis is to assess the implications of urban design principles in terms of sustainability. For example, if urban design would be successful and reduce car use for the work commute, the car might be used by other members of the household for other purposes, thereby potentially even increasing total car mobility. Therefore, in this thesis, we decided to adopt a so-called activity-based approach. This means that the focus of the analysis is on the activity-travel patterns of individuals and households across a day. Information is collected about how various households members organise their daily activities in time and space and about the travel involved.

There are several reasons why an activity-based approach is preferred over other approaches for this and other types of analyses in transportation research. The activity-based approach is comprehensive, justifying the fact that travel and transport are rarely autonomous activities, but are the result of people wanting and needing to participate in activities that are spatially apart. Travel is a means to an end, and not an end in itself. Studying activities, therefore, is expected to give a more complete picture of an individuals’ travel behaviour. Another advantage of the activity-based approach is that it automatically covers all travel motives, including short trips and simple activities like posting a letter, since it looks at complete days. This means that the level of detail in reporting activities is probably better, implying that the reliability of the data is likely to be improved.
Following Chapin [1974], Hägerstrand [1970], and other scholars in the activity-based tradition (see for instance Timmermans [2000] and Axhausen and Gärling [1992]), we assume that new (and existing) urban areas constitute an environment for individuals and households to live in. The urban environment forms a stage for people to act their lives. In doing so, individuals and households try to meet their basic needs and personal preferences, while the environment they live in offers them opportunities and constraints to do so. The fulfilment of needs and preferences within the context of the urban environment results in activity participation of individuals and households. Since activities cannot all be conducted at the same location, individuals have to travel between activity locations. This means that activity participation leads to activity-travel patterns, which show not only what kind of activities are executed but also where, at what times and which transport modes are used.

![Conceptual Framework Diagram]

*figure 4.1 conceptual framework*
Figure 4.1 shows the conceptual framework underlying this study. It is important to know that individuals and household are assumed to organise their daily activity-travel patterns. Such patterns are primarily influenced by personal and household characteristics. For example, the presence of children in a household will induce particular activities and hence travel. Children need to go to school, may be involved in sports, etcetera. Likewise, the activity-travel pattern of a double-earner household is likely very different from the activity-travel pattern of an unemployed individual. Personal and household characteristics lead to particular needs and preferences, and hence induce particular activities that need to be conducted at particular locations.

The urban environment and transportation system offer opportunities to execute the activities. The availability of different transport modes presents options people can choose from. Likewise, the spatial distribution of work places, shops and other facilities directly determines how far people minimally have to travel to conduct their activities. Similarly, the attractiveness of these facilities will influence whether they choose the nearest location, or whether they will trade-off distance (or travel time) and attractiveness. The urban environment and transportation system, however, does not only provide opportunities, but also constrains behaviour. The possible speed on the network, jointly with factors such as opening hours of schools and stores, and working hours, determine the destinations that people can reach within some time horizon. Similarly, the absence of public transport or particular facilities, will restrict the available choice options in a particular neighbourhood.

The role of urban form in this complex conceptualisation is that particular forms, characterised in terms of variables such as urban shape, density, land use configuration and network types, may influence the spatial distribution of residences, jobs and facilities, and the relative accessibility of activity locations. As such, it potentially influences the opportunities and constraints offered by the urban environment.

As indicated in figure 4.1, travel patterns derived from activity patterns are the main focus of this study, hence the use of the term activity-travel patterns. They consist of trips and tours and their characteristics. From the perspective of sustainability, these patterns are considered ‘better’ when non-motorised or public transport modes are used in place of motorised modes and when they result in less kilometres travelled.
4.3 Methodological Principles

4.3.1 Quasi-Experimental Design Data

In the previous section, we have outlined the conceptual framework, underlying this study. This framework suggests that travel patterns and related mobility are the outcome of a highly complex decision-making process in which individuals and households try to realise their individual and group needs and preferences within the opportunities and constraints offered by the urban environment, the transportation system, and the institutional context. People will adjust their behaviour to their environment, and the environment, unless planning intervention dictates otherwise, will adjust to people's behaviour. In case of a disequilibrium, people will consider to move elsewhere or dramatically change their activity-travel patterns.

Given this complexity, a methodologically sound analysis of the relationship between urban form and activity-travel patterns is certainly not straightforward. Many potential pitfalls are encountered. For example, if public transport is absent or poor in a particular neighbourhood, people depending upon this means of transport may decide not to move to this neighbourhood. Hence, there will be selection bias. Likewise, older, central, high-density neighbourhoods with lower rents are occupied relatively more by unemployed or lower income households, who may have a lower mobility profile. If this is true, it means that an analysis, regressing density or centrality against mobility, may lead to spurious results. Lower distance to work statistics in such neighbourhoods are not the result of urban design characteristics but the result of the specific distribution of the unemployed. The association between neighbourhood characteristics and mobility will (partly) disappear if the researcher controls for unemployment. Similarly, the conclusion that people living in suburban neighbourhoods drive longer distances for their non-daily shopping needs is likely tautological as they probably do not have any other option.

The fundamental problem here is that personal and household characteristics may be strongly related to neighbourhood characteristics, implying that they should be controlled if the aim of the analysis is to understand the influence of neighbourhood characteristics on transport mode choice and travel patterns. Or, as stated by Kitamura et al [1997] the question is “Is the observed association between travel and land use real, or is it an artifact of the association between land use and the multitude of demographic,
socioeconomic, and transportation supply characteristics which also are associated with travel?".

In principle, and evidenced in many empirical studies (see e.g., Næss [1995], Kitamura et al [1997], Cervero [1988] and Cervero and Kockelman [1997]), both neighbourhood characteristics and sociodemographic variables may be incorporated in a single regression model. It is well-known, however, that high correlations between these explanatory variables may lead to biased parameters estimates, which under extreme circumstances, may even be of the wrong sign. Hence, methodologically, it is preferable to select neighbourhoods such that the associations between neighbourhood characteristics, including relative location, and a set of sociodemographic variables are very low. This is the principle, underlying quasi-experimental design data. This principle was used in the present study.

4.3.2 Controlling for Bias Due to Scale Differences

In an attempt to estimate the effects of both sociodemographic variables and neighbourhood characteristics, several studies (e.g., Cervero and Kockelman [1997], Hanson [1982], Næss [1995]) have used neighbourhood characteristics as explanatory variables at the individual levels. This practice, however, may lead to largely ignored biases. The analysis of variables that relate to different scales of measurement (e.g. individuals versus neighbourhoods) creates specific statistical problems. The disaggregation implies that the sample size is arbitrarily increased. Consequently, because standard errors are arbitrarily reduced, significance tests will more often reject the null hypothesis than the nominal alpha level suggests. Thus, these studies may have concluded that the results are statistically significant, whereas in reality they are not.

To avoid this problem, the present study uses a multilevel model for its analyses. To explain multilevel analysis, consider the relationship between the number of trips a person makes on a certain weekday and a single individual level independent variable (say, work status) within a single, hypothetical neighbourhood. Assuming this relationship is linear, the regression equation for this relationship would be:

\[ Y_i = \beta_0 + \beta_1 X_i + r_i \] (1)
where

\[ Y_i = \text{the number of trips by individual } i \]
\[ X_i = \text{the work status of individual } i \ (\cdot 0 \cdot = \text{unemployed, } 1 \text{ employed}) \]
\[ \beta_0 = \text{the expected number of trips for an unemployed individual } i \]
\[ \beta_1 = \text{the expected change in the number of trips for an employed individual } i \]
\[ r_i = \text{the error term, representing a unique effect associated with individual } i \]
\[ \text{normally distributed with a mean of zero and variance } \sigma^2 \]

Now, consider individuals distributed across neighbourhoods. The relationship between the number of trips and individual work status in each neighbourhood \( j \) can then be described by the following equation:

\[
Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + r_{ij} \quad (2)
\]

The subscript \( j \) is added to the equation to allow each neighbourhood to have a unique intercept and slope.

Let us now assume that the neighbourhoods vary with regard to their mix of land uses. This can be included in the equation as follows:

\[
\beta_{0j} = \gamma_{00} + \gamma_{01}W_j + u_{0j} \quad (3)
\]
\[
\beta_{1j} = \gamma_{10} + \gamma_{11}W_j + u_{1j} \quad (4)
\]

where

\[ \gamma_{00} = \text{the mean number of trips for an unemployed individual in a mono-functional neighbourhood (the intercept for level 1)} \]
\[ \gamma_{01} = \text{the mean difference in number of trips between mono-functional and multi-functional neighbourhoods (the slope for level 1 intercept)} \]
\[ \gamma_{10} = \text{the average work status slope in mono-functional neighbourhoods (the intercept for the level 1 slope)} \]
\[ \gamma_{11} = \text{the mean difference in work status slopes between mono-functional and multi-functional neighbourhoods (the slope for the level 1 slope)} \]
\[ W_j = \text{land use in neighbourhood } j \]
\[ u_{0j} = \text{the unique effect of neighbourhood } j \text{ on the mean number of trips, holding } W_j \text{ constant} \]
\[ u_{ij} = \text{the unique effect of neighbourhood } j \text{ on the work status slope, holding } W_j \text{ constant} \]

It is assumed that \( u_{0j} \) and \( u_{1j} \) are random variables with zero means, variances \( \tau_{00} \) and \( \tau_{11} \) respectively, and covariance \( \tau_{01} \). These variance-covariance components are conditional variance-covariance components. They represent the variability in \( \beta_{0j} \) and \( \beta_{1j} \) remaining after controlling for \( W_j \). Substituting equations 3 and 4 in equation 2 yields:

\[
Y_j = \gamma_0 + \gamma_{0j} W_j + \gamma_{10} X_{ij} + \gamma_{11} W_j X_{ij} + u_{0j} + u_{1j} X_{ij} + r_{ij}
\]

In this equation we consider the first part \( (\gamma_0 + \gamma_{0j} W_j + \gamma_{10} X_{ij} + \gamma_{11} W_j X_{ij}) \) as the fixed part of the model, and the second part \( (u_{0j} + u_{1j} X_{ij} + r_{ij}) \) as the random part of the model. This is the basis for multilevel analysis or hierarchical linear modelling.

Although it is possible to discern more than two levels in a multilevel analyses, we identified two levels in our analyses. One level for the socioeconomic variables describing the individual and the household he or she is part of, and one level for the spatial variables describing the characteristics of the neighbourhood and the city. In reporting the multilevel analyses (chapters 6 and 7), these levels are referred to as the individual and neighbourhood level. In theory, the city and the household could have been entered in the analyses as separate levels. However, there were several reasons not to do so. In general, the introduction of a third of even fourth level would have dramatically increased the total number of coefficients, including the interactions between the levels. Because the sample size is modest, this would mean that the number of observations to estimate each coefficient is rather small. This consideration, in combination with the fact that for most of the households (86%) only 1 or 2 diaries are available and that the arbitrary increase of observations is therefore limited, led to the decision not to include the household as a separate level. The city was not included as a separate level because the data only included 9 cities. Including a separate city level would mean that at this level the model would be fitted based on only 9 observations.

4.3.3 Avoiding Partial Analysis

One of the advantages of an activity-based conceptualisation is that it draws the attention to comprehensive activity-travel patterns. The analysis of transport mode choice and
distance travelled for specific motives at best only provides a partial answer to the mobility effects of alternative urban designs, and a misleading answer in the worse case. If a car is not used for the work commute, it may be used by other household members for other activities. If work is located close to home, people may decide to have lunch at home during their lunch break. Mixed land use with ample parking may lead people to additional, car-based activities. Perfect accessibility to job locations may lead people to decide to choose a house further away from work, possibly increasing travel for non-work activities. Or the reduction of the time required to go to work may induce people to become involved in more social and leisure activities (Harvey, 2000). Other, similar examples can easily be developed.

These examples do not only raise theoretical doubt about the typically rather simple, one-dimensional argumentation underlying common urban planning and transportation policies, they also indicate the need for a more comprehensive analysis of the total activity-travel patterns of households. Another methodological principle underlying this thesis is therefore to analyse data from activity-travel patterns collected from households, in addition to the more commonly used analysis of travel for specific activities. This analysis allows us to examine whether the findings obtained for single activities still hold if the focus of attention shifts to complete activity-travel patterns.

4.3.4 Avoiding Under-Reporting of Trips

If the goal of the analysis is to have a good understanding of all travel, the data collection instrument should not introduce a bias in the reporting of particular kinds of trips. Information of this kind can be obtained by several ways of data collection, e.g. the traditional questionnaire and the diary [Ettema and Timmermans, 1996]. When using a questionnaire, respondents are typically requested to recall their activities and/or travel decisions. The diary method involves a more systematically prepared and more detailed report about the respondents’ travel behaviour and activities. Respondents are requested (if possible instantaneously) to record information on activities and travel for one or more days. Usually, aspects such as start and end time, location, travel time, travel mode and type of activity are recorded. Two types of diaries can be distinguished: travel diaries and activity diaries. In travel diaries, respondents report the trips made and trip characteristics, while activity diaries focus on activities and consider travel as a derivative.
It has been increasingly recognised that activity diaries offer some potential advantages over conventional transport surveys. For example, Clarke et al [1981] concluded that the use of a format in which participants discussed travel in the context of the day’s activities seems to provide the closest correspondence with the natural storing of information and the planning of activities. Conversely, the conventional trip survey would seem the least satisfactory means of eliciting travel information. The format asking the respondent which trips were made during the period of time under investigation neither ensures that all travel is recorded nor defines the researcher’s notion of trip to the respondent. A questionnaire format with a focus on an average day may result in an under-reporting of trips. There is substantial empirical evidence that travel surveys under-report especially off-peak, non-home based trips of short duration (e.g., Meyburg and Brög, 1981; Dijst, 1993). Thus, Stopher [1992] argued that an activity diary outperforms a travel diary and travel surveys in that short, non-home-based trips are no longer under-reported. This is consistent with the findings of Clarke et al [1981] who reported that the activity diary indicated a significantly higher level of trip making than the travel survey. This finding holds especially for discretionary trips. Compulsory trip purposes did not vary significantly between the methods of data collection.

Similar differences in degree of reporting have also been found in time use studies (e.g., Niemi, 1993). On the other hand, there is also evidence of a systematic under-reporting of walking trips and an under-reporting of walking segments on trips involving more than one mode in diary data. People tend to overlook short, non-vehicular trips with increasing incidence during the diary period [Golob and Meurs, 1986; Murakami and Watterson, 1992]. Given the available empirical evidence, it was decided to develop and use an activity-travel diary. Special care was given to remind respondents not to forget to report their walking trips.

There are several options to administer activity diaries. They can be self-administered or completed by interviewing. Face-to-face interviewing is the most expensive way of data collection, but tends to result in higher response rates and less item non-response than self-administered mail-back surveys. The latter are less costly, yield good quality data and are less susceptible to socially desirable responses, but have the disadvantages of lower response, higher item non-response and difficulties in explaining more complicated tasks. Telephone interviewing is the intermediate between these two types of data collection. Traditionally, questionnaires are of the paper-and-pencil type. However, computer administered questionnaires are also an option. Although computer-
administered questionnaires save time and reduce errors in data processing, they have not been proven to yield better data than paper-and-pencil questionnaires [Ettema and Timmermans, 1996]. Given these considerations and limited financial resources, it was decided to opt for the least expensive method of data collection, the paper-and-pencil mail-back diary. Chapter 5 provides further details about the data collection.

4.4 Conclusions

The research approach adopted in this thesis attempts to deal with a number of potential methodological flaws that emerged from our evaluation of the literature on the relationships between urban form and travel, as discussed in chapter 3. In particular, the following key methodological principles were developed. First, to avoid the problem that a partial analysis of travel patterns by motive may lead to invalid conclusions regarding the overall effects of urban design on mobility, we decided to adopt an activity-based conceptual framework. The basic assumption underlying the activity-based approach is that individuals and households try to meet their basic needs and personal preferences by participating in activities, while the environment they live in offers them opportunities and constraints to do so. According to this approach, travel is the result of the fact that locations for conducting activities are spatially distributed. The activity-based approach is a comprehensive approach, including all travel motives. It is also, by definition, a disaggregate approach focussing on individuals and households.

The advantage of an activity-based approach is that it recognises the fact that travel patterns are the outcome of a highly complex interplay between personal and household characteristics, and features of the urban environment, the transportation system, and the institutional context. It forces the researcher to seek for a more sophisticated methodology to disentangle these effects and avoid as much as possible tautological and/or spurious results. The second methodological principle adhered to in the present study concerns an attempt to collect quasi-experimental design data.

Thirdly, in order to avoid significant coefficients, which in reality are not, we decided to use a multilevel analysis for the tests in this thesis. Multilevel analysis incorporates the fact that the scale of the various units of measurement differ.
In order to examine activity-travel patterns, data about these patterns are required. Activity/travel diaries are considered the best way to obtain these data as they are less sensitive to an under-reporting of particular trips. Therefore, the key data analyses in this study are based on an activity diary. In the next chapter, the data collection is discussed in more detail.
5 | DATA ISSUES

5.1 Introduction

In the previous chapter, the research approach underlying this thesis was discussed. The activity-based approach forms its basis and a quasi-experimental design will be used to select the neighbourhoods for data collection. In this chapter, the research approach will be further operationalised. Various aspects of data and data collection will be addressed. First, the process of data collection, the choice of locations and the design of the questionnaire, will be described. This is followed by a discussion of the response, the characteristics of respondents and the quality of the data. The chapter will finish with an operationalisation of urban form characteristics and socioeconomic variables to be included in the analyses that follow.

5.2 Choice of Locations

The choice of locations for data collection is essential for the quasi-experimental design chosen in this thesis. This section discusses the selection of suitable locations in order to approximate the quintessence of the quasi-experimental design. First, aspects of urban form will be explained, relevant for this purpose. Based on this, a number of cities will be chosen for inclusion. Within these cities, actual locations (neighbourhoods) will be selected and their main features will be outlined. Cities and neighbourhoods will be chosen from medium-sized Dutch cities. In the Netherlands a medium-sized city typically has between 80,000 to 250,000 inhabitants and a mixed supply of jobs, shops and other facilities and services. These cities are the home to almost 1/3 of the Dutch population and since they have the task to develop the majority of new houses that will be needed in the next 2 decades, they are most interesting for our purposes.
5.2.1 Relevant Elements of Urban Form

In order to select the locations for data collection it must be clear what these locations need to represent. It is therefore necessary to make explicit the aspects of urban form on the basis of which locations have to be selected. Morphological characteristics of urban form, such as urban shape and transportation network types, are considered most definite, especially on the scale of the city as a whole. Lower scale characteristics, such as land use mix and density of a neighbourhood are less relevant for location selection since they show much more variation across neighbourhoods. It was decided to use the characteristics urban shape and transportation network type of the city as the basis to select cities. In the next subsections these criteria will be operationalised.

5.2.2 Urban Shape

Morphology is probably most frequently associated with urban form. Some historic concepts are largely based on the choice of the morphological form of the city, for instance the finger shaped city (Copenhagen) or the linear city (Ciudad Lineal). Based on the literature on historic and more recent urban forms and shapes [Rottier, 1980; de Klerk, 1980], we have identified six different urban shapes (figure 5.1). These are the concentric city (1), the lobe city (2), the linear poly-nuclear city (3); the concentric poly-nuclear city (4), the linear city (5) and the grid city (6). In the selection of locations for data collection four city types, viz. the concentric city, the lobe city, the poly-nuclear city and the grid city, were included. With this choice, the linear and grid city types are comprised in one, as well as the linear and concentric poly-nuclear city types.

![Urban Shapes](image)

The concentric city is a morphological form that occurs often in the Netherlands. It is the typical form of a city that has grown from a small (historic) centre along a number
of radial exit roads. Through the years the areas between the radial roads have been filled in and the city has grown into its concentric form. This city shape often comes with a radial road network, based on the historic routes, but there are also combinations possible with ring and grid networks. Often these cities are quite compact and have a strong centre with a mixed supply of facilities. Examples of this city form in the Netherlands are, among others, Apeldoorn, Enschede and Zoetermeer.

The lobe city has an urban morphology that often has a similar history as the radial concentric city. The main difference is that in lobe cities the infill of the areas between the radial exit roads has concentrated on just some of them. The lobe shape can also be the result of the fact that the exit roads have only stretched out in some directions or it can be the result of intentional city planning. Examples of this city form in the Netherlands are, among others, Amsterdam, Eindhoven and Arnhem.

The morphology of poly-nuclear cities can develop in two very different ways. Either, a number of smaller settlements, located close to each other, start to function as one city, or a city is actually designed as a poly-nuclear city. The only example of a true poly-nuclear city in the Netherlands is Almere.

The grid city is the collective noun for cities with a more or less rectangular shape. The linear city can be viewed as an extreme version of this city type. These cities often have a grid-type transportation network for the car, but this is not necessarily the case. In the Netherlands, there are no examples of linear cities. Examples of the grid city type are Leeuwarden, Haarlem and Den Haag.

5.2.3 Transportation Networks

The second basic element is the transportation network. In theory, networks for motorised transport (the road network for the car), non-motorised transport (the network for bicycles and/or pedestrians) and for public transport can be distinguished. However, since not all cities have separate networks for non-motorised transport and the public transport networks in all cities are very similar (most Dutch medium-sized cities have a radial bus network with tangential lines), only networks for motorised transport were considered for the choice of locations. In order to identify different network types, Bolt's study [1982] on urban form and transportation is very useful. Bolt distinguishes between two principle network forms, the square network and the triangle network (a corrupted
depiction of the ‘ideal’ circular network). Based on these two principles five elementary networks can be derived: the linear network (1), the radial network (2), the ring (3), the grid (4) and the shifted grid (5) (figure 5.2). These different network types can be suitable for different transportation modes. In the selection of locations for data collection three network types were included, viz. the radial network, the ring network and the grid network. The linear network was not included since it is a rather extreme network type that hardly occurs in actual cities. Furthermore, the grid and shifted grid networks were comprised into one. Each network type has its specific properties, which will be reflected on shortly.

The radial network is a network type that is suitable for all transportation modes. In the Netherlands, it is the classic network for urban public transport, where busses radiate to and from the city centre/railway station. When used as a network for the other transport modes it offers direct access to the city centre. However, this network type is also prone to congestion problems. In theory, it can be applied to all urban shapes as described in the previous section.

The ring network type is frequently used in the Netherlands, mainly as a network for motorised transport. It offers the opportunity to concentrate a large amount of traffic on a single road, while relieving other roads of traffic nuisance. Especially city centres are often enclosed by a ring structure. This network type is not common for public transport in medium-sized cities, although it would provide good connections between city districts while avoiding a trip to and from the city centre. For motorised and non-motorised transport this network type can be applied to all urban shapes, for public transport this network type is especially suitable for (concentric) poly-nuclear cities.
The (shifted) grid network is a network type that is simple and direct, offers many choices for routes and disperses traffic over many streets. Disadvantages of this network type are the many road crossings in the system and the difficulty to concentrate facilities. It is mainly used for motorised and non-motorised transport and is only useful for public transport when a city has high densities and can therefore support a fine meshed public transport system. In theory, this network type is flexible and can be applied to all urban shapes.

5.2.4 Locations

The choice of locations for data collection was made in two steps. First a number of cities was selected that reflect differences in urban shapes and network types for the main road system for motorised transport, as they have been identified in the previous sections. Next, within these cities, neighbourhoods were selected.

The four urban shapes and three network types for motorised transport that were identified for use in location selection form a matrix. This matrix was filled, as far as possible, by selecting Dutch medium-sized cities.

<table>
<thead>
<tr>
<th></th>
<th>concentric city</th>
<th>lobe city</th>
<th>poly-nuclear city</th>
<th>grid city</th>
</tr>
</thead>
<tbody>
<tr>
<td>radial network</td>
<td>Enschede</td>
<td>Arnhem</td>
<td>Eindhoven</td>
<td></td>
</tr>
<tr>
<td>ring network</td>
<td>Zoetermeer</td>
<td>Eindhoven</td>
<td>Almere</td>
<td>Leeuwarden</td>
</tr>
<tr>
<td>grid network</td>
<td>Apeldoorn</td>
<td></td>
<td></td>
<td>Haarlem</td>
</tr>
</tbody>
</table>

As shown in table 5.1 it was not possible to fill all cells of the matrix. Several combinations of urban shape and main network type for motorised transport are in theory possible but not logical and therefore do not occur in the Netherlands. Furthermore, there is only one poly-nuclear city in the Netherlands (Almere) and this city has a ring network. Consequently, it is not possible to look at the other network types in combination with a poly-nuclear city. Finally, the main network for motorised transport in Eindhoven shows distinct characteristics of both a radial and a ring network. In the southern part of the city the ring network type is dominant, while in the northern
part of the city the radial network type is dominant. This difference will be reflected in the choice of neighbourhoods within the city.

After selecting the cities, neighbourhoods within these cities were selected. In order to choose neighbourhoods that represent the diversity of a Dutch medium-sized city several dominant urban elements were considered. Neighbourhoods should vary with regard to their location in relation to several land use types. The following were chosen: the

<table>
<thead>
<tr>
<th>city</th>
<th>neighbourhood</th>
<th>distance to city centre</th>
<th>distance to main train station</th>
<th>distance to sub-centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almere</td>
<td>Muziekwijk</td>
<td>2-3 kms</td>
<td>3 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Regenboogbuurt</td>
<td>5-6 kms</td>
<td>6 kms</td>
<td>-</td>
</tr>
<tr>
<td>Apeldoorn</td>
<td>Matenveld/Matendonk</td>
<td>3-4 kms</td>
<td>4 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Utrecht</td>
<td>4-5 kms</td>
<td>5 kms</td>
<td>-</td>
</tr>
<tr>
<td>Arnhem</td>
<td>Presikaaf</td>
<td>3-4 kms</td>
<td>5 kms</td>
<td>1 kms</td>
</tr>
<tr>
<td></td>
<td>Alteveer/Cannevelv</td>
<td>2-3 kms</td>
<td>3 kms</td>
<td>-</td>
</tr>
<tr>
<td>Den Haag</td>
<td>Centrum</td>
<td>0-1 kms</td>
<td>2 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Beresteijn</td>
<td>5-6 kms</td>
<td>4 kms</td>
<td>2 kms</td>
</tr>
<tr>
<td></td>
<td>Voorburg Eesesteijn</td>
<td>3-4 kms</td>
<td>6 kms</td>
<td>2 kms</td>
</tr>
<tr>
<td>Eindhoven</td>
<td>Stratum</td>
<td>1-2 kms</td>
<td>2 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Achtse Barrier</td>
<td>5-6 kms</td>
<td>6 kms</td>
<td>3.5 kms</td>
</tr>
<tr>
<td>Enschede</td>
<td>Stadsveld/Bruggert</td>
<td>2-3 kms</td>
<td>3 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Helmerhoek Zuid</td>
<td>4-5 kms</td>
<td>5 kms</td>
<td>-</td>
</tr>
<tr>
<td>Haarlem</td>
<td>Amsterdamse buurt/Slachthuisbuurt</td>
<td>1-2 kms</td>
<td>2 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Schalkwijk Zuid</td>
<td>3-4 kms</td>
<td>4.5 kms</td>
<td>1.5 kms</td>
</tr>
<tr>
<td>Leeuwarden</td>
<td>Centrum</td>
<td>0-1 kms</td>
<td>1 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Camminghaburen</td>
<td>3-4 kms</td>
<td>4.5 kms</td>
<td>-</td>
</tr>
<tr>
<td>Zoetermeer</td>
<td>Centrum</td>
<td>0-1 kms</td>
<td>2 kms</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Rokkeveen</td>
<td>2-3 kms</td>
<td>1 kms</td>
<td>-</td>
</tr>
</tbody>
</table>

- no sub-centre is available or the distance to a sub-centre exceeds the distance to the city centre
location of the neighbourhood in relation to the city centre, to the main IC-train station and, if present, to a sub-centre of services at the city district level. The city centre was regarded as a focal point and neighbourhoods were selected in each city in 1 kilometre wide rings from this centre. Per city, chosen neighbourhoods were dispersed over the city. A list of 5 or 6 neighbourhoods per city was drawn up. The final choice was based on the following considerations: 1) two neighbourhoods per city to obtain an even distribution over the cities; 2) aggregated over all cities at least two neighbourhoods in every ring from the city centre and 3) the best possible combinations with regard to the other urban form characteristics. Ultimately, 19 neighbourhoods were chosen for data collection (see table 5.2). Appendix 2 gives an overview of each city and neighbourhood and their characteristics.

The characteristics of the chosen neighbourhoods were tested for mutual correlations, to check if the chosen neighbourhoods actually allow us to better test the relationships between characteristics of the urban environment and activity-travel patterns. Correlations were calculated for 11 characteristics of urban form: urban shape, city road network type, neighbourhood road network type, local street network type, employment (number of jobs/businesses), location of city within the Netherlands (inside or outside the Randstad Holland), distance from the neighbourhood to the city centre, distance from the neighbourhood to the IC-station, distance from the neighbourhood to a sub-centre of services and degree of urbanisation (neighbourhood and city). Definitions of these characteristics are given in section 5.5.

Results are listed in table 5.3. Different association measures (Pearsons correlation coefficient, symmetric lambda and eta coefficient) were used, depending on the type of variables the association was calculated for. The results were quite satisfactory. Most characteristics are not mutually associated. Only a few characteristics show correlations that exceed a value of 0.5. Distance to city centre and to IC-station are highly correlated (0.845). This can easily be explained by the fact that the main train station is usually (but not always) located in the city centre. Furthermore, the distance to a sub-centre is correlated with the network type neighbourhood ($\varepsilon^2 = 0.857$) and with the degree of urbanisation of the neighbourhood ($\varepsilon^2 = 0.953$). Finally, urban shape is related to the city’s employment level ($\varepsilon^2 = 0.766$).
### Table 5.3 Associations between Neighbourhood Characteristics (n=19)

<table>
<thead>
<tr>
<th></th>
<th>netw. type city</th>
<th>netw. type nghbh</th>
<th>street netw. type</th>
<th>empl. location</th>
<th>dist. to city centre</th>
<th>dist. to ic-station</th>
<th>dist. to sub centre</th>
<th>degree of urbanis. neighbh</th>
<th>degree of urbanis. city</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban form</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$\varepsilon^2 = .77$</td>
<td>ns</td>
<td>$\varepsilon^2 = .06$</td>
<td>$\varepsilon^2 = .06$</td>
<td>$\lambda = .39$</td>
<td>$\lambda = .43$</td>
</tr>
<tr>
<td>Network type city</td>
<td>$\lambda = .42$</td>
<td>ns</td>
<td>$\varepsilon^2 = .07$</td>
<td>ns</td>
<td>$\varepsilon^2 = .12$</td>
<td>$\varepsilon^2 = .17$</td>
<td>$\varepsilon^2 = .06$</td>
<td>ns</td>
<td>$\lambda = .48$</td>
</tr>
<tr>
<td>Network type nghbh</td>
<td>ns</td>
<td>$\lambda = .15$</td>
<td>$\varepsilon^2 = .35$</td>
<td>ns</td>
<td>$\varepsilon^2 = .14$</td>
<td>$\varepsilon^2 = .26$</td>
<td>$\varepsilon^2 = .86$</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Street network type</td>
<td>ns</td>
<td>ns</td>
<td>$\varepsilon^2 = .43$</td>
<td>ns</td>
<td>$\varepsilon^2 = .48$</td>
<td>$\varepsilon^2 = .44$</td>
<td>$\varepsilon^2 = .10$</td>
<td>$\lambda = .38$</td>
<td>ns</td>
</tr>
<tr>
<td>Empl. location</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$\varepsilon^2 = .40$</td>
<td>ns</td>
<td>ns</td>
<td>$\varepsilon^2 = .04$</td>
<td>$\varepsilon^2 = .32$</td>
<td></td>
</tr>
<tr>
<td>Distance to city centre</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$\varepsilon^2 = .01$</td>
<td>$\varepsilon^2 = .02$</td>
<td>$\varepsilon^2 = .06$</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Distance to ic-station</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
</tr>
<tr>
<td>Distance to subcentre</td>
<td>ns</td>
<td>$\varepsilon = .95$</td>
<td>$\varepsilon = .10$</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
<td>$n$s</td>
</tr>
<tr>
<td>Degree of urbanis. neighbh</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$n$s</td>
<td>ns</td>
</tr>
<tr>
<td>Degree of urbanis. city</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>$n$s</td>
<td>ns</td>
</tr>
</tbody>
</table>

$ns = not significant$

### 5.3 Design of the Questionnaire

The activity diary questionnaire consisted of several parts, one of which was the actual activity diary, the core of the questionnaire (figure 5.3). For each successive activity in a two day period, respondents were asked to provide information about i) the kind of activity, ii) the day, start and end time, iii) the location where the activity was conducted,
Urban Form and Activity-Travel Patterns

<table>
<thead>
<tr>
<th></th>
<th>What is the number of this activity in the memory jogger?</th>
<th>ACTIVITY NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Within what category falls this activity?</td>
<td>activity category</td>
</tr>
<tr>
<td>3</td>
<td>Where did you conduct this activity?</td>
<td>location:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>address:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>postal code/city:</td>
</tr>
<tr>
<td>4</td>
<td>How did you reach this location?</td>
<td>mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>time in minutes</td>
</tr>
<tr>
<td>5</td>
<td>How much did parking your car cost?</td>
<td>not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parking was free</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parking cost fl.</td>
</tr>
<tr>
<td>6</td>
<td>How did you park your bicycle?</td>
<td>not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unguarded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>guarded, for free</td>
</tr>
<tr>
<td></td>
<td></td>
<td>guarded, costs fl.</td>
</tr>
<tr>
<td>7</td>
<td>Did you conduct this activity together with others?</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>(multiple answers allowed)</td>
<td>yes, with member(s) of my household</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yes, with other people</td>
</tr>
<tr>
<td>8</td>
<td>Did you have to wait before starting this activity?</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yes, minutes</td>
</tr>
<tr>
<td>9</td>
<td>Did you know this morning that you were going to conduct this activity?</td>
<td>no</td>
</tr>
<tr>
<td>10</td>
<td>Could you have conducted this activity at another time today? If so, how many hours/minutes earlier/later?</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yes, up to minutes earlier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>up to minutes later</td>
</tr>
<tr>
<td>11</td>
<td>Could you have postponed this activity to another day? If so, how many days?</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yes, days later</td>
</tr>
<tr>
<td>12</td>
<td>Could someone else in your household have conducted this activity in your place? (please record first name)</td>
<td>not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td>yes, first name</td>
</tr>
<tr>
<td>13</td>
<td>When did you last conduct this activity before today?</td>
<td>day(s) ago</td>
</tr>
</tbody>
</table>

* strike out whichever is not applicable

figure 5.3  example of activity recording form
iv) the transport mode(chain) and travel time per mode, v) accompanying individuals (alone, other member of household, other), vi) whether the activity was planned and vii) whether the activity could have been done on another day or time or by somebody else. To avoid that respondents were not familiar with a particular way of defining locational information, they could indicate where an activity was conducted by reporting zip codes, street address and/or name of the building. Open time intervals were used to report the start and end times of activities. A pre-coded scheme was used for activity reporting (table 5.4). Choices where made based on the discussion of diary questionnaire options in Ettema and Timmermans [1996].

