LUMA-GIS Thesis nr 2

Daily mobility in Grenoble Metropolitan Region, France. Applied GIS methods in time geographical research

Rickard Hansen

2008
Dept. of Physical Geography and Ecosystem Analysis
Centre for Geographical Information Systems
Lund University
Sölvegatan 12
S-223 62 Lund
Sweden

A Master thesis presented to

Department of Physical Geography and Ecosystem Analysis

Centre for Geographical Information Systems

of

LUND UNIVERSITY

by

Rickard Hansen

in partial fulfilment of the requirements

for the degree of Master in Geographical Information Science

Supervisor: Ulrik Mårtensson

Lund University

2008

ABSTRACT

Time-geography is one of the earliest analytical perspectives to study human activities and movements in space-time. With the increasing availability of geo-referenced individual level data and more powerful computational capabilities, more and more studies are implementing time-geographical constructs in Geographical Information Systems (GIS). This research evaluates the importance of different variables to understand daily mobility for individuals in Grenoble metropolitan region, France. It presents approaches to describe and measure observed travel patterns based on 39 completed travel diaries from 22 households. The activity-space concept is used to describe and measure daily mobility and it is portrayed through the standard deviational ellipse and the standard distance. The data used have been implemented and computed in a GIS. The results show that of the variables investigated; gender, day of week, and work status – work status is most explanatory of observed differences in activity-space. Another aspect of the research has been to examine potential mobility of individuals - this in as extension to the observed daily mobility and looks at the underlying activities to determine the potential spatial choice. The result of the analysis shows that differences in potential mobility can not be explained by the tested variables; gender and day of week.

[Key words: mobility, time geography, potential path area, activity-space, GIS, geostatistics]

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

4SM	4 Step Model
ANOVA	Ananlysis of Variance
BSP	Reach Simulation Programme (Dutch abbreviation)
CARLA	Combinatorial Algorithm for Rescheduling Lists of Activities
COSI	Communaté de Communes du Grèsivaudan
DF	Degrees of Freedom
DPPA	Daily Potential Path Area
GIS	Geographical Information Systems
GPS	Global Positioning System
HRH	Household Responsibility Hypothesis
ICT	Information and Communication Technologies
IGN	Institute Géographique National
PPA	Potential Path Area
PESAP	Programme Evaluating the Set of Alternative Sample Path
SPSS	Statistical Package for the Social Sciences
TDD	Travel Diary Data

1. INTRODUCTION

1.1 Background

Cities and metropolitan regions across the world provide a setting for many millions of people and a wide range of activities. These regions also experience population increase and as a result emerging pressure in form of, for example, environmental emissions and air quality, urban sprawl, auto dependency, and congestion have increased. The complexity of urban mobility is related to the development of these regions, the individuals who make up the population and their daily activities. The changing geography of metropolitan areas could be seen as a dynamic picture, with growing (and also shrinking) material entities in the landscape, and web-like trajectories of people, of which some are stationary in space and other are in motion (Novák and Sýkora, 2007). The development of metropolitan areas also presents relations between immobility and mobility. With the constructions of new immobile properties such as shopping centres, changes in the distribution of retail facilities are brought forward. This is turn change peoples mobility patterns, which adjust their commuting and travel behaviour to make use of newly opened opportunities. These stable properties, e.g. shopping centres, produce a change in the mobility pattern of people and form new patterns. The growth and urban sprawl of cities and metropolitan areas have in this way created a link between immobility and mobility and have also led to a huge increase in faster and longer distance travel, even though that travel time have stayed constant (Banister, 2008).

On a macro level, cities and metropolitan areas are, as part of human societies, formed by the continuous process of individuals performing activities to live their everyday life. Thus by looking at individual's mobility patterns and activities constitutes a proper level of research that may reveal further insight into our complex societies. Our lives consist of different activities, activities that are often only available at specific times and/or locations, i.e. working, shopping, socialising, recreation etc. Individuals have different amounts of times, restrictions and resources available to them to conduct these activities. The transportation network, the available modes of transport (car, bus, metro etc), household characteristics, locations of activities – all these are part of the complexity of what is urban mobility. An important aspect in addressing this complexity of urban mobility involves understanding the spatial characteristics and dynamics of individual and household travel behaviour. Understanding travel behaviour of people is important since it constitutes a large portion of our lives and affects our surroundings. It is, after all, people who live and work in a region that affect, and are affected by, the surroundings around them. Knowledge about travel behaviour is essential to address subjects such as transport planning, environmental problems, and accessibility in the urban context successfully.

1.2 Gender differences in daily mobility

An extensive body of research has identified gender as an important predictor of travel pattern and a constant empirical finding is that women tend to engage in shorter commutes than do men (Turner and Niemeier, 1997). They continue to say that several studies have noted that there is a difference in household responsibilities between men and women even in two-earner household in which the women is employed full-time. This notion has in the literature been referred to as household responsibility hypothesis (HRH), which states that employed women tend to have greater household and child-care responsibilities and, as a result, have far greater time constraints and ultimately choose shorter commutes than employed men (Turner and

Niemeier, 1997). There is, however, a disagreement and findings are contradictory regarding on which factors that contributes to the commute difference. Turner and Neimeier (1997) provide a review of the results of research on the gender difference in commuting with respect to the HRH:

- Hanson and Hanson's (1980) look into gender differences in urban travel patterns in Uppsala, Sweden, Hanson and Johnson's (1985) investigation of gender differences in work trip length in Baltimore, USA, Fagnani's (1987) research which investigated the commuting behaviour of employed mothers in France, Hanson and Pratt's (1990) who examined the spatial characteristics of occupational segregation for women in Worchester, Massachusetts, USA, and Turners and Niemeier's (1997) study of household responsibilities in US metropolitan areas all tend support the HRH.
- Singell and Lillydahl's (1980) look into two-earner households, Madden's (1981) research with a utility maximization framework within to consider gender differences in commuting, and Gordon *et al's.* (1989) study of gender difference in metropolitan travel behaviour are all inconclusive with respect to the HRH. White's (1986) analysis of New York City data presents evidence against the HRH with women with greater household responsibilities engage in longer commutes.

Drawing on the HRH which states, among other things, that when a household consists of a married couple, the level of household responsibility is higher (particularly if the couple has children) and the working women in such a household will tend to have shorter commute lengths than a similarly situated man, this research will examine whether or not this can be applied to activity-spaces as well.

1.3 Aims of the research

This research addresses the spatial mobility patterns of individuals. It presents an approach to describe and measure the daily mobility patterns revealed by individuals over a four day period within in a GIS environment. The aim of the research is too explore how mobility patterns change over time, between genders and work status (working or non-working) based on their routine activity schedule. The empirical focus will be on time-space activity and mobility patterns which will allow us to better understand the spatial outcome of people's daily life. The description and measurements of individuals mobility is based on the geographical concept activity space. Through looking at the distribution of individual's activity locations in space, this research will attempt to contribute to a better understanding of spatial behaviour through the application of time-geographical concept and GIS methods in the research of mobility. The analysis of individual's activity spaces will focus on their realized travel as recorded in the travel diaries. Looking at everyday metropolitan life of individual's activity schedules, this research will attempt to answer the following questions:

- How does the activity-space look like for males and females?
- Are there differences in activity-space among people based on gender?
- Are there differences in activity-space based on day of the week?
- Are there differences in activity-space based on work status?

Another aspect of the research is to explore the potential travel possibilities an individual has according to restrictions placed on him/her by external factors or by himself/herself. This extension of potentiality has often been used in measuring accessibility to activities (see

Weber, 2003; Weber and Kwan 2003; Casas, 2007). The exploration of potential mobility will be done by measuring and analyzing the Potential Path Area (PPA) of individuals by utilizing GIS modelling and put it in the context of gender and day of the week. By using the available data this research will also answer the following questions:

- How does the PPA look like for males and females?
- Are there differences in PPA among people based on gender?
- Are there differences in PPA based on day of the week?

The main goal with the PPA in this research is to show its possibilities as a method in mobility research. This is done by introducing the conceptual idea and presenting its construction. The research questions used in the context of PPA is, however, limited to the information available at hands. PPA does not represent the realized mobility of individuals nor their accessibility to activities in this study; rather it represents the potential mobility individuals have according to their activity schedule (this could of course be extended to include accessibility). This part of the research is more leaned towards exploration of the data, exploration of the activity-based approach and looks into an eventual continuation of this kind of research.

Though there are contradictory results regarding gender and mobility, many studies support that there is a gender bias in the context of mobility. These studies have shown that women tend to have shorter commutes than do men (see above). Leaning on this notion, the hypothesis put forward here is that females will have a significant different activity-space then males. This is also based on the belief that because Wednesday are a free day for children under the age of 11 years old in France and traditionally that have meant that women often stayed home to take care of the children. Furthermore, the activity-space is also expected to be significantly different between different days of the week. First because of Wednesdays (see above) and second because the fourth day included is a Saturday, which is a free day for most people.

The remainder of this research is organized as follows: First, an introduction to time-geographical thoughts and concepts as well as its development. Different approaches to the subject is also presented and discussed. The empirical section starts with a description of the study area and the data used in the research. Several measures and models are also introduced and explained. This is followed by the analysis and the presentation of the results. The research finishes with conclusions of the major findings, a discussion of the results, and the elaboration of future research directions.

2. TIME-GEOGRAPHY AND SPATIAL CONCEPTS

2.1 Time-geography

Hägerstrand's time-geography is a powerful conceptual framework for understanding human spatial behaviour and the constraints on their activity participation in space and time. There has been a resurgence of time-geography over the last decade as researchers have improved the computational representations of basic time-geographic concept such as space-time path and prism (Miller, 2004). This wider resurgence of time-geography has also been supported by the increasing availability of disaggregate data sets derived from, for example, travel diaries and location-aware technologies (e.g. GPS).

Time-geography presents a conceptual framework for the study of an individual's movements in a time-space context according to various constraints applied to or by an individual. It treats time as an equal term as space, and Yu and Shaw (2004) argues that time should therefore be involved when examining activity-based participation. It aims to demonstrate the changeability and dynamism of everything together with giving focus on the significance of the physical world. These two aspects are captured with the simplest and perhaps most fundamental concept in time-geography – the space-time path (trajectory) (Lenntorp, 2004). Any physical body can be represented by the space-time path, which describes an objects history over space. Information about an individual's activities spatial and temporal characteristics is covered by this framework, including start/end times and place, duration, sequence, and relative location of activities. Moreover, activities differ in terms of their flexibility in space and time (Miller, 2004). *Fixed activities* refer to events that are relatively hard to reschedule or relocate such as work; people often have to work at a specific location for a predetermined duration. The home of a person is also usually fixed in space, at least in the shorter run, as well as familial obligations and biological needs. *Flexible activities*, on the other hand, are relatively easy to reschedule and relocate. A person can recreate and socialise in their spare time and also has a choice of where and when. There are restriction to flexible activities as well, e.g. opening hours and location of facilities, friends availability to socialise etc.

A person has a limited time budget to allocate among different activities. Since physical movements in space take time, transportation resources allow individuals to trade time for space to participate in activities that take place in different locations. If an individual wishes to move to another location, he/she must trade the available time for their physical movement and as a result the time available to perform activities at another location is shortened. The possible locations an individual can travel to within a given time period form a continuous space in the orthogonal space-time coordinate system (Yu and Shaw, 2004), which is called space-time prism. The space-time prism is a key concept in time-geography, and it reflects an individuals travel possibilities given a set of constraints (Neutens *et al*, 2007). There are three types of constraints which together shape an individual's space-time prism:

i. Capability constraints are linked to the individual's physical necessities (e.g. sleeping, eating) and/or the resources they command (e.g. access to a car gives the opportunity to travel faster in space than walking).

ii. Coupling constraints restrict travel by imposing where, when, and for how long an individual have to join other people, tools or materials in space and time. For example, having to be at work for certain time period is a coupling constraint.

iii. Authority or ‘steering’ constraints relate to the institutional context, and refer to laws and other regulations which impose certain conditions of access in particular space-time domains. An example is a gated community that can prevent certain “undesirable” individuals from occupying their space, particularly at certain time periods (e.g. from dusk to dawn).

The space-time prism is an extension of the space-time path (trajectory) that measures accessibility to events in space and time (Miller, 2001). Both the space-time path and the space-time prism have been widely applied, especially in studies concerning accessibility and potential movement (see Schönfelder and Axhausen, 2002; Sherman *et al*, 2005; Shoval and Isaacson, 2007). All the space-time paths an individual might have under a specific time budget are gathered by the space-time prism in order to delimit the feasible set of opportunities within a person’s reach (Neutens *et al*, 2007). A projection of a space-time prism onto the two dimensional space is a region known as Potential Path Area (PPA). Figure 2.1 depicts the basic notions of three of time-geographies concepts – path, prism and PPA.