In another part of the questionnaire, information was collected on trips for a number of frequent activities. These included working, shopping and recurring leisure activities. Traditional studies into travel behaviour often focus on these motive specific trips. In this study both motive specific data and complete activity-travel pattern data were collected and analysed.

<table>
<thead>
<tr>
<th>number</th>
<th>activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>work and/or school</td>
</tr>
<tr>
<td>2.</td>
<td>medical care (doctor, dentist, etc.)</td>
</tr>
<tr>
<td>3.</td>
<td>services (post-office, bank, etc.)</td>
</tr>
<tr>
<td>4.</td>
<td>grocery shopping, other shopping, library, video store, take-out food</td>
</tr>
<tr>
<td>5.</td>
<td>sports</td>
</tr>
<tr>
<td>6.</td>
<td>other organised activities (church, club, etc.)</td>
</tr>
<tr>
<td>7.</td>
<td>social activities (visit family/friends)</td>
</tr>
<tr>
<td>8.</td>
<td>leisure activities (go out to diner, go for a walk, visit pub, etc.)</td>
</tr>
<tr>
<td>9.</td>
<td>bringing/taking someone or something</td>
</tr>
<tr>
<td>10.</td>
<td>other activities out-of-home</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>number</th>
<th>activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>11a.</td>
<td>sleep, personal care</td>
</tr>
<tr>
<td>11b.</td>
<td>eating (breakfast, lunch, diner)</td>
</tr>
<tr>
<td>11c.</td>
<td>domestic work (including DIY, gardening, washing car, etc.)</td>
</tr>
<tr>
<td>11d.</td>
<td>having guests</td>
</tr>
<tr>
<td>11e.</td>
<td>work at home (for job)</td>
</tr>
<tr>
<td>11f.</td>
<td>study/do homework</td>
</tr>
<tr>
<td>11g.</td>
<td>volunteer work</td>
</tr>
<tr>
<td>11h.</td>
<td>leisure activities (reading, watching TV, listen to music, etc.)</td>
</tr>
<tr>
<td>11i.</td>
<td>other activities in-home</td>
</tr>
</tbody>
</table>
This way, differences between both approaches can be brought to light. For each of the activities, respondents were asked to report when and where these activities are usually performed, what the origin(s) of the trips to these locations is/are, which transportation modes are used and what the travel time is.

The last part of the questionnaire focussed on various individual and household characteristics. The information collected included year of birth, gender, level of education, personal income, possession of a driver’s license, type of dwelling, and availability of transport modes.

5.4 Response and Respondents

In each neighbourhood 300 randomly selected households received a letter requesting their participation in the project. The letter explained the scope of the research project and briefly described the task respondents had to perform. Households that responded positively received a package containing as many questionnaires as there were individuals aged 13 years and over in the household. The number of positive responses to the letter requesting a households participation in the project varied widely across neighbourhoods, resulting in different numbers of questionnaires being send out to different neighbourhoods. 355 households returned 586 individual questionnaires.

5.4.1 Response Rates

Earlier it has been argued that diary data potentially yields a more detailed recording of activities and related travel. However, the completion of diary questionnaires is rather demanding and could therefore result in higher non-response rates. This section looks at the response rates by geographical origin and by spatial and sociodemographic characteristics.

The response rates for households for the 9 cities included in the data collection varied between 47% and 78%, as shown in table 5.5. To test for any significant differences between these response rates, a probit regression analysis using effect coding was conducted. Dummy variables for each of the cities were used as independent variables. The results indicate that the response rate was significantly lower in Almere and
Data Issues

Table 5.5: Response rates by city of those willing to participate after initial contact

<table>
<thead>
<tr>
<th>City</th>
<th>Response Rate</th>
<th>City</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#%</td>
<td></td>
<td>#%</td>
</tr>
<tr>
<td>Almere</td>
<td>30 46.9%</td>
<td>Enschede</td>
<td>22 50.0%</td>
</tr>
<tr>
<td>Apeldoorn</td>
<td>61 68.5%</td>
<td>Haarlem</td>
<td>27 62.8%</td>
</tr>
<tr>
<td>Arnhem</td>
<td>53 77.9%</td>
<td>Leeuwarden</td>
<td>44 65.7%</td>
</tr>
<tr>
<td>Den Haag</td>
<td>41 51.3%</td>
<td>Zoetermeer</td>
<td>29 52.7%</td>
</tr>
<tr>
<td>Eindhoven</td>
<td>48 57.1%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.6: Probit estimates of city characteristics (n=594)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>-0.01263</td>
<td>-0.112</td>
</tr>
<tr>
<td>Degree of urbanisation</td>
<td>0.05207</td>
<td>0.386</td>
</tr>
<tr>
<td>Population size</td>
<td>0</td>
<td>-0.971</td>
</tr>
<tr>
<td>Employment</td>
<td>0.00141</td>
<td>1.476</td>
</tr>
</tbody>
</table>

Significantly higher in Arnhem (5% probability level). Another probit regression analysis was performed to estimate the effect of location within the Netherlands (inside or outside the Randstad Holland), the degree of urbanisation, population size and employment of each city. These results are listed in table 5.6, and show that none of the effects are statistically significant at the conventional level.

Response rates for the 19 neighbourhoods showed considerable more variation than for the 9 cities (see table 5.7). The lowest percentage is 33.3%, whereas the highest percentage is 80.4%. The results of the probit regression analysis using dummy variables for each of the neighbourhoods indicated that exactly these two neighbourhoods have response rates that differ significantly from the mean response rates. In another probit analysis, the relationship between neighbourhood characteristics and response rates was tested (table 5.8). In particular, the following variables were included in the analysis: distance to city centre, land use mix and degree of urbanisation of the neighbourhood. The latter variable proved to be significantly related to response rate, in the sense that the response rate increases with decreasing density. For further details on the analysis of the response rates, see Snellen et al. [2001].
Urban Form and Activity-Travel Patterns

Table 5.7  Response rates by neighbourhood of those willing to participate after initial contact

<table>
<thead>
<tr>
<th>Neighbourhood</th>
<th>Response Rate</th>
<th>Neighbourhood</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almere Muziekwijk</td>
<td>20 58.8%</td>
<td>Eindhoven Achtse Barrier</td>
<td>17 45.9%</td>
</tr>
<tr>
<td>Almere Regenboogbuurt</td>
<td>10 33.3%</td>
<td>Enschede Stadsveld/Bruggert</td>
<td>9 45.0%</td>
</tr>
<tr>
<td>Apeldoorn Matenveld/Matendonk</td>
<td>27 65.9%</td>
<td>Enschede Helmerhoek Zuid</td>
<td>13 54.2%</td>
</tr>
<tr>
<td>Apeldoorn Ugelchen</td>
<td>34 70.8%</td>
<td>Haarlem Amsterdamse/Slachthuisbuurt</td>
<td>10 52.6%</td>
</tr>
<tr>
<td>Arnhem Alteveer/Cranevelt</td>
<td>37 80.4%</td>
<td>Haarlem Schalkwijk</td>
<td>17 70.8%</td>
</tr>
<tr>
<td>Arnhem Presikhaaf</td>
<td>16 72.7%</td>
<td>Leeuwarden Centrum</td>
<td>20 58.8%</td>
</tr>
<tr>
<td>Den Haag Centrum</td>
<td>9 39.1%</td>
<td>Leeuwarden Camminghaburen</td>
<td>24 72.7%</td>
</tr>
<tr>
<td>Den Haag Beresteijn</td>
<td>6 40.0%</td>
<td>Zoetermeer Centrum</td>
<td>11 55.0%</td>
</tr>
<tr>
<td>Den Haag Voorburg Essesteijn</td>
<td>26 61.9%</td>
<td>Zoetermeer Rokkeveen</td>
<td>18 51.4%</td>
</tr>
<tr>
<td>Eindhoven Stratum</td>
<td>31 66.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.8  Probit estimates of neighbourhood characteristics \((n=594)\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to city centre</td>
<td>-0.0464</td>
<td>-1.08943</td>
</tr>
<tr>
<td>Mono-functional neighbourhood</td>
<td>0.10639</td>
<td>1.86879</td>
</tr>
<tr>
<td>Degree of urbanisation</td>
<td>0.15247</td>
<td>2.67558</td>
</tr>
</tbody>
</table>

5.4.2  Sample Description

Respondent and household characteristics are important to keep in mind when interpreting the results of a survey. Therefore these characteristics will be discussed shortly in this section. Data were collected among all members of the participating households aged 13 years and over.

The average respondent age is 45.6 years \((SD = 21.4)\) and there is a good balance between male and female respondents \((52\%\) females/\(48\%\) males\). 17\% of respondents has no education or only finished primary school, 49\% has completed secondary education (high school or some sort of vocational training at comparable level) and 34\% has finished higher education (higher vocational training, college or university). 46\%
of respondents work full time and 16% work part time, others are not engaged in (paid) work activities. 48% of respondents have personal net income of 30,000,- Dutch guilders or less per year, while 27% earn more than 50,000,- Dutch guilders annually.

94% of respondents have one or more bicycles available. 78% of respondents have a driver’s license, 49% of respondents have a car directly available, while another 26% have a car available which they share with someone else (within or outside the household). Finally, 37% of respondents have some kind of public transport pass. This figures includes people owning a railway discount card (voordeelenkaart) and senior citizens that have a pass that entitles them to bus travel at reduced prices.

From the questionnaire a number of household characteristics were available. 28% of households are single person households, 38% are couples and 32% are families with children. Overall, 68% of households do not have children, 17% have children under 12 years old and 16% have older children. When engagement in work by household members is included in the household typology, we found that 30% of households are dual earner households.

Household income was calculated from the personal incomes of household members and divided into 4 categories. Little over half of responding households have an income of 2 times standard and over, while 21% is below standard, 10% is approximately standard and 18% is between 1 and 2 times standard. The housing situation of responding households was also considered. 25% of households live in a flat or apartment, 54% in a terraced single family house and 21% in a (semi)detached single family house. 61% of households own their house, while 39% rents. 78% of households have a garden, while 19% has a balcony and only 3% does not have outdoor space of any kind. Average number of bedrooms is 3.1 (SD = 1.2). 87% of households owning a car, park this car in the direct vicinity of the house (on driveway, in garage near their house, on the street in front of the house or apartment building, etcetera).

Finally, since the ability to test the relationship between the characteristics of the urban environment and activity and travel patterns could be negatively influenced by strong relations between socioeconomic characteristics of respondents and characteristics of neighbourhoods, we tested for correlations between them. Correlations were calculated between nine socioeconomic characteristics of respondents and households (viz. household composition, household income, dwelling type, gender, age, education level,
personal income, work status and availability of motorised transport) and the characteristics of the urban environment. The results are shown in table 5.9. No correlations exceeding 0.500 were found. In fact, most significant associations were lower that 0.05, which is a very satisfactory result.

<table>
<thead>
<tr>
<th>table 5.9 associations between neighbourhood characteristics and socioeconomic characteristics (n=594)</th>
<th>netw. type</th>
<th>netw. type</th>
<th>street netw. type</th>
<th>empl. location</th>
<th>dist. to city centre</th>
<th>dist. to ic. station</th>
<th>dist. to sub centre</th>
<th>degree urbanis</th>
<th>degree urbanisc</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>ε² = .01</td>
<td>ε² = .02</td>
<td>ε² = .04</td>
<td>ns</td>
<td>ε² = .00</td>
<td>ns</td>
<td>ε² = .01</td>
<td>ε² = .00</td>
<td>ε² = .06</td>
</tr>
<tr>
<td>hh.comp.</td>
<td>λ = .04</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .08</td>
<td>ns</td>
<td>ε² = .05</td>
<td>ε² = .03</td>
<td>ε² = .08</td>
<td>ns</td>
</tr>
<tr>
<td>hh.income</td>
<td>λ = .04</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .03</td>
<td>ns</td>
<td>ε² = .01</td>
<td>ε² = .02</td>
<td>ε² = .05</td>
<td>ns</td>
</tr>
<tr>
<td>dwelling type</td>
<td>λ = .08</td>
<td>ns</td>
<td>λ = .11</td>
<td>ε² = .03</td>
<td>ns</td>
<td>ε² = .09</td>
<td>ε² = .05</td>
<td>ε² = .06</td>
<td>λ = .10</td>
</tr>
<tr>
<td>gender</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .00</td>
<td>ns</td>
<td>ε² = .00</td>
<td>ε² = .00</td>
<td>ε² = .01</td>
<td>ns</td>
</tr>
<tr>
<td>education level</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .00</td>
<td>ns</td>
<td>ε² = .03</td>
<td>ε² = .02</td>
<td>ε² = .04</td>
<td>ns</td>
</tr>
<tr>
<td>personal income</td>
<td>ns</td>
<td>ns</td>
<td>λ = .04</td>
<td>ε² = .01</td>
<td>ns</td>
<td>ε² = .01</td>
<td>ε² = .01</td>
<td>ε² = .03</td>
<td>ns</td>
</tr>
<tr>
<td>work. status</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .01</td>
<td>ns</td>
<td>ε² = .02</td>
<td>ε² = .01</td>
<td>ε² = .02</td>
<td>ns</td>
</tr>
<tr>
<td>car ownership</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ε² = .01</td>
<td>ns</td>
<td>ε² = .02</td>
<td>ε² = .02</td>
<td>ε² = .06</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns = not significant

5.4.3 Data Quality

In their discussion of errors in activity diaries, Arentze and Timmermans [2000] mention that this type of questionnaire is more prone to errors and inconsistencies than other travel surveys. Most common errors are caused by skipping transfer activities (sequence of activity and/or place from outdoors to indoors and vice versa). Other common errors are the result of missing information about other people, about the timing of activities and inconsistencies between activity and place. The data collected for this study was examined to establish whether inconsistencies and errors in the activity diaries were related to the geographical origin of the respondents and/or a number of their socioeconomic characteristics.
Table 5.10 lists the percentage of inconsistencies in the diary data for various cities. Each cell in the table indicates the percentage of errors made, given the number of errors that could have been made. The errors 'wrong end time' and 'home location missing' both show only zeros, since these errors were not possible in our data collection. The figure in the first cell top left, indicates that 6.1% of all schedules of Almere respondents included activities of more than one day. The last row of the table indicates the overall error percentage over all potential errors. This table does not reveal any apparent differences between the cities. The total percentage of errors is roughly the same across the cities. Almere has the lowest percentage of errors, Arnhem the highest, but the difference is only 1%. Incomplete schedules are the most commonly made error (missing the sleeping episode), followed by big time gaps and incomplete travel data.
The other types of errors occur considerably less. In tables 5.11a and b, the attention shifts to the neighbourhood level. The range in the percentage of errors increases, as is to be expected. However, overall differences are still small. The rank order of most commonly made errors is the same as observed for the city level. Incomplete schedules, big time gaps and incomplete travel data are the most commonly made errors.

**table 5.11a inconsistencies in activity diaries by neighbourhood (n=807)**

<table>
<thead>
<tr>
<th></th>
<th>Almere</th>
<th>Apeldoorn</th>
<th>Arnhem</th>
<th>Den Haag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mzw</td>
<td>Rgb</td>
<td>Mvd</td>
<td>Ugc</td>
</tr>
<tr>
<td>schedule more</td>
<td>7.5</td>
<td>0</td>
<td>2.6</td>
<td>9.5</td>
</tr>
<tr>
<td>than 1 day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>91</td>
<td>93.9</td>
<td>82.9</td>
<td>91.6</td>
</tr>
<tr>
<td>schedule</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wrong end</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>time gap</td>
<td>17.2</td>
<td>9.7</td>
<td>14.4</td>
<td>15.2</td>
</tr>
<tr>
<td>big time gap</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.9</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>missing begin/end</td>
<td>1</td>
<td>3.1</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>incomplete</td>
<td>8.8</td>
<td>8.4</td>
<td>6.8</td>
<td>10.7</td>
</tr>
<tr>
<td>travel data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>home location</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unlikely mode</td>
<td>1.9</td>
<td>2.6</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>chain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unlikely</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>activity time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unlikely</td>
<td>1</td>
<td>0.2</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>activity/travel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mzw=Muziekwijk; Rgb=Regenboogbuurt; Mvd=Matenveld/donk; Ugc=Ugchelen; A/C=Alteveer/Cranevelt; Prh=Presikhaaf; Ctr=Centrum; Bsn=Beresteijn; Ves=Voorburg Essesteijn
The results described above are based on a general inspection of the data. Differences in errors may hide differences in sociodemographic composition of cities and neighbourhoods. Therefore, more formal analyses were performed. First, effect coding was used to represent cities, respectively neighbourhoods. The total percentage of errors was regressed (standard linear regression) against this set of variables. Significant regression coefficients would indicate that the corresponding city or neighbourhood would have a percentage of errors that is significantly different from the overall mean. The second analysis involved a regression of the percentage of errors against a set of sociodemographic indicators: average age, percentage of women, percentage of people with higher education, percentage of personal income above standard, percentage of

<table>
<thead>
<tr>
<th>Eindhoven</th>
<th>Enschede</th>
<th>Haarlem</th>
<th>Leeuwarden</th>
<th>Zoetermeer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Str</td>
<td>Abr</td>
<td>S/B</td>
<td>Hlm</td>
<td>A/S</td>
</tr>
<tr>
<td>schedule more than 1 day</td>
<td>1.5</td>
<td>0</td>
<td>6.3</td>
<td>11.1</td>
</tr>
<tr>
<td>incomplete schedule</td>
<td>97</td>
<td>79.1</td>
<td>81.3</td>
<td>85.2</td>
</tr>
<tr>
<td>wrong end time</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>big time gap</td>
<td>16.6</td>
<td>11.2</td>
<td>10.1</td>
<td>18.4</td>
</tr>
<tr>
<td>missing activity type</td>
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<td>1.1</td>
<td>0</td>
<td>1.7</td>
</tr>
<tr>
<td>missing begin/end time</td>
<td>2.9</td>
<td>3</td>
<td>7.8</td>
<td>3</td>
</tr>
<tr>
<td>incomplete travel data</td>
<td>10.1</td>
<td>10.8</td>
<td>12.3</td>
<td>7.9</td>
</tr>
<tr>
<td>home location missing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>unlikely mode chain</td>
<td>2.1</td>
<td>1.8</td>
<td>2.6</td>
<td>0.3</td>
</tr>
<tr>
<td>unlikely activity time</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>unlikely activity/travel</td>
<td>1.6</td>
<td>0.9</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Total | 5.3 | 4.2 | 4.9 | 4.7 | 4.9 | 5 | 5.3 | 4.3 | 4.7 | 5.5 |

Str=Stratum; Abr=Achtse Barrier; S/B=Stadsveld/Bruggert; Hlm=Helmerhoek Zuid; A/S=Amsterdamse/Machthuisbuurt; Skw=Schalkwijk; Cnt=Centrum; Cam=Camminghalbuuren; Cnt=Centrum; Rok=Rokkenveen
household income above standard, percentage of people with a driver's license, percentage of car ownership, percentage of singles, percentage of single family dwellings and percentage of unemployed. Tables 5.12 and 5.13 report the results of these regressions at the city level. From the tables one can see that neither the indicator variables for the cities, nor the coefficients of the city characteristics are significant at the conventional probability level. Thus, the percentage of errors in the activity diaries does

### Table 5.12 Regression of Errors by City (n=9)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>t-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>9.764</td>
<td>0.316</td>
<td>30.899</td>
<td>0</td>
</tr>
<tr>
<td>Almere</td>
<td>-0.282</td>
<td>0.822</td>
<td>-0.343</td>
<td>0.732</td>
</tr>
<tr>
<td>Apeldoorn</td>
<td>0.001</td>
<td>0.655</td>
<td>0.017</td>
<td>0.986</td>
</tr>
<tr>
<td>Arnhem</td>
<td>1.019</td>
<td>0.798</td>
<td>1.277</td>
<td>0.202</td>
</tr>
<tr>
<td>Den Haag</td>
<td>1.046</td>
<td>0.81</td>
<td>1.292</td>
<td>0.197</td>
</tr>
<tr>
<td>Eindhoven</td>
<td>0.469</td>
<td>0.798</td>
<td>0.588</td>
<td>0.557</td>
</tr>
<tr>
<td>Enschede</td>
<td>-1.687</td>
<td>1.157</td>
<td>-1.458</td>
<td>0.147</td>
</tr>
<tr>
<td>Haarlem</td>
<td>-0.971</td>
<td>1.101</td>
<td>-0.882</td>
<td>0.378</td>
</tr>
<tr>
<td>Leeuwarden</td>
<td>0.159</td>
<td>0.848</td>
<td>0.187</td>
<td>0.852</td>
</tr>
</tbody>
</table>

### Table 5.13 Regression of Errors by Socioeconomic Indicators City (n=9)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>t-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>8.551</td>
<td>18.113</td>
<td>0.472</td>
<td>0.637</td>
</tr>
<tr>
<td>Average age</td>
<td>-0.008</td>
<td>0.161</td>
<td>-0.519</td>
<td>0.604</td>
</tr>
<tr>
<td>% of women</td>
<td>-0.406</td>
<td>0.33</td>
<td>-1.23</td>
<td>0.219</td>
</tr>
<tr>
<td>% of people with higher education</td>
<td>0.569</td>
<td>0.38</td>
<td>1.497</td>
<td>0.135</td>
</tr>
<tr>
<td>% of personal income above standard</td>
<td>-0.191</td>
<td>0.179</td>
<td>-1.067</td>
<td>0.287</td>
</tr>
<tr>
<td>% of household income above standard</td>
<td>-0.008</td>
<td>0.152</td>
<td>-0.56</td>
<td>0.575</td>
</tr>
<tr>
<td>% of people with a driver’s license</td>
<td>-0.009</td>
<td>0.151</td>
<td>-0.562</td>
<td>0.575</td>
</tr>
<tr>
<td>% of car ownership</td>
<td>0.005</td>
<td>0.058</td>
<td>0.838</td>
<td>0.402</td>
</tr>
<tr>
<td>% of singles</td>
<td>0.309</td>
<td>0.192</td>
<td>1.613</td>
<td>0.107</td>
</tr>
</tbody>
</table>
not vary more than randomly across the cities nor across the urban indicators. Model performance is low (R-square=0.012) in both cases.

A similar analysis was conducted at the neighbourhood level. The standard regression model performed equally bad with a R-square of 0.02. The results are reported in tables 5.14 and 5.15. Table 5.14 shows that the percentage of errors does not differ significantly from the overall mean in any of the neighbourhoods, which means that there are no significant spatial effects at this level of aggregation. Table 5.15 reports the estimated coefficients for the case where the neighbourhoods have been classified according to a

<table>
<thead>
<tr>
<th></th>
<th>unstandardised coefficients</th>
<th>t-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>9.816</td>
<td>0.338</td>
<td>29.05</td>
</tr>
<tr>
<td>Almere Muziekwijk</td>
<td>-0.007</td>
<td>1.037</td>
<td>-0.07</td>
</tr>
<tr>
<td>Almere Regenboogbuurt</td>
<td>-0.933</td>
<td>1.523</td>
<td>-0.613</td>
</tr>
<tr>
<td>Apeldoorn Matenveld/Matendonk</td>
<td>-1.411</td>
<td>1.004</td>
<td>-1.406</td>
</tr>
<tr>
<td>Apeldoorn Ugchelen</td>
<td>0.988</td>
<td>0.885</td>
<td>1.116</td>
</tr>
<tr>
<td>Arnhem Alteveer/Cranevelt</td>
<td>0.77</td>
<td>1.014</td>
<td>0.759</td>
</tr>
<tr>
<td>Arnhem Presikhaaf</td>
<td>1.395</td>
<td>1.445</td>
<td>0.965</td>
</tr>
<tr>
<td>Den Haag Centrum</td>
<td>1.184</td>
<td>1.877</td>
<td>0.631</td>
</tr>
<tr>
<td>Den Haag Beresteijn</td>
<td>1.549</td>
<td>1.877</td>
<td>0.825</td>
</tr>
<tr>
<td>Den Haag/Voorburg Essesteijn</td>
<td>0.768</td>
<td>1.078</td>
<td>0.714</td>
</tr>
<tr>
<td>Eindhoven Stratum</td>
<td>0.441</td>
<td>1.089</td>
<td>0.405</td>
</tr>
<tr>
<td>Eindhoven Achtse Barrier</td>
<td>0.384</td>
<td>1.271</td>
<td>0.302</td>
</tr>
<tr>
<td>Enschede Stadsveld/Bruggert</td>
<td>-1.482</td>
<td>2.069</td>
<td>-0.716</td>
</tr>
<tr>
<td>Enschede Helmerhoek Zuid</td>
<td>-1.875</td>
<td>1.523</td>
<td>-1.231</td>
</tr>
<tr>
<td>Haarlem Amsterdamse/Slachthuisbuurt</td>
<td>-0.149</td>
<td>1.8</td>
<td>-0.083</td>
</tr>
<tr>
<td>Haarlem Schalkwijk</td>
<td>-1.639</td>
<td>1.523</td>
<td>-1.076</td>
</tr>
<tr>
<td>Leeuwarden Centrum</td>
<td>-0.216</td>
<td>1.411</td>
<td>-0.153</td>
</tr>
<tr>
<td>Leeuwarden Camminghaburen</td>
<td>0.309</td>
<td>1.134</td>
<td>0.273</td>
</tr>
<tr>
<td>Zoetermeer Centrum</td>
<td>-0.601</td>
<td>1.671</td>
<td>-0.36</td>
</tr>
</tbody>
</table>
Urban Form and Activity-Travel Patterns

Table 5.15  *Regression of errors by socioeconomic indicators neighbourhood (n=19)*

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std.Error</th>
<th>t-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>0.965</td>
<td>6.555</td>
<td>0.147</td>
<td>0.883</td>
</tr>
<tr>
<td>average age</td>
<td>0.004</td>
<td>0.101</td>
<td>0.404</td>
<td>0.687</td>
</tr>
<tr>
<td>% of women</td>
<td>0.006</td>
<td>0.057</td>
<td>1.041</td>
<td>0.298</td>
</tr>
<tr>
<td>% of people with higher education</td>
<td>0.003</td>
<td>0.031</td>
<td>0.91</td>
<td>0.363</td>
</tr>
<tr>
<td>% of personal income above standard</td>
<td>0</td>
<td>0.065</td>
<td>0.071</td>
<td>0.943</td>
</tr>
<tr>
<td>% of household income above standard</td>
<td>0.002</td>
<td>0.057</td>
<td>0.332</td>
<td>0.740</td>
</tr>
<tr>
<td>% of people with a driver’s license</td>
<td>-0.146</td>
<td>0.109</td>
<td>-1.341</td>
<td>0.181</td>
</tr>
<tr>
<td>% car ownership</td>
<td>0.2</td>
<td>0.116</td>
<td>1.727</td>
<td>0.085</td>
</tr>
<tr>
<td>% of singles</td>
<td>0</td>
<td>0.064</td>
<td>0.08</td>
<td>0.936</td>
</tr>
<tr>
<td>% of single dwellings</td>
<td>-0.003</td>
<td>0.028</td>
<td>-0.973</td>
<td>0.331</td>
</tr>
<tr>
<td>% unemployed</td>
<td>-0.001</td>
<td>0.052</td>
<td>-0.227</td>
<td>0.820</td>
</tr>
</tbody>
</table>

The analysis described above has relied on socioeconomic variables that were aggregated from individual level data. It implies that we cannot control for individual variation in errors. Moreover, this aggregation results in fewer values for less units of observation, implying that the power of the statistical analysis is reduced. To further explore whether the results may be an artifact of these operational decisions, a multilevel analysis was conducted. This type of analysis, also known as hierarchical linear modelling, was introduced in the previous chapter. More detailed information on model estimation and model performance assessment can be found in chapter 6.

Table 5.16 reports the results of the multilevel analysis. The two levels in the analysis are the individual and the neighbourhood. The results show that the number of errors increases with age and decreases with income. Although these variables are significant (age at the 5% level and income at the 10% level), their explanatory power is very limited (only 1.2%). Important however for the present study is that the estimated effects for
variables describing cities and neighbourhoods are not significant, giving further support to the results obtained with the less advanced methods of analysis.

Table 5.16  multi level analysis of diary inconsistencies (n=370 respondents)

<table>
<thead>
<tr>
<th></th>
<th>Estimated effect (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed part</td>
<td></td>
</tr>
<tr>
<td>individual effects</td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>7.886 (1.082)</td>
</tr>
<tr>
<td>age</td>
<td>0.046 (0.022)</td>
</tr>
<tr>
<td>income standard and over</td>
<td>-0.655 (0.355)</td>
</tr>
<tr>
<td>Random part:</td>
<td></td>
</tr>
<tr>
<td>individual</td>
<td>43.733</td>
</tr>
<tr>
<td>group (neighbourhood)</td>
<td>0.024</td>
</tr>
<tr>
<td>$R^2$ individual</td>
<td>0.012</td>
</tr>
<tr>
<td>$R^2$ group</td>
<td>0.000</td>
</tr>
</tbody>
</table>

5.4.4 Conclusions

In the previous sections, the response rates, the quality of the data and the characteristics of the respondents have been looked at in detail. Results are satisfying. No high correlations were found between characteristics of the individual respondents and responding households and the urban environment they come from. Response rates are rather independent of spatial characteristics. Some significant differences were found. Response rates for the cities of Almere (lower) and Arnhem (higher), and, within these cities, for the neighbourhoods Muziekwijk (lower) and Alteveer/Cranevelt (higher), differ significantly from the overall mean. Furthermore it was found that neighbourhoods with lower densities have slightly higher response rates.

Finally, we looked at the quality of the data by urban form and sociodemographic characteristics. The number of errors in the diaries was regressed against a set of indicators. No significant differences between cities or neighbourhoods were found, nor any significant effects of spatial or sociodemographic descriptors. A more sophisticated analysis, using multilevel modelling, revealed some significant effects of age and income, however, the explanatory power of this model was rather limited.
It can therefore be concluded that there is little bias in the data. Some influence of socioeconomic factors was found, but this was as expected. Hardly any evidence of spatial bias was found. This is a positive result in the sense that no further weighting schemes are required for subsequent analyses.

5.5 Independent Variables

Three groups of variables play an important role in this research project. The first group comprises the dependent variables describing the activity and travel patterns of people. These variables can be derived from the data collection and are described in further detail in chapters 6 and 7. The other two groups are independent variables describing i) the spatial context of the city and neighbourhood and ii) the socioeconomic characteristics of the respondents. These two groups of independent variables are discussed and defined in this section.

5.5.1 Variables Describing the Spatial Context

In the chapters 2 and 3, policy documents and (scientific) literature were studied in order to assess which elements of urban form are expected to yield positive or negative effects when mobility reduction is pursued. In general, policy and literature do not differ all that much. Both work with the same basic principles to achieve mobility (growth) reduction: shorter distances and a shift in mode choice towards non-motorised and public transport. Similar measures and urban design principles are considered to yield positive effects. The most important are concentrated, centralised urban development, mixed land use, high density development, location policy (the right activity at the right place), good public transport, good walking/cycling facilities and an urban design that discourages car use.

The first three items are clearly urban form characteristics and can be operationalised rather straightforward. The items that follow, which focus more on the available transport system, are more complicated. The term ‘good’ is not easy to interpret or operationalise. Especially with regard to public transport, studies and policy documents tend to operationalise ‘good’ mainly in terms of transport service provision, e.g. high frequency, high quality of vehicles, use of rail systems. Rarely, urban design or form elements are associated with ‘good’ public transport. In contrast, ‘good’ walking and
cycling facilities are more often operationalised in urban form or design characteristics. The literature on The New Urbanism offers several examples of this [CNU, 2000a; CNU, 2000b]. Availability of sidewalks and cyclepaths, separate cycle networks and grid type transportation networks are some of the design elements associated with ‘good’ facilities. The last item, urban design that discourages car use, is also sparsely operationalised. Usually this is related to facilities for transportation alternatives and to the availability of activity locations within reach of non-motorised and public transport. The specific contribution of different types of transportation networks is subject of study in the literature on neo-traditional development and New Urbanism. Empirical studies focusing on the effects of these types of development do look at transportation networks, however, a limited set of network types is usually studied (e.g. Friedman et al [1994], Nasar [1997], Florez [1998], Cervero [1996] and Cervero and Gorham [1995]).

The urban form elements that will be studied in this thesis are partly derived from policy and literature and partly form an extension to what has been studied previously. The elements are classified in three main categories. The first category includes the basic urban shape and transportation networks in the urban environment. Although these elements of urban form received relatively little attention in the studies discussed in chapter 3, effects can be expected. Based on the theories with regard to the New Urbanism and neo-traditional development, and the empirical studies in this tradition, it appears to be an interesting path to follow. The second category focusses on relative location of the neighbourhood with regard to different types of land use and land use mix. It looks at different types of facilities available in the neighbourhood and the distance to important other activity centres. Finally, the last category focusses at density.

In the preparatory steps of this study, a larger set of variables describing the spatial environment was considered for inclusion. Some of the variables were deleted from the list. Distance to a city district shopping centre and distance to a secondary train station were deleted because these distances were only considered relevant if they were shorter than the distances to the city centre and the main train station. Only for a subset of neighbourhoods this was the case. Given the relatively small sample size, inclusion of these variables was considered not effective. The variables describing the coverage of a neighbourhood by the local bus service and the distance to the nearest motorway approach were also deleted from the list because these variables showed very little variation over the neighbourhoods.
Below, each of the three categories of spatial variables will be operationalised by a number of variables and their definition. Some of these variables have already been defined in the previous section regarding the choice of locations for data collection. The variable *urban shape* describes the basic morphological form of the city in question. The levels of this variable (see figure 5.4) are ‘concentric’, ‘poly-nuclear’, ‘lobe’ and ‘grid’ and are therefore the same as employed in the selection of cities for data collection (section 5.2.2).

![Urban Shapes](image)

**Figure 5.4 Urban Shapes**

The variable *transportation network type city* describes the basic transportation network type that can be discerned for the city as a whole. Again this is the same variable as employed for the selection of cities for data collection (section 5.2.3) and the levels used are ‘radial’, ‘ring’ and ‘grid’ (figure 5.5). The grey area in the diagrams depicts the built up area of the city.

![Transportation Networks City](image)

**Figure 5.5 Transportation Networks City**

The variable *transportation network type neighbourhood* describes the basic transportation network type that can be discerned for the neighbourhood as a whole. The network types were assessed based on neighbourhood maps and 6 different types were discerned (figure 5.6). The grey area in the diagrams depicts the neighbourhood.
The variable *local street network type* refers to the network type that can be discerned within a neighbourhood on street level. This low level gives an indication of the network type in the immediate proximity of the dwellings. Five network types, some of which are composites, are discerned (see figure 5.7). Levels were assessed based on neighbourhood maps. The grey area in the diagrams depicts the immediate surroundings of a local street.

The variable *location of the city within the country* refers to whether or not the city in question is located inside or outside the Randstad Holland, the western, most urbanised area of the Netherlands (see figure 5.8).

The variable *employment city* is defined as the number of jobs in the city per 1,000 inhabitants. It gives an indication of the jobs/population balance and therefore the towns ability to be self contained. For some of the analyses this continuous variable is
converted into an ordinal variable with three categories: ‘low’ (less than 300 jobs per 1,000 inhabitants), ‘average’ (between 300 and 500 jobs per 1,000 inhabitants) and ‘high’ (more than 500 jobs per 1,000 inhabitants). National average is 388 jobs/1,000 inhabitants. Data was obtained from Statistics Netherlands.

*Land use mix neighbourhood* describes the measure to which the land use in the neighbourhood is mixed. Mono-functional neighbourhoods (residential with few facilities for the local population such as a small shopping centre) are defined as not mixed. Neighbourhoods that include industrial and/or office functions, or that have ample shopping facilities (such as neighbourhoods with a city district shopping centre) are defined as mixed. Mixing was assessed based on neighbourhood maps and data on businesses and shops (yellow pages).

*Distance to the city centre* describes the distance from the neighbourhood to the city centre. It is the same variable as was used for the choice of neighbourhoods. *Distance to inter-city station* simply describes the distance from the centre of the neighbourhood to the nearest inter-city train station.

The variable *locally available shopping facilities*, describes the locally available shopping facilities in the neighbourhood in 5 levels. Neighbourhoods are classified based on the highest level shopping facility available in the neighbourhood. The levels discerned are described below. Classification was made based on neighbourhood maps and data from the yellow pages. The first category is ‘none or just a few local shops’, for example a single bakery or butcher’s, florist or tobacconist. The second category is the ‘small neighbourhood shopping centre’ consisting of a supermarket and possibly several supporting shops such as a discount food market, some specialist food stores (bakery, butcher’s, greengrocer’s, etcetera), some daily non food stores (drugstore, tobacconist, florist, etcetera) and some services (bank or post-office, hairdresser’s, cafeteria, etcetera). The ‘large neighbourhood shopping centre’ consists of 2 or more supermarkets and a wide selection of the following: a complete supply of specialist food stores, several non-food shops (also including shops for household goods and textiles, household appliances, books, etcetera), several services, limited supply of clothing and shoes. The fourth category is the ‘city district shopping centre’, consisting of a wide range of food stores and supermarkets, a wide range of non-food shops and services, ample supply of fashion and shoe stores catering for several target groups, a department store and supporting facilities such as cafeteria’s, a restaurant and/or a leisure facility. Finally, the ‘city centre’
consists of a large number of shops in all categories, at least two department stores, and all sorts of supporting facilities, food supply is often limited and concentrated in streets of the main shopping street.

The variable *locally available sports facilities* describes whether or not a neighbourhood has sports facilities, such as a tennis court, a soccer field, a sports park and/or an indoor sports centre locally available. Classification was made based on neighbourhood maps.

Three variables describe in different ways the density of the city as a whole. These are *housing density city*, *population density city* and *degree of urbanisation city*. The housing and population density simply describe the number of dwellings and inhabitants per hectare surface area of the city. For some of the analyses these densities were categorised. Population density has the following categories: ‘low’ ($\leq 10$ inhabitants/hectare), ‘moderate’ (10-30 inhabitants/hectare), ‘fairly high’ (30-50 inhabitants/hectare) and ‘high’ (> 50 inhabitants/hectare). Housing density also has four categories: ‘low’ ($\leq 4$ dwellings/hectare), ‘moderate’ (4-10 dwellings/hectare), ‘fairly high’ (10-30 dwellings/hectare) and ‘high’ (> 30 dwellings/hectare). Data was obtained from Statistics Netherlands and the municipalities in question. The degree of urbanisation is a measure based on the ‘surrounding address density’. This is the average number of addresses per square kilometre within a 1 kilometre radius. For each address in the city the individual surrounding address density is calculated and then the average across all addresses is obtained. Based on this density measure, 5 degrees of urbanisation were identified: ‘very strongly urbanised’ (surrounding address density of 2500 and over), ‘strongly urbanised’ (surrounding address density between 1500 and 2500), ‘moderately urbanised’ (surrounding address density between 1000 and 1500), ‘little urbanised’ (surrounding address density between 500 and 1000) and ‘not urbanised’ (surrounding address density below 500). Data was obtained from Statistics Netherlands.

Another three variables describe the density of the neighbourhood. These are *housing density neighbourhood*, *population density neighbourhood* and *degree of urbanisation neighbourhood*. The housing and population density simply describe the number of dwellings and inhabitants per hectare surface area of the neighbourhood. For some of the analyses these densities were categorised. Population density has the following categories: ‘low’ (20-40 inhabitants/hectare), ‘moderate’ (40-60 inhabitants/hectare), ‘fairly high’ (60-80 inhabitants/hectare) and ‘high’ (>80 inhabitants/hectare). Housing
density also has four categories: ‘low’ (≤ 10 dwellings/hectare), ‘moderate’ (10-20 dwellings/hectare), ‘fairly high’ (20-30 dwellings/hectare) and ‘high’ (> 30 dwellings/hectare). The degree of urbanisation of a neighbourhood is defined similar to the degree of urbanisation of the city, as described above. Data was obtained from Statistics Netherlands and the municipalities in question.

5.5.2 Socioeconomic Variables

The last group of variables relevant for the analysis of the relationship between urban form and travel patterns are the socioeconomic control variables describing individual and household characteristics. All of these data were obtained from the questionnaires. The socioeconomic data include the following individual characteristics: age, gender, education level, personal income, possession of a driver’s license and employment status. Additionally, a number of household characteristics was included: car availability, household income, socioeconomic class, household type, dwelling type and average distance to chosen location. Characteristics were selected based on the prevalence of variables in the literature. Appendix 3 gives an overview of definitions and classifications for each of these variables.

Some characteristics initially selected were not included in the final analysis. Possession of a public transport pass was not included. There were some concerns about the nature of this variable. If people decide to choose public transport, then they will see whether some kind of pass is in their interest. Hence, inclusion of this variable is likely to confound the effect of truly ‘causal’ variables such as distance and frequency. Although this could also be the case for car ownership, we feel that the decision to buy a car is based on many more considerations than the decision to get a public transport pass. Furthermore, possession of a bicycle and participation in a car sharing plan were not included because of lack of variation. 94% of respondents owns one or more bicycles and only 1% of respondents participated in a car sharing plan. Housing tenure was not included as a separate variable because of its overlap with household income and dwelling type. Finally, having a garden and/or balcony was not included because this is largely covered by dwelling type and only 2% of respondents have neither one.
5.6 Summary and Conclusions

This chapter described the data collection process followed for this study. It discussed the selection of locations based on a number of dominant urban form characteristics: urban shape, main transportation network type, location in relation to the city centre and main urban functions. It also discussed the design of the activity diary questionnaire. The response that was the result of the data collection was discussed and analysed, both with regard to the response rates and the quality of the response. Finally, the independent variables that will be used in data analysis were discussed and defined.

It was found that, although the positive responses to our request to participate in the research varied widely over neighbourhoods, both the response of those that received a questionnaire, and the quality of the response are satisfying. Response rates proved, to a large extent, to be independent of spatial characteristics. The quality of the data proved not to be associated with spatial characteristics. Associations were found with age and income. However, the explanatory power of this model was very limited. Overall, it can be concluded that there is little bias in the data, especially with regard to spatial characteristics. Most importantly, the methodological principle that socioeconomic and sociodemographic characteristics should be as independent as possible from urban form characteristics was realised.
6 | TRAVEL FOR FREQUENT ACTIVITIES

6.1 Introduction

A limited set of recurring, frequent activities takes up a large part of the total number of trips and the total number of kilometres travelled by individuals and households. This makes it interesting to see if, and how, these trips are influenced by spatial and socioeconomic variables. This chapter will discuss the results for four types of trips for recurring frequent activities, viz. home-to-work trips, grocery shopping trips, non-grocery shopping trips and recurring leisure trips (such as regular trips to sports and club activities). In 1998 these activities accounted for 50 percent of all trips and 49 percent of all kilometres [CBS, 1999]. Although we have argued that an analysis by motive may lead to an incomplete assessment, we decided to conduct such an analysis anyhow because it allows us to actually compare an analysis by motive and an analysis of complete activity-travel patterns. The results of the latter analysis are reported in chapter 7.

The relationship between urban form, socioeconomic variables and travel characteristics will be analysed using multilevel analysis. As argued in chapter 4, this methodology allows us to account for the fact that the independent variables (spatial and socioeconomic) are measured at different levels of aggregation.

This chapter is organised as follows. In section 6.2 a general description of the travel data on frequently made trips is given. Section 6.3 elaborates the basic discussion of the multilevel model as presented in chapter 4. The results of the multilevel analyses are discussed in section 6.4. In section 6.5 conclusions will be drawn.
6.2 General Description of the Data

Our data on frequently made trips included trips originating from home with the purpose of grocery shopping, non-grocery shopping, recurring leisure and work. Data on grocery shopping trips was provided by 392 respondents, on non-grocery shopping trips by 460 respondents, on recurring leisure trips by 340 respondents and on home-to-work trips by 200 respondents. The following characteristics of travel behaviour were obtained from the data: i) the total numbers of kilometres and trips, ii) the number of kilometres and trips per mode and iii) mode shares for both kilometres and trips. The numbers of kilometres travelled are based on straight line calculations of trip distances. The time span for the dependent variables differed by travel motive. Grocery shopping trips, recurring leisure trips and home-to-work trips were measured per month, non-grocery shopping trips were measured per year. Motorised travel, non-motorised travel and travel by public transport are discerned as transport modes in this study. Motorised travel comprises travel by private car and by motorcycle. Non-motorised travel comprises walking, cycling and travelling by moped. Public transport travel comprises all sorts of public transport, such as travel by bus, by tram, by metro and by train. The data for grocery shopping and recurring leisure showed that public transport is very rarely chosen for these travel motives. Therefore, for these travel motives only the travel modes ‘motorised’ and ‘other’ are included in the discussion. The category ‘other’ can be considered almost equal to ‘non-motorised’.

In the following subsections, a general description of the data on frequently made trips will be given. For each travel motive the travel behaviour characteristics were set out against the socioeconomic and spatial variables defined in the previous chapter. For the nominal independent variables the means for each level were calculated, while for the continuous independent variables the correlation coefficient was obtained as a basis for the discussion. The discussion below includes only remarks on significant differences or correlations. In order to establish whether differences between the means and the correlations are significant, different tests were used, depending on the nature of the variables of interest. If the assumption could be made that the variances at the different levels of the nominal variables are equal, significance tests were based on One-Way-ANOVA. If this assumption could not be made, the non-parametric Kruskal-Wallis test was used. The significance of correlations was assessed using the Pearson correlation coefficient. In appendix 4, all data is listed.
6.2.1 Trips for Grocery Shopping

On average, people that do grocery shopping make 15 trips originating from home for this purpose per month. In doing so, they travel a total of 20 kilometres (one way). The modal share for motorised modes is 39% for kilometres and 35% for trips. This shows that travel modes as walking and cycling are the preferred modes for grocery shopping. With increasing age, we find an increasing number of trips for grocery shopping. Results show that high income people make less trips than lower income people. The modal split also changes with income, showing more use of motorised modes with higher incomes. People without a job go grocery shopping more often than those with a part time or full time job. Full time workers have a notable higher modal share for motorised modes. Driver’s license owners make less trips for grocery shopping. As can be expected, the mode share of motorised modes is much higher for license owners than for others. Similar results hold for having a car at your disposal. For household income we find similar results for modal shares as with personal incomes. Finally, the modal share of non-motorised modes is much higher for those in a flat/apartment than those in a single family dwelling.

When the travel behaviour characteristics for grocery shopping are grouped by spatial characteristics of the neighbourhood or city, we find the following. Trip frequencies differ significantly over city types. In the poly-nuclear city (Almere) we find the lowest number of trips, while trip frequencies are highest in concentric cities. The modal share differs from average in the poly-nuclear city (Almere), where we find much higher shares for motorised travel for both kilometres and trips. Looking at neighbourhood transportation network types, we find that the modal share for motorised modes is notably higher in loop network neighbourhoods and notably lower in grid network neighbourhoods. The modal share for motorised modes for kilometres and trips is highest in loop/grid type local street networks. In grid type local street networks, we find the lowest modal share for motorised modes for both kilometres and trips. In neighbourhoods with a limited mix of land use, the modal share of motorised kilometres is lowest, while the modal share of motorised trips is lowest in neighbourhoods with ample land use mixing. Looking at locally available shopping facilities, the situation appears to be as can be expected. The modal share of motorised modes decreases when better facilities become available. Furthermore, the modal share of motorised trips decreases with increasing housing density in the neighbourhood. Finally, within the
Randstad Holland people make more of their trips by motorised modes than their counterparts outside the Randstad area.

### 6.2.2 Trips for Non-Grocery Shopping

On average, respondents make 51 trips for non-grocery shopping per year (approximately 1 per week). For this purpose, the average shopper travels 146 kilometres per year. Motorised and non-motorised modes are most popular, motorised slightly more than non-motorised. Only 12% of trips and 15% of kilometres are travelled by public transport. Trip frequencies and numbers of kilometres travelled hardly differ significantly over the socioeconomic and spatial characteristics. Women make more trips for non-grocery shopping than men. With increasing age, people make less trips for non-grocery shopping and the shares of non-motorised kilometres and trips decrease in favour of public transport. The share of motorised modes is much lower for those with no education or only primary school, while shares for non-motorised and public transport are much higher. This might indicate a specific shopping pattern for youngsters. People with an income below minimum make more trips and travel more kilometres, but also less often use motorised transport modes. The use of motorised modes increases with income. The use of public transport is highest for those without a job. Possession of a driver’s license goes with more trips. Not having a driver’s license goes with more non-motorised and public transport trips and kilometres. Similar effects are found for possession of a car. People in low income households tend to mainly use non-motorised modes for non-grocery shopping trips, while the use of motorised modes increases with income level of the household. Single people show the highest shares of non-motorised trips and kilometres and the lowest share of motorised trips. Car use is highest for inhabitants of a (semi)detached house, while the shares of non-motorised travel are highest for those in a flat or apartment.

In the poly-nuclear city (Almere) motorised transport is the favourite travel mode. Especially the share of non-motorised modes is very low in this city type. The shares of non-motorised kilometres and trips are highest in grid type cities. In radial cities, non-motorised transport is used less than average, while the share of public transport kilometres is highest. People in grid neighbourhoods use non-motorised modes most often. In radial network neighbourhoods the use of non-motorised modes is also higher than average, while the use of motorised modes is lower. In loop network neighbourhoods, motorised modes are most favourite, while in axial neighbourhoods
the shares for public transport are highest. In grid type local streets, the use of non-motorised modes is notably higher, while in loop/tree network local streets people use public transport more than average. The use of motorised modes is highest in loop/grid local streets. The data show that in mixed land use neighbourhoods people use much more non-motorised modes. Results for shopping facilities are similar. When better facilities are locally available, the use of non-motorised modes increases and motorised modes are chosen less often. With increasing distance to the city centre we find opposite results, more use of motorised modes and less use of non-motorised modes. The number of kilometres travelled decreases with higher densities for the city. The use of non-motorised modes increases with density of the neighbourhood and city, while the shares of motorised and public transport increase with an increase of the degree of urbanisation of the neighbourhood. Finally, in the Randstad Holland people have a higher share of car use for non-grocery shopping and a lower share of public transport use.

### 6.2.3 Trips for Recurring Leisure Activities

Per month, people participating in recurring leisure activities make on average 6 trips and travel 24 kilometres for this purpose. Motorised modes take up 58% of kilometres and 55% of trips. Trip frequencies and numbers of kilometres travelled do not differ significantly over any of the socioeconomic and spatial characteristics. Travel behaviour for recurring leisure activities is most constant over socioeconomic variables, in comparison to the other travel motives. With increasing age, the share of motorised trips increases. Not having a car available goes with a higher number of trips and lower shares of motorised kilometres and trips. The latter also holds for not having a driver’s license. People in a flat/apartment make relatively few of their trips by motorised modes.

Travel behaviour for recurring leisure shows more differences by spatial characteristics of the neighbourhood or city. In radial network cities, the shares of motorised kilometres and trips are highest. In ring network cities, the share of motorised kilometres is lowest. In grid network neighbourhoods we find the lowest share of motorised trips. In loop network neighbourhoods people show the highest share of motorised trips. The use of motorised modes is lowest in grid type local streets. Relatively high shares of motorised modes we find in loop/grid, loop/tree and tree type local streets. In neighbourhoods with ample land use mix we find a favourable travel pattern: the lowest shares of motorised trips and kilometres. The availability of local sports facilities goes, strikingly, with higher
shares of motorised trips and kilometres. With increasing distance to the centre of the city or the inter-city station, we find an increase in the shares of motorised trips and kilometres.

6.2.4 Home-to-Work Trips

On average workers make 16 trips per month for this purpose and travel 225 kilometres doing so. Motorised modes are used slightly more than non-motorised modes. Public transport is only used for 13% of trips and kilometres. Men travel more kilometres getting to and from work than women. Men also show a lower share of non-motorised trips. Both the number of trips and the number of kilometres increase with education level. All respondents that recorded home-to-work trips while having no or only primary education (21 respondents) travel by non-motorised modes. The number of kilometres travelled increases greatly with personal income, yet the number of trips is only notably lower for the group of people with a personal income below minimum. The use of motorised travel is highest for those with high incomes, while the use of non-motorised modes decreases sharply with increasing personal income. Part time workers travel less kilometres, as can be expected. They also show a higher share of non-motorised trips. Not having a driver’s license and not having a car available go with no use of motorised modes and, therefore, more use of non-motorised modes and public transport. People in families show a lower share of motorised trips than people in other household types. Finally, the number of home-to-work trips is highest for those in a flat or apartment and lowest for those in a (semi)detached house.

In the poly-nuclear city (Almere) we find low shares of non-motorised trips and kilometres and the highest share of public transport trips. In lobe type cities the share of non-motorised trips is highest. In ring network cities the number of kilometres travelled is highest, while in grid network cities the number of trips and kilometres are lowest. Most striking differences between neighbourhood network types can be found for shares of public transport. We find high shares in loop and tangential neighbourhoods and low shares in radial, axial and grid network neighbourhoods. The lowest number of trips is found in loop/tree type local streets. In tree type local streets people show the highest share of motorised kilometres and the lowest share of non-motorised kilometres. In grid type local streets we find the lowest share of motorised kilometres and the highest share of non-motorised kilometres, while in loop/grid local streets the share of public transport trips is notably higher. In neighbourhoods with
ample land use we find that people choose non-motorised modes most often. A higher employment in the city goes with a lower share of public transport trips and a higher share of non-motorised trips. Finally, inside the Randstad Holland the shares of public transport trips and kilometres are higher and the share of non-motorised kilometres is lower than outside the Randstad area.

6.3 The Multilevel Model: Model Estimation and Testing

As has been argued in the state-of-the-art review part of this thesis, the kind of results reported in section 6.2 only provide a partial answer to the research question and fail to rigorously disentangle the effects of socioeconomic and spatial variables on aspects of mobility. The travel data on frequent activities will be therefore further analysed using multilevel analyses. The multilevel model, or hierarchical linear model, assumes that the independent variables are measured at different levels of aggregation. An introduction to the model was given in chapter 4. Here, this introduction is complemented with a discussion of model estimation and model testing.

Hox [1995] discusses model estimation techniques for the multilevel model. Maximum Likelihood (ML) estimators are often used in multilevel analysis. Computing the ML estimates requires an iterative procedure. First, single level Ordinary Least Squares (OLS) estimates are generated as the starting values for various parameters. After one iteration, this gives Generalised Least Squares (GLS) estimates. When the iterative process converges, it results in ML estimates. Two different types of Maximum Likelihood estimation are commonly used in multilevel regression analysis. In Full Maximum Likelihood (FML) estimation, both the regression coefficients and the variance components are included in the likelihood function. In Restricted Maximum Likelihood (RML) estimation, only the variances of the random components are included in the likelihood function. FML estimation treats the estimates of the regression coefficients as known quantities when the variance components are estimated, while RML estimation treats the regression coefficients as estimates that carry some amount of uncertainty. RML estimation is more realistic and should lead to better estimates, especially when the number of groups is small [Bryk and Raudenbush, 1992]. Therefore, we used RML estimation.
The choice for RML estimation does however pose a limitation to model performance and hypothesis testing [Snijders and Bosker, 1999]. With the parameter estimation, a likelihood is also provided. From this likelihood the deviance, an indication of the lack of fit between the model and the data, can be calculated (deviance = -2 ln(likelihood)). This deviance can be used to compare different models since the difference in deviance between two models can be used as a chi-square distributed test statistic. However, this method can only be applied when one model is an extension of the other and when FML estimation is used. With RML estimation, deviance tests can only be used if the models that are compared have the same fixed parts and differ only in their random parts. However, since the objective of this study is not to build a model that can be used for simulation purposes, but to learn which variables are of significant influence, individually or in combination with others, the advantages of RML estimation regarding data with a small number of groups is preferred over the comparison advantages of FML estimation.

Model performance can also be assessed by looking at the amount of variance in the dependent variable that is explained by the independent variables in the model. In standard linear regression, the measure for this is $R^2$, the squared multiple correlation coefficient. For the hierarchical linear model, however, the assessment of the explained proportion of variance is more complicated. In their introduction to multilevel analysis, Snijders and Bosker [1999] discuss an alternative measure of $R^2$ for use with hierarchical linear models. They present separate measures for the explained proportion of variance at both levels for a random intercept model (a model that only contains error terms associated with the intercept). The explained proportion of variance at level 1 ($R^2_1$) is the proportional reduction in the value of $\sigma^2 \tau_0^2$ due to inclusion of independent variables. Given two models A and B, the explained proportion of variance of model B over model A is calculated as follows:

$$R^2_1 = 1 - \frac{\sigma^2_B + \tau^2_{0B}}{\sigma^2_A + \tau^2_{0A}}$$

(6.1)

where:

$\sigma^2_A$ = the variance of $r_{ij}$ in model A

$\sigma^2_B$ = the variance of $r_{ij}$ in model B

$\tau^2_{0A}$ = the variance of $u_{0j}$ in model A

$\tau^2_{0B}$ = the variance of $u_{0j}$ in model B
The explained proportion of variance at level 2 ($R^2_2$) is the proportional reduction in mean squared prediction error. $R^2_2$ is estimated as the proportional reduction in the value of ($\sigma^2 / n$) + $\tau_0^2$, where $n$ is a representative value for the group size. Again, given the models A en B to compare, the explained proportion of variance at the second level is calculated as follows:

$$R^2_2 = 1 - \frac{\sigma^2_A / n + \tau^2_0}{\sigma^2_B / n + \tau^2_0}$$

(6.2)

A complicating factor here is the assessment of $n$. Sometimes a representative value of $n$ is easily available. If the research focusses on performance of school children grouped in classes, and a usual class size is 30 children, then $n = 30$ even if the values of $n_j$ in the data set are not on average 30. In case of varying group sizes, and no obvious representative group size (as is the case in this study), the harmonic mean can be used. The harmonic mean equals $N / \sum_j (1/n_j)$, where $N$ is the total number of respondents and $n_j$ is the number of individuals in group $j$.

As mentioned before, the calculation of the explained proportion of variance described here, applies to random intercept models. However, in case of a model that contains random slopes, the calculation of $R^2_1$ and $R^2_2$ is more complicated. Snijders and Bosker [1999] proposed a method that very closely approximates the exact values of $R^2_1$ and $R^2_2$. One re-estimates the random slopes model as a random intercept model with the same fixed part. Then $R^2_1$ and $R^2_2$ are calculated in the usual way. An example given by Snijders and Bosker [1999] indicates that, when using this method to calculate model performance, values over 40% can be considered indicating a good performance. This measure was adopted in this thesis.

6.4 Multilevel Models of Trip Characteristics

In section 6.2, a general description of the travel data on frequently made trips was given. In this section, the multilevel models of these data will be discussed. Multilevel models were estimated for i) the total numbers of kilometres and trips, ii) the number of kilometres and trips per mode and iii) mode shares motorised transport for both kilometres and trips (percentage of kilometres or trips by motorised transport). Models
were estimated using data from respondents who indicated that they participated in these activities. The models for the total number of kilometres and trips (by mode) give an indication of the total mobility and their relationships with the independent variables, while the models for the modal shares give an indication of the relationship between the choice of transport modes for certain trips and the independent variables. Since multilevel analysis with HLM does not allow for missing data, the analyses reported below are based on data from 241 respondents reporting grocery shopping trips, 300 respondents reporting non-grocery shopping trips, 176 respondents reporting recurring leisure trips and 128 respondents reporting home-to-work trips.

Effect coding was used for the nominal independent variables. Consequence of this coding is that the effect of one of the levels of each nominal independent variable is not estimated, but equals the negative sum of the effects of all other levels of that variable. A step-by-step method was followed to develop the models. In this process, first socioeconomic variables (at the individual level) were entered in the model before the spatial variables at the neighbourhood level were entered. In the last step, the interaction effects between the individual and the neighbourhood levels were introduced. Independent variables were included in the model when significant effects at the 10% level were found. In the next sections, however, only effects significant at the 5% level will be discussed. All continuous independent variables in the analyses were centred around their grand mean. Models were estimated using HLM software [Bryk et al, 1996]. Appendix 5 contains a complete overview of the models’ performance and their estimated parameters.

Although a linear model, such as the multilevel model, in theory should be applied only to variables measured at interval level, in practice it is accepted to apply the methodology to variables at the ratio level. Similarly, for count data, such as trip frequencies, Poisson regression would be more suitable. However, examples in the literature on multilevel modelling concern ratio level dependent variables (see for instance Bullen et al [1997], Coombes and Raybould [1997] and Hox [1995]), while in transportation research it is accepted to apply linear regression to count data (see for instance Kitamura et al [1997] and Sun et al [1998]). For proportions as dependent variables, according to the literature, logit or arcsinus transformations are appropriate transformation methods [Hox, 1995]. Since our data did not allow the use of a logit transformation (because of many occurrences of 0% and 100%), the arcsinus transformation was applied. Comparison of the model estimation results with and without transformation learned that the non-
transformed estimations yielded largely the same results, both in terms of the significance of the independent variables and the relative magnitude and direction of the parameters. Since model estimation without the arcsinus transformation makes the interpretation of parameters much easier, the non-transformed data were used.

It should be emphasised that multilevel analysis as applied here is a statistical method describing the nature and strength of a relationship. The dependent variables are not choice proportions. Hence, these models should not be interpreted as choice probability models.

6.4.1 Model Performance

An overview of the performance of the estimated models is given in table 6.1. $R_1^2$ is the explained proportion of variance at the individual level (between individuals), while $R_2^2$ is the explained proportion of variance at the neighbourhood level (between neighbourhoods). The number of significant independent variables in the models varied considerably. The models for recurring leisure trips are rather limited, with only six independent variables being significantly related to trip characteristics, while models for home-to-work trips include a total of fourteen different significant variables. In general, the explained proportion of variance at the neighbourhood level is higher than at the individual level. This is as expected because of the differences in degree of freedom. Note that the explained proportion of variance at both levels can be influenced by independent variables at both levels. The models for the number of kilometres perform best with $R_1^2$ and $R_2^2$ of over 75% for all travel motives, with the exception of the model for non-grocery shopping. The models for the total number of motorised kilometres for grocery shopping and recurring leisure also perform very well.

models for grocery shopping

Most of the models for grocery shopping perform reasonably to very well with regard to explaining the variance between neighbourhoods, except those for the total number of trips and the number of non-motorised kilometres. The explained proportion of variance between individuals is generally low, except for the models for the total number of kilometres and the number of motorised kilometres. All models include one or more significant independent variables. This varies from just one independent variable in the models for the number of kilometres and the number of non-motorised kilometres, up
Travel for Frequent Activities

Table 6.1  

<table>
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<th>explained proportion of variance</th>
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<td>spatial level (max. = 10)</td>
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</tr>
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<td>number of motorised trips</td>
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</tr>
<tr>
<td>number of non-motorised trips</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>modal share motorised trips</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>non-grocery shopping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total number of kilometres</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>number of motorised kilometres</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>number of non-motorised kilometres</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>number of public transport kilometres</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>modal share motorised kilometres</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>modal share non-motorised kilometres</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>modal share public transport kilometres</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>total number of trips</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>number of motorised trips</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>number of non-motorised trips</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>number of public transport trips</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>modal share motorised trips</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>modal share non-motorised trips</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>modal share public transport trips</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

to six independent variables in the models for the modal shares of trips. Most models combine level 1 and level 2 variables.

Models for non-grocery shopping

The explained proportion of variance for the models for non-grocery shopping is reasonable with regard to the variation between neighbourhoods and poor with regard to the variation between individuals. Exceptions are the model for the number of motorised kilometres, which performs well in explaining the variation between individuals, and the models for the modal split of motorised and non-motorised kilometres, the models for the number of motorised and public transport trips and all
three modal split models for trips, that perform well in explaining the variation between neighbourhoods. All models include one or more significant independent variables. This varies from one independent variable in the model for total number of public transport kilometres to five independent variables in the models for modal share motorised kilometres and modal share non-motorised trips. Most models combine individual and neighbourhood level variables.

<table>
<thead>
<tr>
<th>dependent variable</th>
<th>number of significant variables</th>
<th>explained proportion of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>socioeconomic (max. = 10)</td>
<td>spatial (max. = 10)</td>
</tr>
<tr>
<td><strong>recurring leisure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total number of kilometres</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>number of motorised kilometres</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>number of other kilometres</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>modal share motorised kilometres</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>total number of trips</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>number of motorised trips</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>number of other trips</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>modal share motorised trips</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

| **home-to-work**                       |                                |                                |                  |                   |
| total number of kilometres             | 1                             | 0                               | 0.784            | 0.757             |
| number of motorised kilometres         | 2                             | 0                               | 0.508            | 0.349             |
| number of non-motorised kilometres    | 2                             | 1                               | 0.088            | 0.099             |
| number of public transport kilometres | 2                             | 1                               | 0.310            | 0.213             |
| modal share motorised kilometres      | 3                             | 1                               | 0.312            | 0.461             |
| modal share non-motorised kilometres  | 4                             | 0                               | 0.333            | 0.378             |
| modal share public transport kilometres| 1                             | 2                               | 0.181            | 0.491             |
| total number of trips                  | 3                             | 1                               | 0.284            | 0.150             |
| number of motorised trips              | 3                             | 1                               | 0.297            | 0.443             |
| number of non-motorised trips          | 3                             | 3                               | 0.890            | 0.526             |
| number of public transport trips       | 1                             | 1                               | 0.125            | 0.483             |
| modal share motorised trips            | 3                             | 1                               | 0.316            | 0.474             |
| modal share non-motorised trips        | 4                             | 1                               | 0.363            | 0.426             |
| modal share public transport trips     | 3                             | 1                               | 0.172            | 0.498             |
models for recurring leisure activities
Model performance on average is poor. The models are not able to explain a reasonable amount of variation between individuals or neighbourhoods. Positive exceptions are the models for the total number of (motorised) kilometres (both showing a high explained proportion of variance between individuals and neighbourhoods) and the number of other trips (performing well at the neighbourhood level). All models include one or more independent variables. In general, trip characteristics for recurring leisure trips are not very sensitive to the studied independent variables. Only four independent variables were significant. From the eight estimated models, just three combine individual and neighbourhood level variables.

models for home-to-work trips
At the individual level, performance is generally poor. Positive exceptions to this are the models for (motorised) kilometres. These perform well at this level. Most models are able to explain a reasonable to large proportion of the variation between neighbourhoods, with the exception of the models for the number of non-motorised kilometres and for the total number of trips. All the dependent variables describing home-to-work trips were significantly related to one or more independent variables. This varied from just one independent variable in the model for total number of kilometres, to six independent variables in the model for number of non-motorised trips. Almost all of the fourteen estimated models combine individual and neighbourhood level variables, with the exception of the models for the number of (motorised) kilometres and for the modal share of non-motorised kilometres.