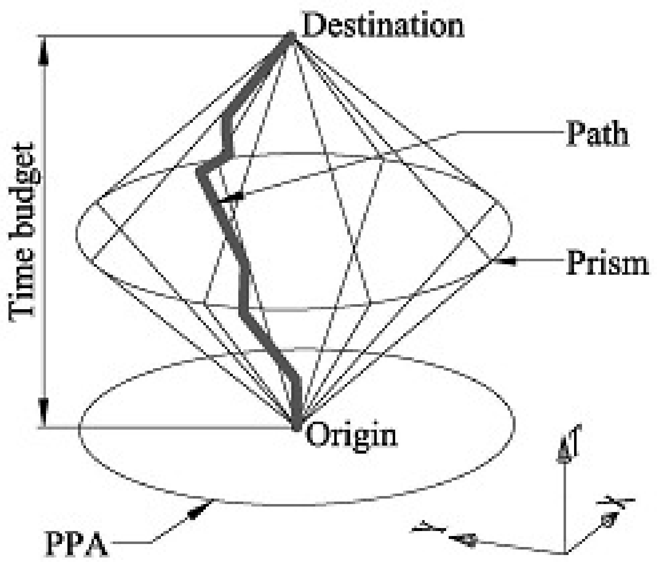

Figure 2.1 Concepts of time-geography: path, prism and PPA (Neutens et al, 2007).

Both the path and the prism are fundamental time-geographic measures of accessibility (Miller, 2004). The number of paths that a given fixed and flexible activity schedule allows could be a surrogate for potential mobility and accessibility.

2.2 Critique

The main criticism directed to time-geography is that it ignores the importance and capacity of the human agency and gives no answers to a lot of questions on how and why (Lenntorp, 1999). Harvey (1999) exemplifies this by saying that Hägerstrand’s scheme is a useful descriptor of how the daily life of individuals unfolds in space and time but that it does not make any attempt to understand why certain social relations dominate others, or how meaning gets assigned to places, spaces, history, and time. Lenntorp (1999) fires back by arguing that that to answer to these questions and explore the realms of e.g., dominating social relations, would be to cross into the borderland of the time-geographic approach and move into the domain of social theory. He continues to say that time-geography should be seen as a foundation for theory-building, and as such, would not be captured by certain theories. Within this foundation lies the time-geographical notion of the importance of the physical world. Lenntorp concludes with that the time-geographical approach is a basic approach and that each and every research can use it in his or her own way.

Another critique that have been put forward in activity-based research and in the time-geographical context concerns the use of *activity type* (work, school, leisure, shop etc.) by researchers as a preliminary, if not primary, means to explain when and how activity patterns are formed (Doherty, 2006). He continues saying "…work, school and other "mandatory", or recurring activities are often assumed to be fixed in space and time and are thus of "higher priority", whereas more "discretionary" activities such as leisure, visiting friends, entertainment, and especially shopping, are assumed to be more flexible and thus of lesser priority". The hypothesis he is putting forward is that flexibility of a given activity is likely to vary among different people and in different situations, thus making the rigid assumptions of fixed and flexible activities difficult to maintain. The results presented by Doherty (2006) provide convincing and strong evidence that activities do not share a stable level of flexibility, and therefore casts doubts on the validity of the assumption of otherwise.

2.3 Existing time-geographical contributions

Time-geography was developed by Hägerstrand and his colleagues at Lund during the 1950s and 1960s. The resources available to them can't be compared to today's increasingly powerful computers and relatively cheap data in abundance. In fact, they lacked all of it. The time-geography of that era was characterised by unrealistic assumptions such as maximum velocity that is uniform across space and time as well as great difficulties in collecting data (Miller, 2004). It was in the late 1970 that the first significant implementation of time-geographic constructs took place. Bo Lenntorps PESAP model (Programme Evaluating the Set of Alternative Sample Path) was a constraint-based model which evaluates to what extent the spatio-temporal environment is facilitating the performance of activity programmes (Neutens *et al*, 2007). Given the immature geocomputational standard at the time and the data hungry character of the research, there were immense computing times which also required considerable time for the construction of geographic data. There were other models that followed Lenntorps approach, such as CARLA (Combinatorial Algorithm for Rescheduling Lists of Activities) and BSP ((Dutch abbreviation for) Reach Simulation Program). The first to provide a profound discussion of time-geographic concepts within a GI-system was Miller, 1991, where he introduced a general method to derive PPA's using a network model (Neutens *et al,* 2007).

These earlier studies of activity-travel behaviour can be described as theoretically rich, with theory on a micro-level, whereas the focus of application was mainly on an aggregate level (Buliung and Kanaroglou, 2006). With the increased availability of disaggregate activity-travel survey data in the early 1990s and the more and more advanced spatial management and analytical capabilities of GIS, the focus changed to the individual level. Buliung and Kanaroglou (2006) point out that the convergence of GIS software, object-oriented technologies and activity-travel survey data can facilitate the complexity of the data, giving rise to spatio-temporal construct that can be applied to improve our understanding of individual and household activity-travel behaviour. Much of the work with GIS as a time-geographic method has been focused on geocomputational algorithms that describe the observed or realized activity participation of individuals over space i.e. accessibility (see Thériault *et al*, 1999; Weber 2003; Kim and Kwan, 2003; Sherman *et al*, 2007). Some of these studies are based on the time-geographic concept of PPA, which is the area that contains the travel possibilities of an individual given a set of constraints. GIS provides an effective environment to implement geocomputational algorithms for representations of real-world complexities and to manage the large amount of geographic data (Kwan, 2004).

Over the past few years there have been an effort to develop database systems that support query and retrieval of activity-based disaggregate data. Frihida *et al* (2002) developed an object-oriented spatio-temporal data model which provides a description of an individual's travel behaviour over space and time and responds to spatio-temporal queries. Yu and Shaw (2004) designed and implemented an operational GIS system that handles certain types of spatio-temporal problems but stresses that it does not support spatio-temporal queries. Like Frihida *et al* (2002), the behavioural unit of interest in their research is the individual. Shaw and Wang (2004) observed, through their implementation of disaggregated spatio-temporal travel data, that there are several advantages with a GIS environment: (1) the ability of mapping travel patterns of one individual or a group of individuals (e.g. household) according to any spatial, temporal, and/or attribute data, is a visualisation tool of great potential; (2) to minimize data redundancy and to maximize data consistency a relational implementation of the disaggregate diary data set have proven the importance of developing an efficient data organisation; (3) the study has shown the benefit by separating the spatial, temporal, and attribute data associated with trips while keeping them linked to each other.

2.3.1 Human extensibility

The notion of human extensibility is based on the concept of an individual as an extensible agent is nothing new. It was first formulated by Janelle (1973) and represents the ability of a person to overcome the friction of distance by using space-adjusting technologies such as transportation and communication (Kwan, 2004). Human extensibility does not only expand an individual's scope of sensory access and knowledge but also enables individuals to participate and engage in social action which may extend across disparate geographical regions and historical episodes. A part of the renewed interest in time-geography is linked to the increasing importance of information and communication technologies (ICT) in people's daily lives. To depict human extensibility includes both activities from the physical world as well as from the virtual world. A challenging topic during the last decade has been to expand existing space-time models to encompass both the physical and virtual world (Neutens *et al*, 2007). Hägerstrand's firm assumption that a person only can be at one place at the time should be reconsidered to reflect the situation today and the context of the Information Age. Both the space-time path and prism gives a good representation of individual activities and their location changes in physical space over time. However, this relationship is broken when ICTs, such as mobile phone and the Internet, are used to carry out certain activities (Yu, 2006). The new environment that is enabled by ICTs allows people to carry out some activities without a physical presence. The use of ICTs free up some of the constraints placed upon individuals in physical space e.g. a person can use ICT to participate in an activity or interact with people without physically move to a specific location. As a result, space-time path and prism are no longer sufficient to depict the complete spatial and temporal relationships of activities and interactions conducted by an individual, says Hu (2006).

Kwan *et al* (2007) developed two geovisualization approaches using 3D and 2D GIS techniques to explore human hybrid activity-travel patterns (i.e. the pattern of individual's activities and/or travel in both the physical and virtual world). They extend the traditional time-geographic construct of space-time path by the use of information cubes to represent people's accessibility to cyberspatial opportunities. The results presented reveal gender differences in cyberspatial activity patterns. Men do not only have a greater accessibility to cyberspatial opportunities than women, they also are more likely to use cyberspace for recreational purposes. Women, on the other hand, perform more household related activities online than men. Kwan *et al* (2007) concludes with that the patterns of physical-virtual interactions are highly complex, but also that the extension of the traditional time-geographical framework in this direction is a fruitful and useful project.

2.4 Activity space

The activity space concept – which was developed during the 1960s and 1970s – carries many connotations in the literature. Sherman *et al* (2005) points out that researchers working in different traditions such as medical geography, spatial behaviour, time-space studies, planning, and travel and transportation studies have defined and theorised activity space in different ways. They mention that activity space have been described as a measure of an individual's degree of mobility, including needs, constraints, resources for movement and preferences. Other researchers have used methods and concepts very similar to activity space. For example, the "daily potential path area" (Kwan, 2004) have been used to measure the access individuals have of urban opportunities. In this research activity space is defined as "the spatial area which holds the places which an individual move or travel to over a period of time", and will follow Schönfelder and Axhausen's (2002) view that activity space is an (geometric) measure of the observed or realized daily travel pattern. The activity space concept, as the observed or realized daily travel pattern, may or may not represent the maximal area an individual could engage in activities. Golledge and Stimson (1997) describe three main three determinants that decide the geometry, size and the inherent structure of activity spaces:

1) Home: The location of the travellers home, the duration of residence, the supply of activity locations in the vicinity of home and the resulting neighbourhood travel
2) Regular activities: Mobility to and from frequently visited activity locations such as work and school
3) Travel between and around nodes: Movements between the centres of daily life travel

Within their activity spaces, individuals choose the routes in time and space to meet their obligations, needs and desires (Schönfelder and Axhausen, 2002). They are however constrained by their spatial knowledge, reasoning abilities and by the time available to them to choose the optimal routes. Activity space, in a wider sense, is comprised both of the locations an individual have personal experience from and of the location an individual have second hand knowledge about (the knowledge space) through friends, family, media and other sources.

Activity space is two dimensional given that it is comprised of both directional and temporal components of spatial movement in addition to distance. Furthermore, activity space provides more information by demonstrating point patterns and degree of eccentricity - both the distribution of opportunities and individual characteristics are critical factors in determining geographical access and utilisation (Sherman *et al*, 2005). The Standard Deviational Ellipse (SDE) has historically been used to operationalise the activity space concept (Lefever, 1926; Yuill, 1971)**.** As a bivariate measure, the SDE provides a comparable estimate of an individual's activity space. The main limitation of the SDE is that it is a Euclidean measure and does not account for actual spatial arrangements of geographic or human features; it is an abstract representation of where people go. The past decade have witnessed a renewed interest in the SDE (see Schönfelder and Axhausen, 2002; Sherman *et al*, 2005; Vandermissen, 2006; Buliung and Kanaroglou, 2006), together with the development of other measures of activity space.

2.5 Potential Path Area (PPA)

The Potential Path Area (PPA) is the area an individual potentially can reach within his/her time-budget. The PPA contains all possible combinations of routes an individual can traverse while travelling between two activities (from the location of the previous fixed activity to the location of the next fixed activity) within the time-budget available to them (Weber and Kwan, 2003). The PPA as a concept presents a potential activity-space of mobility for an individual and is an extension of the activity-space concepts into the realms of "possibility". It is based on visited activity location where certain activities (e.g. home, work, school related) are assigned a "higher priority" than other, more flexible activities (e.g. shopping, leisure, sports etc.). The Daily Potential Path Area (DPPA) is the sum of all PPA over the course of a day and represent the spatial reach of an individual according to his/her time constraints. See figure 3.9 for a schematic of the DPPA.

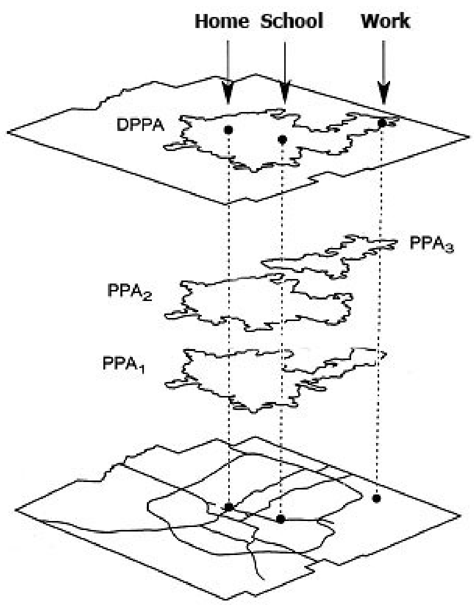

Figure 2.2 A schematic representation of the DPPA. The sum of the three different PPAs results in the DPPA (Kwan, 2004).

2.6 Approaches

During the past several decades there has been a dramatic paradigm shift in the approach of mobility research and travel behaviour. The shift has gone from a trip-based approach towards an activity-based approach by the argument that an understanding of travel is impossible without an examination of the activities that give rise to travel in the first place. Before discussing the approach taken in this research, a look at both the trip-based approach as well as the activity-based approach is made to establish the fundamentals of both of them.

2.6.1 Trip-based approach

The conventional trip-based model of travel demand forecasting, which is exemplified in the four-step model (4SM), has always lacked a valid representation of underlying travel behaviour. It is best seen within the overall framework of transportation systems analysis which positions travel demand and network performance procedures as determining flows which tend toward equilibrium with input from and feedback to location and supply procedures (McNally, 2000). It was introduced in the 1950s and has since then been significantly enhanced and modified since its first applications but still clings to the framework that *trips* are the fundamental units of analysis. The four steps in the 4SM consist of *trip generation, trip distribution, mode choice,* and *route choice*.