6.4.2 Discussion of the Results of the Multilevel Analyses

In this section the results of the multilevel analyses will be discussed. The focus will be on the effects of the spatial independent variables. All spatial independent variables significant at the 5% confidence level will be considered here, regardless of the values of R² at both levels for the models. In the tables in this section the significant effects from spatial variables will be reported. For interaction effects, the accompanying socioeconomic variable will be listed in footnotes with each table. For a complete overview of all models, including the significant socioeconomic effects see appendix 5.
table 6.2 significant effects of the independent variables on the number of kilometres travelled for grocery shopping (n=241, standardised coefficients between brackets)

<table>
<thead>
<tr>
<th>variable</th>
<th>level</th>
<th>number of kilometres</th>
<th>number of motorised kilometres</th>
<th>number of other kilometres</th>
<th>share motorised kilometres</th>
</tr>
</thead>
<tbody>
<tr>
<td>neighbourhood transportation network type</td>
<td>loop</td>
<td></td>
<td>+26.6 (0.28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>local shopping facilities</td>
<td>none or just a few shops</td>
<td></td>
<td>+16.51 (0.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>large</td>
<td></td>
<td>-26.32 (-0.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>neighbourhood shopping centre</td>
<td></td>
<td>+20.11 (0.23)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 interaction effect in combination with car available
2 interaction effect in combination with working part time
3 interaction effect in combination with working full time

the number of kilometres for grocery shopping

No effects were found from the independent urban form characteristics on the number of kilometres travelled for grocery shopping, in total and by mode (table 6.2). However, the modal split of grocery shopping kilometres is influenced by urban form characteristics. Effects were found for the neighbourhood transportation network type and the local shopping facilities. In loop network neighbourhoods we found a higher share of motorised kilometres. A similar effect was found for none or just a few shopping facilities locally available, albeit only for car owners. It appears that especially car owners do not content themselves with simple local facilities and decide to go elsewhere by car. When working full time, the same holds for a large neighbourhood shopping centre. People working part time show a lower share of motorised kilometres in combination with a large local shopping centre.

the number of trips for grocery shopping

Effects of urban form on the number of grocery shopping trips and their modal split were also found (table 6.3). Inhabitants of the Randstad Holland, in general make less grocery shopping trips than people living outside this area. The number of trips by transportation mode is influenced by locally available shopping facilities. More specifically, when a large local shopping centre is available we found a higher number of motorised trips and a lower number of other trips. However, the latter effect is not
true for those working part time, they show a slight reverse effect. A city district shopping centre available in the neighbourhood is associated with more other trips, yet again we find a reverse effect here for those working part time (in standardised form this effect is limited). The share of motorised trips is influenced by the neighbourhood transportation network type and the locally available shopping facilities. In loop network neighbourhoods a larger share of motorised trips is found, which is coherent with the larger share of motorised kilometres found. Ring network neighbourhoods also show a larger share of motorised kilometres, but only for those working full time. For those working part time, we find a smaller share of motorised transport trips when a large neighbourhood shopping centre is available. This is consistent with the finding that part time workers make more non-motorised trips for grocery shopping when a large neighbourhood shopping centre is available.

<table>
<thead>
<tr>
<th>variable</th>
<th>level</th>
<th>trips</th>
<th>motorised trips</th>
<th>other trips</th>
<th>share motorised trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>neighbourhood transportation network type</td>
<td>ring</td>
<td></td>
<td></td>
<td></td>
<td>+17.3 (0.24)</td>
</tr>
<tr>
<td></td>
<td>loop</td>
<td></td>
<td></td>
<td></td>
<td>+25.7 (0.28)</td>
</tr>
<tr>
<td>location city</td>
<td>inside Randstad</td>
<td>-3.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Holland</td>
<td>(-0.17)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>local shopping facilities</td>
<td>none or just a few</td>
<td>-4.5</td>
<td></td>
<td>+15.6 (0.19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>shops</td>
<td>(-0.27)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>large neighbourhood shopping centre</td>
<td>+2.3 (0.23)</td>
<td>-3.6 (0.19)</td>
<td>-32.2 (0.33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>city district shopping centre</td>
<td>+5.7 (0.20)</td>
<td>-10.1 (0.21)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 interaction effect in combination with working full time
2 interaction effect in combination with working part time
3 interaction effect in combination with car available
Urban Form and Activity-Travel Patterns

Table 6.4 Significant effects of the independent variables on the number of kilometres travelled for non-grocery shopping (n=300, standardised coefficients between brackets)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Kilometres</th>
<th>Motorised Kilometres</th>
<th>Non-motorised Kilometres</th>
<th>Public Transport Kilometres</th>
<th>Share Motorised Kilometres</th>
<th>Share Non-Motorised Kilometres</th>
<th>Share Public Transport Kilometres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation network type</td>
<td>City</td>
<td>ring</td>
<td>+49.4</td>
<td>(0.29)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood transportation network type</td>
<td>Loop</td>
<td>-25.3</td>
<td>(-0.31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radial</td>
<td>-38.3</td>
<td>(-0.51)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Axial</td>
<td>-18.2</td>
<td>(-0.26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local street network type</td>
<td>Loop/grid</td>
<td>-25.7</td>
<td>(-0.28)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loop</td>
<td>-24.3</td>
<td>(-0.33)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to city centre</td>
<td>-</td>
<td>+4.6</td>
<td>(0.14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local shopping facilities</td>
<td>Large</td>
<td>+48.0</td>
<td>(0.84)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of urbanisation</td>
<td>Neighbourhood</td>
<td>+13.5</td>
<td>(0.49)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Interaction effect in combination with always car available
2 Interaction effect in combination with secondary education

The number of kilometres for non-grocery shopping

The number of motorised kilometres is influenced by the transportation network type of the city (Table 6.4). In ring network cities we found a lower number of motorised kilometres, yet only for those that always have a car available. No influence of urban form characteristics was found on the total number of kilometres, the number of non-motorised kilometres or the number of public transport kilometres. The modal split of non-grocery shopping kilometres is influenced by the transportation network type of the neighbourhood, the local street network type, the distance to the city centre, the locally
available shopping facilities and the degree of urbanisation of the neighbourhood. The share of motorised kilometres is lower in radial and axial type neighbourhoods. Looking at the standardised coefficients this effect is most substantial in the radial type neighbourhood. The share of motorised kilometres increases with increasing distance to the city centre. This is very plausible, since the city centre is often the destination for non-grocery shopping. The share of non-motorised kilometres is affected by the local street network type. Loop/grid and loop type local streets decrease this share. Finally, the modal share of public transport kilometres is lower in loop network type neighbourhoods (for those with secondary education), is higher when a large local shopping centre is available (looking at the standardised coefficient this effect is substantial) and increases with increasing degree of urbanisation (decreasing address density). The latter means that in lower (address) density areas, public transport use for non-grocery shopping is higher. This is remarkable, since lower densities are usually associated with less public transport. Apparently, for non-grocery shopping trips that often have the city centre as a destination, public transport is an interesting option.

The number of trips for non-grocery shopping

The numbers of trips for non-grocery shopping by mode are influenced by the neighbourhood transportation network type, the local street network type, the locally available shopping facilities and the degree of urbanisation of the neighbourhood (table 6.5). The number of motorised trips is lower in radial and axial network neighbourhoods. The number of non-motorised trips is lower in neighbourhoods with a small or large neighbourhood shopping centre and with a loop/grid local street network. However, the latter effect is only true for those with a car. The number of public transport trips is related to the degree of urbanisation of the neighbourhood. The number increases with increasing degree of urbanisation (decreased address density). This is a similar finding as for non-grocery shopping kilometres. However, this effect is stronger with increasing age and neutralised almost completely when people have a car available. The modal split for non-grocery shopping trips is influenced by the local street network type, the distance to the city centre and the degree or urbanisation of the neighbourhood. The share of motorised trips increases with increasing distance to the city centre. This is consistent with what was found for the share of motorised kilometres. The share of non-motorised trips decreases with increasing distance to the city centre, and decreases with increasing degree of urbanisation (decreased address density) in combination with age. Both findings are consistent and plausible. The standardised
Urban Form and Activity-Travel Patterns

<table>
<thead>
<tr>
<th>variable</th>
<th>level</th>
<th>trips</th>
<th>motorised trips</th>
<th>non-motorised trips</th>
<th>public transport trips</th>
<th>share motorised trips</th>
<th>share non-motorised trips</th>
<th>share public transport trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>neighbourhood transportation network type</td>
<td>radial</td>
<td>-24.8</td>
<td>(-0.52)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>axial</td>
<td>-14.2</td>
<td>(-0.30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>local street network type</td>
<td>loop/grid</td>
<td>-34.1</td>
<td>(-0.36)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>loop/tree</td>
<td>+15.1</td>
<td>(0.30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>local shopping facilities</td>
<td>small</td>
<td>-22.7</td>
<td>(-0.40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>large</td>
<td>-18.5</td>
<td>(-0.27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to city centre</td>
<td>-</td>
<td>+7.4</td>
<td>-9.8</td>
<td>(0.22)</td>
<td>(0.30)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>degree of urbanisation neighbourhood</td>
<td>-</td>
<td>+11.4</td>
<td>-0.3</td>
<td>(0.63)</td>
<td>(0.45)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-10.2</td>
<td>(-1.09)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>+0.2</td>
<td>(0.63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 interaction effect in combination with always car available
2 interaction effect in combination with car available
3 interaction effect in combination with age

coefficients show that the effects of degree of urbanisation neighbourhood are most substantial. Finally, the share of public transport trips is correlated with the local street network type. The share is higher in loop/tree type local streets.

kilometres and trips for recurring leisure
The effects found from urban form on trip characteristics for recurring leisure trips is

-102-
very limited. Significant effects were found only for the local availability of sports facilities. We found that the local availability of sports facilities increases the share of motorised kilometres and the number of motorised trips, while decreasing the number of other trips (tables 6.6 and 6.7). This could be the result of the fact that the analyses only include the trips originating from home. When no local facilities are available, people might be inclined to combine leisure trips with other trips. When local facilities are available, they visit these from the home location. Giving the more frequent occurrence of these types of activities in the evening, the car is more easily chosen for the trip, regardless of the trip length.

| Table 6.6 | Significant effects of the independent variables on the number of kilometres travelled for recurring leisure (n=176, standardised coefficients between brackets) |
|---|---|---|---|---|---|
| variable | level | number of kilometres | number of motorised kilometres | number of other kilometres | share motorised kilometres |
| local sports facilities | available | | | | +24.6 (0.39) |

| Table 6.7 | Significant effects of the independent variables on the number of trips for recurring leisure (n=176, standardised coefficients between brackets) |
|---|---|---|---|---|
| variable | level | trips | motorised trips | other trips |
| local sports facilities | available | | +1.6 (0.29) | -2.0 (-0.37) |

kilometres for home-to-work trips

The number of kilometres by mode for home-to-work trips is related to the transportation network type of the city (table 6.8). In ring network cities the number of public transport kilometres is higher. Note that this effect is only true for those in a multi-person household. In radial network cities, the number of non-motorised kilometres is higher. The modal split of kilometres for home-to-work trips is influenced by the urban shape and the local street network type. The share of motorised kilometres is lower in loop/grid type local streets. The share of non-motorised kilometres is not affected by urban form characteristics. The public transport kilometres share is larger in the poly-nuclear shaped city (Almere).
### Table 6.8: Significant effects of the independent variables on the number of home-to-work kilometres (n=128, standardised coefficients between brackets)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Kilometres</th>
<th>Motorised Kilometres</th>
<th>Non-Motorised Kilometres</th>
<th>Public Transport Kilometres</th>
<th>Share Motorised Kilometres</th>
<th>Share Non-Motorised Kilometres</th>
<th>Share Public Transport Kilometres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Shape</td>
<td>Poly-nuclear (Almere)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation Network Type</td>
<td>Ring</td>
<td>+54.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>Radial</td>
<td>+19.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Street</td>
<td>Loop/Grid</td>
<td>-22.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Interaction effect in combination with a multi-person household

### Table 6.9: Significant effects of the independent variables on the number of home-to-work trips (n=128, standardised coefficients between brackets)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Trips</th>
<th>Motorised Trips</th>
<th>Non-Motorised Trips</th>
<th>Public Transport Trips</th>
<th>Share Motorised Trips</th>
<th>Share Non-Motorised Trips</th>
<th>Share Public Transport Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation Network Type</td>
<td>Radial</td>
<td>+3.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>Radial</td>
<td>+3.6</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local Street</td>
<td>Loop/Grid</td>
<td>-3.8</td>
<td></td>
<td>+4.4</td>
<td>-23.7</td>
<td>+23.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of City</td>
<td>Inside Randstad</td>
<td>-16.3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Distance to City Centre</td>
<td>-</td>
<td>-1.2</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

-104-
trips for home-to-work trips

The numbers of trips by mode for home-to-work trips are influenced by the transportation network types of the city and the neighbourhood, the local street network type and the distance to the city centre (table 6.9). The number of motorised trips is lower in loop/grid local streets, which is consistent with the effect found for motorised kilometres. With increasing distance to the city centre the number of non-motorised trips decreases, while it is higher in radial network cities (consistent with the effect for kilometres). Finally, the number of public transport trips increases in loop/grid local streets. The modal split of home-to-work trips is influenced by the local street network type and the location of the city. The share of motorised trips is lower for loop/grid local streets. The share of non-motorised trips is lower inside the Randstad Holland. This could be caused by the fact the Randstad is more urbanised and has busier traffic than non-Randstad cities, making walking and cycling less attractive options. Finally, the share of public transport kilometres is higher with loop/grid local streets.

6.5 Summary and Conclusions

In this chapter, mode choice and the numbers of trips and kilometres for frequently made trips were analysed. First a general description of the data was given, followed by multilevel analysis of the data. In the general description of the data quite some significant differences in the characteristics of the trips by urban form characteristics were highlighted. However, the results of the multilevel analysis show few effects of urban form characteristics on trips for grocery shopping, non-grocery shopping, recurring leisure and home-to-work trips. Many potential relationships were analysed, yet a limited set proved to be significant. We therefore have to conclude that, when controlling for socioeconomic factors in a multilevel context, the effects of urban form characteristics on trip characteristics are limited.

While controlling for socioeconomic variables describing characteristics of individuals and households, significant effects were found for some spatial variables. It was also found that while the effects of some urban form characteristics and their levels are unambiguous, others show contradictory results. Table 6.10 summarises the effects for each urban form characteristic and level for which a significant effect was found. Effects are classified as positive, negative or undecided. An effect is considered positive when the number of kilometres or trips is reduced, when the number of motorised kilometres
or trips is reduced and/or when the share of transport modes alternative to motorised travel is increased. For negative effects the opposite holds. An increase in the number of non-motorised or public transport trips or kilometres is considered undecided when it is not accompanied by a reduction of motorised trips or kilometres.

The following characteristics can be considered positive: the poly-nuclear city (Almere), the radial and axial transportation network neighbourhoods and the loop/grid and loop/tree local street networks. In contrast, the ring transportation network city, the loop and ring transportation network neighbourhoods, the loop local street network, none or just a few shops locally available, local sports facilities available, increasing distance to the city centre, a location inside the Randstad Holland and increasing degree of urbanisation neighbourhood (= decreasing local address density) can be considered negative. The results for the radial transportation network city and the small or large neighbourhood shopping centre or city district shopping centre locally available are undecided.

It can be concluded that these results do not strongly support hypotheses that can be derived from literature and practice. Especially for variables describing the local availability of services, we have not been able to unambiguously confirm the claims described in chapter 2 and 3. For instance, none or just a few shops locally available yield a negative effect, but better local shopping facilities do not result in a positive effect on mobility choices. The hypotheses with regard to density, prominently present in the international literature, can only partially be supported by our findings. In particular, it should be noted that no effects were found for overall city density. Only neighbourhood densities seem to be of influence, and then only for non-grocery shopping trips. The results support the compact city concept, indicating that the use of motorised modes increases with distance to the city centre. In contrast to literature and practice, no effects were found for land use mix in the neighbourhood. This could be related to the fact that medium-sized Dutch cities are so small that some degree of land use mix is always the case, although not always within the limits of the neighbourhood as we defined them.

This chapter focussed on data on frequent activities, and therefore included a limited set of travel motives. In the next chapter data available from the activity-travel diaries will be analysed. These data include trips for all travel motives.
<table>
<thead>
<tr>
<th>urban form characteristic</th>
<th>level</th>
<th>travel motive</th>
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<th>undecided</th>
<th>negative</th>
</tr>
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<td>urban shape</td>
<td>poly-nuclear (Almere)</td>
<td>home-to-work</td>
<td>• more public transport kilometres</td>
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<td></td>
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<tr>
<td>city transportation network type</td>
<td>ring</td>
<td>non-grocery shopping</td>
<td></td>
<td>• more motorised kilometres (with always car available)</td>
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<tr>
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<td></td>
<td>home-to-work</td>
<td>• more public transport kilometres (with multi-person household)</td>
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<td>radial</td>
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<td>• larger share motorised trips</td>
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<td></td>
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<td></td>
<td>• smaller share public transport kilometres (with secondary education)</td>
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<tr>
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<td>ring</td>
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<td>Travel Motive</td>
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<td>Undecided</td>
<td>Negative</td>
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<td>-----------</td>
<td>----------</td>
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<td>• Larger share public transport trips</td>
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<td></td>
<td>Home-to-work</td>
<td>• Smaller share motorised kilometres</td>
<td>• Less motorised trips</td>
<td>• Larger share public transport trips</td>
</tr>
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<td>Loop</td>
<td>Non-Grocery Shopping</td>
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</tr>
<tr>
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<td>Loop/Tree</td>
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</tr>
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<td>• Larger share motorised kilometres (with car available)</td>
<td>• Larger share motorised trips (with car available)</td>
</tr>
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<td>Non-Grocery Shopping</td>
<td>• Less non-motorised trips</td>
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<tr>
<td></td>
<td>Large Neighbourhood Shopping Centre</td>
<td>Grocery Shopping</td>
<td>• Smaller share motorised kilometres (with working part time)</td>
<td>• More other trips (with working part time)</td>
<td>• Larger share motorised kilometres (with working full time)</td>
</tr>
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<td></td>
<td></td>
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<td>• More motorised trips</td>
</tr>
<tr>
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<td>Travel Motive</td>
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<td>Undecided</td>
<td>Negative</td>
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<td>Grocery Shopping</td>
<td>More other trips</td>
<td>Less non-motorised trips</td>
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</tr>
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<td>Grocery Shopping</td>
<td>More other trips (with working part time)</td>
<td>Less other trips</td>
<td></td>
</tr>
<tr>
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<td>Recurring Leisure</td>
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<td>Less motorised trips</td>
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<td>More motorised trips</td>
<td>More motorised trips</td>
<td></td>
</tr>
<tr>
<td>Home-to-work</td>
<td></td>
<td>Non-grocery Shopping</td>
<td>More motorised trips</td>
<td>More motorised trips</td>
<td></td>
</tr>
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<td>Location Inside Randstad Holland</td>
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<td>More trips</td>
<td>Less trips</td>
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<tr>
<td>Home-to-work</td>
<td></td>
<td>Non-grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
<td></td>
</tr>
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<td>Less trips</td>
<td></td>
</tr>
<tr>
<td>(Increase = Decrease Address Density)</td>
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<td>Grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
<td></td>
</tr>
<tr>
<td>Home-to-work</td>
<td></td>
<td>Non-grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
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</tr>
<tr>
<td>Larger Share Public Transport Kilometres</td>
<td></td>
<td>Non-grocery Shopping</td>
<td>More trips</td>
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</tr>
<tr>
<td>Larger Share Motorised Trips</td>
<td></td>
<td>Grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
<td></td>
</tr>
<tr>
<td>More Public Transport Kilometres (Effect Moderated with Car Available / Increased with Age)</td>
<td></td>
<td>Grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
<td></td>
</tr>
<tr>
<td>Larger Share Non-Motorised Trips</td>
<td></td>
<td>Grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
<td></td>
</tr>
<tr>
<td>More Public Transport Kilometres (Increases with Age)</td>
<td></td>
<td>Grocery Shopping</td>
<td>More trips</td>
<td>Less trips</td>
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</tbody>
</table>
7 | ACTIVITY-TRAVEL PATTERNS

7.1 Introduction

As discussed in the chapter on data collection, the analyses reported in this thesis involve two kinds of data. First, similar to most other studies into the relationship between urban form and travel, respondents were asked to report trip frequency, distance, and some other characteristics of frequently conducted activities. The results of these analyses were reported in the previous chapter. However, it is well known in the literature that these data are relatively prone to reporting bias. Moreover, a more fundamental objection against such data is that they cannot capture all travel generated by a household. For example, one household member reporting less car use to work may cause other household members to use the car more, since it is available for other purposes. Therefore, the conventional travel survey of frequently conducted activities was supplemented with a two-day activity diary. Although such diaries are not error-free either, they provide a more comprehensive picture of activity-travel patterns. The results of the analyses conducted on these activity diary data are reported in this chapter.

The focus thus shifts from trips by motive to total activity-travel patterns observed for a single day. The activity diary data described in chapter 5 were analysed in order to test the assumed relationship between urban form characteristics and indicators of daily travel behaviour. A multilevel analysis was conducted on a number of travel behaviour indicators derived from the activity diaries, in order to explore more complicated relationships between urban form and travel behaviour, while controlling for socioeconomic characteristics of the individual and the household.

This chapter is organised as follows. Sections 7.2 and 7.3 provide a general discussion of the diary data. In section 7.2 some characteristics of the activity-travel patterns are presented, followed by a general description of the indicators that were derived from the activity-travel diaries for analysis in section 7.3. Section 7.4 discusses the multilevel
analyses applied to the data and their results. Finally, in section 7.5 conclusions will be drawn.

7.2 Characteristics of Activity-Travel Patterns

Before addressing the analyses of the travel performance indicators derived from the activity diaries, this section discusses the activity-travel patterns in these diaries in a more general way. More specifically, the activity diaries were analysed using the relevant module of the ALBATROSS model [Arentze et al, 1999; Arentze and Timmermans, 2000].

Leisure activities and work are the most common activities conducted outside the home, closely followed by grocery shopping and bring/get activities such as bringing/getting a child to/from school. Distinct differences can be seen in activity patterns between mornings, afternoons and evenings (see figure 7.1). Staying at home (not making a trip) is most common in the evening and much less in the afternoon. Home-work-home patterns are most common in mornings and afternoons, and are rare in evenings. Bring/get activities occur throughout the day. Service trips (post-office, hairdressers', etcetera) occur mainly during office hours, yet more in the afternoon than in the morning. Trips for leisure or social activities occur more frequently later in the day. And finally, combining several activities in one tour (trip chaining) is most common in the afternoon. Most frequently occurring activity combinations (in one tour) are work and service, work and social or leisure, social or leisure and service or combinations of more activities.

Most diaries do include out-of-home activities. Only 12% of diaries do not include any tours. A tour begins and ends at home and can include one or more stops and therefore one or more trips. This concept is comparable to the concept of a journey in travel research [Axhausen, 1995]. One or two tours on a day are most common. Only 15% of all diaries include 3 or more tours. Over three quarters of all tours is a single-stop tour, while combining more than 3 stops in a tour is very rare. Most out-of-home activities have a considerable duration. More than half of all-out-of-home activities take more than an hour and over 30% take even more than two hours.
Most tours are short to very short. Almost half of all tours is (in a straight line) less than 2 kilometres long, and another quarter is between 5 and 10 kilometres (see figure 7.2). This is also reflected in trip lengths. 38% is less than 1 kilometre long and over three quarters is below 5 kilometres. Combining all tours for one day, we find that about one third of the individuals do not travel more than 2 kilometres in a day, and about a quarter travel less than 5 kilometres. The frequent occurrence of short and very short trips is partly reflected in mode choice (see figure 7.3). Most tours are made using only one mode of transportation and this is most often a non-motorised mode (walking or cycling), closely followed by the car. Most common combinations of transportation modes are motorised transport and non-motorised transport or public transport and non-motorised transport. Other combinations are rare.
7.3 General Description of Activity Pattern Indicators

The returned questionnaires provided us with useful data from 436 respondents on 807 diary days. Data on weekday diaries was available from 320 respondents on 528 diary days. For the analysis of the activity diaries a set of transportation performance indicators was used. These indicators summarise aspects of activity-travel patterns on a single day.
of a single individual and are derived from the diary data using the ALBATROSS model [Arentze and Timmermans, 2000]. The following indicators, both for weekdays and all days, were used in the analyses:

- total time spent travelling in minutes per day;
- total time spent travelling by motorised transport in minutes per day;
- modal split motorised transport in travel time;
- total number of trips per day;
- total number of tours per day;
- number of trips per tour, the trip/tour ratio;
- total distance travelled in kilometres per day;
- total distance travelled by motorised transport in kilometres per day;
- modal split motorised transport in travel distance.

Similar as in chapter 6, distances were measured in a straight line, based on locational information provided by the respondents.

Below, a general description of a subset of the transportation performance indicators will be given. Each indicator was set out against the socioeconomic and spatial variables defined in chapter 5. For the nominal independent variables the means for each level were calculated, while for the continuous independent variables the correlation coefficient was obtained as a basis for the discussion. The discussion below includes only remarks on significant differences. In order to establish whether differences between the means and the correlations are significant, different tests were used, depending on the nature of the variables of interest. If the assumption could be made that the variances at the different levels of the nominal variables are equal, significance tests were based on One-Way-ANOVA. If this assumption could not be made, the non-parametric Kruskal-Wallis test was used. The significance of correlations was assessed using the Pearson correlation coefficient. In appendix 6, all data is listed.

On average a diary day of the respondents included 4 trips and 1.7 tours, which means that an average tour, starting and ending at home, included 2.4 trips. Average travel time was 60 minutes and half of this time was spend in a motorised transport mode. Average distance travelled on a diary day was 33 kilometres and the modal share for motorised transport was 55%. On weekdays we find a somewhat different pattern. An average weekday included 4.5 trips and 1.9 tours. Trip/tour ratio remains the same. Travel time is 10 minutes longer and people travel 5 kilometres more on a weekday than on average. Modal shares of motorised travel are comparable to the data for all diary days. Overall,
the trip and tour frequencies and the trip/tour ratio show few differences over the socioeconomic and spatial characteristics. Differences can mainly be found in travel time and travel distance and more so for weekday diaries than for all diary days.

Women make more trips and tours than men, both on average and on weekdays. However, men travel more kilometres on weekdays. The modal shares of motorised travel time and kilometres increase with education level, both in total and for weekdays only. Similarly, the use of motorised modes increases with personal income. Travel distance, in total and on weekdays, is highest for those in the highest income group. Total travel time increases with personal income. The number of tours and trips on weekdays, is lower for lower income groups. Similar findings are obtained for work status. Full time workers spend most time travelling, both in total and on weekdays. In total, they also travelled the highest number of kilometres. However, on weekdays part time workers travel more kilometres. They also have the highest number of tours, both in total and on weekdays only. Trip-chaining is most frequent with full time workers. People without a driver’s license make, in total, less trips and tours, their trip/tour ratio is lower, they travel less kilometres and spend less time travelling. The picture is almost the same for those without a car available. On weekdays, we find a similar pattern for those without a license or car, although the differences in numbers of tours and trips and in travel time are no longer significant. People in higher income households travel a higher share of their weekday kilometres by motorised transport. People in two person households make fewer trips and, on weekdays, fewer tours than people in other household types. Trip chaining is more common for singles. The use of motorised modes is lowest for people in families with children. People in a flat or apartment spend most time travelling on weekdays. The share of motorised travel time on weekdays is highest for those in a (semi)detached house.

Looking at travel behaviour by characteristics of the spatial environment, we again find more differences on weekdays than for all diary days. Differences between transportation network types for the city are found for weekdays only. In ring network cities travel time and travel distance are highest, while in radial network cities they are lowest. In grid and loop/grid type local streets people travel the highest number of kilometres, both in total and on weekdays only. These network types also show the highest share of motorised kilometres. In loop/tree network local streets trip frequencies are lowest. For all days, the number of tours and the travel time are also lowest in this network type. In neighbourhoods with ample land use mixing we find, on average, the lowest share of
motorised travel time. In city centres and in neighbourhoods with none or just a few
shops, people make more trips and spend more time travelling on weekdays. In
neighbourhoods with a large neighbourhood shopping centre or a city district centre,
people spend less time travelling and travel less kilometres on weekdays. Finally, with
increasing distance to the city centre, the travel distance on weekdays decreases.

7.4 Multilevel Models of Activity-Travel Diary Data

The previous section a general description of the activity-travel pattern indicators was
given. In this section, the results of multilevel analysis of the indicators are presented.
Multilevel analysis, which was also used for the analysis of frequent activities and
described in chapters 4 and 6, enables us to analyse activity-travel pattern indicators,
while controlling for multiple socioeconomic factors, keeping in mind that individual
and spatial variables are measured at different levels. Since multilevel analyses with
HLM does not allow for missing data, the analyses are based on data from 306
respondents on 567 diary days.

Similar to the analyses discussed in chapter 6, effect coding was used for nominal
independent variables and similar steps were followed to develop the best models for
each aspect. In this process, first socioeconomic variables (at the individual level) were
entered in the model before the spatial variables at the neighbourhood level were
entered. In the last step, the interaction effects between the individual and the
neighbourhood levels were introduced. Independent variables were included in the
model when effects were significant at the 10% level. In the next sections, only effects
significant at the 5% level will be discussed. All continuous independent variables in the
analyses were centred around their grand mean. Again, non-transformed continuous
data was used (see section 6.3). Models were estimated using HLM-software [Bryk et al,
1996]. Appendix 7 contains a complete overview of each models' performance and
parameters.
### Activity-Travel Patterns

#### 7.4.1 Model Estimation and Performance

In total, 18 models were estimated. Nine models were estimated based on all data, nine models on weekday data only. The indicators describe travel time and distance (by mode), numbers of tours and trips and their ratio. Model performance for the multilevel models of activity-travel pattern indicators is not as good as for the models in the previous chapter (see table 7.1). For many of the models, the intra-class correlation was small, indicating a very limited influence of neighbourhood characteristics (the intra-class correlation is the variance component of the neighbourhood level divided by the sum of the variance components on both the individual and the neighbourhood level).

On average, the explained proportion of variance between neighbourhoods was higher

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<td></td>
<td>individual level</td>
<td>neighbrhd level</td>
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<td>0.181</td>
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<tr>
<td>0.394</td>
<td>0.385</td>
</tr>
<tr>
<td>0.144</td>
<td>0.145</td>
</tr>
<tr>
<td>0.144</td>
<td>0.482</td>
</tr>
<tr>
<td>0.356</td>
<td>0.366</td>
</tr>
</tbody>
</table>
than between individuals (which is consistent with the results in chapter 6) and was higher for the total data than for the data on weekdays.

The models for the shares of total motorised travel time and distance had the highest explained proportions of variance between neighbourhoods. From the 9 models for all diaries, these models also had the highest explained proportion of variance between individuals, however these figures are still below 30%. The models for total number of trips, total number of tours, total travel distance and total motorised travel distance can also be considered performing well. From the models for weekday diaries, only the model for total motorised travel distance can be considered performing well, with almost 50% of variance explained both between individuals and between neighbourhoods.

7.4.2 Results of Multilevel Models

In this section the results of the multilevel analyses will be discussed. The focus will be on the effects of the spatial independent variables. All spatial independent variables significant at the 5% confidence level will be considered here, regardless of the values of $R^2$ at both levels for the models. In case of interaction effects, the accompanying socioeconomic variable will be listed in footnotes with each table. For a complete overview of all models, including the significant socioeconomic effects see appendix 7.

<table>
<thead>
<tr>
<th>variable</th>
<th>level</th>
<th>total number of tours</th>
<th>total number of trips</th>
<th>trip/tour ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>transportation</td>
<td>radial</td>
<td></td>
<td>-0.9$^1$ (-0.14)</td>
<td></td>
</tr>
<tr>
<td>network type</td>
<td>axial</td>
<td></td>
<td>+1.0$^2$ (0.20)</td>
<td></td>
</tr>
<tr>
<td>neighbourhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>local street network type</td>
<td>loop</td>
<td></td>
<td>+1.1$^3$ (0.23)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>grid</td>
<td></td>
<td>+0.6 (0.14)</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ interaction effect in combination with household income 1-2 x standard
$^2$ interaction effect in combination with working part time
$^3$ interaction effect in combination with household type couple
**total number of trips and tours**

No significant effects of spatial characteristics on the total number of tours and the trip/tour ratio were found (table 7.2). However, the number of trips is influenced by the transportation network type of the neighbourhood and the local street network type. A grid type local street network increases the number of trips. A similar increasing effect was found for loop type local streets, yet only for those in a two person household. For this household type we also found a higher number of trips when living in a neighbourhood with an axial transportation network type. Finally, the number of trips is lower for households with an income between 1 and 2 times standard in a neighbourhood with a radial network.

<table>
<thead>
<tr>
<th>variable</th>
<th>level</th>
<th>number of tours</th>
<th>number of trips</th>
<th>trip/tour ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>land use mix</td>
<td>limited</td>
<td>-0.6 (-0.80)</td>
<td>-0.51 (-0.45)</td>
<td>+0.61 (-0.44)</td>
</tr>
<tr>
<td></td>
<td>ample</td>
<td>+0.8 (0.91)</td>
<td>+0.6¹ (-0.44)</td>
<td></td>
</tr>
</tbody>
</table>

¹ interaction effect in combination with higher education

**trips and tours on weekdays**

For the number of trips and tours and their ratio on weekdays, only the effect of land use mix on the trip tour ratio is significant at the 5% level (table 7.3). No effects for urban form characteristics on the number of trips and tours on weekdays were found. A limited land use mix is related to reduced trip chaining, especially for those with higher education. An ample land use mix yields the opposite result. The standardised coefficients show that the first order effects are more substantial than the interaction effects.

**total travel time and distance**

Again, only a few of the tested relationships proved to have significant effect (table 7.4). The significant effects on travel time and travel distance that were found are mainly interaction effects. In other words, these effects of spatial characteristics only hold for certain socioeconomic groups. Travel time is hardly influenced by variables describing
Urban Form and Activity-Travel Patterns

the spatial environment. Only for the transportation network type of the city a significant relationship was found. The total amount of time spent on travelling increases in ring network cities for those with an income of 2 times standard and more. For the same income group, travel time by motorised modes is influenced by the land use mix of the neighbourhood. Their travel time is lower in neighbourhoods with a limited land use mix and higher in neighbourhoods with ample land use mix. A limited land use mix is also negatively related to the modal share of travel time by motorised modes, yet only for those with always a car available. Total travel distance is not at all related to urban form characteristics, however, the travel distance by motorised modes and the

table 7.4  **significant effects of the independent variables on the total travel time and distance**
(360 respondents, 567 diary days, standardised coefficients between brackets)

<table>
<thead>
<tr>
<th>variable level</th>
<th>total travel time</th>
<th>total motorised travel time</th>
<th>modal share motorised travel time</th>
<th>total travel distance</th>
<th>total motorised travel distance</th>
<th>modal share motorised travel distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>transportation network type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>city</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ring</td>
<td>+13.7</td>
<td>(0.19)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>loop/tree</td>
<td>+0.14</td>
<td>(0.15)</td>
<td>+0.10</td>
<td>(0.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>loop/grid</td>
<td>-0.19</td>
<td>(+0.17)</td>
<td>+0.25</td>
<td>(0.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>land use mix</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>limited</td>
<td>-15.9</td>
<td>(-0.25)</td>
<td>-0.13</td>
<td>(-0.29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ample</td>
<td>+29.7</td>
<td>(0.35)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to city centre</td>
<td></td>
<td></td>
<td></td>
<td>-8.1</td>
<td>(-0.10)</td>
<td></td>
</tr>
<tr>
<td>distance to IC-station</td>
<td></td>
<td></td>
<td></td>
<td>-3.2</td>
<td>(-0.12)</td>
<td></td>
</tr>
</tbody>
</table>

1  interaction effect in combination with personal income > 2x standard
2  interaction effect in combination with personal income 1-2x standard
3  interaction effect in combination with always car available
modal split is. The travel distance by motorised modes is lower when an inter-city station is further away and decreases even more for those with an income of 2 times standard or more when the distance to the city centre increases. This is a striking finding, one would expect the opposite. Finally, the modal share of motorised transport in kilometres is affected by the local street network type. The share for motorised transport is higher when local streets have a loop/tree network.

**travel time and distance on weekdays**

When evaluating the results for travel time and distance on weekdays, we find that the results for weekday patterns differ substantially from those pertaining to total patterns (table 7.5). We find several effects on travel distance for weekdays, while total travel distance was not related to urban form characteristics at all. It appears as if those who travel many kilometres during weekdays, travel less during weekends and vice versa. On weekdays, travel distances can be influenced (in a limited way) by the spatial environment, yet this effect is lost when looking at all diary days. Another interesting finding is that travel time on weekdays is not affected by urban form characteristics. Apparently, in all types of urban forms people spend a comparable amount of time on weekday travelling. Total travel distance proves to vary considerably with local street network type, but only for selected groups with specific socioeconomic characteristics. In loop, loop/tree and loop/grid network streets, couples travel less. In loop/tree network streets, those with a minimum to standard income travel more, while they travel less in loop/grid networks. This is also the only socioeconomic group that is sensitive to distance to the city centre. With increasing distance to the city centre, they travel less. This income group appears to have a small action space on weekdays, choosing destinations near their home location. People with a slightly higher income (1-2x standard) travel more in loop/grid networks. Travel distance on weekdays by motorised modes is also related to local street network types. In loop/grid type streets we find higher numbers of kilometres by motorised modes. However, the opposite is true for couples. In grid type streets we find higher numbers of kilometres by motorised modes for those with higher education and for couples. Finally, a small effect of population density of the neighbourhood on the modal share of motorised travel was found. This share increases slightly with density.
Urban Form and Activity-Travel Patterns

Table 7.5  Significant Parameters Travel Time and Distance on Weekdays (225 Respondents, 372 Diary Days, Standardised Coefficients Between Brackets)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Total Travel Time</th>
<th>Total Motorised Travel Time</th>
<th>Modal Share Motorised Travel Time</th>
<th>Total Travel Distance</th>
<th>Total Motorised Travel Distance</th>
<th>Modal Share Motorised Travel Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Street Network Type</td>
<td>Loop</td>
<td>-55.0^1</td>
<td>3 (-0.43)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loop/Tree</td>
<td>+157.9^1</td>
<td>(0.80)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-113.3^3</td>
<td>(-0.85)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loop/Grid</td>
<td>-167.6^2</td>
<td>(-0.88)</td>
<td>+136.9^3</td>
<td>(0.80)</td>
<td>-95.0^3</td>
<td>(-0.63)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grid</td>
<td>+232.0^5</td>
<td>(1.63)</td>
<td>+53.9^1</td>
<td>(0.44)</td>
<td>+72.3^3</td>
<td>(0.62)</td>
</tr>
<tr>
<td>Distance to City Centre</td>
<td>-</td>
<td>-21.5^5</td>
<td>(-0.98)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Density</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+0.01</td>
</tr>
</tbody>
</table>

^1 Interaction effect in combination with higher education
^2 Interaction effect in combination with personal income 1-2x standard
^3 Interaction effect in combination with household type couple
^4 Interaction effect in combination with personal income minimum to standard

7.5 Summary and Conclusions

In this chapter, travel indicators derived from activity diaries were discussed. First a general description of the indicators was given. Further on, they were analysed using multilevel analysis. The indicators included the number of trips, the number of tours, the trip/tour ratio, the total travel time, the motorised travel time, the modal share
motorised travel time, the travel distance, the motorised travel distance and the modal share motorised travel distance. This set of indicators was generated from the activity diaries for weekdays only and for all days.

In chapter 6, where trips for frequent activities were analysed, few effects of urban form characteristics on trip characteristics were found using multilevel analysis. In this chapter, looking at total activity-travel patterns, we again find few significant results. Where the general description of the data by spatial characteristics highlighted several interesting differences in travel behaviour, using multilevel analysis a very limited set of urban form characteristics was found to influence the travel indicators, most important being the local street network type and the land use mix in the neighbourhood. These are interesting findings. Both variables describe the spatial characteristics of the immediate surroundings of the home and they appear to be more important than larger scale characteristics. This is consistent with the findings of some of the studies discussed in chapter 2, where for instance significant effects of the presence of sidewalks were found. Furthermore, rather sizable differences in travel distance on weekdays were found for certain socioeconomic characteristics. However, in the analyses of all travel diaries these effects disappeared, thus indicating compensating travel behaviour in weekends. We have to conclude that the relationship between urban form and travel patterns is weak and that a substantial reduction of (motorised) travel using urban form measures cannot be expected.

Table 7.6 summarises the effects for each urban form characteristic and level for which a significant effect was found. Effects are classified as positive or negative. An effect is considered positive when the number of kilometres or trips is reduced, when the number of motorised kilometres or trips is reduced and/or when the share of motorised travel is decreased. Some urban form characteristics have unambiguous positive or negative effects. For other characteristics contradictory results were found. However, after further deliberation, most characteristics can be classified as positive or negative, considering for instance that an increase in travel time is less of a negative effect than an increase in travel distance or when a negative effect is found only for a certain socioeconomic group. Based on these considerations, the following characteristics can be considered positive: the radial neighbourhood transportation network, limited land use mix and increasing distance to the city centre and the inter-city train station. Negative effects were found for the ring city transportation network, the axial neighbourhood transportation network, the loop and loop/tree and grid local street...
networks and population density of the neighbourhood. The ambiguous effects found for loop/grid local street networks and for ample land use mix make it difficult to place them either on the positive or on the negative side. When comparing the results to the general description of the data, we find that some of the significant effects found with multilevel analysis, controlling for socioeconomic factors, are consistent with the results of the general inspection of the data. However, also contradictory results are found.

These few results hardly support the hypotheses derived from the literature and practice. Longer distances to the city centre and the inter-city train station have positive effects (although only for specific groups), which is the opposite of the expectations. In the analyses of frequent activities the distance to the city centre was found to have a negative effect for non-grocery shopping, but apparently this effect does not apply to total travel patterns. Both ample and limited land use mix show mixed results. Ample land use mix is difficult to classify as positive or negative. However, limited land use mix tends to have more positive than negative effects. As for the transportation network types, no clear hypotheses were available, although the new urbanism theories propagate grid type networks. The grid street network however scores negative in these analyses, just like loop and loop/tree networks. A better interconnected street network makes travel easier, therefore apparently inducing more travel.

Finally, the results of the analyses of the diaries were compared with the results of the analyses of the frequently made trips. This comparison was possible on four dependent variables: number of kilometres, number of motorised kilometres, modal share of motorised kilometres and number of trips. Across all analyses we find that the number of kilometres travelled is rather independent of the spatial environment. For none of the frequently made trips a significant effect of spatial characteristics on the number of kilometres was found, nor were such significant effects found for activity-travel diaries. Weekday diaries however, do show significant effects of spatial characteristics (local street network type and distance to the city centre) on total mobility, yet only for specific socioeconomic groups. Significant effects on the number of motorised kilometres were found for all diaries and for weekday diaries and for non-grocery shopping trips. However, for each of these dependent variables, one or more different urban form characteristics proved to have a significant effect. Again, effects were found of local street network type and distance to the city centre, complemented with the transportation network type of the city and the distance to the inter-city train station. The modal share of motorised trips is significantly influenced by spatial characteristics for all frequently
made trips and for both weekday and total diaries. Yet again, we find that for different dependent variables, different (levels of) spatial variables show a significant effect. Transportation network type of the neighbourhood, local street network, local facilities (for shopping or sports) and the population density of the neighbourhood affect the modal split. Finally, only the number of trips for grocery shopping and the number of trips in all activity-travel diaries are affected significantly by spatial characteristics. Different spatial characteristics for both dependent variables are found to have significant effects. Transportation network type neighbourhood and local street network type affect the number of trips in all diaries, while the location of the city in relation to the Randstad affects the number of trips for grocery shopping.

This comparison of results from both motive-specific trips and activity-travel diaries shows that for these four dependent variables, more effects are found in the analysis of diary data than in the analysis of motive-specific trips. The effects found are rather inconsistent. This could partly be caused by the differences in the number of cases. However, for the few (levels of) spatial characteristics that influence more than one dependent variable we also find that results often contradict each other. This comparison strengthens our conclusion that the effect of urban form on travel behaviour is rather limited. It also indicates that the analysis of complete activity-travel patterns describing the travel behaviour of total days can lead to different conclusions on the influence of spatial characteristics on travel behaviour.
<table>
<thead>
<tr>
<th>Urban form characteristic</th>
<th>Level</th>
<th>Positive effect</th>
<th>Negative effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation network type city</td>
<td>ring</td>
<td>• less trips (total) (with household income 1-2x standard)</td>
<td>• more total travel time (with income &gt; 2x standard)</td>
</tr>
<tr>
<td>Transportation network type neighbourhood</td>
<td>radial</td>
<td>• less trips (total) (with household income 1-2x standard)</td>
<td>• more trips (total) (with working part time)</td>
</tr>
<tr>
<td></td>
<td>axial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local street network type</td>
<td>loop</td>
<td>• less kilometres weekdays (with household type couple)</td>
<td>• more trips (total) (with household type couple)</td>
</tr>
<tr>
<td></td>
<td>loop/tree</td>
<td>• less kilometres on weekdays (with household type couple)</td>
<td>• higher share total motorised travel time (with income &gt; 2x standard)</td>
</tr>
<tr>
<td></td>
<td>loop/grid</td>
<td>• lower share total motorised travel time (with income &gt; 2x standard)</td>
<td>• higher share total motorised travel time (with income 1-2x standard)</td>
</tr>
<tr>
<td></td>
<td>grid</td>
<td></td>
<td>• more trips (total)</td>
</tr>
<tr>
<td>Land use mix</td>
<td>limited</td>
<td>• less travel time (with income &gt; 2x standard)</td>
<td>• less trip chaining on weekdays (especially with higher education)</td>
</tr>
<tr>
<td></td>
<td>ample</td>
<td>• more trip chaining on weekdays (especially with higher education)</td>
<td>• more total travel time (with income &gt; 2x standard)</td>
</tr>
</tbody>
</table>
### Table 7.6 Summary of Results (continued)

<table>
<thead>
<tr>
<th>Urban Form Characteristic</th>
<th>Positive Effect</th>
<th>Negative Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Inter-City Train Station</td>
<td>• Less total motorised kilometres</td>
<td></td>
</tr>
<tr>
<td>Distance to City Centre</td>
<td>• Less total motorised kilometres (with income &gt; 2x standard)</td>
<td>• Less kilometres on weekdays (with income minimum to standard)</td>
</tr>
<tr>
<td>Population Density Neighbourhood</td>
<td>• Higher share motorised kilometres on weekdays</td>
<td></td>
</tr>
</tbody>
</table>
8 | CONCLUSIONS AND DISCUSSION

8.1 Introduction

Activity-travel patterns of individuals and households are the complex manifestation of their pursuit of basic needs and personal preferences within the opportunities and constraints offered by the urban environment. With this realisation in mind, this thesis has presented the results of an extensive research project that examined the nature of the relationship between urban form and activity-travel patterns in a Dutch context.

In the first chapters it was argued that existing spatial mobility planning practice in the Netherlands is often based on explicit or implicit assumptions and reasoning about the relationship between urban form and travel behaviour. Unfortunately, there is, especially within the Netherlands, a lack of (methodologically sound) empirical evidence about the existence of such a relationship. The studies that exist have typically focussed on single aspects of travel behaviour as opposed to comprehensive activity-travel patterns. It is well-known that such a focus on a single aspect, for example the work commute, may potentially yield unrealistic and irrelevant results. When the trip to work is only short, people may have more energy left to engage in additional evening activities and trips, increasing their total mobility. Moreover, existing studies, both national and international, have rarely attempted to systematically disentangle the effects of urban form and the effects of socioeconomic factors. Socioeconomic and urban characteristics may be strongly correlated, implying it is difficult to estimate the effects of urban characteristics, unless appropriate methodological decisions are made.

This study was motivated by the expectation that a contribution to this field of study could be made by conducting a methodologically more rigorous study that examines the relationship between urban form and complete daily activity-travel patterns. The contribution of this study to the international literature is threefold:
- It is the first study to examine the impact of urban form on comprehensive activity-travel patterns as opposed to single motives.
- It is the first study that has used a quasi-experimental design approach to better disentangle the effects of urban form characteristics and socioeconomic characteristics.
- It is the first study to apply a multilevel analysis to obtain more reliable estimates of the effects of urban form characteristics on travel behaviour.

8.2 Short Summary of the Study

The objective of this thesis was to examine the relationship between urban form characteristics and travel patterns. An empirical study was conducted to empirically test the implicit or explicit car mobility reduction claims, underlying Dutch mobility and land use policies. The activity-based approach was adopted, since data on activity-travel patterns give a more comprehensive account of travel behaviour. The approach allowed us to examine whether the findings obtained for single activities hold if the focus shifts to complete activity patterns.

A quasi-experimental design was chosen for data collection. Characteristics of urban form were carefully selected for inclusion in the study, based on the literature. Neighbourhoods for data collection were selected such that the association between urban form characteristics and a set of socioeconomic variables is low. In 19 selected neighbourhoods in 9 Dutch cities data on activity and travel patterns was collected by administering activity-travel diaries. The data collected included both activity-travel diary data and travel data on a set of frequently conducted activities. Multilevel analysis was used for examining the data collected. Multilevel analysis is very appropriate for this study since it allows us to identify the contribution of various variables, specified at different levels, to the variance in the dependent variable. The independent variables in this study were measured at the level of the individual/household and the level of the neighbourhood. Using multilevel analysis, arbitrarily increasing the sample size for the neighbourhood characteristics by disaggregating them to the individual level, is avoided.

The results of the analyses of both the motive-specific trip data and the complete activity-travel diaries indicate that, when controlling for socioeconomic characteristics, the influence of urban form on travel behaviour is limited. Only a few of the examined
relationships proved to yield significant results. Effects were found from urban shape, transportation network types at different levels, available services and land use mix in the neighbourhood, degree of urbanisation of the neighbourhood, population density of the neighbourhood and distance to the city centre or inter-city train station. Note that the effects of urban shape, available services and degree of urbanisation are only found in the analyses of motive specific trips. More effects were found from characteristics of the neighbourhood than from characteristics of the city. This implies that neighbourhood design is more influential than characteristics of the city or town as a whole. The list of independent variables that were found to be significantly related to travel behaviour, includes variables that also frequently appears in theories, empirical studies and policies on the relationship between urban form and travel behaviour. However, the results from this investigation do not necessarily confirm the hypotheses derived from the available literature. Some of the effects are the opposite of expectations and some are only true in combination with specific socioeconomic characteristics of the individual or household. Furthermore, only very few effects were found on total (motorised) mobility. This leads us to the conclusion that, within the current social, cultural and economic context, the potential of urban design as a measure to reduce (motorised) travel in Dutch medium sized cities is very limited, yet that urban design of neighbourhoods can influence some elements of the travel behaviour of their inhabitants.

The evaluation of the activity-travel diary data distinguished between weekday data and all data. It was found that differences in travel distance on weekdays can be rather sizable for certain urban form characteristics (in combination with some socioeconomic characteristics). In the analysis of diary data for all days, these effects disappear. This is an indication of compensation behaviour in weekends. It appears that what is gained by influencing weekday trips, is mostly lost in the total travel pattern. Finally, the comparison of the results for complete activity-travel diaries and for motive-specific trips revealed mixed results, even for the same characteristics. This indicates that the analysis of complete activity-travel diaries can lead to different conclusions than the analysis of motive-specific trips. Given that the analysis of travel behaviour for specific motives does not yield results similar to the analysis of diaries, and given that activity-travel diaries give a more comprehensive picture of travel behaviour, we argue that the analysis of activity-travel diaries is to be preferred over the analysis of motive-specific trips when studying the influence of the spatial environment.
8.3 Discussion of the Study

As with any study, positive and negative remarks can be made with regard to the approach chosen and the operational decisions taken. This is intrinsic to the necessity to make choices during the research process, and to the courses left open as a consequence of these operational choices. In this section, some of the choices made will be discussed. Furthermore, some critical observations will be made on the study itself.

First some remarks on choices regarding the selection independent variables. With the recognition that travel is derived from activity participation, the researcher is snowed under with factors that are potentially related to the matter under study, travel. Everything influencing activity participation is also a potentially important factor for travel analysis. In this study, we chose to focus on the effects of spatial characteristics of the urban environment on travel, while controlling for socioeconomic characteristics of individuals and households. This is just a subset of the extensive set of potentially influencing factors. Cultural background or personal attitudes of households and individuals, group attitudes and influence and other social and psychological factors have not been taken into account. This does by no means imply that these factors can be ignored. We are well aware of their possible effects and encourage any initiative to examine their influence. However, they did not fit within the scope of this study.

Furthermore, based on the literature and an analysis of spatial mobility policies in the Netherlands a set of urban form characteristics was chosen for the present study. This is, by definition, not an exhaustive list. The study is limited to basic urban shapes, structures and characteristics. It might be argued that urban shapes are too abstract to identify and study. On the other hand, a typology of such urban forms belongs to the core of urban design.

This is also the place for some critical observations regarding the methodology of the study. The sophistication of the chosen method of analysis not only demands a high data quality, but, in order to obtain significant relationships, also a rather large amount of data. The analyses of data quality indicated that the data showed little bias, indicating that our quasi-experimental design for data collection has yielded the desired result. However, we also had to accept the fact that the response rate, and therefore the total number of respondents, was lower than we had hoped for. The rather low total number of cases, both in total and, consequently, by urban form characteristic, could be the cause
of a relatively low number of significant results that were found. However, this does not influence the strength of the effects found. A larger sample size will, ceteris paribus, only increase the significance of results, not the strength of relationships.

8.4 Recommendations for Planning and Policy

The aim of this study was to test the claims in current Dutch mobility reduction policies that urban form characteristics can help reduce (motorised) mobility. Based on the results of this study we have to conclude that the potential of urban design measures to reduce the number of trips made and the number of kilometres travelled and to induce a shift in the modal split is limited. We found a small number of effects for urban form characteristics. However, the results found do suggest that urban form should be a factor in policy making for mobility reduction. Characteristics such as neighbourhood network type, street network type, land use mix, density and distance to the city centre or inter-city station appear to be related to travel and mode choice. The radial neighbourhood network, limited land use mix and distance to the city centre and inter-city station have a positive effect on travel behaviour, as can be seen in the analyses of activity-travel diaries. Negative effects are found for the ring network city, the axial network neighbourhood, the loop, loop/tree and grid local street networks and increasing density of the neighbourhood. Especially the results from network types give reason to pay more attention to qualitative design characteristics, in addition to the existing attention to quantitative measures such as density or distance. Furthermore, the finding that neighbourhood characteristics are more influential than characteristics of the city indicate that neighbourhood design matters.

In the introduction to this chapter, we have argued that activity-travel patterns are the result of a complex interplay between personal needs and preferences and the opportunities and constraints the urban environment offers. The results of this study lead us to the conclusion that most households are not primarily driven by the opportunities and constraints offered by the environment. Apparently, the choice of city and the choice of neighbourhood is not heavily influenced by mobility considerations. This finding, by the way, is consistent with the findings in housing research [Hunt et al, 1994].
Planners and policy makers should keep in mind that spatial planning and design choices determine the characteristics of the urban environment for decades ahead. This study has investigated the travel and activity patterns of present day people in the urban environment of Dutch medium sized cities. In doing so, the social, cultural and economic features of this day and age are contextual factors in the study. Results hold for this context. In these circumstances, as argued above, it appears that the urban environment on average poses little constraints on people’s travel and activity patterns. Money and time appear to be sufficient to choose activity-travel patterns that fulfill the basic needs and personal preferences best, yet might not be the most efficient from a transportation point of view. The findings of compensation between weekdays and weekends indicate that individuals will try to realise and optimise their desires. Distances and/or travel time appear to play only a minor role in this context. However, social, cultural and economic circumstances can change. The time may come that money and time or people’s attitudes towards travel and transportation or environmental issues change. Under such changed circumstances, the opportunities and constraints offered by the urban environment may become more influential on people’s activity-travel patterns. Therefore, it is important that the urban environment as it is being designed today enables future users to employ efficient and effective travel patterns. This means that urban design should be such that it enables people to reduce their travel by shortening distances and it induces the choice of travel modes alternative to motorised modes, even though the immediate effect is limited. Such a well-designed, sustainable, urban environment may not immediately benefit (motorised) mobility reduction. However, one should keep in mind that it may prevent substantial losses in the future.
REFERENCES


References


Stopher, P.R. [1992] Use of an Activity-Based Diary to Collect Household Travel Data. 


This appendix includes a summary of the empirical studies discussed in chapter 3. First the studies with the region as the unit of analysis are summarised in alphabetical order of author, then the studies with the city as the unit of analysis are summarised in a similar way and, finally, the studies with the neighbourhood as the unit of analysis follow accordingly.
### Empirical Studies at the Regional Level

<table>
<thead>
<tr>
<th>Source</th>
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<th>Data</th>
<th>Control Socio-Economic Variables</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gordon [1997]</td>
<td>Regression</td>
<td>Newman &amp; Kenworthy data set, National Travel Survey and travel to work data from 193 regions</td>
<td>Yes</td>
<td>Density, size, mix and accessibility influence mode choice and energy use</td>
</tr>
<tr>
<td>Handy [1993]</td>
<td>Correlations</td>
<td>Aggregate data on non-work travel from the San Francisco Bay Area in 550 zones</td>
<td>No</td>
<td>Mixed land use influences mode choice for shopping, but not the total mobility</td>
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<tr>
<td>Miller &amp; Ibrahim [1998]</td>
<td>Regression</td>
<td>Aggregate data from the Toronto region in 1404 zones</td>
<td>No</td>
<td>Centralisation in city centre and subcentres reduces average commuting distance</td>
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<tr>
<td>Mogridge [1995]</td>
<td>Comparative</td>
<td>Aggregate data from London and Paris regions</td>
<td>Yes</td>
<td>Limited effects found from density and public transport provision</td>
</tr>
<tr>
<td>Næss [1993]</td>
<td>Regression</td>
<td>Aggregate data from 15 Swedish Urban Regions</td>
<td>Yes</td>
<td>Density, concentration and degree of urbanisation explain 39% of variation in energy use</td>
</tr>
<tr>
<td>Næss &amp; Sandberg [1996]</td>
<td>Regression</td>
<td>Disaggregate commuting data from 6 companies in the Oslo region</td>
<td>Yes</td>
<td>Geographical location company influences mode choice and energy use</td>
</tr>
<tr>
<td>Newman &amp; Kenworthy [1989]</td>
<td>Regression</td>
<td>Aggregate data on worldwide metropolitan areas, gasoline use and density</td>
<td>No</td>
<td>Energy consumption decreases with density</td>
</tr>
<tr>
<td>Schimek [1996]</td>
<td>Comparative</td>
<td>Aggregate data from Toronto and Boston regions</td>
<td>No</td>
<td>Higher densities, greater concentration of jobs and better public transport facilities induce more transit use and lower car use</td>
</tr>
<tr>
<td>Source</td>
<td>Method</td>
<td>Data</td>
<td>Control Socio-economic Variables</td>
<td>Main Findings</td>
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<tr>
<td>------------------------</td>
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<td>---------------------------</td>
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<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Banister, Watson &amp; Wood [1996]</td>
<td>Stepwise regression</td>
<td>Disaggregate data from 4 British and 1 Dutch city, each city studied separately</td>
<td>Yes</td>
<td>Mixed land use works when both qualitative and quantitative; density, open space and city size also influence energy use</td>
</tr>
<tr>
<td>Frank &amp; Pivo [1994]</td>
<td>Regression</td>
<td>Disaggregate data on home-to-work and shopping trips from the Puget Sound survey</td>
<td>Yes</td>
<td>Mixing of land use and population and job density influence mode choice</td>
</tr>
<tr>
<td>Næss [1993]</td>
<td>Regression</td>
<td>Aggregate data from 97 Swedish towns</td>
<td>Yes</td>
<td>19% of variation in energy use is explained by population density</td>
</tr>
<tr>
<td>Næss, Sandberg &amp; Røe [1996]</td>
<td>Regression</td>
<td>Aggregate data from 22 Nordic towns</td>
<td>Yes</td>
<td>Population density and concentration reduce energy use</td>
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### Empirical Studies at the Neighbourhood Level

<table>
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<th>Main Findings</th>
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</thead>
<tbody>
<tr>
<td>Cervero [1988]</td>
<td>Stepwise regression (R² between 0.37 and 0.66)</td>
<td>Disaggregate data on home to work trips from 57 large suburban centres in the USA</td>
<td>Yes</td>
<td>Single office settings induce solo commuting, mixing increases alternative modes, especially when retail is available</td>
</tr>
<tr>
<td>Cervero [1996]</td>
<td>Comparative &amp; regression (R² = 0.46)</td>
<td>Aggregate data on matched pair neighbourhoods in the San Francisco Bay Area (transit vs. car-oriented neighbourhoods)</td>
<td>Solely by matching on income</td>
<td>Residential density and transit facilities increase transit use home-to-work, in transit neighbourhoods more walk, cycle and transit</td>
</tr>
<tr>
<td>Cervero &amp; Gorham [1995]</td>
<td>Regression (R² = 0.55)</td>
<td>Disaggregate commuting data from the San Francisco Bay Area and Southern LA (transit vs. car-oriented neighbourhoods)</td>
<td>Solely by matching on income</td>
<td>Density and neighbourhood type and their interaction influence transit use to work</td>
</tr>
<tr>
<td>Cervero &amp; Kockelman [1997]</td>
<td>Regression (R² between 0.17 and 0.20)</td>
<td>Disaggregate data from 50 sampled neighbourhoods in the USA</td>
<td>Yes</td>
<td>Increased accessibility reduces total travel, intensity (composite variable of density and land use mix), vertical land use mix and grid streets reduce non-work travel, high proportion of rectangular block increase total and non-work travel</td>
</tr>
<tr>
<td>Dumbaugh, Ewing &amp; Brown [2001]</td>
<td>Regression (R² = 0.47)</td>
<td>Aggregate data from 22 neighbourhoods in South Florida</td>
<td>No</td>
<td>Internal capture rates (rate of trips within area) are higher in high density neighbourhoods with commercial functions and a jobs/housing balance comparable to the total region</td>
</tr>
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<td>control socio-economic variables</td>
<td>main findings</td>
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</tr>
<tr>
<td>Ewing, Halyur &amp; Page [1994]</td>
<td>comparative</td>
<td>aggregate data from a diary based survey in six</td>
<td>solely by matching on income</td>
<td>high density and land use mix reduce use of motorised transport</td>
</tr>
<tr>
<td></td>
<td>(ANOVA)</td>
<td>neighbourhoods in Florida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Florez [1998]</td>
<td>comparative</td>
<td>disaggregate data from 3 neighbourhoods in Caracas</td>
<td>solely by matching on income</td>
<td>in traditional neighbourhoods less car use, more transit use and lower travel time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(traditional vs. clustered neighbourhoods)</td>
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<td></td>
</tr>
<tr>
<td>Friedman, Gordon &amp; Peers [1994]</td>
<td>comparative</td>
<td>aggregate data from San Francisco (traditional vs.</td>
<td>matching on income and housing price</td>
<td>standard suburban neighbourhoods show higher trip rates (both total and by car)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>standard suburban)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handy [1996]</td>
<td>comparative</td>
<td>disaggregate data from 4 neighbourhoods in San</td>
<td>matching</td>
<td>higher accessibility gives shorter trips, higher trip frequency and more walking, higher accessibility in combination with more variation in destinations gives longer trips</td>
</tr>
<tr>
<td></td>
<td>(ANOVA)</td>
<td>Francisco Bay Area (modern vs. traditional)</td>
<td></td>
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<tr>
<td>Hanson [1982]</td>
<td>regression</td>
<td>disaggregate data from the Uppsala travel diary</td>
<td>yes</td>
<td>mixing of functions near home or workplace influences travel behaviour</td>
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<tr>
<td></td>
<td>(R² between</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.10 and</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitamura, Mokhtarian &amp; Laidet</td>
<td>regression</td>
<td>disaggregate data from travel diaries in 5 San</td>
<td>yes</td>
<td>residential density, public transport</td>
</tr>
<tr>
<td>[1997]</td>
<td>(R² between</td>
<td>Francisco Bay Area neighbourhoods</td>
<td></td>
<td>accessibility, mixed land use and having side walks influence number of trips and mode choice</td>
</tr>
<tr>
<td></td>
<td>0.03 and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.16)</td>
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<td></td>
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<td>method</td>
<td>data</td>
<td>control socio-economic variables</td>
<td>main findings</td>
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<td>----------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Konings, Kruythoff &amp; Maat [1996]</td>
<td>regression</td>
<td>disaggregate data from 909 recently moved households in newly developed areas in the Netherlands</td>
<td>yes</td>
<td>no effect from spatial variables in regression analysis</td>
</tr>
<tr>
<td>MuConsult [2000]</td>
<td>regression</td>
<td>disaggregate data from 713 respondents in the Netherlands</td>
<td>yes</td>
<td>travel distance is influenced by street type, density and walk/cycle friendliness, number of trips is influenced by street type and accessibility of shopping facilities</td>
</tr>
<tr>
<td>Næss, Røe &amp; Larsen [1995]</td>
<td>regression</td>
<td>disaggregate data from 30 residential areas in Oslo</td>
<td>yes</td>
<td>distance to downtown influences total travel distance and energy use, residential density influences public transport use and local service accessibility influences energy use</td>
</tr>
<tr>
<td>Nasar [1997]</td>
<td>comparative</td>
<td>disaggregate data from 2 neighbourhoods in Ohio (neotraditional vs. suburban)</td>
<td>yes</td>
<td>small differences between neighbourhoods found for total number of trips and some trip purposes</td>
</tr>
<tr>
<td>Røe [1999]</td>
<td>regression</td>
<td>disaggregate data from 400 respondents in 30 residential neighbourhoods in Oslo</td>
<td>yes</td>
<td>distance from home to work and distance from home to private services influence total travel distance and time, distance from home to city centre influence total travel distance</td>
</tr>
<tr>
<td>Scott Rutherford, McCormack &amp; Wilkinson [1996]</td>
<td>comparative</td>
<td>aggregate data from travel diaries in 4 Seattle neighbourhoods</td>
<td>yes, but limited</td>
<td>mixed land use is linked to less travel</td>
</tr>
<tr>
<td>source</td>
<td>method</td>
<td>data</td>
<td>control socio-economic variables</td>
<td>main findings</td>
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<td>------------------------</td>
<td>------------</td>
<td>----------------------------------------------</td>
<td>----------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sun, Wilmot &amp; Kasturi [1998]</td>
<td>regression</td>
<td>disaggregate data from the Portland travel survey</td>
<td>yes</td>
<td>land use balance and accessibility influence total travel, no influence of spatial variables on number of trips</td>
</tr>
<tr>
<td>McCormack, Rutherford &amp; Wilkinson [2001]</td>
<td>ANOVA</td>
<td>aggregate data from travel diaries in Seattle Region and 3 mixed land use neighbourhoods</td>
<td>yes, limited</td>
<td>mixed land use is linked to less kilometres travelled, and more use of walking and transit; no effect found on travel time</td>
</tr>
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## APPENDIX 2 | City and Neighbourhood Characteristics

### Almere

<table>
<thead>
<tr>
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<td>poly-nuclear</td>
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<td>city road network type</td>
<td>ring</td>
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<tr>
<td>location</td>
<td>inside Randstad</td>
</tr>
<tr>
<td>employment (jobs/1000 inhabitants)</td>
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</tr>
<tr>
<td>population density (per hectare)</td>
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</tr>
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<td>housing density (per hectare)</td>
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<td>degree of urbanisation</td>
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### Almere Muziekwijk (1)

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<td>neighbourhood road network type</td>
<td>ring</td>
</tr>
<tr>
<td>local street network type</td>
<td>loop/grid</td>
</tr>
<tr>
<td>distance to city centre</td>
<td>2-3 kilometres</td>
</tr>
<tr>
<td>distance to IC station</td>
<td>3 kilometres</td>
</tr>
<tr>
<td>land use mix</td>
<td>limited</td>
</tr>
<tr>
<td>local shopping facilities</td>
<td>none or just a few shops</td>
</tr>
<tr>
<td>local sports facilities</td>
<td>yes</td>
</tr>
<tr>
<td>population density (per hectare)</td>
<td>54</td>
</tr>
<tr>
<td>housing density (per hectare)</td>
<td>20</td>
</tr>
<tr>
<td>degree of urbanisation</td>
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### Almere Regenboogbuurt (2)

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<tr>
<td>local street network type</td>
<td>loop/grid</td>
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<td>5-6 kilometres</td>
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<td>distance to IC station</td>
<td>6 kilometres</td>
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<tr>
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</tr>
<tr>
<td>local shopping facilities</td>
<td>none or just a few shops</td>
</tr>
<tr>
<td>local sports facilities</td>
<td>no</td>
</tr>
<tr>
<td>population density (per hectare)</td>
<td>54</td>
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<tr>
<td>housing density (per hectare)</td>
<td>20</td>
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<td>degree of urbanisation</td>
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Apeldoorn

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<td>population density (per hectare)</td>
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<td>housing density (per hectare)</td>
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### Apeldoorn Matenveld/donk (3)

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<tr>
<td>Local street network type</td>
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<tr>
<td>Distance to IC station</td>
<td>4 kilometres</td>
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<tr>
<td>Land use mix</td>
<td>limited</td>
</tr>
<tr>
<td>Local shopping facilities</td>
<td>Large neighbourhood shopping centre</td>
</tr>
<tr>
<td>Local sports facilities</td>
<td>yes</td>
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<tr>
<td>Population density (per hectare)</td>
<td>65</td>
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<tr>
<td>Housing density (per hectare)</td>
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<td>Neighbourhood road network type</td>
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<tr>
<td>Distance to city centre</td>
<td>4-5 kilometres</td>
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<td>Distance to IC station</td>
<td>5 kilometres</td>
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<td>Land use mix</td>
<td>limited</td>
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<td>Local shopping facilities</td>
<td>Small neighbourhood shopping centre</td>
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<td>Population density (per hectare)</td>
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Arnhem

<table>
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<td>576</td>
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<td>housing density (per hectare)</td>
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### Arnhem Alteveer/Cranevelt (5)

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<td>Loop/tree</td>
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<tr>
<td>Distance to city centre</td>
<td>2-3 kilometres</td>
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<td>Distance to IC station</td>
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<tr>
<td>Land use mix</td>
<td>None</td>
</tr>
<tr>
<td>Local shopping facilities</td>
<td>Small neighbourhood shopping centre</td>
</tr>
<tr>
<td>Local sports facilities</td>
<td>Yes</td>
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<td>Population density (per hectare)</td>
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<tr>
<td>Housing density (per hectare)</td>
<td>17</td>
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### Arnhem Presikhaaf (6)

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<td>Local street network type</td>
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<td>Distance to city centre</td>
<td>3-4 kilometres</td>
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<td>Distance to IC station</td>
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<td>City district shopping centre</td>
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<td>Land use mix</td>
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<td>Local shopping facilities</td>
<td>City centre</td>
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<td>local sports facilities</td>
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APPENDIX 3 | Definitions of Socioeconomic Variables

education level
The variable ‘education level’ refers to the highest education level successfully finished by the individual in question. Three levels are discerned: no education or just primary school, secondary education (general or vocational) and higher education (higher vocational or university).

personal income
Personal income refers to the individual net income per year. Income has been classified based on the standard income as used by Statistics Netherlands (website). The standard income is the income of a standard employee. A standard employee is an employee with two children below the age of 12 and an income just below the income limit for the Dutch national health service (ziekenfondsgrens). The following categories are discerned: below minimum (yearly income below approximately 15,000 guilders), between minimum and standard (yearly income between 15,000 and 30,000 guilders approximately), between standard and 2x standard (yearly income between 30,000 and 50,000 guilders approximately) and 2x standard and more (yearly income over 50,000 guilders).

driver’s license possession
Driver’s license possession is a personal characteristic describing whether or not the individual has a driver’s license.

employment status
This variable indicates whether a person is not employed, part time employed or full time employed. Employment is considered part time when a person works less than 32 hours per week. Voluntary work that has a regular recurring pattern is also treated as a job.
Car availability
Car availability is defined on the individual level in three categories: no car available, always a car available (main user of a car in the household) and sometimes a car available (secondary user of a car in the household or car shared with others outside the household).