McNally (2000) makes the comparison that trying to infer underlying behaviour from the observation of trips only, as in the trip-based approach, is somewhat similar to trying to understand the behaviour of an octopus by only examining the tentacles. He continues with summarizing the weaknesses and limitations of the trip-based models as:

1) Ignorance of travel as a demand derived from activity participation decisions;

2) Focus on individual trips, ignoring the spatial and temporal interrelationship between all trips and activities comprising the individual activity pattern;

3) Misrepresentation of overall behaviour as an outcome of a true choice process, rather than as defined by a range of complex constraints which delimit (or even define) choice;

4) Inadequate specification of the interrelationships between travel and activity participation and scheduling, including activity linkages and interpersonal constraints;

5) Misspecification of individual choice sets, resulting from the inability to establish distinct choice alternatives available to the decision maker in a constrained environment;

6) The construction of models based strictly on the concepts of utility maximization, neglecting substantial evidence relative to alternate decision strategies involving household dynamics, information levels, choice complexity, discontinuous specifications, and habit formation.

As a concluding remark he says that trip-based models do not reflect the temporal constraints and dependencies of activity scheduling, the linkages between activities and trips, nor the underlying activity behaviour that generates the trips.

2.6.2 Activity-based approach

It is the fundamental contributions of Hägerstrand (1970), Chapin (1974) and Fried *et al.* (1977) that are seen as the intellectual roots of activity analysis (McNally, 2000). While Hägerstrand pushed forward the time-geographic approach on activity participation in time-space, Chapin identified the patterns of behaviour across space and time. Fried *et al.* looked at the question why people participate in activities as well as the social structure of activities. The fundamental principle of the activity approach is that travel decisions are driven by a collection of activities of that form an agenda for participation (McNally, 2000). This means that travel decisions can only be understood and modelled within the context of the entire agenda, and therefore cannot be analyzed on an individual trip basis. Activity-based approaches are characterized by several interrelated themes; methods and models generally reflect one or more of these themes (McNally, 2000):

1) Travel is derived from the demand for activity participation;

2) Sequences or patterns of behaviour, and not individual trips, are the relevant unit of analysis;

3) Household and other social structures influence travel and activity behaviour;

4) Spatial, temporal, transportation, and interpersonal interdependencies constrain activity/travel behaviour;

5) Activity-based approaches reflect the scheduling of activities in time and space

The basic unit of analysis in the activity-based approach is the travel/activity pattern, which is defined as the revealed pattern of behaviour represented by both the travel and the activities over a specified period of time (often a single day). The approach explicitly recognizes and addresses the inability of more conventional trip-based models to reflect the underlying behaviour. McNally (2000) says that it is a rich, more holistic framework in which travel is analyzed as daily or multiday patterns of behaviour related to and derived from differences in lifestyles and activity participation among the population. The criticism of the activity approach is that it lacks a solid theoretical basis. However, this is shot down by McNally (2000) who make the statement that this is akin to draw a similar conclusion about the weather or the stock market, and that it reflects a lack of understanding of the complexity of such phenomena.

2.6.3 Establishing the perspective

The approach taken in this research stems from the activity-based approach with the reflection that the unit of analysis can't be the individual trips themselves, since it is the underlying activities that form our daily decisions of travel. Through looking at the activities that individuals are performing throughout the day, and the constraints placed on them in terms of "fixed and flexible activities", "available time", and "place", this research strives to examine the daily mobility of men and women, as well as the potential mobility of men and women according to the constraints placed upon them.

Even though evidence of the contrary were presented and discussed in an earlier chapter, this research will work with the assumptions of categorizing activities into fixed and flexible activities. In the context of the research questions put forward this does not have any large implications. The use of the activity-space concept, the statistical measure of the standard deviational ellipse and the time scale of a full day, is not influenced by fixed or flexible activities. Rather all activity locations (regardless of activity) are used in the analysis. When it comes to the exploration and analysis of the PPA, the discussion about fixed and flexible activities are more relevant. However, over the course of our daily lives and routine activities, some activities are still rendered more fixed than other. There can of course be different degrees of flexibility for different people and in different situation. The approach taken here reflects the thought that some activities are of a “higher priority” than other e.g. work provides an income, home provide a shelter, school an education and so on. This research has limited the fixed activities to that of work, home and school.

3. DATA AND METHODOLOGY

3.1 Isère and Grésivaudan

The data used for this research were obtained from a 2003 travel diary survey conducted in the valley of Grésivaudan, Isère (see figure 3.1). The valley is running from Grenoble in a northeast direction toward Chambéry. It was formed by the river Isère and is situated between the mountain ranges of Chartreuse to the west and Belledonne to the east. The presence of the river has divided the valley in two parts, with each of the two parts displaying different geographical characteristics although both sides of the river have had an important role concerning the establishment of housing and its related activities. The west side of the river is made up of large areas with hospitable environments basking in sunlight. Agriculture was the predominant activity until the 1950s. It has since then been replaced by industrial activities specialised in high technologies.

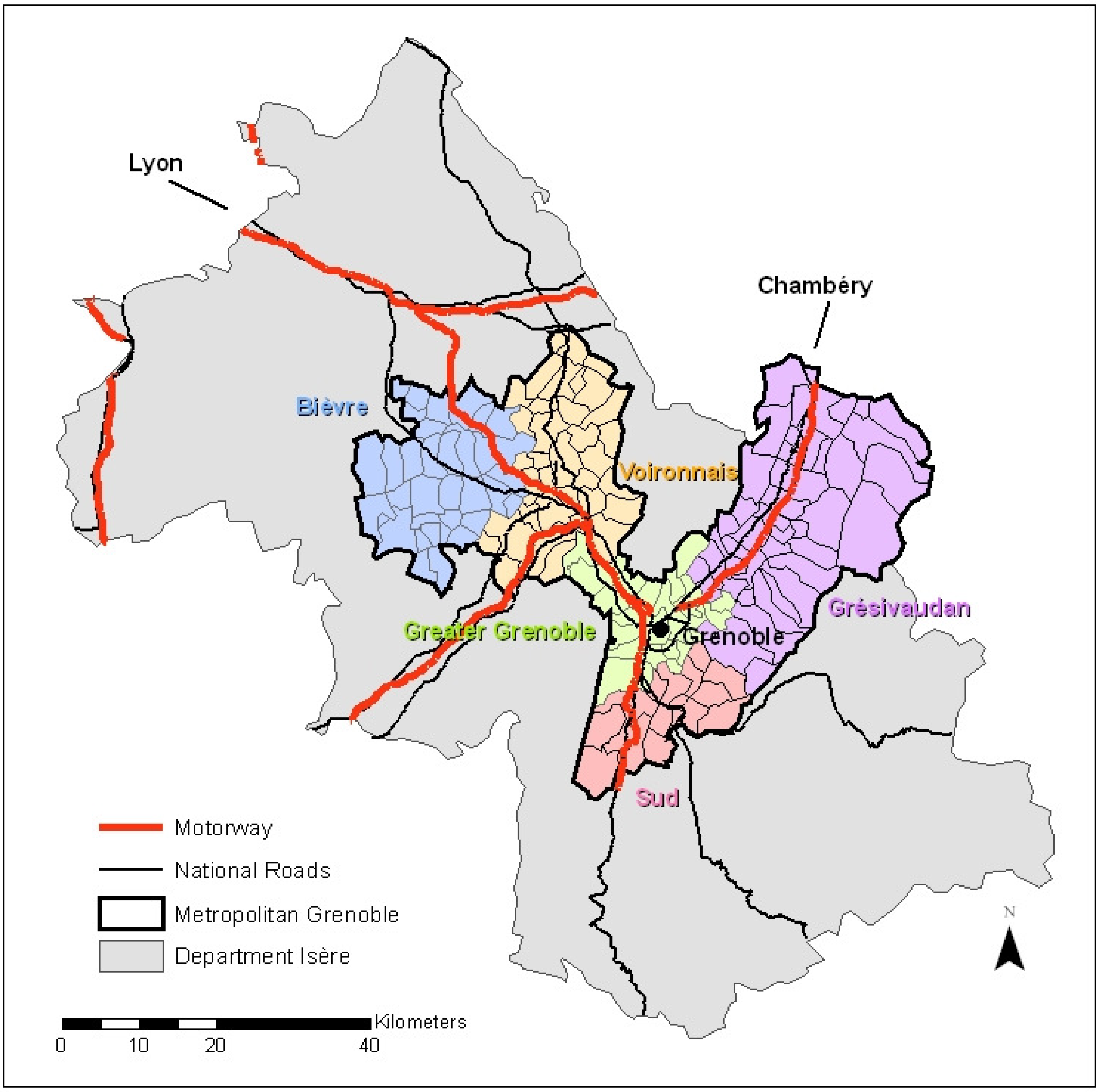

Figure 3.1 Department Isère and metropolitan Grenoble with its five regions (Base map IGN,).

This part of the valley has enjoyed a demographic development in the second half of the 20th century due to the increased population of Grenoble and its suburbanisation. It is a relatively affluent area. The opposite side of the valley is located on the mountainside and is a narrow corridor squeezed in between the river and Belledonne. A strong and dynamic industry connected to hydroelectricity existed here until the 1950s and the population was mainly working class. Starting with the decline of hydroelectric activities this part of the valley was plagued for a long time with unemployment and no real economic activities. Today, the valley of Grésivaudan is trying to stimulate the east side by establishing relations between different parts of the valley. An example is the COSI (Communauté de Communes du Moyen Grésivaudan), which is made up of four municipalities from the west side (Bernin, Crolles, Lumbin and La Terrasse) and six municipalities from the east side of the valley (Le Versoud, Villard-Bonnot, Froges, Le Champ Près Froges, La Pierre and Tencin). Among the five geographic sectors that make up metropolitan Grenoble (Grenoble, Grésivaudan, Voironais, le Sud and Bièvre), Grésivaudan is the one who have the highest economical and demographical growth. Through the presence of important industrial groups specialised in high technology, Grésivaudan is a key region within metropolitan Grenoble, establishing it as one of the major areas of micro electronics in Europe. The investments are very important and allows for a considerable increase of employment opportunities which in turn have led to a significant population increase. Between 1968 and 1999 the population went from 43 630 inhabitants to 86 360 inhabitants, an increase of almost 100 %.

3.2 Travel diary data

The data used in this research comes from a travel diary data survey conducted during the spring of 2003. It was conducted and realized in order to study daily mobility in the valley of Grésivaudan and the impact of daily mobility on the urban agglomeration of Grenoble. 23 families were contacted for the survey and agreed to complete the travel diary. One of the families chose to abandon the survey and did not complete it; the others were not affected by this. The travel diary data were collected during four days, starting on a Wednesday and finishing on a Saturday.

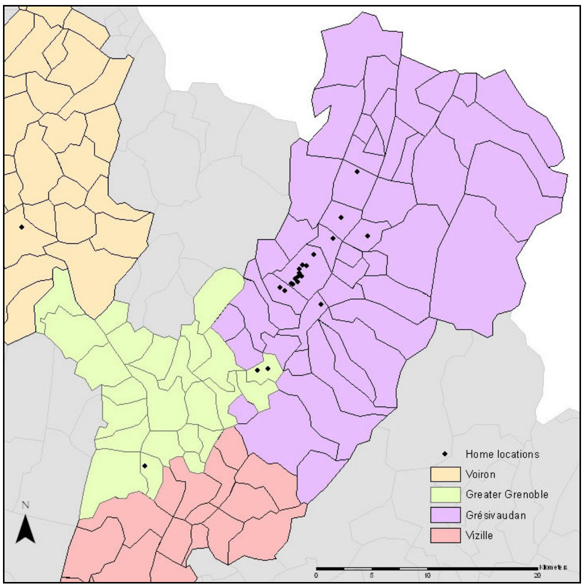

Figure 3.2 Home locations of respondents (Base map IGN).

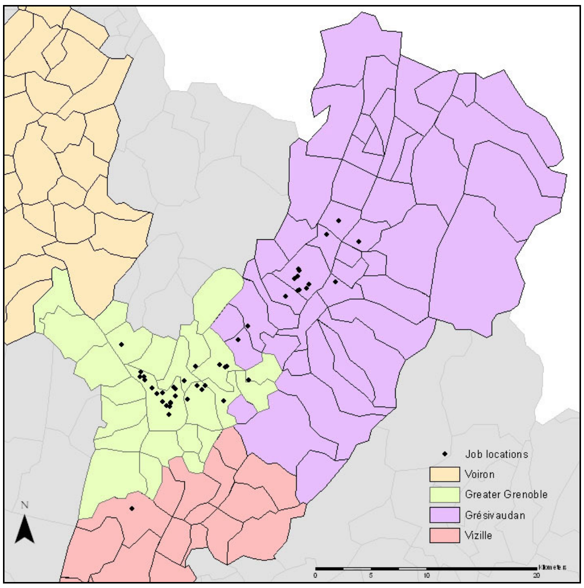

Figure 3.3 Job locations of respondent (Base map IGN).