Household income
Household income has been calculated from the data available on the personal incomes of each of the household members. The variable is categorised based on the standard income, in the same categories as are used for personal income.

Household type
As household type were distinguished singles, couples and families with children.

Dwelling type
‘Dwelling type’ refers to the type of house the household in question lives in. Distinction is made between flats or apartments, terraced housing and (semi)detached housing.

Average distance to chosen location (for analysis of frequent activities only)
This variable describes the average distance from home to the chosen locations for recurring trips such as (grocery) shopping, sports and work. In this study, the distance to the chosen location per trip or average distance to the chosen locations per individual are considered variables at the individual level, since choice for a location is a personal choice and can be influenced by many factors. From tentative linear regression analysis it was found that for the travel motives grocery shopping, non-grocery shopping and recurring leisure, this distance per trip cannot be explained by the other spatial and socioeconomic variables included in the research. For home-to-work trips it was found that personal income and gender are related to the distance to the chosen location. For the average distance to chosen location per individual, a multi level analysis showed that again for the motives grocery shopping, non-grocery shopping and recurring leisure, the average distance cannot be explained by the other spatial and socioeconomic variables. For home-to-work trips, gender, age, household income and employment in the city were significantly related to average distance.
APPENDIX 4 | General Description Frequent Activities

The tables listed below contain the figures that go with the general description of the frequent activities data reported on in section 6.2. The tables for grocery shopping and recurring leisure activities include data on total number of kilometres travelled and trips made, as well as the modal share for motorised kilometres and trips. The tables for non-grocery shopping and home-to-work trips include data on total number of kilometres travelled and trips made, as well as the modal shares for motorised, non-motorised and public transport kilometres and trips.

Cells that contain significant differences at the 5% level are grey. For the ordinal independent variables, significance of differences has been established using one-way ANOVA or the Kruskal Wallis test, depending on whether the variances between groups could be considered equal. For the continuous independent variables Pearson correlation coefficient was calculated.
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### Appendix 4

**Travel Characteristics Grocery Shopping by Spatial Characteristics (n=392)**

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**Urban Form and Activity-Travel Patterns**

**correlation coefficients grocery shopping (n=392)**

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## Appendix 4

### Travel Characteristics Non-Grocery Shopping by Individual and Household Characteristics (1)

*(n=460)*

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### Urban Form and Activity-Travel Patterns

**travel characteristics non-grocery shopping by individual and household characteristics (2)**

\[(n=460)\]

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### Travel Characteristics Non-Grocery Shopping by Spatial Characteristics (n=460)

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### Travel Characteristics Non-Grocery Shopping by Spatial Characteristics (2) (n=460)

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### Appendix 4

**Correlation Coefficients for Non-Grocery Shopping (1) \( (n=460) \)**

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**Correlation Coefficients for Non-Grocery Shopping (2) \( (n=460) \)**

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<td>Distance to ic station</td>
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### Travel Characteristics Recurring Leisure Activities by Individual and Household Characteristics (n=340)

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### Travel Characteristics Repeating Leisure Activities by Spatial Characteristics (n=340)

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### Correlation Coefficients Recurring Leisure Activities (n=340)

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## Appendix 4

### Travel Characteristics home-to-work by Spatial Characteristics (1) (n=200)

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### correlation coefficients home-to-work (1) (n=200)

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APPENDIX 5 | Multilevel Analyses Frequent Activities

The tables listed below report the results from the multilevel analyses on frequent activity data, as discussed in chapter 6. The analyses reported in this appendix are based on data on grocery shopping trips from 392 respondents, on non-grocery shopping trips from 460 respondents, on recurring leisure trips from 340 respondents and on home-to-work trips from 200 respondents.

Parameters reported in bold face type are significant at the 5% level, parameters reported in italics are significant at the 10% level. The tables report parameter values and t-values, as is usual when reporting multilevel analysis results.

In the tables the following abbreviations are used for layout reasons:
TNTC = transportation network type city
TNTN = transportation network type neighbourhood
LSNT = local street network type
### Total Number of Kilometres Grocery Shopping

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<td></td>
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Intra class correlation = 0.0%

### Total Number of Motorised Kilometres Grocery Shopping

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<td></td>
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Intra class correlation = 0.1%

### Total Number of Non-Motorised Kilometres Grocery Shopping

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Intra class correlation = 0.1%
Urban Form and Activity-Travel Patterns

<table>
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<tr>
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<th>individual</th>
<th>group</th>
<th>slope average distance</th>
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modal split kilometres grocery shopping

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<tbody>
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<td></td>
</tr>
<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>38.208 (4.229)</td>
<td>24.871 (4.156)</td>
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<tr>
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<td>14.220 (4.022)</td>
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<tr>
<td>working part time</td>
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<tr>
<td>working full time</td>
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<td>TNTN ring</td>
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<td>TNTN loop</td>
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<td>TNTN radial</td>
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<tr>
<td>TNTN axial</td>
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<tr>
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<tr>
<td>car * large neighb. shopping centre</td>
<td>1.321 (5.793)</td>
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<tr>
<td>car * city district shopping centre</td>
<td>-9.982 (11.076)</td>
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<tr>
<td>part time* none or just a few shops</td>
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<tr>
<td>part time* small neighb. shopping centre</td>
<td>-1.728 (7.319)</td>
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<tr>
<td>part time* large neighb. shopping centre</td>
<td>-26.346 (8.562)</td>
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<tr>
<td>part time* city district shopping centre</td>
<td>23.534 (16.285)</td>
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<tr>
<td>full time* small neighb. shopping centre</td>
<td>1.529 (6.352)</td>
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</tr>
<tr>
<td>full time* large neighb. shopping centre</td>
<td>20.148 (7.677)</td>
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Results given are for share of motorised kilometres. Parameters for non-motorised kilometres are identical, but with opposite sign and intercept = 75.129 (4.156).

### Total number of trips grocery shopping

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<td>Intercept</td>
<td>14.511 (0.682)</td>
<td>16.271 (0.992)</td>
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<tr>
<td>Age</td>
<td>0.149 (0.248)</td>
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</tr>
<tr>
<td>Personal income over standard</td>
<td>-1.308 (0.641)</td>
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</tr>
<tr>
<td>Working part time</td>
<td>0.016 (0.971)</td>
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<tr>
<td>Working full time</td>
<td>-2.652 (0.967)</td>
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</tr>
<tr>
<td>Group effects</td>
<td></td>
<td></td>
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<tr>
<td>Location in Randstad</td>
<td>-3.402 (1.479)</td>
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<tr>
<td>$R^2_{\text{group}}$</td>
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<tr>
<td>Intra class correlation</td>
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### Total number of motorised trips grocery shopping

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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>3.826 (0.482)</td>
<td>1.417 (0.689)</td>
</tr>
<tr>
<td>Secondary education</td>
<td>1.166 (0.657)</td>
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<tr>
<td>Higher education</td>
<td>0.079 (0.662)</td>
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</tr>
<tr>
<td>Car available</td>
<td>1.702 (0.431)</td>
<td></td>
</tr>
<tr>
<td>Single family dwelling</td>
<td>0.846 (0.465)</td>
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</tr>
</tbody>
</table>
### Urban Form and Activity-Travel Patterns

#### group effects
- none or just a few shops: $0.228 (0.823)$
- small neighbourhood shopping centre: $0.050 (0.643)$
- large neighbourhood shopping centre: $2.301 (0.731)$
- city district shopping centre: $-1.448 (1.333)$

#### random part
- individual: $30.4$ $27.9$
- group: $1.7$ $0.0$

| $R^2$ individual | 0.129 |
| $R^2$ group | 0.501 |

*Intra class correlation = 5.3%*

#### total number of non-motorised trips grocery shopping

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<tr>
<td>individual effects</td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>$10.673 (0.813)$</td>
</tr>
<tr>
<td>car available</td>
<td>$-2.305 (0.744)$</td>
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<tr>
<td>working part time</td>
<td>$-0.532 (1.398)$</td>
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<tr>
<td>working full time</td>
<td>$-4.281 (0.853)$</td>
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<tr>
<td>none or just a few shops</td>
<td>$-4.457 (1.434)$</td>
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<tr>
<td>small neighbourhood shopping centre</td>
<td>$-0.544 (1.161)$</td>
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<tr>
<td>large neighbourhood shopping centre</td>
<td>$-3.622 (1.380)$</td>
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<tr>
<td>city district shopping centre</td>
<td>$5.744 (2.435)$</td>
</tr>
<tr>
<td>interaction effects</td>
<td></td>
</tr>
<tr>
<td>part time* none or just a few shops</td>
<td>$0.788 (1.985)$</td>
</tr>
<tr>
<td>part time * small neighb. centre</td>
<td>$1.481 (1.589)$</td>
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<tr>
<td>part time * large neighb. centre</td>
<td>$4.103 (1.743)$</td>
</tr>
<tr>
<td>part time * city district shopping centre</td>
<td>$-10.098 (3.453)$</td>
</tr>
</tbody>
</table>

| random part | |
| individual | $107.4$ | $84.4$ |
| group | 3.2 | 0.8 |

| $R^2$ individual | 0.230 |
| $R^2$ group | 0.389 |

*Intra class correlation = 2.9%*
### modal split trips grocery shopping

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</tr>
<tr>
<td><strong>individual effects</strong></td>
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<tr>
<td>intercept</td>
<td>34.221 (3.771)</td>
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<tr>
<td>personal income std to 2x standard</td>
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<tr>
<td>personal income over 2x standard</td>
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<tr>
<td>car available</td>
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<td>working part time</td>
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<td>-2.716 (6.671)</td>
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<tr>
<td>working full time</td>
<td></td>
<td>5.727 (4.265)</td>
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<tr>
<td><strong>group effects</strong></td>
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<td></td>
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<td>1.524 (5.721)</td>
</tr>
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<td>TNTN loop</td>
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<td><strong>interaction effects</strong></td>
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<td>car * none or just a few shops</td>
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<td>car * small neighb. shopping centre</td>
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<tr>
<td>part time * LSNT loop</td>
<td></td>
<td>6.545 (7.937)</td>
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<tr>
<td>part time * LSNT loop/tree</td>
<td>8.934 (7.796)</td>
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<tr>
<td>part time * LSNT grid</td>
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<td>12.584 (9.310)</td>
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<td>part time * none or just a few shops</td>
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<td>part time * small neighb. shopping centre</td>
<td>-6.009 (9.434)</td>
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<tr>
<td>part time * large neighb. shopping centre</td>
<td>-32.192 (9.173)</td>
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<tr>
<td>part time * city district shopping centre</td>
<td>9.689 (15.502)</td>
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<td>full time * TNTN ring</td>
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<td>17.307 (6.104)</td>
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<td>full time * TNTN loop</td>
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<td>8.831 (8.496)</td>
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<td>0.429 (6.016)</td>
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-191-
Results given are for share of motorised trips. Parameters for non-motorised trips are identical, but with opposite sign and intercept = 77.372 (3.857).

### Total number of kilometres other shopping

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<tr>
<td>individual effects</td>
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<tr>
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<td>degree of urbanisation neighbourhood</td>
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<td>intra class correlation</td>
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### Total number of motorised kilometres other shopping

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<tr>
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<td>64.403 (9.432)</td>
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<td>47.970 (13.409)</td>
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<tr>
<td>always car available</td>
<td>31.493 (15.508)</td>
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<td>interaction effects</td>
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<tr>
<td>always car * TNTC radial</td>
<td>0.985 (21.967)</td>
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<td>always car * TNTC ring</td>
<td>49.381 (18.319)</td>
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-192-
### Appendix 5

#### random part

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### $R^2$

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Intra class correlation = 4.1%

#### total number of non-motorised kilometres other shopping

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### fixed part

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<td>intercept</td>
<td>51.719 (13.150)</td>
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</tr>
<tr>
<td>average distance</td>
<td>7.187 (3.813)</td>
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<tr>
<td>working full time</td>
<td>-32.824 (14.609)</td>
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### random part

<table>
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<th>slope average distance</th>
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<td>51428.7</td>
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### $R^2$

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<th>group</th>
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<tr>
<td>$R^2$ group</td>
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Intra class correlation = 0.0%

#### total number of public transport kilometres other shopping

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<tbody>
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### fixed part

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<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>intercept</td>
<td>27.537 (5.483)</td>
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<td>secondary education</td>
<td>-31.989 (21.950)</td>
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<tr>
<td>higher education</td>
<td>-24.187 (22.125)</td>
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### random part

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<th>group</th>
<th>slope average distance</th>
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<td>4.9</td>
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### $R^2$

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<th>group</th>
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</tr>
<tr>
<td>$R^2$ group</td>
<td>0.006</td>
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Intra class correlation = 0.1%

---

-193-
## Urban Form and Activity-Travel Patterns

### modal share motorised kilometres other shopping

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<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>individual effects</td>
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<td></td>
</tr>
<tr>
<td>intercept</td>
<td>46.851 (5.069)</td>
<td>18.414 (9.259)</td>
</tr>
<tr>
<td>car available</td>
<td>39.828 (5.474)</td>
<td>39.828 (5.474)</td>
</tr>
<tr>
<td>terraced dwelling</td>
<td>8.850 (6.715)</td>
<td>8.850 (6.715)</td>
</tr>
<tr>
<td>(semi)detached dwelling</td>
<td>17.230 (7.603)</td>
<td>17.230 (7.603)</td>
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<tr>
<td><strong>group effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to city centre</td>
<td>4.624 (2.003)</td>
<td>4.624 (2.003)</td>
</tr>
<tr>
<td>TNTN ring</td>
<td>-4.679 (7.306)</td>
<td>-4.679 (7.306)</td>
</tr>
<tr>
<td>TNTN loop</td>
<td>-0.937 (11.137)</td>
<td>-0.937 (11.137)</td>
</tr>
<tr>
<td>TNTN radial</td>
<td>-38.267 (7.913)</td>
<td>-38.267 (7.913)</td>
</tr>
<tr>
<td>TNTN axial</td>
<td>-18.181 (7.819)</td>
<td>-18.181 (7.819)</td>
</tr>
<tr>
<td>TNTN grid</td>
<td>-1.336 (15.119)</td>
<td>-1.336 (15.119)</td>
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<td><strong>random part</strong></td>
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<tr>
<td>individual</td>
<td>1763.0</td>
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<td>group</td>
<td>338.3</td>
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<td>$R^2$ individual</td>
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<td>0.273</td>
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<td>$R^2$ group</td>
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<td>0.757</td>
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<tr>
<td>intra class correlation</td>
<td>16.1%</td>
<td>16.1%</td>
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### modal share non-motorised kilometres other shopping

<table>
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<tr>
<th></th>
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<th>best model</th>
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<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>38.359 (5.071)</td>
<td>80.671 (11.664)</td>
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<tr>
<td>age</td>
<td>-0.408 (0.157)</td>
<td>-0.408 (0.157)</td>
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<tr>
<td>car available</td>
<td>-24.263 (5.476)</td>
<td>-24.263 (5.476)</td>
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<tr>
<td><strong>group effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSNT loop/grid</td>
<td>-25.711 (11.437)</td>
<td>-25.711 (11.437)</td>
</tr>
<tr>
<td>LSNT loop/tree</td>
<td>-13.388 (10.643)</td>
<td>-13.388 (10.643)</td>
</tr>
<tr>
<td>LSNT grid</td>
<td>14.959 (11.447)</td>
<td>14.959 (11.447)</td>
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-194-
<table>
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<tr>
<th>random part</th>
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<th>group</th>
<th>$R^2$ individual</th>
<th>$R^2$ group</th>
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<tbody>
<tr>
<td></td>
<td>1617.8</td>
<td>349.3</td>
<td>0.239</td>
<td>0.717</td>
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<td>intra class correlation</td>
<td>17.8%</td>
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### modal share public transport kilometres other shopping

#### fixed part

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<th>best model</th>
</tr>
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<tbody>
<tr>
<td>intercept</td>
<td>14.916 (2.308)</td>
<td>19.765 (21.618)</td>
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<tr>
<td>secondary education</td>
<td>8.427 (13.248)</td>
<td>8.517 (13.743)</td>
</tr>
<tr>
<td>higher education</td>
<td>-7.612 (21.576)</td>
<td></td>
</tr>
<tr>
<td>car available</td>
<td></td>
<td>14.916 (21.576)</td>
</tr>
<tr>
<td>group effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>none or just a few shops</td>
<td>-1.271 (23.142)</td>
<td></td>
</tr>
<tr>
<td>small neighbourhood shopping centre</td>
<td>6.452 (21.894)</td>
<td></td>
</tr>
<tr>
<td>large neighbourhood shopping centre</td>
<td>47.983 (21.584)</td>
<td></td>
</tr>
<tr>
<td>city district shopping centre</td>
<td>7.373 (24.568)</td>
<td></td>
</tr>
<tr>
<td>degree of urbanisation neighbourhood</td>
<td>13.548 (4.654)</td>
<td></td>
</tr>
<tr>
<td>interaction effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>secondary education * TNTN ring</td>
<td>-9.921 (8.011)</td>
<td></td>
</tr>
<tr>
<td>secondary education * TNTN loop</td>
<td>-25.338 (11.270)</td>
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</tr>
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<td>secondary education * TNTN radial</td>
<td>-12.357 (9.099)</td>
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</tr>
<tr>
<td>secondary education * TNTN axial</td>
<td>4.726 (9.049)</td>
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</tr>
<tr>
<td>secondary education * TNTN grid</td>
<td>-13.802 (21.039)</td>
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</tr>
<tr>
<td>car available * none/few shops</td>
<td>-2.428 (6.866)</td>
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</tr>
<tr>
<td>car available * small neighb. centre</td>
<td>-8.597 (25.088)</td>
<td></td>
</tr>
<tr>
<td>car available * large neighb. centre</td>
<td>-51.456 (25.121)</td>
<td></td>
</tr>
<tr>
<td>car available * city district centre</td>
<td>34.437 (29.594)</td>
<td></td>
</tr>
<tr>
<td>car available * degree urbanisation nghb</td>
<td>-10.327 (5.488)</td>
<td></td>
</tr>
</tbody>
</table>

#### random part

| individual | 1005.5 | 818.3 |
| group      | 29.5   | 41.2  |
| slope secondary education             | 931.0 |
| slope higher education                 | 1667.7 |
| slope car available                    | 1240.0 |
Urban Form and Activity-Travel Patterns

\[
R^2 \text{ individual} \quad 0.091 \\
R^2 \text{ group} \quad 0.330 \\
\text{intra class correlation} = 2.9\%
\]

total number of trips other shopping

<table>
<thead>
<tr>
<th>fixed part</th>
<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>48.780 (2.947)</td>
<td>67.738 (9.801)</td>
</tr>
<tr>
<td>sometimes car available</td>
<td>-16.494 (8.822)</td>
<td>-12.856 (9.058)</td>
</tr>
<tr>
<td>always car available</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| group effects |            |            |
| TNTN ring      |            |            |
| TNTN loop      |            |            |
| TNTN radial    |            |            |
| TNTN axial     |            |            |
| TNTN grid      |            |            |

| random part |            |            |
| individual  | 1905.6     | 1778.3     |
| group        | 34.6       | 341.2      |
| slope sometimes car available |            |            |
| slope always car available |            |            |

\[
R^2 \text{ individual} \quad 0.018 \\
R^2 \text{ group} \quad 0.040 \\
\text{intra class correlation} = 1.8\%
\]

total number of motorised trips other shopping

<table>
<thead>
<tr>
<th>fixed part</th>
<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>19.976 (3.259)</td>
<td>19.160 (3.619)</td>
</tr>
<tr>
<td>car available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>single family dwelling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-196-
### Appendix 5

**group effects**
- TNTN ring: $-8.737 (5.621)$
- TNTN loop: $3.927 (7.760)$
- TNTN radial: $-24.839 (6.271)$
- TNTN axial: $-14.185 (6.107)$
- TNTN grid: $-20.638 (10.703)$

**random part**

<table>
<thead>
<tr>
<th></th>
<th>individual</th>
<th>group</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNTN</td>
<td>712.8</td>
<td>140.9</td>
</tr>
<tr>
<td>LSNT</td>
<td>663.5</td>
<td>19.2</td>
</tr>
</tbody>
</table>

**$R^2$**
- Individual: $0.200$
- Group: $0.673$

**intra class correlation = 16.5%**

### total number of non-motorised trips other shopping

<table>
<thead>
<tr>
<th>fixed part</th>
<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>individual effects</td>
<td>23.730 (3.015)</td>
<td>56.300 (7.216)</td>
</tr>
<tr>
<td>age</td>
<td>-0.316 (0.337)</td>
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</tr>
<tr>
<td>sometimes car available</td>
<td>-23.169 (5.968)</td>
<td></td>
</tr>
<tr>
<td>always car available</td>
<td>-10.111 (10.792)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>group effects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>none of just a few shops</td>
<td>7.647 (8.389)</td>
<td></td>
</tr>
<tr>
<td>small neighbourhood shopping centre</td>
<td>-22.746 (7.333)</td>
<td></td>
</tr>
<tr>
<td>large neighbourhood shopping centre</td>
<td>-18.526 (8.116)</td>
<td></td>
</tr>
<tr>
<td>city district shopping centre</td>
<td>-4.274 (11.503)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>interaction effects</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>always car available * LSNT loop/grid</td>
<td>-34.055 (13.254)</td>
<td></td>
</tr>
<tr>
<td>always car available * LSNT loop</td>
<td>-18.712 (11.430)</td>
<td></td>
</tr>
<tr>
<td>always car available * LSNT loop/tree</td>
<td>-4.056 (10.933)</td>
<td></td>
</tr>
<tr>
<td>always car available * LSNT grid</td>
<td>14.095 (12.430)</td>
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</tbody>
</table>

**random part**

<table>
<thead>
<tr>
<th></th>
<th>individual</th>
<th>group</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNTN</td>
<td>1397.9</td>
<td>69.2</td>
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<tr>
<td>LSNT</td>
<td>1220.4</td>
<td>0.4</td>
</tr>
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</table>

**$R^2$**
- Individual: $0.168$
- Group: $0.511$

**intra class correlation = 4.7%**
### total number of public transport trips other shopping

<table>
<thead>
<tr>
<th></th>
<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>fixed part</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>5.504 (1.538)</td>
<td>14.221 (3.287)</td>
</tr>
<tr>
<td>age</td>
<td>0.147 (0.070)</td>
<td>-11.299 (3.647)</td>
</tr>
<tr>
<td>car available</td>
<td>-13.121 (3.287)</td>
<td></td>
</tr>
<tr>
<td>group effects</td>
<td></td>
<td>11.425 (2.973)</td>
</tr>
<tr>
<td>degree of urbanisation neighbourhd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interaction effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age * degree urbanisation neighb.</td>
<td>0.168 (0.038)</td>
<td>-10.240 (3.293)</td>
</tr>
<tr>
<td>car available * degree urbanisation nghb</td>
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</tr>
<tr>
<td><strong>random part</strong></td>
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<td></td>
</tr>
<tr>
<td>individual slope car available</td>
<td>455.0</td>
<td>352.8</td>
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<td>group</td>
<td>15.4</td>
<td>73.4</td>
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<td>86.4</td>
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<td>$R^2$ individual</td>
<td>0.149</td>
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<tr>
<td>$R^2$ group</td>
<td>0.443</td>
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<tr>
<td>intra class correlation</td>
<td>3.5%</td>
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### modal share of motorised trips other shopping

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<th>best model</th>
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</thead>
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<td></td>
</tr>
<tr>
<td>individual effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>455.25 (5.490)</td>
<td>4.281 (7.999)</td>
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<tr>
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<td>34.799 (5.621)</td>
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<tr>
<td>single family dwelling</td>
<td>13.883 (6.837)</td>
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<tr>
<td>working part time</td>
<td>-3.018 (6.883)</td>
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<tr>
<td>working full time</td>
<td>9.371 (5.136)</td>
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</tr>
<tr>
<td>group effects distance to city centre</td>
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<td>7.404 (2.798)</td>
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<tr>
<td></td>
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</tr>
<tr>
<td><strong>random part</strong></td>
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<tr>
<td>individual</td>
<td>1723.1</td>
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<td>group</td>
<td>432.4</td>
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\[
\begin{array}{l}
\begin{aligned}
R^2_{\text{individual}} &= 0.232 \\
R^2_{\text{group}} &= 0.475 \\
\text{intra class correlation} &= 19.7% \\
\end{aligned}
\end{array}
\]

**modal share non-motorised trips other shopping**

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</tr>
<tr>
<td>individual effects</td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>43.605 (5.873)</td>
</tr>
<tr>
<td>age</td>
<td>-0.286 (0.161)</td>
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<tr>
<td>car available</td>
<td>-20.050 (5.569)</td>
</tr>
<tr>
<td>multi person household</td>
<td>-15.734 (6.609)</td>
</tr>
<tr>
<td><strong>group effects</strong></td>
<td></td>
</tr>
<tr>
<td>distance to city centre</td>
<td>-9.811 (2.710)</td>
</tr>
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<td><strong>interaction effects</strong></td>
<td></td>
</tr>
<tr>
<td>age * degree urbanisation neighb.</td>
<td>-0.261 (0.127)</td>
</tr>
<tr>
<td><strong>random part</strong></td>
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</tr>
<tr>
<td>individual</td>
<td>1592.9</td>
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<tr>
<td>group</td>
<td>512.9</td>
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\[
\begin{array}{l}
\begin{aligned}
R^2_{\text{individual}} &= 0.222 \\
R^2_{\text{group}} &= 0.545 \\
\text{intra class correlation} &= 24.4% \\
\end{aligned}
\end{array}
\]

**modal share public transport trips other shopping**

<table>
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<th>best model</th>
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<tbody>
<tr>
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<tr>
<td>individual effects</td>
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<tr>
<td>intercept</td>
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<td>working full time</td>
<td>-11.503 (3.683)</td>
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<td><strong>group effects</strong></td>
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<tr>
<td>LSNT loop/grid</td>
<td>1.011 (7.100)</td>
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<tr>
<td>LSNT loop</td>
<td>5.073 (6.404)</td>
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<tr>
<td>LSNT loop/tree</td>
<td>15.086 (6.578)</td>
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<tr>
<td>LSNT grid</td>
<td>-5.477 (7.044)</td>
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</table>
Urban Form and Activity-Travel Patterns  

<table>
<thead>
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<th>820.3</th>
<th>718.4</th>
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<tbody>
<tr>
<td>group</td>
<td>51.2</td>
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<td>72.3</td>
</tr>
<tr>
<td>slope car available</td>
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<td>114.2</td>
<td></td>
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$R^2$ individual 0.111

$R^2$ group 0.524

intra class correlation = 5.9%

<table>
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<tr>
<th>total number of kilometres recurring leisure</th>
</tr>
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<tbody>
<tr>
<td>fixed part</td>
</tr>
<tr>
<td>individual effects</td>
</tr>
<tr>
<td>intercept</td>
</tr>
<tr>
<td>average distance</td>
</tr>
<tr>
<td>group</td>
</tr>
<tr>
<td>slope average distance</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>random part</th>
<th>individual</th>
<th>7740.0</th>
<th>1166.9</th>
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</thead>
<tbody>
<tr>
<td>group</td>
<td>37.7</td>
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<td>94.1</td>
</tr>
<tr>
<td>slope average distance</td>
<td></td>
<td>9.5</td>
<td></td>
</tr>
</tbody>
</table>

$R^2$ individual 0.825

$R^2$ group 0.836

intra class correlation = 0.7%

<table>
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<tr>
<th>total number of motorised kilometres recurring leisure</th>
</tr>
</thead>
<tbody>
<tr>
<td>fixed part</td>
</tr>
<tr>
<td>individual effects</td>
</tr>
<tr>
<td>intercept</td>
</tr>
<tr>
<td>average distance</td>
</tr>
<tr>
<td>group</td>
</tr>
<tr>
<td>slope average distance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>random part</th>
<th>individual</th>
<th>5828.3</th>
<th>458.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>group</td>
<td>30.5</td>
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<td>60.8</td>
</tr>
<tr>
<td>slope average distance</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

$R^2$ individual 0.876

$R^2$ group 0.880

intra class correlation = 0.5%
total number of other kilometres recurring leisure

<table>
<thead>
<tr>
<th>fixed part</th>
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<th>best model</th>
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<td>0.467 (0.107)</td>
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<td>17.458 (6.022)</td>
<td>-0.321 (4.348)</td>
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<td>-0.321 (4.348)</td>
<td>-0.321 (4.348)</td>
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<td>0.168</td>
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modal share motorised kilometres recurring leisure

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<tr>
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<tr>
<td>intercept</td>
<td>60.220 (3.345)</td>
<td>19.869 (9.914)</td>
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<tr>
<td>sometimes car available</td>
<td>15.864 (8.537)</td>
<td>15.864 (8.537)</td>
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<tr>
<td>always car available</td>
<td>31.369 (8.333)</td>
<td>15.864 (8.537)</td>
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<td>average distance</td>
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<td>sports facilities</td>
<td>24.562 (9.257)</td>
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<tr>
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Results given are for share of motorised kilometres. Parameters for other kilometres are identical, but with opposite sign and intercept is $80.191 (9.914)$. 
### total number of trips recurring leisure

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<tr>
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<tr>
<td>intercept</td>
<td>6.431 (0.288)</td>
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</tr>
<tr>
<td>$R^2$ individual</td>
<td>0.043</td>
<td>0.142</td>
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intra class correlation = 0.1%

### total number of motorised trips recurring leisure

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<tr>
<td>group effects</td>
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<tr>
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<tr>
<td>individual</td>
<td>12.2</td>
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<td>$R^2$ individual</td>
<td>0.043</td>
<td>0.142</td>
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intra class correlation = 0.2%
### total number of other trips recurring leisure

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<tr>
<td>individual effects</td>
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</tr>
<tr>
<td>intercept</td>
<td>2.770 (0.377)</td>
<td>6.647 (0.841)</td>
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<td>-3.042 (0.711)</td>
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<td>sports facilities</td>
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<td>-2.014 (0.781)</td>
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<tr>
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### modal share motorised trips recurring leisure

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<tr>
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</tr>
<tr>
<td>individual effects</td>
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<tr>
<td>intercept</td>
<td>57.421 (3.307)</td>
<td>29.557 (9.087)</td>
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<td>15.342 (8.570)</td>
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<td>working full time</td>
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<td>individual</td>
<td>1908.5</td>
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<tr>
<td>( R^2 ) individual</td>
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<td>0.156</td>
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<tr>
<td>( R^2 ) group</td>
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<tr>
<td>intra class correlation</td>
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<td>0.1%</td>
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</tbody>
</table>

Results given are for share of motorised trips. Parameters for other trips are identical, but with opposite sign and intercept is \( 70.443 (9.087) \).
## Urban Form and Activity-Travel Patterns

### Total number of kilometres home-to-work

<table>
<thead>
<tr>
<th></th>
<th>Null Model</th>
<th>Best Model</th>
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<tr>
<td><strong>Fixed Part</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual effects</td>
<td></td>
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</tr>
<tr>
<td>Intercept</td>
<td>237.340 (43.302)</td>
<td>245.631 (13.137)</td>
</tr>
<tr>
<td>Average distance</td>
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<td>17.058 (1.723)</td>
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<tr>
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<td>Group</td>
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<tr>
<td>Slope average distance</td>
<td>4194.4</td>
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| $R^2_{individual}$  | 0.784 |
| $R^2_{group}$       | 0.757 |