There were five families in which only the female completed the travel diary. In total 22 females and 17 males filled in the survey. Seven respondents also completed a fifth day – Sunday. This day has however not been used in this research. The families were contacted with homogeneity in mind. The aim was to find families with similar socio-economic characteristics i.e. similar life situation or life style. This is reflected in the age brackets, profession, number of children and so forth. It was also a matter of location i.e. the families should preferable live in Grésivaudan, or if that wasn't possible, work there. The households that lives outside of Grèsivaudan have at least one adult that is employed and work in the valley (see figure 3.2 and figure 3.3).

To illustrate the relative homogeneity of the households, a quick summary of the household characteristics follows (for a full description of the socio-economic data, see Appendix A: Socio-economic characteristics):

- Of the 22 families that participated in the survey, 17 households have male and female (16 two-earner household and one household with only one earner) and 5 households have just the female (all one-earner households).

- 16 males are working full-time whereas 9 of the females are working full-time, 1 male and 12 females are working part-time and 1 female is without employment.

- The age brackets range from 30-50 years, where 28 of the respondents are to be found in the 40-45 year group

- 21 of the 22 households have children

- All of the households have at least one car

The data were collected by using a travel diary format in which the respondents recorded their activities and whereabouts in 15 minute slots for the whole 24 hour day during the survey period (see figure 3.2 for an extract of the travel survey). The survey has been constructed to allow respondents to record a main activity as well as a secondary activity, for example if a respondent is cooking *and* watching the children at the same time. When a respondent record a trip activity, mode of transport and accompanying people are also filled out as well as information about the destination. The geographical position during the trips has not been recorded, only the origin and destination of the trip have been included.

HEURE	ACTIVITE PRINCIPALE	ACTIVITE(S) SECONDAIRE(S)	MODE DEPLACEMENT (le cas échéant)	PERSONNES ACCOMPAGNANTES	Description Fine de localisation
0 :00					
0:15					
0:30					
0:45					
1:00					
1:15					
1:30					
1:45					
2:00					
2:15					
2:30					
2:45					
3:00					
3:15					
3:30					
3:45					
4:00					
4:15					
4:30					
4:45					

Figure 3.4 Travel diary format (Cayer-Barrioz, 2004).

The activities recorded in the survey have later been coded into three different levels starting with a coarse level through to a more detailed level e.g. code 1: Physiological need; code 12: Personal care; code: 121 Personal hygiene. There are nine different activity categories, each with additional levels of detail as discussed above, including: (1) Physiological needs, (2) Professional work and education, (3) Household duties, (4) Care of other people, (5) Social activities, (6) Leisure, (7) Other, (8) Trips, and (9) Writing the diary (see Appendix B for a full description of activities and codes).

Additional socio-economic data such as gender, age, employment, education, number of children, and number of cars have also been collected. Furthermore, two conditions have been set for the respondents concerning the travel diary data collection: (1) only the couple (as individuals) of the family is allowed to fill in the travel diaries. They must start on the same day and the children in the family (if there are any) are not allowed to fill in the travel dairies; (2) the individuals have to fill in the travel diaries for four consecutive days. The decision that the travel diary was to begin on a Wednesday is related to the fact that Wednesdays are specifically devoted to take care of the children in France i.e. the children do not go to school but have a free day. Traditionally this mean that many parents (usually one) stay at home with the child/children on a Wednesday. Moreover, by collecting data from Wednesday thru to Saturday allows for comparison between weekdays and a weekend days.

3.3 Reorganisation and implementation of data

The data collected from the 2003 travel diary data survey and used here were already available in spreadsheet format, although it had to be properly explored, cleaned and reorganised to fit this research. All the data have been separated and reorganised into individual tables containing only one set of information e.g. activity data, household data etc. The information at hand by the start of the reorganisation was used to create the tables Activity_1, Activity_2, Activity_3, Households, Persons, Locations, Time and TDD (Travel Diary Data). Two other tables had to be created and information added for this research – PPA (Potential Path Area) and Trip (see table 3.1).

Table 3.1 The data reorganized into different tables.

Data Table	Description
Activity_1	Contain the information about activity level 1* and an ID
Activity_2	Contain the information about activity level 2* and an ID
Activity_3	Contain the information about activity level 3* and an ID
Household	Stores information related to household i.e. family name, number of children, present school level of children, number of cars, and an ID
Person	Keep information on each respondent: sex, age, profession, employment status, and an ID
Location	Stores information about all locations: X and Y coordinates, descriptive name, and an ID

Time	Stores the temporal information i.e. YYMMDD, weekday, HH_MM (hour and minutes), Quarter (15 minutes slots), and an ID
TDD	This is the main table in the dataset. It contains all the 15 minute slots of all individuals participating in the travel diary. It does not actually contain any valuable information by itself; instead it connects to the other tables through the use of ID's**.
PPA	Stores information about trips made between two fixed activities. It keeps the information about origin, destination, mode of transport, duration, adjusted duration***, and an ID.
Trip	Keeps information about *all* trips made during the survey period: origin, destination, mode of transport, duration, adjusted duration***, and an ID.

** Activities are stored in different levels of details, see chapter 3.3 for a more detailed explanation.*
*** The connections between the tables are discussed and explained in chapter 3.5*
**** Adjusted duration is five minutes less than recorded by the respondent. It is discussed and explained in chapter 3.7.3.*

The additional information that has been created and added and did not exist before work begun is stored in the tables PPA and Trip. Both these tables store information about trips made by individual people, however in a slightly different manner. The PPA table contains data about trips made between two *fixed* activities. As discussed above, fixed activities have in this research been defined to activities that take place at home, at locations where professional work or training is undertaken, and at school when dropping off/picking up children. The Trip table, on the other hand, stores data about *all* trips made by all individuals. There is a difference between the two since a trip between two *fixed* activities can be the same as a single trip (between two locations) or with *n* of stops (for example, a trip made between work and home might include a stop at the grocery store and a stop at a gym and thus consist of three *single* trips).

3.3.1 Quality and errors

The travel diary is filled out during four consecutive days, each day with 96 unique slots (15 min slots) for each individual. Each individual records 384 unique slots over the course of the survey period. Most activities are continuous in time and often take up several 15 minutes slots, for example sleeping might take 32 slots (or 8 hours) and working another 32 slots (or 8 hours). However, all of this information (a total of 14 976 records) has been coded from the travel diaries into a spreadsheet format and inevitable errors have sneaked in. The travel diary data that have been coded and were available have been compiled into more than one spreadsheet. This has made it possible to make a comparison between two different spreadsheets of the same data to assess quality and errors. Out of 14 976 records, 85 records have been found to contain errors i.e. 85 records does not match between the different spreadsheets of the same information (e.g. location code and/or activity code(s) does not match between the different spreadsheets used to make the comparison). This is a falling of

0,57 % and is insignificant. The affected records have been deleted and are not used any further in the research.

Other inconsistencies have also been found in relation to the location data. All the information concerning the locations (X and Y coordinates, description of the location) were also available in a spreadsheet table as well as georeferenced in a GIS. The data were georeferenced manually by using the information recorded in the travel diary (location information) together with scanned IGN (Institut Géographique National) maps. The respondents have in some cases not recorded the precise location (the address) of their activities. In these cases only the name of the location have been available and used to search to find the correct addresses with the help of Internet. The georeferenced data were no different from the other data in that it needed a good clean-up and reorganisation. The data contained a lot of redundancy and some incomplete information. 296 unique locations were stored in the data, 4 of these locations did not disclose any X and Y coordinates with no more than a name reference to the locations. These 4 locations were deemed useless since the name references could refer to more than one specific location (e.g. many names are the same for villages, municipalities and other points of interest) and deleted from the dataset. This is a falling of 1,35 % and is insignificant. These locations have not been used any further in the study.

3.4 Geographical data

The backbone of the data used in this research is the travel diary data collected in 2003. However, this data on its own does not complete the picture. France is split into several different administrative levels - 22 regions (plus 4 overseas regions) and 96 departments. The appropriate level of study has here been determined to the department area (see figure 3.1). The main geographical dataset used here is the Isère department in the Rhone-Alpes region. This dataset contains the boundary of the department, the boundaries of all municipalities that lie within the department, area, population and density.

A road network dataset is also introduced and used in this research. It is the road network for Isère department and stores the roads in 4 different levels: Motorway, National, Departmental and Local. Other information such as number of lanes, road number etc. is also available in this dataset. The modelling of the road network has been based on available information to make as few assumptions as possible about the conditions and constraints placed on the network. The different types on roads in the network have been given different speed limits:

Table 3.2 The different types of roads and their speed limits.

Type of road	Speed limit
Motorway	107,5 km/h
National roads	77 km/h
Departmenal roads	77 km/h
Local roads	50 km/h

These speed limits are based on André and Hammarstöm's (2000) study about driving speeds in Europe to estimate emissions. The study also presents a different average speed between urban and rural areas. Urban areas, with its many more obstacles (intersections, lights, other traffic etc.), only sustain an average speed of 20 km/h. Urban areas are defined as areas with a minimum of 1 000 persons and no fewer than 400 persons per square kilometre (Statistics

Canada, 2001). All the roads within municipalities that can be defined as urban have therefore been given an average speed of 20 km/h regardless of type of road. The choice of using an average speed of 20 km/h on all types of road in urban areas might seem strange since the average speed on, for example, motorways is generally higher than on smaller city streets. However, other factors reduce the average speed on the motorways in Grenoble. For example, congestion on the two-lane motorway during rush hour reduces average speed significantly. Another factor that reduces the average speed is that during days with peak pollution (Grenoble is a known as a city with bad pollution problems) the speed limit is reduced in order to cut emissions. This information, together with lack of better validated average speed data, has been the main reason to use an average speed of 20 km/h for all types of roads in urban areas. The network has been modelled as a free flowing network i.e. once a movement in the network begins, it will continue until it reaches its destination without stopping. Due to the lack of available information, the network model carries many assumptions. It is possible, in the network, to make turns everywhere (no turn restrictions), traverse any road (no pedestrian streets etc.), there is no difference in speed between busy thoroughfares and smaller streets in the urban areas, and there are no accountability for cul-de-sacs, street lights, or tramway crossings in the model. Furthermore, no difference is made between different time of day regarding the flow of traffic and its effects. All these, or rather the lack of them, make the network model fairy simple, unrealistic and with many assumptions. Two other networks have also been modelled to accommodate different travelling speeds depending on the mode choice of the individual. The speed limits have been set to 5 km/h for walking and 15 km/h for biking and are based Reneland's (2002) study about accessibility with car, bus, bike and walking. These two networks apply the same assumption as the road network (see above). The network were modelled and implemented in ArcGIS 9.1. All the geographical datasets used in this research have been produced by IGN in 2003.

3.5 Database design

All the information presented earlier in this chapter and that have been cleaned, reorganised and value-added have also been implemented into a spatio-temporal database. Considering the size of the datasets used in this research (not very large), the design and implementation of the spatio-temporal database have been a fairy straightforward process on both the conceptual and practical level. The database consists exclusively of tabular classes which in turn are connected to feature classes through the uses of special made models. The heart of the database lies in the table TDD. All other information is connected to this table either directly or indirectly through the use of IDs. The TDD is built upon the earlier discussed travel diary format (with 15 minutes slots) and ID information in different columns corresponding to different rows of information in the other tables. Both the time table and the location table are directly related to the TDD; Household is related to Person which in turn is related to the TDD; the activity tables are related to each other in a hierarchy (Activity 3 is related to Activity 2 which is related to Activity 1) and then related to the TDD; PPA and Trip are both related to the TDD; there is also a relation between PPA and Trip (see figure 3.5). This simple but yet powerful connectivity between the tables allows for an easy and quick querying and presentation of data. It also fit the relatively small size of the datasets.

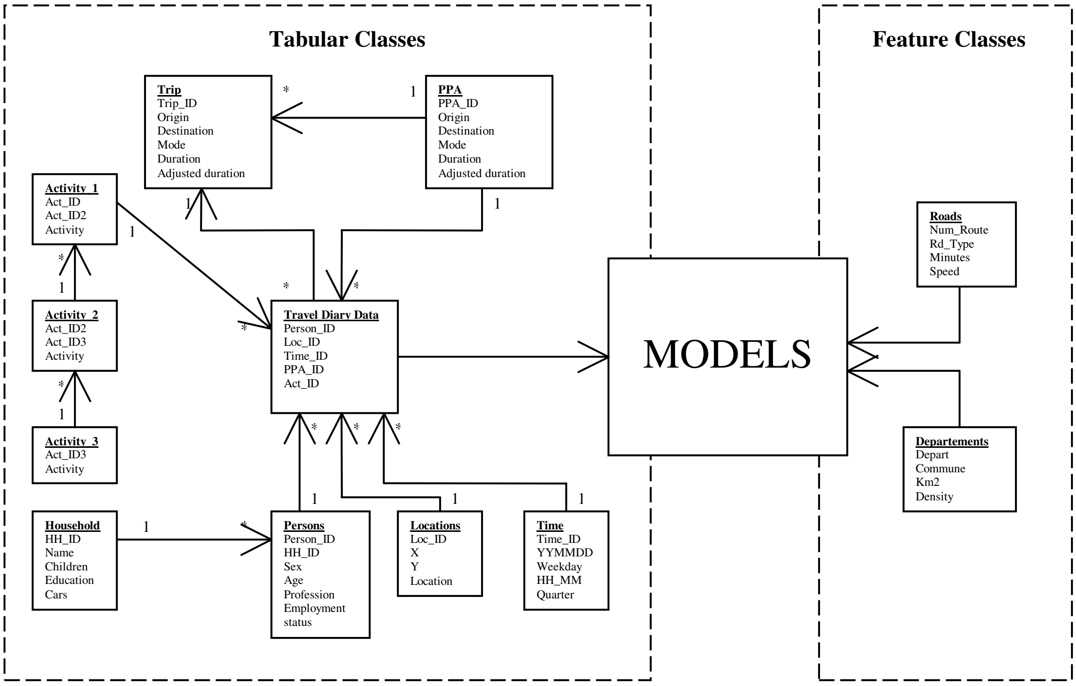

Figure 3.5 Conceptual schema of the database (the database schema corresponds to the tabular classes).

The two key intentions of the database were that it would serve as a powerful platform for queries and as an explorative base to investigate a possible extension of the mobility research issue. The easy and simple organisation of the tabular classes has kept the redundancy of data to a minimum and through the use of models, connections to the feature classes have been made available and simple. The database has been implemented in the ArcGIS 9.1 environment using the personal geodatabase concept. The feature classes consist of the class Road and the class Departement. The road class is a road network with information about the road number, road type, minutes (how long time it take to traverse a single part), and the speed. The Departement class is keeping the geographical base information such as Department, Commune, Km², and Density. The data derived from the database is used together with the feature classes through certain models corresponding to the analyses to be done. The models that connect the database and the feature classes are explained below.

3.6 Measurements

To measure activity space isn't something that is completely straightforward. There exists no one measure or sets of measure that *should* be applied. In the literature many different measures have been put forward and tried in different contexts and situations. For example Schönfelder and Axhausen (2002) uses SDE, kernel densities and a road network buffer to measure and describe activity space in Karlsruhe and Halle in Germany. Sherman et al (2005) uses SDE, standard travel time polygon, relative travel time polygon and a road network buffer to measures activity space and accessibility to primary care locations for citizens in mountain rural region in western North Carolina, USA. While the SDE is calculated in abstract space, both the road network buffer, standard travel time polygon and relative travel time polygon are calculate within in a network model. Another measure of activity space is kernel density. The basic process behind this measure is to transform a point pattern (such as locations visited) into a continuous surface of density in a wider area. The estimation is an interpolation which generalizes events or points to the area they are found in. Kernel densities have already been applied in research of activity spaces (see Schönfelder and Axhausen, 2002), and accessibility (see Weber, 20003; Weber and Kwan, 2003). It is usually the observed daily visited locations that are used to represent the activity-space in all the measures introduced above. In this research the standard deviational ellipse will be used to measure activity-space which is derived from the observed visited locations by individuals. Standard distance will also be applied to the activity-spaces as another measure. The third measure in this research is PPA which is used to explore the potential mobility of individuals.

3.6.1 Standard Distance

Standard distance measures the degree to which features are concentrated or dispersed. It is a useful statistics since it provides a single summary measure of feature distribution around the mean centre from the equation:

$$\sqrt{\frac{\sum_{i=1}^{n}(x_i - x')^2 + \sum_{i=1}^{n}(y_i - y')^2}{N}} \qquad \text{(Formulae 1)}$$

where n is the number of x-coordinates, x_i is the x-coordinate of one point (from the feature distribution), x' is the x-coordinate for the mean, y_i is the y-coordinate of the same one point (from the feature distribution), y' is the y-coordinate for the mean, and N is the total number of points. Standard distance is largely used to compare distributions and is essentially the average distance of points from the centre. The calculation is based on Euclidean distance. The graphic presentation of the standard distance is a circle polygon drawn with a radius equal to the standard distance value. Figure 3.6 shows a graphical presentation of the standard distance and table 3.3 present the corresponding calculation.

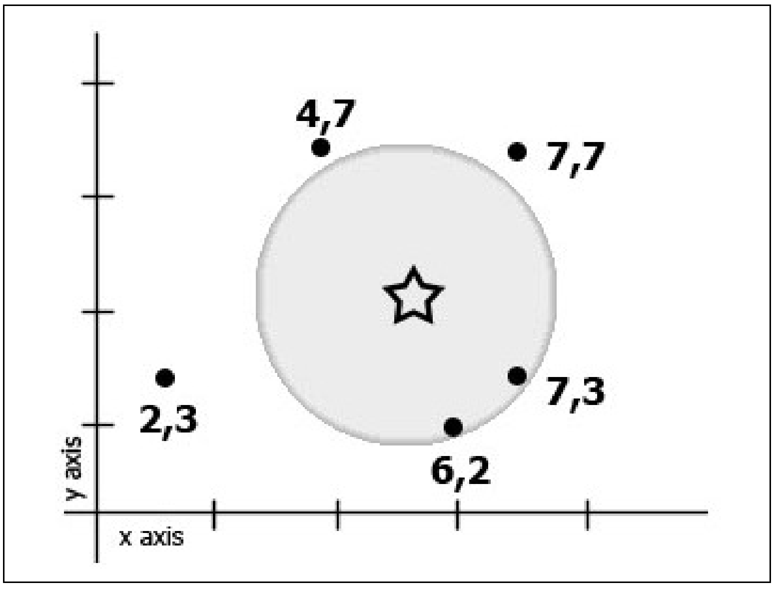

Figure 3.6 The graphical result of the standard distance is a circle polygon drawn with a radius equal to the standard distance value.

Table 3.3 The calculation of standard distance

i	x	y	(x-x')²	(y-y')²
1	2	3	10,2	2,0
2	4	7	1,4	6,8
3	7	7	3,2	6,8
4	7	3	3,2	2,0
5	6	2	0,6	5,8
Sum	26	22	18,8	23,2
Centroid (Mean)	5,2	4,4		
			Sum of sums	42
			Divede *N*	8,4
			Sq rt	2,90

Standard distance can be applied to a situation where the SDE doesn't work, i.e. it can be used when an individual only have visited two locations during the day, whereas the SDE requires at least three different locations. This is of course an advantage; however, the standard distance doesn't take into account the potential skewness of the distribution. The standard distance can be based on an optional weight (e.g. frequency, duration etc.) which allows for locations to be influenced. Both the unweighted and weighted options are available in ArcGIS 9.1 which has been used for the implementation of this measure. The standard distance will be used in comparisons of the results derived from the SDE measures.

3.6.2 Standard Deviational Ellipse (SDE)

The standard deviational ellipse (SDE) is a method that calculates the standard distance of the x coordinates and the y coordinates from the mean centre to define the axes of the ellipse. The mean centre is the same as the centre of gravity of the spatial distribution of a phenomenon. One important aspect to remember about the mean centre is that it is *not* an average of the characteristics of a phenomenon, but that it is a point representing the average location of a distribution (Lebeau, 1987). The formula behind this measure is based on the x and y coordinates of the phenomenon and is determined from the mean centre of these coordinates. The SDE is derived from the standard distance calculation, which is the "quadratic mean of distances between any point in a distribution and the mean centre of the distribution" (Bachi, 1963, p.90).

The SDE is determined by three components: the deviation along the major (long) axis, the deviation along the minor (short) axis and the angle of rotation. The major axis is in the direction in which there is the largest spread. The minor axis, perpendicular to the major axis, is in the direction of the smallest spread. Lee and Wong (2000) explain "The two axes can be though of x and y in the Cartesian coordinate system but rotated to a particular angle corresponding to the geographic orientation of the point distribution. The angle of rotation is the angle between north and the y axis rotated clockwise. Note that the rotated *y* axis can be either the major or the minor axis". The SDE is calculated as follows (Lee and Wong, 2000, p. 48-49):

Calculate the coordinates of the mean centre (x_{mc} y_{mc}).
For each point, *p*, in the distribution, transform its coordinate by:

$$x_i' = x_i - x_{mc}$$
$$y_i' = y_i - y_{mc}$$ (Formulae 2)

where x_i is the x-coordinate of one point (from the feature distribution) and y_i is the y-coordinate of the same one point (from the feature distribution)

Calculate the angle of rotation, tanθ, such as:

$$\tan\theta \frac{\left(\sum_{i=1}^{n} x'^2_i - \sum_{i=1}^{n} y'^2_i\right) + \sqrt{\left(\sum_{i=1}^{n} x'^2_i - \sum_{i=1}^{n} y'^2_i\right)^2 + 4\left(\sum_{i=1}^{n} x' \sum_{i=1}^{n} y'\right)^2}}{2\sum_{i=1}^{n} x'_i \sum_{i=1}^{n} y'_i}$$ (Formulae 3)

tanθ can be positive or negative. If the tangent is positive, it means that the rotated *y* axis is the major (long) axis and rotates clockwise from north. If the tangent is negative, it means that the major axis rotated counter clockwise from north. If the tangent is positive, we can simply take the inverse of tangent θ (arctan) to obtain for θ subsequent steps. If the tangent is negative, taking the inverse of the tangent of a negative number will yield a negative angle (such as $-x$) i.e. rotating counter clockwise. But angle of rotation is defined as the angle rotating clockwise to the *y* axis, therefore, 90 degrees have to be added to the negative angle (i.e. $90 - x$) to derive θ. With tan θ, the deviation (δ) along the x and y axes can be calculated with the following formulas:

$$\delta_x = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i' \cos\theta - y_i' \sin\theta\right)^2}{n}}$$ (Formulae 4)

and

$$\delta_x = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i' \sin\theta - y_i' \cos\theta\right)^2}{n}}$$ (Formulae 5)

The SDE captures the dispersion of a phenomenon as well as the potential skewed nature of the data. It has the advantage of being less sensitive to the influence of spatial outliers, while describing the dispersion and orientation of point events. The calculation of SDE is based on Euclidean distance. Both weighted and unweighted measures of the SDE are available in ArcGIS 9.1, which have been used to implement the measures, and allows for locations to be influenced by an attribute value (e.g. weighted by frequency, duration etc.) associated with the phenomenon. One main drawback with the SDE is that it needs at least 3 points (locations) to be used. This means that any activity space for an individual that only contains 1 or 2 locations can not be included in the analysis. This situation might occur if an individual only move his/herself between e.g. home and work (or not at all) during the course of a day. This will induce an error in the final analysis.

Two measures have been derived from the Standard Deviational Ellipse. The first measure, AREA, depicts the size of an individual's activity space. The second measure, FULLNESS, is the difference between the major axis and the minor axis of the ellipse. It measures the degree of "fullness" of the ellipse. For example, an ellipse with a fullness of 0 would be a straight line, whereas an ellipse with a fullness of 1 would be a complete circle. It is an indication of the deviation from a linear type of activity-space, which for example could be a representation of home-work travel and the decision to participate in activities along a route. This research will concentrate to examine the hypothesized difference between the groups: male and female as well as between different days of the week.

3.6.3 Potential Path Area (PPA)

Two measures of potential mobility have been constructed by using the PPA concept. The Daily Potential Path Area (DPPA), which is the sum of the PPA's for an individual over the course of a day, have been constructed and used to derive the two measures. The first measure, AREA, is the area of the DPPA which represent an overall potential spatial reach of an individual. The second measure, KILOMETRE, is the total kilometres of all routes within the DPPA. This measure is an indication of potential reach and mobility within the overall DPPA (density of routes). The survey behind the data was not designed with analyses of PPA in mind. This is reflected in the 15 minutes slot design of the survey. No exact start or stop time have been collected, only the 15 minute slot of the start and stop of each journey. This causes a likely overestimation of the potential path area since the shortest possibly trip can only be 15 minutes, and every increase in length of time is by 15 minutes. In other words, there are no trips that are 7 minutes, 18 minutes, 22 minutes and so on. Due to the lack of this essential information, caution must be taken before drawing any conclusions of the potential path area analyses. An assumption has been mad regarding the time available to use in the calculation. For an activity to be rendered meaningful, at a minimum of five minutes is assumed to be needed. Therefore five minutes has been subtracted before the PPA-model has been allowed to run i.e. if a person has 30 minutes in time-budget between to fixed activities, only 25 minutes have been used to calculated the PPA.

3.7 ANOVA

The ANOVA test is a method to determine if population means are equal or not. It is used in this research to see if there exist enough difference between subpopulations (between gender or between days of week) to be of statistical significance. This is tested by the use of different quantitative variables: AREA and FULLNESS from SDE; standard distance; AREA and KILOMETRE from DPPA, which are representations of activity-space and daily potential path area. In other words, this research strives to find out if, for example, gender has an impact on the size (area) of the ellipse (area is here a measure/representation of the activity-space).

The ANOVA test compares the variation (measured by the variance) *between* groups (in this case gender or day of week) with the variation *within* groups. If the variation *between* groups is much larger than the variation *within* groups, the means of the different groups will not be equal and a statistical difference between the groups will exist. If the variation *between* groups and *within* groups is approximately the same size, then there will be no significant difference between the groups means (see figure 3.7 for a conceptual explanation). However, how can we assess if this arithmetic difference is significant, that it reflects a real difference of behaviour in the studied population? We have to balance this difference between female mean and male mean with the variation of individual values within each group. This is done by the F-ratio given by:

F = between group mean square / within group mean square

Given the F-value and according to the degrees of freedom[*], the Fisher-Snedecor distribution[**] provides the probability whether the difference between the means is trivial (it is due to chance) or significant (it is a real behaviour difference) in the studied population.