Intra class correlation = 2.0%

### Total number of motorised kilometres home-to-work

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<tr>
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<tr>
<td>Individual effects</td>
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<tr>
<td>Intercept</td>
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<td>163.131 (33.244)</td>
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<td>Average distance</td>
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<tr>
<td><strong>Random Part</strong></td>
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<td>175060.7</td>
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<td>Group</td>
<td>5547.31</td>
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<td>Slope average distance</td>
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<td>76.7</td>
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| $R^2_{individual}$  | 0.508 |
| $R^2_{group}$       | 0.349 |

Intra class correlation = 3.1%
### total number of non-motorised kilometres home-to-work

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<td>23.158 (4.141)</td>
<td>41.617 (6.399)</td>
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<tr>
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<tr>
<td>personal income standard to 2x standard</td>
<td>2.626 (7.018)</td>
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</tr>
<tr>
<td>personal income 2x standard and over</td>
<td>-10.304 (6.066)</td>
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</tr>
<tr>
<td>car available</td>
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<td>-12.910 (5.619)</td>
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<tr>
<td><strong>group effects</strong></td>
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<td></td>
</tr>
<tr>
<td>TNTC radial</td>
<td></td>
<td>19.868 (6.907)</td>
</tr>
<tr>
<td>TNTC ring</td>
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<td>-10.127 (5.552)</td>
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### total number of public transport kilometres home-to-work

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<tr>
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<tr>
<td>intercept</td>
<td>59.719 (27.876)</td>
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<td>multi person household</td>
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<td>22.071 (11.892)</td>
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<td>2.786 (1.631)</td>
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<tr>
<td><strong>interaction effects</strong></td>
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<tr>
<td>multi person * TNTC radial</td>
<td>-22.280 (18.093)</td>
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<tr>
<td>multi person * TNTC ring</td>
<td>54.337 (15.193)</td>
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<tr>
<td>average distance * TNTC radial</td>
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<tr>
<td>average distance * TNTC ring</td>
<td>2.965 (1.408)</td>
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### modal share motorised kilometres home-to-work

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<tr>
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<tr>
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<td>-14.736 (9.908)</td>
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### modal share non-motorised kilometres home-to-work

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<tr>
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<td>intercept</td>
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### random part

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\[ R^2 \]

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intra class correlation = 6.0%

### modal share public transport kilometres home-to-work

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<tr>
<td>poly-nuclear city (Almere)</td>
<td>22.484 (6.742)</td>
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<td>TNTN ring</td>
<td>-4.028 (5.083)</td>
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<td>TNTN loop</td>
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<td>TNTN radial</td>
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<td>TNTN grid</td>
<td>1.524 (8.390)</td>
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\[ R^2 \]

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intra class correlation = 11.6%

### total number of trips home-to-work

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<td>individual effects</td>
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<tr>
<td>intercept</td>
<td>17.141 (0.590)</td>
<td>16.280 (0.628)</td>
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<tr>
<td>personal income above average</td>
<td>1.216 (0.533)</td>
<td>1.265 (0.661)</td>
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<tr>
<td>couple</td>
<td>-1.123 (0.661)</td>
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</tr>
<tr>
<td>family with children</td>
<td>0.291 (0.652)</td>
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</tr>
<tr>
<td>working full time</td>
<td>2.390 (0.383)</td>
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</table>
group effects
  TNTC radial          1.734 (0.918)
  TNTC ring           -0.096 (0.768)

random part
  individual           35.7          24.7
  group               1.0           1.6

\[ R^2 \text{ individual} = 0.284 \]
\[ R^2 \text{ group} = 0.150 \]
intra class correlation = 2.7%

**total number of motorised trips home-to-work**

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<td>7.786 (0.895)</td>
<td>4.803 (0.976)</td>
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<td>personal income (minimum to standard)</td>
<td>0.440 (1.232)</td>
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<td>personal income (standard to 2x standard)</td>
<td>-0.454 (1.237)</td>
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<td></td>
<td>personal income (over 2x standard)</td>
<td>3.193 (1.243)</td>
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<td>sometimes car available</td>
<td>-0.564 (1.109)</td>
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<tr>
<td></td>
<td>always car available</td>
<td>5.242 (1.059)</td>
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<td>1.448 (1.152)</td>
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<td>LSNT grid</td>
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<td>group</td>
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\[ R^2 \text{ individual} = 0.297 \]
\[ R^2 \text{ group} = 0.443 \]
intra class correlation = 4.2%
## total number of non-motorised trips home-to-work

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<tr>
<td>intercept</td>
<td>6.929 (0.872)</td>
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<tr>
<td>minimum to standard</td>
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<tr>
<td>personal income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard to 2x standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>personal income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>over 2x standard</td>
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<td></td>
</tr>
<tr>
<td>car available</td>
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</tr>
<tr>
<td>average distance</td>
<td>-1.170 (0.493)</td>
<td>1.847 (1.112)</td>
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<td><strong>group effects</strong></td>
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<td>-1.170 (0.493)</td>
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<td>1.847 (1.112)</td>
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<td>0.230 (1.397)</td>
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<td>poly-nuclear city</td>
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<td>(Almere)</td>
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<td>TNTC ring</td>
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<tr>
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\[ R^2 \] individual 0.390  
\[ R^2 \] group 0.526  

intra class correlation = 7.1%

## total number of public transport trips home-to-work

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<tr>
<td>individual effects</td>
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<td></td>
</tr>
<tr>
<td>intercept</td>
<td>2.489 (0.694)</td>
<td>2.636 (0.532)</td>
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<td>average distance</td>
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<td>0.041 (0.022)</td>
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<td>LSNT loop/grid</td>
<td>4.384 (1.135)</td>
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<td>LSNT loop</td>
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Urban Form and Activity-Travel Patterns

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intra class correlation = 11.2%

modal share of motorised trips home-to-work

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<td>44.406 (4.614)</td>
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<td>22.353 (9.174)</td>
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<td>sometimes car available</td>
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<td>1.156 (5.304)</td>
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<td>17.932 (9.389)</td>
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<td>30.262 (4.942)</td>
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</tr>
<tr>
<td>LSNT grid</td>
<td>-3.032 (6.662)</td>
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random part

| individual | 1920.6 | 1238.8 |
| group      | 99.5   | 18.6   |

slope average distance

$R^2$ individual | 0.316 |
$R^2$ group      | 0.474 |

intra class correlation = 4.9%
modal share non-motorised trips home-to-work

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<tr>
<td>individual effects</td>
<td></td>
<td></td>
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<tr>
<td>intercept</td>
<td>42.465 (4.457)</td>
<td>83.339 (9.973)</td>
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<td>-16.696 (9.119)</td>
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<tr>
<td>higher education</td>
<td>-11.927 (9.552)</td>
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<tr>
<td>personal income min. to standard</td>
<td>-2.094 (5.774)</td>
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<tr>
<td>personal income std. to 2x standard</td>
<td>0.521 (5.672)</td>
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<tr>
<td>personal income over 2x standard</td>
<td>-19.927 (6.112)</td>
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<tr>
<td>car available</td>
<td>-21.102 (4.554)</td>
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<td>location in Randstad Holland</td>
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modal share public transport trips home-to-work

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### Urban Form and Activity-Travel Patterns

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intra class correlation = 11.3%
APPENDIX 6 | General Description Activity-Travel Pattern Indicators

The tables listed below contain the figures that go with the general description of the activity-travel patterns indicators reported on in section 7.3.

Cells containing significant differences at the 5% level are grey. For the ordinal independent variables, significance of differences has been established using one-way ANOVA or the Kruskal Wallis test, depending on whether the variances between groups could be considered equal. For the continuous independent variables Pearson correlation coefficient was calculated.
### Performance Indicators: Activity-Travel Diaries by Individual and Household Characteristics

(436 respondents, 807 diary days)

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<th>Modal Share Motorised Travel Time</th>
<th>Total Travel Distance</th>
<th>Modal Share Motorised Travel Distance</th>
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<td>32.6</td>
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<td>64.2</td>
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<td>0.59</td>
<td>38.0</td>
<td>0.65</td>
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<tr>
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<td>37.7</td>
<td>0.53</td>
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### Appendix 6

**Performance indicators: activity-travel diaries by individual and household characteristics (2)**

(436 respondents, 807 diary days)

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### performance indicators: activity-travel diaries by spatial characteristics (1)

*(436 respondents, 807 diary days)*

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### performance indicators activity-travel diaries by spatial characteristics (2)

*(436 respondents, 807 diary days)*

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**correlation coefficients performance indicators activity-travel diaries (1)**

*(436 respondents, 807 diary days)*

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**correlation coefficients performance indicator activity-travel diaries (2)**

*(436 respondents, 807 diary days)*

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### Appendix 6

**Performance indicators: activity-travel diaries weekdays by spatial characteristics (1)**

(320 respondents, 528 diary days)

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Urban Form and Activity-Travel Patterns

Performance indicators: activity-travel diaries weekdays by spatial characteristics (2)
(320 respondents, 528 diary days)

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### Correlation Coefficients: Performance Indicators Activity-Travel Diaries Weekdays (1)

(320 respondents, 528 diary days)

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<th>Modal Share Motorised Travel Time</th>
<th>Total Travel Distance</th>
<th>Modal Share Motorised Travel Distance</th>
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<tr>
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<td>-0.1</td>
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</tr>
<tr>
<td>Distance to City Centre</td>
<td>-0.11</td>
<td>0</td>
<td>-0.15</td>
<td>-0.01</td>
</tr>
<tr>
<td>Distance to IC Station</td>
<td>-0.13</td>
<td>0.04</td>
<td>-0.13</td>
<td>0.04</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.13</td>
<td>-0.05</td>
<td>-0.08</td>
<td>-0.09</td>
</tr>
<tr>
<td>Population Density Nghbhd</td>
<td>0.07</td>
<td>-0.06</td>
<td>0.03</td>
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<tr>
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<td>0.05</td>
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<tr>
<td>Housing Density City</td>
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### Correlation Coefficients: Performance Indicators Activity-Travel Diaries Weekdays (2)

(320 respondents, 528 diary days)

<table>
<thead>
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<th>Trips</th>
<th>Tours</th>
<th>Trip/Tour Ratio</th>
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<td>Age</td>
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<td>-0.05</td>
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<td>Distance to City Centre</td>
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<tr>
<td>Distance to IC Station</td>
<td>-0.07</td>
<td>-0.04</td>
<td>-0.07</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.1</td>
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<tr>
<td>Population Density Nghbhd</td>
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<td>0.03</td>
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<tr>
<td>Housing Density Nghbhd</td>
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<td>0.08</td>
<td>0.02</td>
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<td>Population Density City</td>
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<td>0.01</td>
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<td>-0.08</td>
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<tr>
<td>Degree Urbanisation City</td>
<td>-0.05</td>
<td>-0.05</td>
<td>0.04</td>
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APPENDIX 7 | Multilevel Analyses Activity Diaries

The tables listed below report the results from the multilevel analyses on activity diary indicators, as discussed in chapter 7. The analyses reported in this appendix are based on data on 467 diary days, 320 of which concern weekdays.

Parameters reported in bold face type are significant at the 5% level, parameters reported in italics are significant at the 10% level. The tables report parameter values and t-values, as is usual when reporting multilevel analysis results.

In the tables the following abbreviations are used for layout reasons:
TNTC = transportation network type city
TNTN = transportation network type neighbourhood
LSNT = local street network type
### total travel time

<table>
<thead>
<tr>
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<th>best model</th>
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</thead>
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<tr>
<td>fixed part</td>
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</tr>
<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>64.523 (3.251)</td>
<td>63.033 (3.574)</td>
</tr>
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<td></td>
<td></td>
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<tr>
<td>(minimum to standard)</td>
<td>-3.075 (4.880)</td>
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<tr>
<td>(standard to 2x standard)</td>
<td>-3.069 (4.733)</td>
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</tr>
<tr>
<td>(over 2x standard)</td>
<td>15.633 (5.489)</td>
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</tr>
<tr>
<td>group effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TNTC radial</td>
<td>-8.860 (5.446)</td>
<td></td>
</tr>
<tr>
<td>TNTC ring</td>
<td>9.252 (4.807)</td>
<td></td>
</tr>
<tr>
<td>interaction effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 2x standard*TNTC radial</td>
<td>-7.584 (7.327)</td>
<td></td>
</tr>
<tr>
<td>&gt; 2x standard*TNTC ring</td>
<td>13.679 (6.384)</td>
<td></td>
</tr>
<tr>
<td>random part</td>
<td></td>
<td></td>
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<tr>
<td>individual</td>
<td>2289.28</td>
<td>2120.23</td>
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<tr>
<td>group</td>
<td>4575</td>
<td>80.58</td>
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<tr>
<td></td>
<td>$R^2$ group</td>
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</tr>
<tr>
<td>intra class correlation</td>
<td>= 1.9%</td>
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</tbody>
</table>

### total motorised transport travel time

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<th>best model</th>
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</thead>
<tbody>
<tr>
<td>fixed part</td>
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<td></td>
</tr>
<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>34.497 (2.534)</td>
<td>29.389 (2.539)</td>
</tr>
<tr>
<td>personal income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(minimum to standard)</td>
<td>-2.247 (4.138)</td>
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</tr>
<tr>
<td>(standard to 2x standard)</td>
<td>-5.225 (4.058)</td>
<td></td>
</tr>
<tr>
<td>(over 2x standard)</td>
<td>24.803 (5.038)</td>
<td></td>
</tr>
<tr>
<td>sometimes car available</td>
<td>4.931 (3.533)</td>
<td></td>
</tr>
<tr>
<td>always car available</td>
<td>12.490 (3.197)</td>
<td></td>
</tr>
<tr>
<td>interaction effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 2x standard*limited land use mix</td>
<td>-15.933 (6.244)</td>
<td></td>
</tr>
<tr>
<td>&gt; 2x standard*ample land use mix</td>
<td>29.712 (9.373)</td>
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Urban Form and Activity-Travel Patterns

<table>
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<th>1847.62</th>
<th>1545.06</th>
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<tbody>
<tr>
<td>group</td>
<td>5.41</td>
<td>8.28</td>
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</table>

\[ R^2 \] individual \quad 0.163

\[ R^2 \] group \quad 0.00

intra class correlation = 0.0%

<table>
<thead>
<tr>
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<tr>
<td>fixed part</td>
</tr>
<tr>
<td>null model</td>
</tr>
<tr>
<td>fixed part</td>
</tr>
<tr>
<td>individual effect</td>
</tr>
<tr>
<td>intercept</td>
</tr>
<tr>
<td>personal income (minimum to standard)</td>
</tr>
<tr>
<td>personal income (standard to 2x standard)</td>
</tr>
<tr>
<td>personal income (over 2x standard)</td>
</tr>
<tr>
<td>sometimes car available</td>
</tr>
<tr>
<td>always car available</td>
</tr>
<tr>
<td>interaction effects</td>
</tr>
<tr>
<td>1-2x standard*LSNT loop/grid</td>
</tr>
<tr>
<td>1-2x standard*LSNT loop</td>
</tr>
<tr>
<td>1-2x standard*LSNT loop/tree</td>
</tr>
<tr>
<td>1-2x standard*LSNT grid</td>
</tr>
<tr>
<td>&gt; 2x standard*LSNT loop/grid</td>
</tr>
<tr>
<td>&gt; 2x standard*LSNT loop</td>
</tr>
<tr>
<td>&gt; 2x standard*LSNT loop/tree</td>
</tr>
<tr>
<td>&gt; 2x standard*LSNT grid</td>
</tr>
<tr>
<td>always car*limited land use mix</td>
</tr>
<tr>
<td>always car*ample land use mix</td>
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<tr>
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<tr>
<td>individual</td>
</tr>
<tr>
<td>group</td>
</tr>
<tr>
<td>slope 1-2x standard</td>
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<tr>
<td>slope sometimes car available</td>
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</table>

\[ R^2 \] individual \quad 0.284

\[ R^2 \] group \quad 0.984

intra class correlation = 1.4%
### Total Number of Tours

<table>
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<tr>
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<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.695 (0.052)</td>
<td>1.857 (0.071)</td>
</tr>
<tr>
<td>Household income (app. standard)</td>
<td>0.321 (0.148)</td>
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</tr>
<tr>
<td>Household income (standard to 2x standard)</td>
<td>-0.110 (0.107)</td>
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</tr>
<tr>
<td>Household income (over 2x standard)</td>
<td>-0.133 (0.083)</td>
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</tr>
<tr>
<td>Working full time</td>
<td>0.264 (0.091)</td>
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</tr>
<tr>
<td>Working part time</td>
<td>-0.203 (0.071)</td>
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<tr>
<td>Random Part: Individual</td>
<td>0.83</td>
<td>0.79</td>
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<tr>
<td>Group R²</td>
<td>0.00</td>
<td>0.00</td>
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</table>

Intra class correlation = 0.0%

### Total Number of Trips

<table>
<thead>
<tr>
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<td></td>
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<tr>
<td>Intercept</td>
<td>4.000 (0.129)</td>
<td>3.984 (0.217)</td>
</tr>
<tr>
<td>Household income (app. standard)</td>
<td>0.933 (0.169)</td>
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</tr>
<tr>
<td>Household income (standard to 2x standard)</td>
<td>-0.296 (0.279)</td>
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<tr>
<td>Household income (over 2x standard)</td>
<td>-0.198 (0.221)</td>
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</tr>
<tr>
<td>Car available</td>
<td>0.633 (0.160)</td>
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</tr>
<tr>
<td>Couple</td>
<td>-0.620 (0.216)</td>
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</tr>
<tr>
<td>Family with children</td>
<td>0.456 (0.205)</td>
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</tr>
<tr>
<td>Working part time</td>
<td>0.106 (0.268)</td>
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</tr>
<tr>
<td>Working full time</td>
<td>-0.567 (0.176)</td>
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<tr>
<td>Group Effects</td>
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<tr>
<td>LSNT loop/grid</td>
<td>-0.362 (0.330)</td>
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</tr>
<tr>
<td>LSNT loop</td>
<td>-0.355 (0.244)</td>
<td></td>
</tr>
<tr>
<td>LSNT loop/tree</td>
<td>0.047 (0.307)</td>
<td></td>
</tr>
<tr>
<td>LSNT grid</td>
<td>0.649 (0.293)</td>
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</table>
interaction effects

- $1$-2x standard*TNTN ring: $-0.480 (0.420)$
- $1$-2x standard*TNTN loop: $1.002 (0.577)$
- $1$-2x standard*TNTN radial: $-0.924 (0.464)$
- $1$-2x standard*TNTN axial: $0.619 (0.527)$
- $1$-2x standard*TNTN grid: $-0.686 (0.762)$
- couple*LSNT loop/grid: $-0.145 (0.482)$
- couple*LSNT loop: $1.086 (0.345)$
- couple*LSNT loop/tree: $-0.351 (0.352)$
- couple*LSNT grid: $-0.267 (0.359)$
- part time*TNTN ring: $0.431 (0.348)$
- part time*TNTN loop: $-0.706 (0.621)$
- part time*TNTN radial: $0.503 (0.402)$
- part time*TNTN axial: $1.016 (0.379)$
- part time*TNTN grid: $-1.142 (0.756)$

random part

- individual: $5.02$  $4.36$
- group: $0.00$  $0.00$

$R^2$ individual: $0.131$
$R^2$ group: $0.893$

Intra class correlation = 0.0%

Ratio total number of tours / trips

<table>
<thead>
<tr>
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<th>null model</th>
<th>best model</th>
</tr>
</thead>
<tbody>
<tr>
<td>fixed part</td>
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<td></td>
</tr>
<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>$2.381 (0.042)$</td>
<td>$2.338 (0.048)$</td>
</tr>
<tr>
<td>higher education</td>
<td>$0.059 (0.033)$</td>
<td></td>
</tr>
<tr>
<td>car available</td>
<td>$0.095 (0.040)$</td>
<td>$0.040 (0.040)$</td>
</tr>
<tr>
<td>couple</td>
<td>$0.222 (0.047)$</td>
<td>$0.125 (0.047)$</td>
</tr>
<tr>
<td>family with children</td>
<td></td>
<td></td>
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</tbody>
</table>

random part

- individual: $0.31$  $0.30$
- group: $0.01$  $0.01$

$R^2$ individual: $0.034$
$R^2$ group: $0.280$

Intra class correlation = 3.6%
## total travel distance

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<th>best model</th>
</tr>
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<tr>
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<td></td>
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<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>36.604 (3.210)</td>
<td>27.221 (4.079)</td>
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<tr>
<td>personal income (minimum to standard)</td>
<td>-7.977 (5.494)</td>
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<td>-6.661 (5.426)</td>
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<td>12.246 (5.201)</td>
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</tr>
<tr>
<td>car available</td>
<td>9.833 (3.912)</td>
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<tr>
<td>working part time</td>
<td>-0.141 (5.439)</td>
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<tr>
<td>working full time</td>
<td>8.567 (4.524)</td>
<td></td>
</tr>
<tr>
<td><strong>group effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>degree of urbanisation city</td>
<td>-8.765 (4.578)</td>
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</tr>
<tr>
<td><strong>random part</strong></td>
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<td>2893.72</td>
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<td>group</td>
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<td>$R^2$ group</td>
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<td>intra class correlation</td>
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## total travel distance motorised transport

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<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>22.272 (2.398)</td>
<td>19.652 (3.335)</td>
</tr>
<tr>
<td>personal income (minimum to standard)</td>
<td>-8.880 (3.961)</td>
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</tr>
<tr>
<td>personal income (standard to 2x standard)</td>
<td>-3.404 (3.912)</td>
<td></td>
</tr>
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<td>personal income (over 2x standard)</td>
<td>18.252 (3.661)</td>
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</tr>
<tr>
<td>car available</td>
<td>10.282 (2.880)</td>
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</tr>
<tr>
<td>multi-person household</td>
<td>-6.071 (3.090)</td>
<td></td>
</tr>
<tr>
<td><strong>group effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>distance to inter-city station</td>
<td>-3.217 (1.387)</td>
<td></td>
</tr>
<tr>
<td><strong>interaction effects</strong></td>
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<td></td>
</tr>
<tr>
<td>&gt; 2x standard*distance to city centre</td>
<td>-8.057 (2.273)</td>
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### Random part

<table>
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<tr>
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<th>Group</th>
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<tr>
<td></td>
<td>1719.79</td>
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<tr>
<td>$R^2$</td>
<td>0.168</td>
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Intra class correlation = 0.0%

### Modal split total distance motorised transport

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<th>Best Model</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.548 (0.031)</td>
<td>0.443 (0.026)</td>
</tr>
<tr>
<td>sometimes car available</td>
<td>-0.006 (0.031)</td>
<td>0.303 (0.029)</td>
</tr>
<tr>
<td>always car available</td>
<td>-0.063 (0.046)</td>
<td>0.002 (0.051)</td>
</tr>
</tbody>
</table>

**Group effects**

- LSNT loop/grid: 0.002 (0.051)
- LSNT loop: 0.008 (0.066)
- LSNT loop/tree: 0.097 (0.043)
- LSNT grid: -0.063 (0.046)

**Interaction effects**

- always car available * land use mix: -0.050 (0.026)

**Random part**

<table>
<thead>
<tr>
<th></th>
<th>Individual</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.19</td>
<td>0.13</td>
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</table>

**Intra class correlation = 3.0%**

### Travel time on weekdays

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<th>Best Model</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>90.088 (9.182)</td>
<td>97.713 (8.992)</td>
</tr>
<tr>
<td>higher education</td>
<td>13.644 (10.195)</td>
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<tr>
<td>children in household</td>
<td>-24.198 (8.124)</td>
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</table>

-230-
interaction effects

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>higher education*LSNT loop/grid</td>
<td>26.629 (17.878)</td>
</tr>
<tr>
<td>higher education*LSNT loop</td>
<td>6.013 (13.973)</td>
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<tr>
<td>higher education*LSNT loop/tree</td>
<td>-32.469 (27.318)</td>
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<tr>
<td>higher education*LSNT grid</td>
<td>7.846 (18.655)</td>
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random part

<table>
<thead>
<tr>
<th>Term</th>
<th>Estimate (SE)</th>
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<tbody>
<tr>
<td>individual</td>
<td>4048.30</td>
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<tr>
<td>group</td>
<td>104.72</td>
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$R^2$ individual: 0.229

$R^2$ group: 0.398

intra class correlation = 2.5%

---

motorised transport travel time on weekdays

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<tr>
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<tr>
<td>fixed part</td>
<td></td>
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</tr>
<tr>
<td>individual effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>52.731 (9.508)</td>
<td>80.207 (12.450)</td>
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<td>higher education</td>
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<td>29.961 (7.682)</td>
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<td>couple</td>
<td>-9.569 (9.101)</td>
<td>-40.243 (13.342)</td>
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<tr>
<td>family with children</td>
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</table>

interaction effects

higher education*distance to city centre: -9.650 (5.474)

random part

<table>
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<th>Term</th>
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<tr>
<td>individual</td>
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<td>group</td>
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<td>slope couple</td>
<td>2242.12</td>
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<tr>
<td></td>
<td>218.61</td>
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<td></td>
<td>2685.91</td>
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$R^2$ individual: 0.203

$R^2$ group: 0.00

intra class correlation = 0.1%
### modal split motorised transport travel time on weekdays

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<tr>
<td>individual effect</td>
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<tr>
<td>intercept</td>
<td>0.546 (0.059)</td>
<td>0.572 (0.062)</td>
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<tr>
<td>higher education</td>
<td>0.132 (0.036)</td>
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<tr>
<td>sometimes car available</td>
<td>0.038 (0.078)</td>
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<tr>
<td>always car available</td>
<td>0.178 (0.068)</td>
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<td><strong>group effects</strong></td>
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<td></td>
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<tr>
<td>population density neighbourhood</td>
<td>0.005 (0.003)</td>
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<td><strong>random part</strong></td>
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<tr>
<td>individual</td>
<td>0.19</td>
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<td>group</td>
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<tr>
<td><strong>$R^2$ individual</strong></td>
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### number of tours on weekdays

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<tr>
<td>individual effect</td>
<td></td>
<td></td>
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<tr>
<td>intercept</td>
<td>2.000 (0.152)</td>
<td>2.024 (0.138)</td>
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<tr>
<td>personal income (minimum to standard)</td>
<td>-0.008 (0.234)</td>
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<td>personal income (standard to 2x standard)</td>
<td>-0.561 (0.204)</td>
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<tr>
<td>personal income (over 2x standard)</td>
<td>-0.298 (0.292)</td>
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<td><strong>random part</strong></td>
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<tr>
<td>individual</td>
<td>1.25</td>
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<td>group</td>
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<td>0.03</td>
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### Number of Trips on Weekdays

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<tr>
<td>Individual Effect</td>
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<tr>
<td>Intercept</td>
<td>4.760 (0.384)</td>
<td>5.631 (0.584)</td>
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<tr>
<td>Personal income standard and over</td>
<td>-1.005 (0.391)</td>
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<tr>
<td>Sometimes car available</td>
<td>1.188 (0.563)</td>
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<tr>
<td>Always car available</td>
<td>-0.100 (0.535)</td>
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<td><strong>Group Effects</strong></td>
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<tr>
<td>Limited land use mix</td>
<td>-1.389 (0.712)</td>
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<tr>
<td>Ample land use mix</td>
<td>1.574 (1.064)</td>
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<td><strong>Random Part</strong></td>
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<tr>
<td>Individual</td>
<td>7.92</td>
<td>6.54</td>
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<td>Group</td>
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<tr>
<td><strong>R² Individual</strong></td>
<td>0.175</td>
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<td><strong>R² Group</strong></td>
<td>0.181</td>
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Intra class correlation = 0.1%

### Ratio Number of Tours / Trips on Weekdays

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<tr>
<td>Individual Effect</td>
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<tr>
<td>Intercept</td>
<td>2.444 (0.107)</td>
<td>2.804 (1.334)</td>
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<td>Higher education</td>
<td>0.600 (0.129)</td>
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<tr>
<td>Terraced house</td>
<td>0.234 (0.120)</td>
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<tr>
<td>(Semi)detached house</td>
<td>-0.191 (0.140)</td>
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<td><strong>Group Effects</strong></td>
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<td>Limited land use mix</td>
<td>-0.571 (0.180)</td>
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<tr>
<td>Ample land use mix</td>
<td>0.843 (0.275)</td>
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<td><strong>Interaction Effects</strong></td>
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<td>Higher education* limited mixing</td>
<td>-0.451 (0.169)</td>
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<tr>
<td>Higher education* ample mixing</td>
<td>0.387 (0.249)</td>
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<td>Individual</td>
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<td>0.37</td>
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<tr>
<td>Group</td>
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### Urban Form and Activity-Travel Patterns

\[
\begin{align*}
R^2_{\text{individual}} & = 0.394 \\
R^2_{\text{group}} & = 0.395 \\
\text{intra class correlation} & = 0.1\% \\
\end{align*}
\]

### Travel Distance on Weekdays

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<td></td>
</tr>
<tr>
<td><strong>Individual Effect</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>intercept</td>
<td>55.925 (10.747)</td>
<td>131.053 (20.150)</td>
</tr>
<tr>
<td>personal income min to std</td>
<td>2.131 (24.169)</td>
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</tr>
<tr>
<td>personal income std to 2x std</td>
<td>-168.411 (36.327)</td>
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<tr>
<td>personal income over 2x std</td>
<td>35.136 (15.591)</td>
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</tr>
<tr>
<td>couple</td>
<td>-32.907 (21.195)</td>
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</tr>
<tr>
<td>family with children</td>
<td>-102.535 (26.115)</td>
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</tr>
<tr>
<td><strong>Interaction Effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>income min-standard*distance city centre</td>
<td>-21.438 (9.994)</td>
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<tr>
<td>income min-standard*LSNT loop/grid</td>
<td>-167.616 (68.629)</td>
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<tr>
<td>income min-standard*LSNT loop</td>
<td>11.80 (29.028)</td>
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</tr>
<tr>
<td>income min-standard*LSNT loop/tree</td>
<td>157.871 (60.610)</td>
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<tr>
<td>income min-standard*LSNT grid</td>
<td>52.117 (47.319)</td>
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<td>income 1-2x standard*LSNT loop/grid</td>
<td>136.879 (47.272)</td>
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<td>income 1-2x standard*LSNT loop</td>
<td>68.887 (36.468)</td>
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<td>income 1-2x standard*LSNT loop/tree</td>
<td>-43.404 (83.044)</td>
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<tr>
<td>income 1-2x standard*LSNT grid</td>
<td>-42.162 (45.879)</td>
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<tr>
<td>couple*LSNT loop/grid</td>
<td>-95.005 (31.729)</td>
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<tr>
<td>couple*LSNT loop</td>
<td>54.987 (27.136)</td>
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<td>couple*LSNT loop/tree</td>
<td>-113.302 (45.698)</td>
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<td>couple*LSNT grid</td>
<td>232.003 (45.838)</td>
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<td><strong>Random Part</strong></td>
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<td>individual</td>
<td>6201.02</td>
<td>2180.14</td>
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<td>group</td>
<td>7.11</td>
<td>503.26</td>
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<tr>
<td>slope family with children</td>
<td>4781.97</td>
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\[
\begin{align*}
R^2_{\text{individual}} & = 0.144 \\
R^2_{\text{group}} & = 0.145 \\
\text{intra class correlation} & = 0.1\% \\
\end{align*}
\]
### Appendix 7

#### Travel Distance Motorised Transport on Weekdays

<table>
<thead>
<tr>
<th>Fixed Part</th>
<th>Null Model</th>
<th>Best Model</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
<td>38.704 (9.861)</td>
<td>81.905 (17.341)</td>
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<tr>
<td>Higher Education</td>
<td>20.685 (12.143)</td>
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<tr>
<td>Couple</td>
<td>-22.748 (20.903)</td>
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<tr>
<td>Family with children</td>
<td>-73.282 (17.265)</td>
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<table>
<thead>
<tr>
<th>Group Effects</th>
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<tr>
<td>LSNT Loop/Grid</td>
<td>57.741 (22.625)</td>
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<tr>
<td>LSNT Loop</td>
<td>18.209 (20.964)</td>
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<tr>
<td>LSNT Loop/Tree</td>
<td>-6.623 (52.182)</td>
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<tr>
<td>LSNT Grid</td>
<td>-21.713 (23.961)</td>
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<thead>
<tr>
<th>Interaction Effects</th>
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<tr>
<td>Higher Education*LSNT Loop/Grid</td>
<td>-16.650 (20.414)</td>
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<tr>
<td>Higher Education*LSNT Loop</td>
<td>-1.178 (15.738)</td>
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<tr>
<td>Higher Education*LSNT Loop/Tree</td>
<td>-18.685 (30.065)</td>
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</tr>
<tr>
<td>Higher Education*LSNT Grid</td>
<td>33.947 (19.815)</td>
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<tr>
<td>Couple*LSNT Loop/Grid</td>
<td>-67.287 (29.694)</td>
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<tr>
<td>Couple*LSNT Loop</td>
<td>-38.834 (29.498)</td>
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<tr>
<td>Couple*LSNT Loop/Tree</td>
<td>-50.534 (61.898)</td>
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<tr>
<td>Couple*LSNT Grid</td>
<td>72.346 (34.057)</td>
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<td>Individual</td>
<td>5221.64</td>
<td>2704.63</td>
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<tr>
<td>Group</td>
<td>5.72</td>
<td>1.12</td>
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$R^2$ individual: 0.482

$R^2$ group: 0.486

Intra class correlation = 0.1%

#### Modal Split Distance Motorised Transport on Weekdays

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<th>Best Model</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>0.362 (0.061)</td>
<td>0.533 (0.070)</td>
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<td>Higher Education</td>
<td>0.121 (0.057)</td>
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<tr>
<td>Car Available</td>
<td>0.201 (0.063)</td>
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<tr>
<td>group effects</td>
<td></td>
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<tr>
<td>---------------------------------------------------</td>
<td>----------------</td>
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<tr>
<td>population density neighbourhood</td>
<td>0.006 (0.003)</td>
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<table>
<thead>
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<tbody>
<tr>
<td>individual</td>
<td>0.20</td>
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<tr>
<td>group</td>
<td>0.00</td>
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</tbody>
</table>

| $R^2$ individual                                   | 0.356          |
| $R^2$ group                                        | 0.366          |

intra class correlation = 0.2%
AUTHOR INDEX

Abraham  132, 137
Arentze   65, 68, 111, 114, 134, 140
AVV       6, 134
Axhausen  44, 111, 134
Banister  31, 134, 143
Boarnet   27, 134
Bolt      56, 134
Borgers   65, 140
Bosker    90, 91, 92, 140
Brown     40, 136, 144
Brög      51, 137
Bryk      90, 93, 116, 134
Bullen    93, 134
CBS (Statistics Netherlands)  6, 7, 8, 84, 135
Cervero    34, 35, 38, 47, 77, 135, 144
Chapin    44, 135
Clarke    51, 135
Congress for the New Urbanism (CNU)  22, 77, 135
Coombes   93, 135
Congdon   93, 116, 134
Crane     24, 26, 135
Dix       51, 135
Duncan    93, 134
Dijst     51, 135