Table 3.4 Example of an ANOVA result table

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	2556.34	3	852.115	8.88	0.0003
Within groups	2607.63	28	95.9866		
Total	5243.97	31			

Table 3.4 is an example of an ANOVA result table. The P-value is 0.0003 and reports the significance level. It means that there is a 0.03 % risk that the difference between the mean area of males and the mean are of females is due to chance. In this example the conclusion would be that gender impacts the area of the ellipses (which are representation of activity-space).

[*] The number of degrees of freedom (DF) for the between group is one less than the number of groups; the number of DF for the within group is the total number of the variables minus the total number of groups. One important point to remember is that the total DF is one less than the total number of observations making up the analysis.

[**] It is beyond the scope of this research to go into the explanation of the Fisher-Snedecor distribution (F-distribution). For further information regarding this issue a visit to these sources are recommended: WolframMathWorld (1999-2008) “F-distribution”, http://mathworld.wolfram.com/F-Distribution.html; University of Regina (2007) “Appendix K, The F-distribution”, uregina.ca/~gingrich/f.pdf;

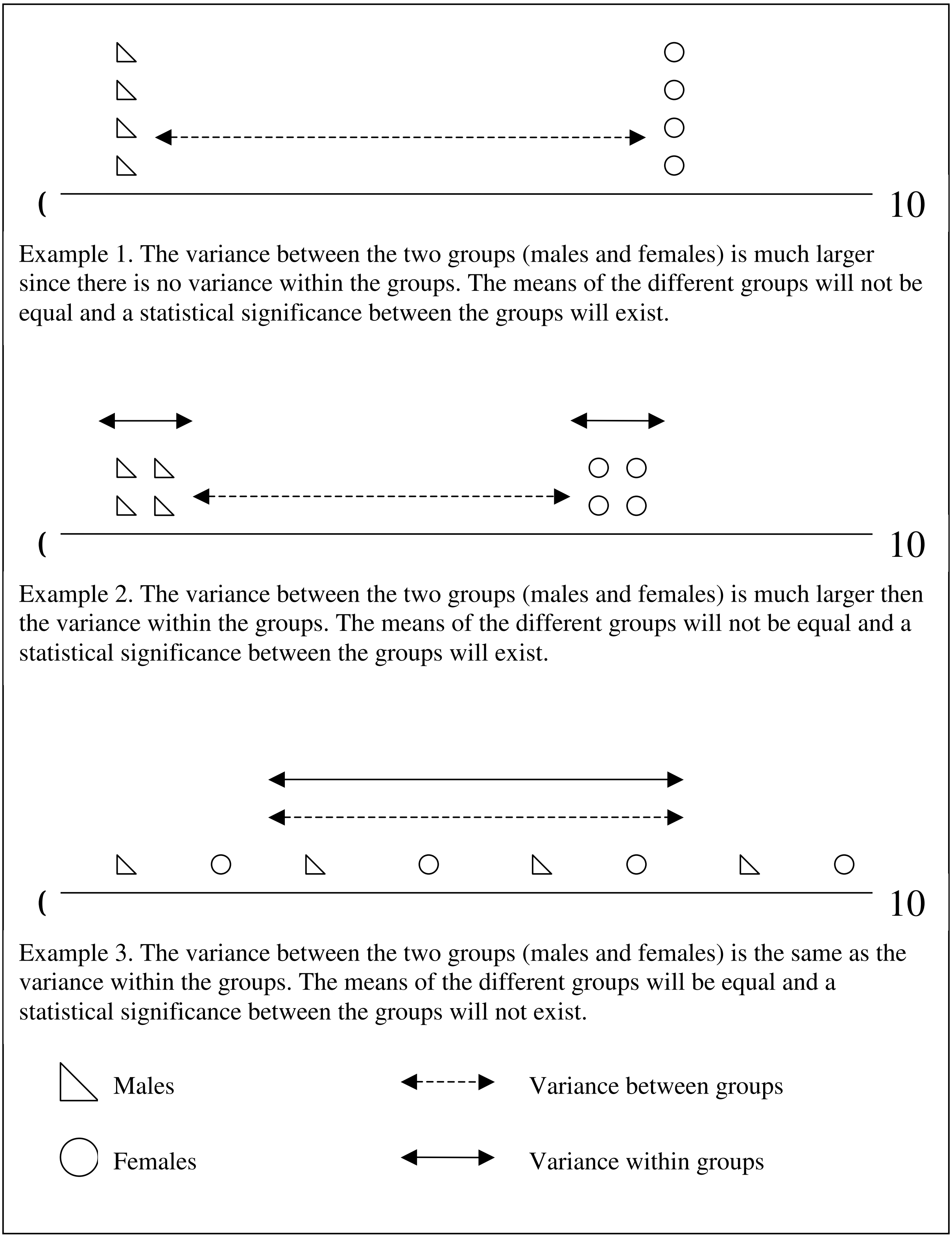

Figure 3.7 Conceptual explanation of ANOVA

3.8 Models

The model connecting the tabular classes with the feature classes have been constructed with the two main purposes of this research. The first is the exploration of daily mobility between gender through the concepts of activity space and the use of standard deviational ellipses. The second is to explore a potential mobility based on the constraints placed upon an individual during the course of a day. The models have been built using ArcGIS ModelBuilder and have been constructed by the use of different geoprocessing tools available in ArcGIS 9.1. The calculation of the standard deviational ellipse is already available as a script in ArcGIS 9.1 but has here been modified to include the calculation of mean centre. Both are essentially two different scripts which have been brought together to automate the process. The calculation of the standard deviational ellipse only uses the tabular classes and takes it starting point from the X and Y coordinates stored in the location table.

The calculation of PPA is, as opposed to the standard deviational ellipse (SDE), dependent on the road network. The conceptual model is based on a "service area" around the point of origin and the point of destination of an individual's trip. A service area is the area reachable within *n* of minutes from a specific point. The area is represented as "rings" around the point with different reach in minutes, the first ring 0-1 minute (from-to), the second ring 1-2 minutes (from-to) etc. The result is one service area for each point with "rings" around them representing different minutes reach (every "ring" have two values, one value for "from" and one value for "to"). In the example below 6 minutes have been set as the maximum reach (see figure 3.8).

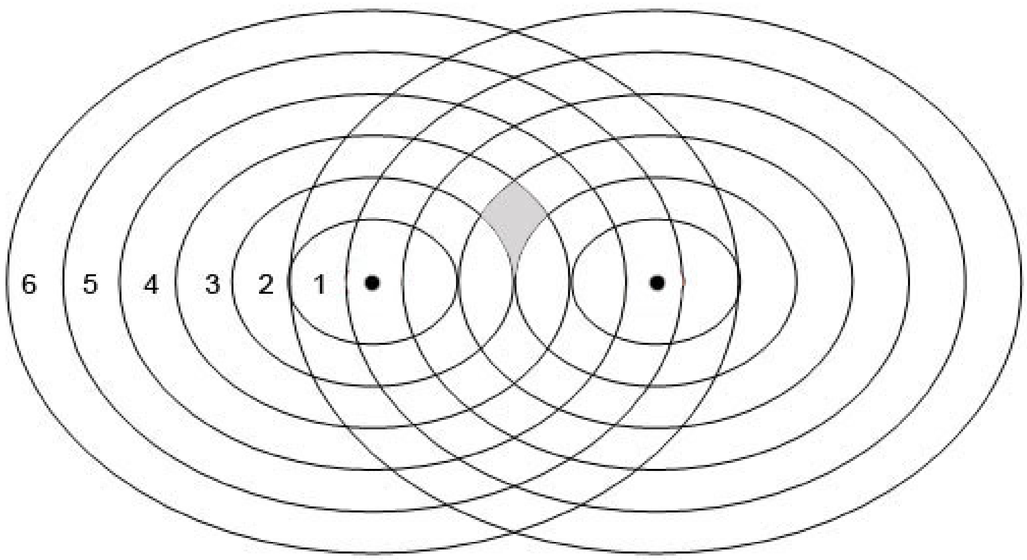

Figure 3.8 The conceptual representation of two service area polygons with a reach up to six minutes around each point (origin and destination) and how they overlap each other. The different rings represent different reach in time-space. The grey area represents the closer look in the following figure.

These two service areas are intersected with each other and the overlapping "rings" creates many smaller polygons, each which represent a spatial reach in minutes from the two points. The resulting table contains four different values (from-to values from *both* points). The resulting polygons cover thus an area of reach between, for example, 2-3 minutes from the point of origin and 2-3 minutes from the point of destination (see figure 3.9). Within this area, the reach will vary from minimum 4 minutes (2 +2) to maximum 6 minutes (3+3).

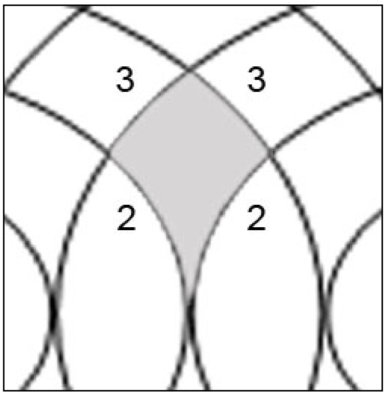

Figure 3.9 The overlap of the service areas creates several smaller polygons, each with a time-space reach of two minutes. The grey area has a time-space reach between 4 and 6 minutes i.e. to visit any location within this area from any of the two points a time-budget between 4 and 6 minutes is required.

In this example I want to find out the PPA with a time-budget of 6 minutes. Each polygon will cover a time-space of two minutes, and will therefore always give one minute over- or underestimation, depending on your choice. This research have chosen to overestimate the areas instead of underestimate them. See figure 3.10 for the resulting PPA with a time-budget of six minutes.

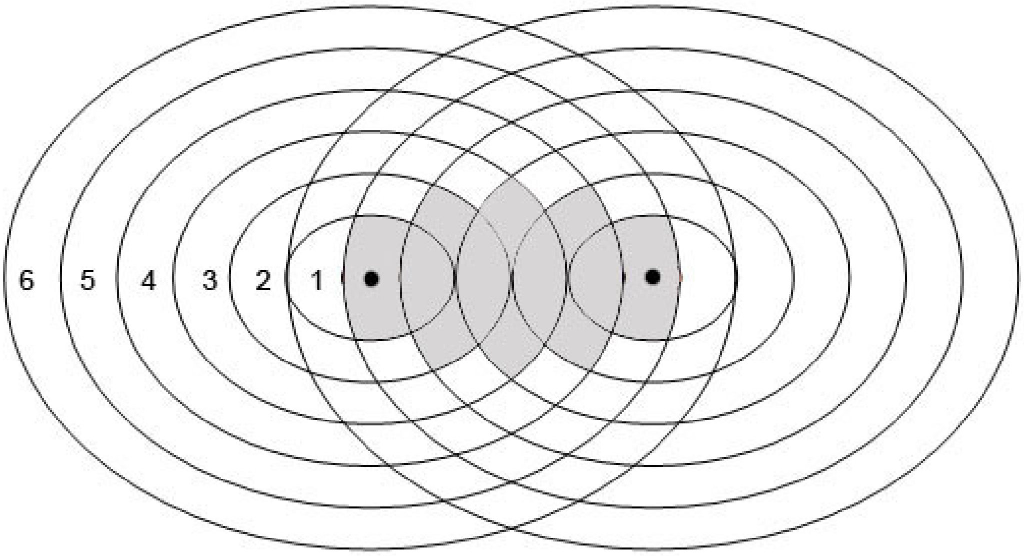

Figure 3.10 The grey area shows the resulting PPA after the model have been run. With a time-budget of 6 minutes to travel between the two points, the grey area represents the possible area one could visit with one stop.

The example is a conceptual description of the calculation of PPA. Considering the PPA is dependent on the road network model and the constraints placed upon that model, the shape and form of the resulting PPAs will be highly irregular. The PPA also takes it starting points from the X and Y coordinates stored in the location table. The construction of the model in ArcGIS 9.1 consists of several available geoprocessing scripts tied together in a flowchart type model (see figure 3.11).