Dumbaugh  40, 136, 144
Ettema    3, 50, 52, 63, 136
Ewing     32, 40, 136, 144, 145
Florez    34, 77, 136, 145
Frank     30, 136, 143
Friedman  32, 77, 136, 145
Gärling   44, 134
Gibson    24, 136
Giuliano  25, 136
Golob     51, 136
Gordon, I. 28, 136, 142
Gordon, S.P.  32, 77, 136, 145
Gorham    36, 135, 144
Haliyur   32, 136, 145
Hägerstrand 44, 136
Handy     28, 29, 33, 136, 142, 145
Hanson    27, 35, 47, 136, 145
Heidemij Advies  17, 138
Hilbers   24, 25, 140
Hofman    111, 134
Hox       90, 93, 136
HSPE-council  2, 5, 8, 15, 17, 136
Hunt      132, 137
Ibrahim   29, 137, 142

-237-
<table>
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<tr>
<th>Janse</th>
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<tbody>
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</tr>
<tr>
<td>Ministry of TPWW (V&amp;W)</td>
<td>10, 11, 12, 13, 15, 17, 138</td>
</tr>
<tr>
<td>Mogridge</td>
<td>19, 138, 142</td>
</tr>
<tr>
<td>Mokhtarian</td>
<td>3, 27, 37, 46, 47, 93, 137, 145</td>
</tr>
<tr>
<td>MuConsult</td>
<td>27, 39, 138, 146</td>
</tr>
<tr>
<td>Murakami</td>
<td>51, 139</td>
</tr>
<tr>
<td>Nasar</td>
<td>34, 77, 139, 146</td>
</tr>
<tr>
<td>Newman</td>
<td>28, 29, 139, 142</td>
</tr>
<tr>
<td>Niemi</td>
<td>51, 139</td>
</tr>
<tr>
<td>NOVEM</td>
<td>19, 137, 139</td>
</tr>
<tr>
<td>Næss</td>
<td>26, 27, 29, 30, 31, 36, 47, 139, 142, 143, 146</td>
</tr>
<tr>
<td>Page</td>
<td>32, 136, 145</td>
</tr>
<tr>
<td>Peers</td>
<td>32, 77, 136, 145</td>
</tr>
<tr>
<td>Pivo</td>
<td>30, 136, 143</td>
</tr>
<tr>
<td>Raudenbush</td>
<td>90, 93, 116, 134</td>
</tr>
<tr>
<td>Raybould</td>
<td>93, 135</td>
</tr>
<tr>
<td>Rottier</td>
<td>55, 139</td>
</tr>
<tr>
<td>Ryan</td>
<td>25, 137</td>
</tr>
<tr>
<td>Røe</td>
<td>27, 31, 36, 39, 139, 143, 146</td>
</tr>
<tr>
<td>Sarmiento</td>
<td>27, 134</td>
</tr>
<tr>
<td>Sandberg</td>
<td>27, 30, 31, 139, 142, 143</td>
</tr>
<tr>
<td>Schimek</td>
<td>28, 29, 139, 142</td>
</tr>
<tr>
<td>Scott Rutherford</td>
<td>33, 137, 139, 146, 147</td>
</tr>
<tr>
<td>Small</td>
<td>25, 136</td>
</tr>
<tr>
<td>Smits</td>
<td>24, 25, 140</td>
</tr>
<tr>
<td>Snellen</td>
<td>65, 140</td>
</tr>
<tr>
<td>Snijders</td>
<td>90, 91, 92, 140</td>
</tr>
<tr>
<td>Stopher</td>
<td>51, 140</td>
</tr>
<tr>
<td>Sun</td>
<td>27, 38, 93, 140, 147</td>
</tr>
<tr>
<td>Timmermans</td>
<td>3, 44, 50, 52, 63, 65, 68, 111, 114, 134, 136, 140</td>
</tr>
<tr>
<td>Verroen</td>
<td>14, 24, 25, 140</td>
</tr>
<tr>
<td>Watson</td>
<td>31, 134, 143</td>
</tr>
<tr>
<td>Watterson</td>
<td>51, 139</td>
</tr>
<tr>
<td>WCED</td>
<td>10, 12, 140</td>
</tr>
</tbody>
</table>
Wilkinson  33, 137, 139, 146, 147
Wilmot     27, 38, 93, 140, 147
Wood       31, 134, 143
SUBJECT INDEX

accessibility 1, 5, 6, 10-13, 15-18, 22-24, 28, 29, 32, 33, 36-41, 45, 50, 57, 142, 144-147
accessibility profiles 10
activity-based approach 3, 4, 43, 44, 49, 52, 54, 129
activity locations 22, 40, 44, 45, 77
activity participation 23, 40, 44, 131
activity patterns 16, 45, 67, 76, 111-113, 129, 133
activity-travel patterns 2-4, 20, 24, 26, 42-46, 49, 50, 53, 60, 63, 84, 110, 113, 116, 117, 123, 125, 128, 129, 132, 133, 214
ALBATROSS model 111, 114
Almere 56, 58, 59, 64-66, 69, 70, 72, 73, 75, 86, 87, 89, 103, 104, 106, 107, 148, 149, 167, 172, 176, 177, 180, 184, 185, 208, 210, 217, 218, 222, 223
data collection 4, 43, 50-55, 57-64, 69, 76, 78, 83, 129, 131
data quality 54, 68-76
Den Haag 56, 58, 59, 65, 66, 69, 70, 72, 73, 154-156, 167
diary 4, 32, 35, 50-53, 61, 63, 64, 69, 75, 83, 110, 113-116, 118-122, 125, 129, 130, 145, 225
effect coding 64, 71, 93, 116
Eindhoven 56, 58, 59, 65, 66, 69, 71-73, 157, 158, 167
empirical studies 1, 3, 20, 21, 24, 26, 27-42, 47, 51, 77, 128-130, 141-147
Enschede 56, 58, 59, 65, 66, 69, 71-73, 159, 160, 167
generalisation 3, 21, 41, 42
Haarlem 56, 58, 59, 65, 66, 69, 71-73, 161, 162, 167
harmonic mean 92
hierarchical linear model 49, 74, 90, 91

chi-square analysis 27, 91
compact city 1, 9, 16, 25, 106
conceptual framework 4, 43-46, 52
correlation 28, 30, 31, 42, 47, 60, 67, 68, 75, 85, 91, 114, 117, 142, 170, 173, 178, 181, 186, 214, 219, 224
data quality 54, 68-76
diary 4, 32, 35, 50-53, 61, 63, 64, 69, 75, 83, 110, 113-116, 118-122, 125, 129, 130, 145, 225
effect coding 64, 71, 93, 116
Eindhoven 56, 58, 59, 65, 66, 69, 71-73, 157, 158, 167
empirical studies 1, 3, 20, 21, 24, 26, 27-42, 47, 51, 77, 128-130, 141-147
Enschede 56, 58, 59, 65, 66, 69, 71-73, 159, 160, 167
generalisation 3, 21, 41, 42
Haarlem 56, 58, 59, 65, 66, 69, 71-73, 161, 162, 167
harmonic mean 92
hierarchical linear model 49, 74, 90, 91
Subject Index

Kruskal-Wallis test  85, 114, 170, 214

Leeuwarden  56, 58, 59, 65, 66, 69, 71-73, 163, 164, 167
location policy  1, 9-11, 13, 15-20

matched pair analysis  32, 34, 36, 144
methodological flaws  3, 42, 43, 52
mobility  1-3, 5-10, 12, 13, 15-17, 20, 23-25, 38, 41-43, 46, 50, 52, 90, 93, 106, 124, 128, 130, 132, 142
mobility profiles  10, 11
mobility reduction  1-3, 8, 10, 16, 17, 20, 22, 24, 28, 41, 42, 76, 129, 132, 133
modal shift  8, 15-17, 20, 31
modal split  26, 29, 30, 34, 37, 86, 93, 95-98, 100, 101, 103, 105, 114, 115, 117, 120-122, 124, 125, 132, 170
model performance  94-97, 117-118
morphology  3, 55, 56
multilevel analysis  74, 75, 84, 90, 91, 93, 94, 97, 103, 110, 116, 118, 122, 123, 129, 187-213, 225-237
multilevel model  84, 90-93, 116-118
neo-traditional design  24-26, 32-35, 77
New Urbanism  22, 24, 38, 77, 124
probit regression analysis  64-66
Poisson regression  93
quasi-experimental design  43, 46, 47, 52, 54, 129, 131
questionnaire  4, 50, 52, 54, 61-64, 67, 68, 82, 83, 113
regression analysis  29-31, 34-40, 42, 46, 47, 71-75, 91, 93, 142-147, 169
research design  4, 42, 53, 54, 120, 131
response  4, 51, 54, 64-66, 75, 83, 85, 93, 113, 116, 131, 167
sample  21, 47, 49, 66-68, 77, 106, 129, 132
simulation studies  21, 24-26, 41, 91
socioeconomic characteristics
definitions  82, 168-169
spatial characteristics
definitions  78-82
spatial mobility policy  1-3, 5-21, 25, 42, 50, 76, 77, 129-132
spatial planning  1, 2, 4-6, 8, 10, 11, 15-17, 19, 29, 41, 50, 56, 128, 132
standardised coefficients  98-104, 118-120, 122
sustainability  1, 12, 43, 45, 133
theoretical studies  21-24, 28, 40, 41, 77, 124, 130
transportation models  25, 26
travel behaviour  21-41, 43, 50, 63, 84-130, 132
travel patterns  2, 3, 22, 24, 25, 27, 28, 32, 33, 45, 46, 52, 67, 76, 82, 88, 123, 124, 129, 130, 133
travel survey  27, 28, 32, 36, 38, 39, 51, 66, 68, 110, 142, 143, 145, 147
Urban Form and Activity-Travel Patterns

urban design  1, 2, 9, 12, 16-19, 22-26, 32, 36, 38, 40, 41, 43, 46, 50, 52, 56, 76, 77, 130-133
urban form  1-4, 14, 16, 17, 20-22, 24, 26-28, 31, 40-43, 45, 46, 52, 54-61, 75-824, 98, 100, 102, 103, 105-110, 119-132
validity  21, 26, 52
VINEX  1, 10, 15
Zoetermeer  56, 58, 59, 65, 66, 69, 71-73, 165-167
SAMENVATTING (DUTCH SUMMARY)

In Nederland wordt de laatste jaren hard gewerkt aan de ontwikkeling van VINEX-wijken. Deze grote woningbouwlocaties zijn het resultaat van het Rijksbeleid in de jaren negentig en moeten ervoor zorgen dat aan de enorme woningvraag voldaan wordt. Bij het ontwerp van deze locaties worden belangrijke beslissingen genomen met betrekking tot de ruimtelijke structuur van de wijken. De inrichting zou moeten bijdragen aan het realiseren van beleidsdoelen zoals duurzaamheid en vermindering van de automobiliteit. Het is echter onduidelijk welke ruimtelijke inrichting de beste bijdrage levert aan deze doelen. Empirische kennis op dit punt ontbreekt grotendeels. In de literatuur zien we veelvuldig dat ruimtelijke inrichting in verband wordt gebracht met mobiliteit. Maar helaas zijn er een aantal bezwaren in te brengen tegen deze literatuur. Meestal wordt gerapporteerd over studies die uitgevoerd zijn in andere landen en op andere continenten, hetgeen vragen oproept over de toepasbaarheid in de Nederlandse situatie. Daarnaast kennen bestaande studies een aantal methodologische bezwaren. De studie die in dit proefschrift wordt gerapporteerd is erop gericht de relatie tussen ruimtelijke inrichting en de reductie van (auto)mobiliteit empirisch te testen in de Nederlandse situatie. De vraag daarbij is of er een relatie is tussen ruimtelijke inrichting en verplaatsingspatronen, en zo ja, hoe sterk die relatie is. De aandacht richt zich daarbij op kenmerken van de wijk en de stad. Verplaatsingen worden in deze studie benaderd als een afgeleide van activiteiten-participatie. De ruimtelijke inrichting wordt beschouwd als een omgeving die mogelijkheden biedt en tevens beperkingen oplegt om activiteiten en verplaatsingen te ondernemen.

Hoofdstuk 2 van het proefschrift belicht de beleidsmatige achtergrond van het onderwerp van studie. Eerst wordt het mobiliteits-vraagstuk kort toegelicht: de (auto)mobiliteit is in de afgelopen jaren sterk gegroeid en een verdere groei valt te verwachten. Vervolgens geeft het hoofdstuk een overzicht gegeven van de lijnen die door de ministeries van Volkshuisvesting, Ruimtelijke Ordening en Milieu (VROM) en van Verkeer en Waterstaat (V&W) zijn uitgezet op het gebied van ruimtelijk
mobiliteitsbeleid. Hieruit blijkt dat de Nederlandse overheid al zo’n dertig jaar een ruimtelijk mobiliteitsbeleid voert en dat de belangrijkste doelen van het beleid in deze periode nauwelijks veranderd zijn. Reductie van verplaatsingsafstanden en promotie van alternatieve vervoerwijzen zijn altijd de kernpunten van het beleid geweest. Twee hoofdlijnen van beleid kunnen daarbij onderscheiden worden, nl. beleid dat gericht is op het bepalen van locaties voor activiteiten en beleid dat gericht is op de verbindingen tussen deze locaties. De maatregelen die in het ruimtelijke mobiliteitsbeleid door de jaren heen zijn voorgesteld en geïmplementeerd, zijn steeds gebaseerd geweest op de aannames en verplaatsingspatronen van individuen en huishoudens (sterk) beïnvloed worden door de ruimtelijke constellatie waarin zij zich begeven. Echter, empirisch bewijs voor deze aannames ontbreekt grotendeels.

Hoofdstuk 3 van het proefschrift belicht de bestaande literatuur over de relatie tussen ruimtelijke inrichting en verplaatsingsgedrag van individuen en huishoudens. Daarbij is onderscheid gemaakt tussen theoretische discussies, simulatie studies en empirisch onderzoek. De beschikbare literatuur laat zien dat er nogal wat tegenstrijdige meningen bestaan en tegenstrijdige resultaten beschikbaar zijn met betrekking tot de onderzochte relatie. Dit maakt het moeilijk om conclusies te trekken. Over het algemeen is er wel overeenstemming over de factoren die potentieel van invloed zijn op verplaatsingspatronen, namelijk dichtheid, functiemenging en bereikbaarheid per openbaar vervoer. De meeste theoretische ideeën gaan uit van deze factoren, op basis waarvan wordt beredeneerd dat hogere dichtheden en functiemenging verplaatsingsafstanden korter maken. Deze kortere afstanden, in combinatie met beter openbaar vervoer, zouden alternatieve vervoerwijzen aantrekkelijker moeten maken. Het is echter meer de vraag of mensen volgens deze theorie handelen. Ook simulatiestudies zijn veelal gebaseerd op deze theoretische achtergrond en laten zien dat een ‘goede’ inrichting tot een aanzienlijke reductie van de (auto)mobiliteit kan leiden. De vergelijking met de praktijk wijst echter vaak anders uit. De empirische studies, tenslotte, geven resultaten die variëren van geen invloed van ruimtelijke inrichting op verplaatsingsgedrag tot een aanzienlijke, significante invloed. We zien hier dezelfde factoren weer terugkomen. Helaas moeten we ook vaststellen dat veel studies methodologische gebreken kennen. Veel studies vergelijken slechts 2 of 4 wijken en in een aantal studies wordt niet gecontroleerd voor sociaal-economische en demografische kenmerken. Vaak moeten onderzoekers, noodgedwongen, gebruik maken van gegevens die voor andere doeleinden zijn verzameld of worden er alleen gegevens bestudeerd van trips voor specifieke motieven, in plaats van complete verplaatsingspatronen. Tenslotte
Samenvatting (Dutch Summary)

is er tot op heden geen enkele studie bekend die recht doet aan feit dat de gegevens die bestudeerd worden zich op verschillende niveaus bevinden. Studies die methodologisch het best in elkaar zitten laten zien dat de invloed van ruimtelijke kenmerken beperkt is. Maar zelfs wanneer we de meest positieve resultaten beschouwen, blijft het de vraag of de resultaten van deze, meest Noord-Amerikaanse studies, te generaliseren zijn naar de Nederlandse situatie.

In hoofdstuk 4 komt de opzet van het onderzoek aan de orde. De keuze voor de activiteitenbenadering wordt toegelicht en tevens wordt aangegeven hoe we de methodologische beperkingen die zijn aangetroffen in veel andere studies willen voorkomen. De activiteitenbenadering is te verkiezen boven andere (vaak motief- of vervoermiddel-specifieke) benaderingen om een aantal redenen. De activiteitenbenadering is een integrale benadering die erkent dat verplaatsen zelden een doel op zich is, maar vrijwel altijd de afgeleide is van de wens en noodzaak om activiteiten te verrichten op plaatsen die ruimtelijk gescheiden zijn. Daarnaast omvat de activiteitenbenadering alle trips, inclusief korte trips, in plaats van zich toe te spitsen op bepaalde verplaatsingsmotieven of vervoermiddelen. Het detailniveau is hoger en de betrouwbaarheid van de gegevens groter.

In het conceptueel model dat ten grondslag ligt aan deze studie worden twee groepen kenmerken van invloed gedacht op participatie in activiteiten en verplaatsingspatronen, namelijk kenmerken van het individu en het huishouden (bepalend voor hun basisbehoeften en persoonlijke voorkeuren) en kenmerken van de ruimtelijke inrichting (de mogelijkheden en beperkingen die deze biedt). Verplaatsingspatronen zijn het gevolg van activiteitenparticipatie en deze patronen bestaan uit verplaatsingen en hun kenmerken.

Met de opzet van het onderzoek wordt een viertal frequent voorkomende methodologische problemen voorkomen. Ten eerste is er sprake van een quasi-experimenteel design. Hiermee willen we voorkomen dat er in de gegevens een verband bestaat tussen de kenmerken van de individuen en huishoudens in een wijk en de ruimtelijke kenmerken van de wijk. Voor de gegevensverzameling zijn wijken daarom zodanig geselecteerd dat dit verband zo laag mogelijk is. Ten tweede wordt in de studie een analyse verricht van complete verplaatsingspatronen. Veel studies bekijken slechts een of twee belangrijke verplaatsingsmotieven. Daarmee wordt uit het oog verloren dat winst die behaald wordt op een bepaalde verplaatsing, weer verloren kan gaan bij andere
verplaatsingen. Wanneer mensen bijvoorbeeld dicht bij hun werk wonen, kan het best zijn dat ze 's avonds meer energie hebben om activiteiten buitenhuis te doen, terwijl mensen met een langere reistijd naar het werk er misschien vaker voor kiezen 's avonds thuis te blijven. Analyse van de verplaatsing naar het werk geeft dan onvolledige informatie. Als derde willen we vermijden dat de data die we verzamelen onvolledig is. Wanneer mensen wordt gevraagd om hun verplaatsingen te rapporteren, blijkt vaak dat korte verplaatsingen, zoals een brief posten, hierbij worden vergeten. Daarom is in dit onderzoek gekozen voor gegevensverzameling met behulp van activiteiten dagboekjes, waarin niet wordt gevraagd naar verplaatsingen maar naar activiteiten. Tenslotte willen we voorkomen dat schaalverschillen in de gegevens invloed hebben op de resultaten. In veel studies worden zowel kenmerken van wijken en steden als van individuen/huishoudens opgenomen. Dan wordt meestal het individu of het huishouden als eenheid voor de analyse gehanteerd, waarmee de steekproefgrootte van de wijkkenmerken ten onrechte wordt opgehoogd. Als gevolg worden er mogelijk meer significante resultaten gevonden dan er feitelijk bestaan. Om dit probleem te voorkomen wordt in deze studie gebruik gemaakt van multi-level analyse, een vorm van lineaire regressie analyse waarbij rekening wordt gehouden met het feit dat gegevens van verschillende niveaus aanwezig zijn. In dit geval betekent dat, dat de elementaire regressievergelijking de kenmerken van de individuen/huishoudens bevat, en dat de constante en de parameters voor deze kenmerken op hun beurt weer afzonderlijke regressievergelijkingen zijn die, naast een constante, ook de kenmerken van de stad/wijk kunnen bevatten. De parameters voor de individuele/huishoudenskenmerken kunnen dus verschillen naar wijk/stad.

Hoofdstuk 5 behandelt de gegevensverzameling. Deze heeft plaatsgevonden in 19 wijken in 9 middelgrote Nederlandse steden. Er is gekozen voor middelgrote steden omdat het juist deze steden zijn die het grootste deel van de woningbehoefte in de komende periode moeten opvangen. De steden zijn zodanig geselecteerd dat er een variatie aan stedelijke vormen en ontsluitingsprincipes vertegenwoordigd is in de verzamelde gegevens. Binnen de steden zijn de wijken zodanig geselecteerd dat er een grote variatie is met betrekking tot de ligging ten opzichte van het centrum, een eventueel stadsdeelcentrum en beschikbare treinstations. Er zijn in deze wijken gegevens verzameld van 586 individuen in 344 huishoudens, een respons van 58%. De vragenlijst die is afgenomen bestond uit verschillende delen. Het belangrijkste onderdeel, het activiteitendagboek, besloeg 2 dagen. Men werd onder andere gevraagd te rapporteren wat men gedaan heeft, waar, met wie, begin- en eindtijd, gebruikte vervoermiddel(en)
en reistijd. Naast het dagboekje bestond de vragenlijst uit een deel waarin informatie werd gevraagd over een aantal frequent voorkomende activiteiten (zoals werken, boodschappen doen, winkelen en regelmatig terugkerende vrije tijd activiteiten) en een deel waarin gegevens werden gevraagd over persoonlijke en huishoudenskenmerken. De respons en de kwaliteit van de respons zijn op diverse wijzen geanalyseerd. Daaruit bleek dat de respons en de kwaliteit van de gegevens niet of nauwelijks verschillen tussen de wijken waar gegevens verzameld zijn en de ruimtelijke kenmerken van die wijken. We konden concluderen dat er geen noodzaak bestond om weegfactoren toe te passen op de gegevens.

Op de verzamelde gegevens is multi-level analyse toegepast. Hoofdstukken 6 en 7 behandelen de resultaten hiervan. Hoofdstuk 6 gaat in op de multi-level analyses die zijn uitgevoerd op de gegevens over frequent voorkomende activiteiten, namelijk werken, boodschappen doen, winkelen en regelmatig terugkerende vrije tijd activiteiten. Deze analyses zijn uitgevoerd om deze motief-specifieke benadering te kunnen vergelijken met de integrale activiteitenbenadering die we in dit onderzoek voorstellen. Er zijn voor elk motief modellen geschat voor het aantal kilometers, het aantal trips, het aantal kilometers en trips per vervoerwijze en de aandelen per vervoerwijze voor kilometers en trips. Het aantal significante effecten dat werd gevonden varieerde aanzienlijk over de geschatte modellen. De verklaarde variantie van de modellen was in vrijwel alle gevallen hoger op het niveau van de wijk/stad dan op het niveau van het individu/huishouden. Toch werden er over het algemeen meer effecten gevonden voor individuele en huishoudenskenmerken dan voor ruimtelijke kenmerken. De verklaarde variantie op het ene niveau kan bij multi-level analyse ook beïnvloed worden door variabelen op het andere niveau.

We moeten uit de resultaten concluderen dat de invloed van de ruimtelijke inrichting op het verplaatsingsgedrag voor frequente activiteiten beperkt is. De volgende significante effecten van ruimtelijke kenmerken werden gevonden. Positieve invloed gaat uit van de meerkernige stad (Almere), een radiale of axiale ontsluiting van de wijk en lus/raster en lus/boom ontsluitingen op straatniveau. Negatieve effecten werden gevonden voor een ring ontsluiting van de stad, lus en ring ontsluitingen voor de wijk, een lus ontsluiting op straatniveau, een buurtsteunpunt alsinkelvoorziening in de wijk, sportvoorzieningen in de wijk, grotere afstand tot het stadscentrum, liggining binnen de Randstad en een lagere stedelijkheid van de wijk. Sommige andere ruimtelijke kenmerken
kenmerken vertoonden wel significante invloeden, maar deze waren tegenstrijdig tussen de verschillende modellen.

In hoofdstuk 7 zijn de resultaten gerapporteerd van de multi-level analyses van de gegevens die verzameld zijn met behulp van de dagboeken. Uit de verstrekte gegevens van elke respondent en voor elke dagboek-dag zijn een aantal indicatoren afgeleid. Deze indicatoren geven aan hoeveel verplaatsingen en tours (een tour begint thuis en eindigt thuis en kan meerdere trips en activiteiten bevatten) een individu heeft gemaakt op een dag, welke reistijd en reisafstand daarmee gepaard zijn gegaan, met welk vervoermiddel gereisd is en in welke mate verplaatsingen zijn gecombineerd. Er zijn modellen geschat voor elk van deze indicatoren en daarnaast is onderscheid gemaakt tussen gegevens voor alle dagen en gegevens specifiek voor weekdagen. Ook nu weer was de verklaarde variantie op het niveau van de wijk/stad hoger dan op het niveau van het individu/huishouden en werden er meer significante effecten gevonden van sociaal-economische kenmerken van individuen/huishoudens dan van ruimtelijke kenmerken. Veel modellen bevatten slechts één of geen enkel ruimtelijk kenmerk. De volgende significante effecten van ruimtelijke variabelen werden gevonden. Positieve invloed gaat uit van een radiale wijkontsluiting, een beperkte functiemenging in de wijk en een grotere afstand tot het centrum en het intercity station. Negatieve effecten werden gevonden voor een ringontsluiting van de stad, een axiale wijkontsluiting, lus, lus/boom en raster ontsluitingen op straatniveau en een hogere inwonerdichtheid van de wijk. Deze zeer beperkte resultaten bieden nauwelijks steun aan de hypothesen en aannamen die aan het Nederlands ruimtelijke mobiliteitsbeleid ten grondslag liggen en die uit de beschikbare literatuur kunnen worden afgeleid, of zijn soms zelfs tegengesteld hieraan.

De analyses van de totale dagboekgegevens leverden, met name op de totale kilometrage, opmerkelijke verschillen op met de analyses van de dagboekgegevens van weekdagen. Daar waar weekdagen meer en grotere effecten van ruimtelijke kenmerken te zien gaven, verdwenen deze effecten in de analyse van de totale activiteitenpatronen over alle dagen van de week. Blijkbaar treedt er met betrekking tot reisafstanden tussen weekenden en weekdagen een compenserend effect op, waarbij diegenen die door de week veel reizen dat in het weekend minder doen en omgekeerd.

Tenslotte blijkt uit een vergelijking van de analyses van motief-specifieke verplaatsingen en van complete dagboekjes dat de resultaten nogal variëren, zelfs voor dezelfde ruimtelijke kenmerken. De analyse van dagboekjes kan dus tot andere conclusies leiden.
Samenvatting (Dutch Summary)

dan de analyses van trips voor bepaalde motieven. Omdat dagboekjes een veel integraler beeld geven van verplaatsingsgedrag zijn wij van mening dat analyse van dagboekjes te prefereren is boven de analyse van motief-specifieke trips.

In hoofdstuk 8 worden de belangrijkste punten uit het proefschrift nog eens voor het voetlicht gehaald. De bijdrage die de studie levert aan de beschikbare internationale literatuur bestaat uit drie delen. Ten eerste betreft het de eerste studie die de invloed analyseert van de ruimtelijke omgeving op complete activiteiten-verplaatsingspatronen, in plaats van te kijken naar afzonderlijke verplaatsingsmotieven. Ten tweede is het de eerst studie die een quasi-experimenteel design hanteert om de effecten van ruimtelijke en sociaal-economische variabelen beter te kunnen onderscheiden. Tenslotte is het de eerste studie die multi-level analyse toepast om betrouwbare schattingen te verkrijgen van de effecten van ruimtelijke kenmerken op verplaatsingsgedrag.

Uit de studie blijkt dat, controllerend voor sociaal-economische kenmerken van individuen en huishoudens, de invloed van ruimtelijke kenmerken op het verplaatsingsgedrag, en met name de totale mobiliteit, beperkt is. Veel potentiële relaties zijn onderzocht en slechts een beperkt aantal bleken van significante invloed. Wijkkenmerken blijken van grotere invloed dan stadkenmerken, wat impliceert dat de vormgeving van de wijk van groter belang is dan het ontwerp van de stad. Ook is naar voren gekomen dat er sprake is van compenserend gedrag in verplaatsingspatronen. Een compenserend effect is aangetroffen tussen dagboekdagen. De effecten die gevonden zijn bevestigen niet zonder meer de hypothesen die uit de bestaande literatuur kunnen worden afgeleid. Sommige gevonden effecten zijn zelfs tegenstrijdig met de verwachtingen en andere gelden alleen in interactie met specifieke sociaal-economische factoren. Daarnaast werden er vrijwel geen effecten van ruimtelijke kenmerken op de totale (gemotoriseerde) mobiliteit gevonden. Hieruit moeten we concluderen dat, binnen de huidige sociale, culturele en economisch context, de potentie van het ruimtelijk ontwerp als instrument om de (gemotoriseerde) mobiliteit te beïnvloeden in Nederlandse middelgrote steden minimaal is, maar dat bepaalde kenmerken van ruimtelijke inrichting (zoals ontsluitingsstructuren, functiemenging en afstand tot het centrum) sommige aspecten van het verplaatsingsgedrag wel kunnen beïnvloeden.

Hoofdstuk 8 belicht ook een aantal beperkingen van de studie. Er is voor gekozen de aandacht te richten op de invloed van kenmerken van de ruimtelijke omgeving op activiteiten-verplaatsingspatronen. Daarbij is gecontroleerd voor een groot aantal sociaal-
economische kenmerken, maar worden kenmerken als culturele achtergrond, attitudes en andere sociologische en psychologische factoren niet meegenomen. Deze pasten niet binnen de reikwijdte van de studie, waarmee we geenszins de indruk willen geven dat deze kenmerken niet belangrijk zijn. Daarnaast is de lijst van ruimtelijke kenmerken die meegenomen zijn uiteraard beperkt. Ook is er een kritische kanttekening te plaatsen bij de hoeveelheid data waarop de analyses gebaseerd zijn. De relatief beperkte omvang van de dataset heeft ongetwijfeld een rol gespeeld in het aantal gevonden significante effecten.

In deze studie zijn activiteiten-verplaatsingspatronen benaderd als het resultaat van een complex samenspel van persoonlijke behoeften en voorkeuren en de mogelijkheden en beperkingen die de ruimtelijke omgeving biedt. Uit de studie blijkt een beperkt effect van ruimtelijke kenmerken op de totale mobiliteit. Deze resultaten leiden tot de conclusie dat, in de huidige context, de meeste individuen en huishoudens zich niet in grote mate laten beperken door de ruimtelijke omgeving. Geld en tijd lijken voldoende voorhanden om het gewenste activiteitenpatroon te ontplooien, ook als daarvoor langere afstanden moeten worden afgelegd. Echter, bepaalde ontsluitingsprincipes, een beperkte menging van functies en de afstand tot het stadcentrum of het intercity station kunnen sommige keuzes met betrekking tot verplaatsingsgedrag positief beïnvloeden. Dit geeft aanleiding tot blijvende aandacht voor het ruimtelijk ontwerp, zowel in kwantitatieve als kwalitatieve zin, ook met het oog op de toekomst. De ruimtelijke omgeving die nu ontwikkeld wordt moet immers nog tientallen jaren mee. In die jaren kunnen er allerlei omstandigheden veranderen, waardoor de invloed van de ruimtelijke omgeving, alhoewel nu nog beperkt, een belangrijkere rol kan gaan spelen. Deze omgeving moet toekomstige gebruikers, in gewijzigde omstandigheden, nog steeds de mogelijkheid bieden om hun keuzes te maken en uit te voeren. Een goed ontworpen stedelijke omgeving, die het mogelijk maakt reisafstanden zo kort mogelijk te houden en die de keuze voor alternatieve vervoermiddelen stimuleert, levert op korte termijn wellicht geen directe winst op, op de langere termijn zouden verliezen kunnen worden voorkomen.
CURRICULUM VITAE

I was born in the summer of 1972. My parents raised me in Kelpen, a small village in the South of the Netherlands. I went to primary school there, which was within walking distance from home. From 1984 to 1990, I attended the Philips van Horne Scholengemeenschap in Weert, a 10 kilometre bicycle ride from home. I successfully finished my VWO (pre university education) in June 1990.

In September 1990, I continued my education at the Eindhoven University of Technology, Faculty of Building, Architecture and Planning. This drastically changed my daily travel patterns. The first few months, I cycled to the train station in Weert in the morning, caught a train to Eindhoven and walked from the train station to the university buildings. Evenings were in reverse order. Later, I moved to Eindhoven, at cycling distance from the university. In my student years, I was employed as a student assistant at the urban planning group for several assignments related to research and teaching. I was also actively involved in the educational committee of the Students' Association. For several years I was a student member of the Faculty Council and of the Faculty Education Committee. Within the building and architecture program, I chose the direction of urban planning, specialising in the relationship between urban planning and transport issues. I finished my Masters' thesis, entitled 'New Towns in the Netherlands: a typology for alternative developments', in September 1995.

Immediately after graduating, I started working at the same university on a Ph.D. project, advancing my knowledge about urban planning and transport issues. During the project, I moved from Eindhoven to 's-Hertogenbosch, which changed my daily activity-travel pattern significantly, back to the cycle-train-walk-chain. In addition to my research activities, I thought courses and supervised students at the same department and I was a member of the Faculty Council. At the moment I am a researcher/policy consultant at SGBO in Den Haag, commuting by train on a daily basis. Moving from 's-Hertogenbosch to Woerden has recently reduced my home-to-work travel time by one third. The time saved I gratefully use for other activities, some of which involve travel.