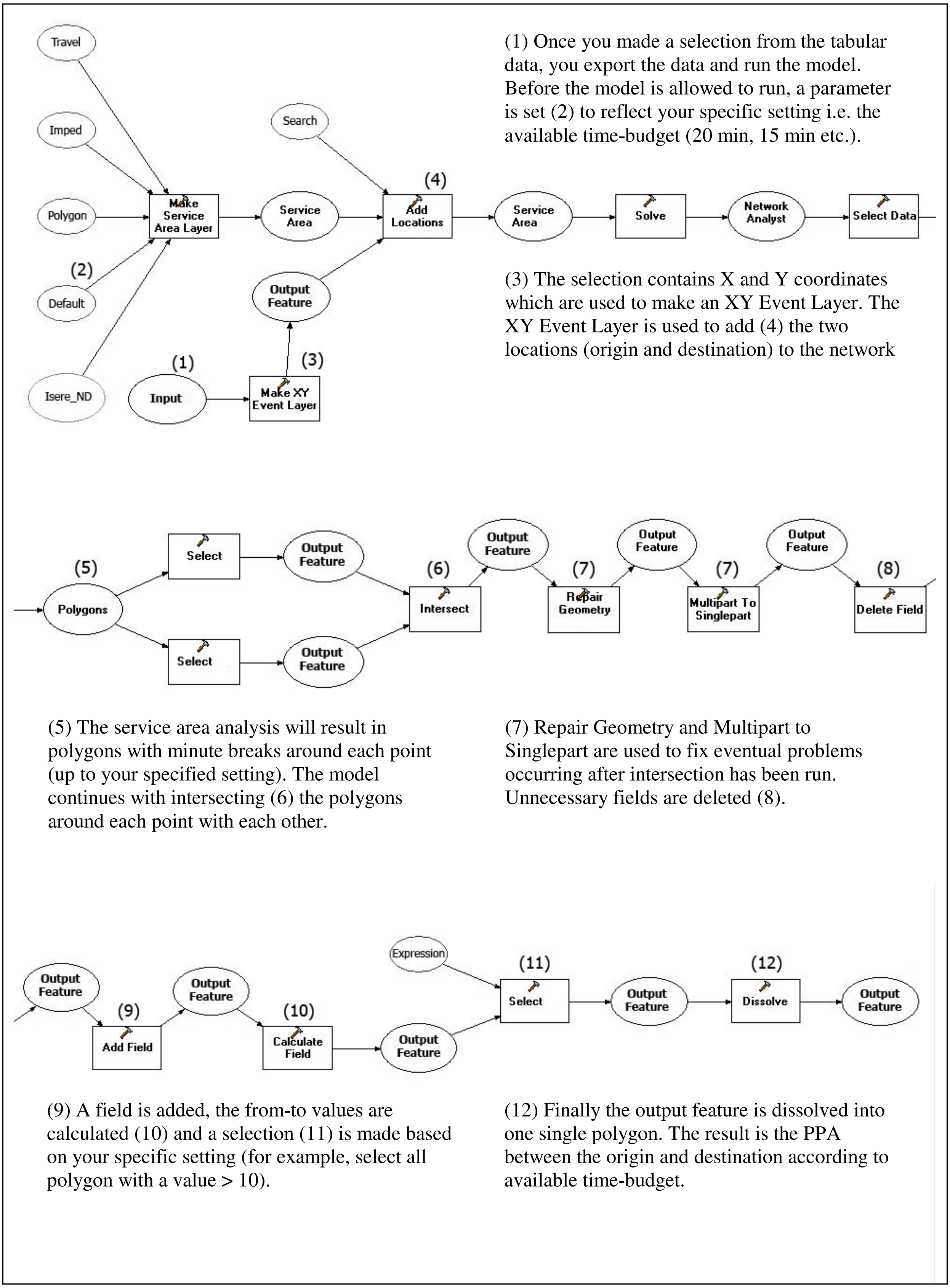

Figure 3.11 The model of the Potential Path Area calculation in ArcMaps modelbuilder.

4. ANALYSIS AND RESULTS

4.1 Introduction

The analyses have been carried out by using the different measures derived from the SDE, standard distance and DPPA. Both the SDE and the standard distance measure the observed or realized activity-space, whereas DPPA looks into the potential mobility of the same groups. The statistical analysis have been completed with the ANOVA test and carried out with SPSS (Statistical Package for the Social Sciences). Both the SDE and the standard distance have been calculated with and without weight. The weight represents the duration of the stay at each location an individual has made. The locations where an individual spends more time have thus a greater influence in the calculation of the SDE and the standard distance. Due to the construction of the travel diary, each 24 hour day consists of 96 fifteen minute slots. In the weighted analyses, each slot have been given a weight of 1 resulting in that the measures will be pulled toward the location exerting more influence. By using weighted analysis, a possible difference between the variables could be found even though individuals maybe have visited the same locations. It has been applies to both SDE and standard distance. A P-value of < 0,05 have been used for all ANOVA test to indicate a statistical significance. As a complement to the statistical analyses, visual analysis has also been used to characterize and compare the distributions of the various variables. It must be said that the visual analysis and presentations only act as a compliment, on a more general level, and are only used in descriptive purposes.

4.2 Standard Deviational Ellipse (SDE)

The sample of data consists of 39 individuals who have recorded their whereabouts over a period of four days. This would give a total of 156 different activity-spaces. Due to the construction of the SDE (where an input of at least three locations is necessary) some individuals activity-space has not been calculated (when an individual only have visited two or less locations). Furthermore, two activity-spaces (two different days) of an individual (male) have been deleted from the analyses. These two activity-spaces are both extreme values (i.e. they not representative for the data as a whole). Both the non-weighted and the weighted analyses are affected by this. 127 out of a total of 156 activity-spaces are included in the analyses. Of the 127 activity-spaces, 71 belong to women and 56 belong to men.

4.2.1 Non-weighted standard deviational ellipse

The first ANOVA was calculated on size (area) of activity-space and gender. The activity-spaces represent the whole study period i.e. four consecutive days. The locations visited by each group (males and females) are presented in figure 4.1 and the corresponding standard deviational ellipses are shown in figure 4.2. The results of the ANOVA test are presented in table 4.1. The analysis was not significant: a P-value of 0,952 is far from the statistical significant P-value of > 0,05. The visual analysis indicate that there are some minor differences in size (area) as can be seen in relation to the larger SDE's. However, the overall trend of the SDE's of females and males support the statistical result. It is very difficult to make a comparison on a detailed level; but on a more general note the outcome pattern is fairly similar. Table 4.2 presents the results of the second ANOVA which was calculated on fullness of activity-spaces and gender. The analysis was not significant. A P-value of 0,988 does not fall within range of the statistical significant level. The visual analysis of the SDE's supports the statistical result that there is no significant difference between the two groups.

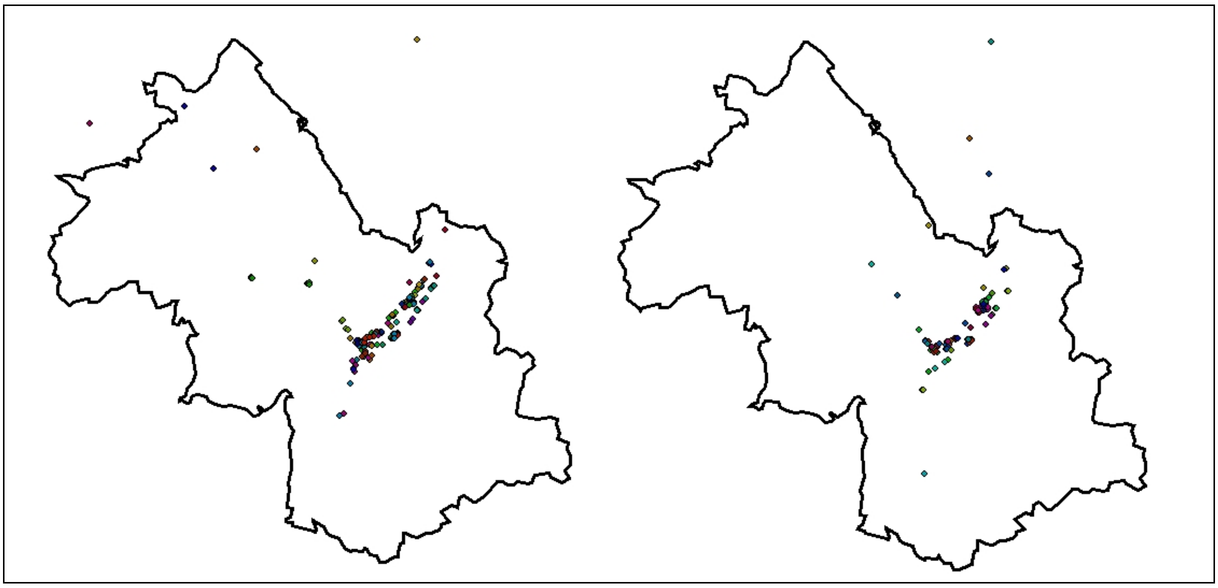

Figure 4.1 All locations visited by females (left) and males (right).

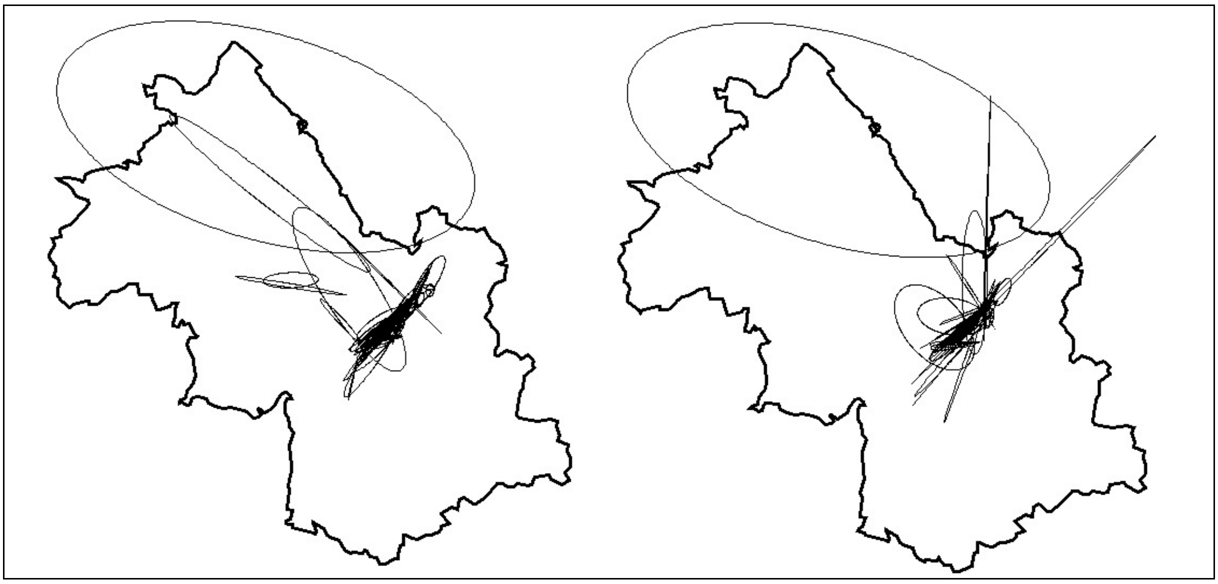

Figure 4.2 Non-weighted SDE's for females (left) and males (right).

Table 4.1 ANOVA results for non-weighted size (area) according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1107,590	1	1107,590	0,004	0,952
Within groups	37298410,490	125	298387,284		
Total	37299518,080	126			

Table 4.2 ANOVA results for non-weighted fullness according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,000	1	0,000	0,000	0,988
Within groups	3,777	125	0,030		
Total	3,777	126			

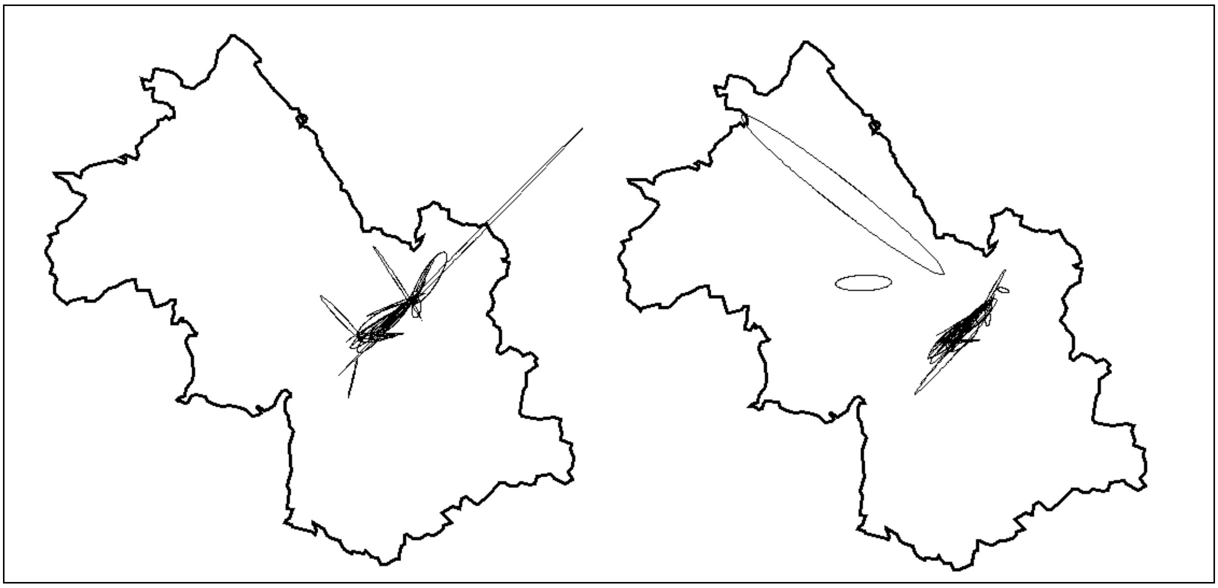

Figure 4.3 Non-weighted SDE's for Wednesday (left) and Thursday (right).

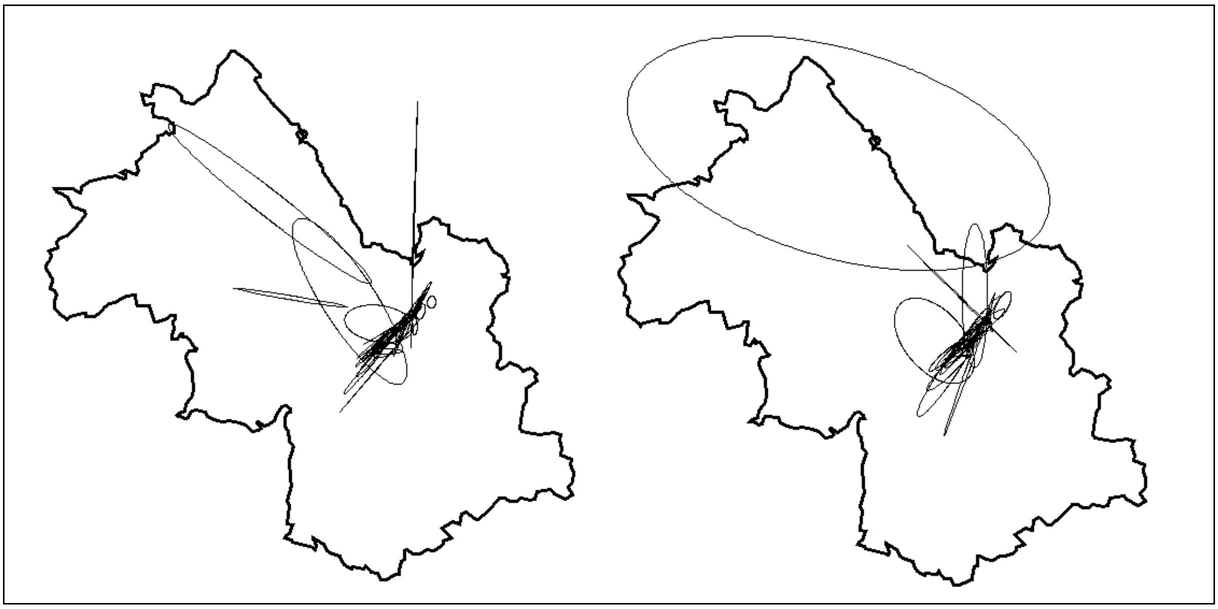

Figure 4.4 Non-weighted SDE's for Friday (left) and Saturday (right).

Table 4.3 ANOVA results for non-weighted size (area) according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1740133,992	3	580044,664	2,006	0,117
Within groups	35559384,088	123	289100,684		
Total	37299518,080	126			

Table 4.4 ANOVA results for non-weighted fullness according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,185	3	0,062	2,114	0,102
Within groups	3,591	123	0,029		
Total	3,777	126			

The following ANOVA was calculated on size (area) of activity-spaces and day of the week. Figure 4.3 and figure 4.4 shows the SDE's according to each day of the week included in the research (Wednesday, Thursday, Friday, and Saturday). Table 4.3 shows the results from the corresponding ANOVA test which was calculated on size (area) of the activity-spaces and day of week. The analysis was not significant. A P-value of 0,117 does not fall within the level of significance. The value is relatively close to the 95 % confidence limit (> 0,05) but since it does not fall within it, a statistical difference can not be said to exist. A visual description and comparison of the ellipses between the days indicate that the bulk of the ellipses a similar in terms of size (area). The differences that exist and are identifiable are mostly limited to the fewer, larger ellipses. Table 4.4 presents the results from the next ANOVA was calculated on fullness of the activity-spaces and day of the week. The analysis was not significant with a P-value of 0,102. The visual interpretation of the SDE's clearly present some differences between them, however they are limited to the larger ellipses. The main parts are still very alike and homogeneous for all days.

One more variables have been analyzed: work status (whether individuals work or not), to see if this could be an explanatory variable. The results of ANOVA calculated on size (area) according to work status for non-weighted SDE are not significant. The results are presented in table 4.5. ANOVA was also run for fullness according to work status, table 4.6 show the results. The analysis was significant with a P-value of 0,012 it falls well within the 95 % confidence limit. Figure 4.5 illustrates the differences between the groups. The SDE's for work status seem to suggest that when individuals are working their activity-spaces reflects this. The visual impression of their activity-spaces is more elongated then the activity-spaces of the non-working individuals. To verify this impression a look at the mean of the different groups is necessary. The mean values correspond to the visual analysis that ellipses are more elongated the days when individuals are working (see table 4.7).

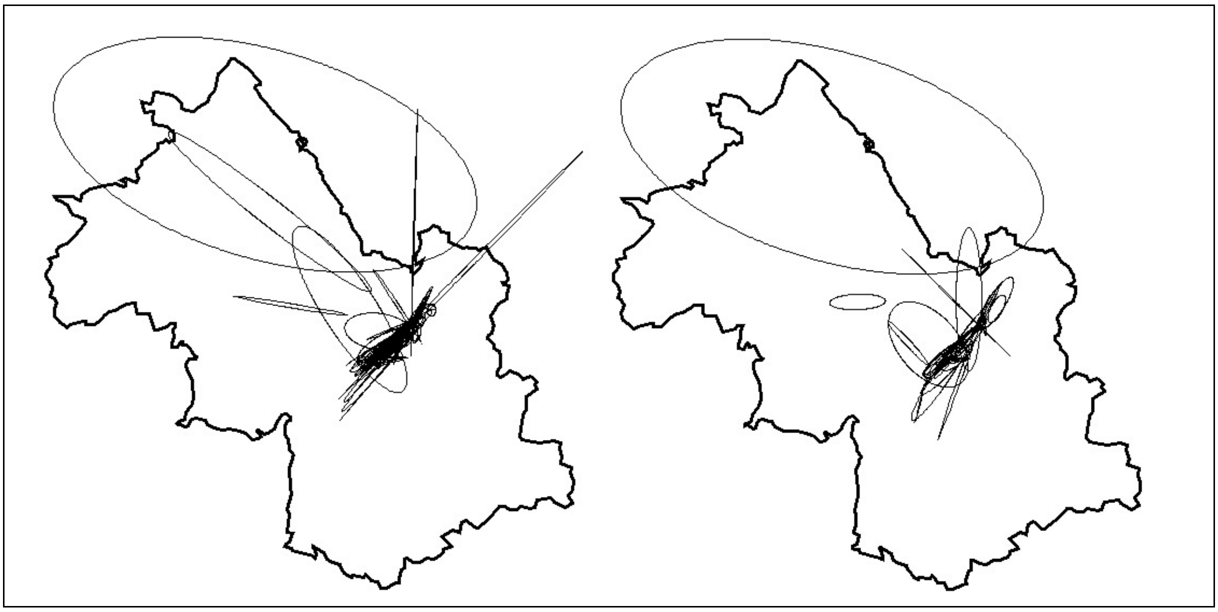

Figure 4.5 Non-weighted SDE's for working people (left) and non-working people (right).

Table 4.5 ANOVA results for non-weighted size (area) according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	59668,326	1	59668,326	0,200	0,655
Within groups	37239849,8	125	297918,798		
Total	37299518,1	126			

Table 4.6 ANOVA results for non-weighted fullness according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,187	1	0,187	6,495	0,012
Within groups	3,590	125	2,872E-02		
Total	3,777	126			

Table 4.7 Mean values.

Variable	Mean*
Working	0,14252658
Non working	0,22307064

** Mean ranges between 0 (=straight line) and 1 (=full circle)*

4.2.2 Weighted standard deviational ellipse

A look at the weighted activity-spaces follows next. By using duration (time spent at a location) as a weight, localities such as home and work exert a strong influence over the activity-spaces shape and size (area). Table 4.8 presents the results of the ANOVA calculated on size (area) of the activity-spaces and gender. With a P-value of 0,946 the analysis is not significant. This is also supported by the visual interpretation of the SDE's (see figure 4.6). Most of the weighted ellipses are reminiscent of each other in terms of size, however between the fewer, larger ellipse, difference in area are more easily spotted. The ANOVA calculated on fullness of the activity-spaces and genders are shown in table 4.6. As can be seen in the table, the analysis is not significant with a P-value at 0,712. With a look at the visual presentation of the ellipses, the overall trend supports the results derived from the ANOVA test.

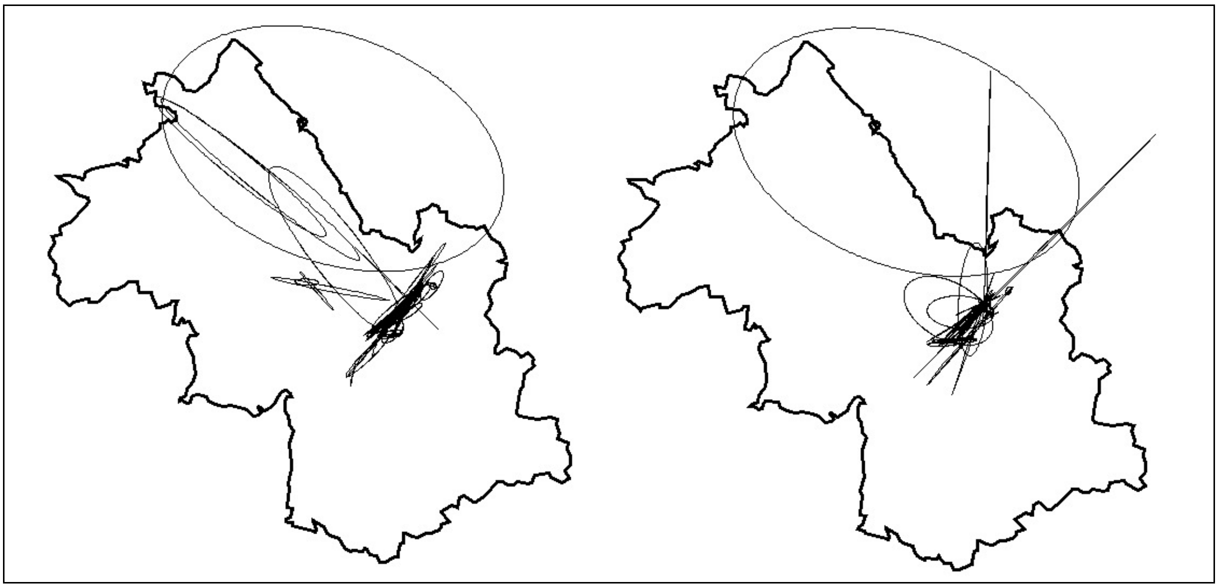

Figure 4.6 Weighted SDE's for females (left) and males (right).

Table 4.8 ANOVA results for weighted size (area) according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1123,083	1	1123,083	0,005	0,946
Within groups	30769570,806	125	246156,566		
Total	30770693,890	126			

Table 4.9 ANOVA results for weighted fullness according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,004	1	0,004	0,137	0,712
Within groups	3,828	125	0,031		
Total	3,832	126			

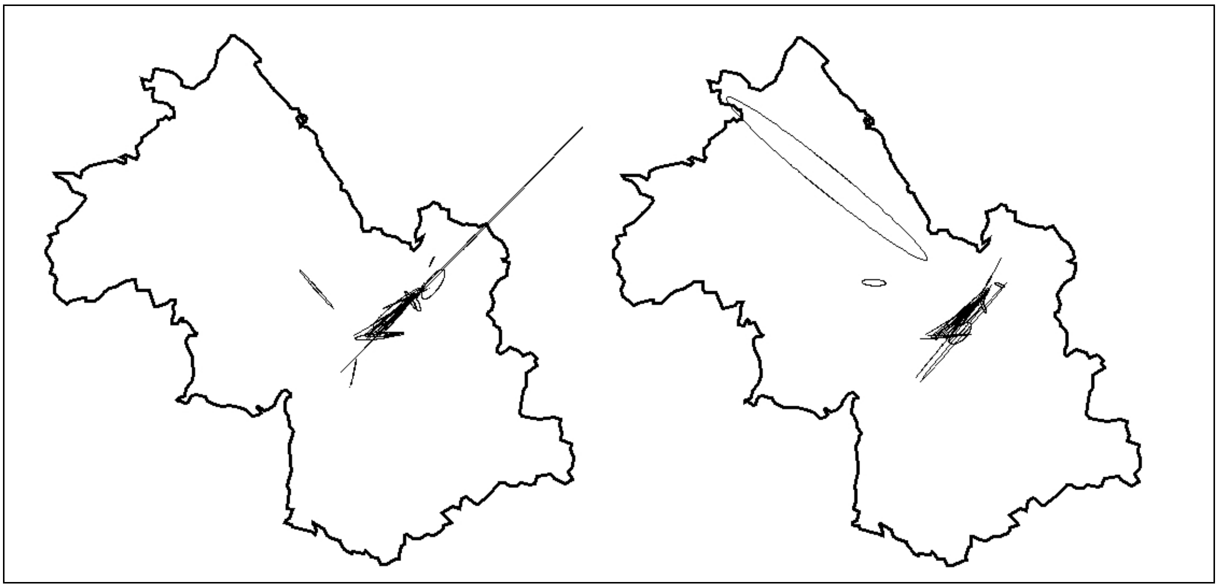

Figure 4.7 Weighted SDE's for Wednesday (left) and Thursday (right).

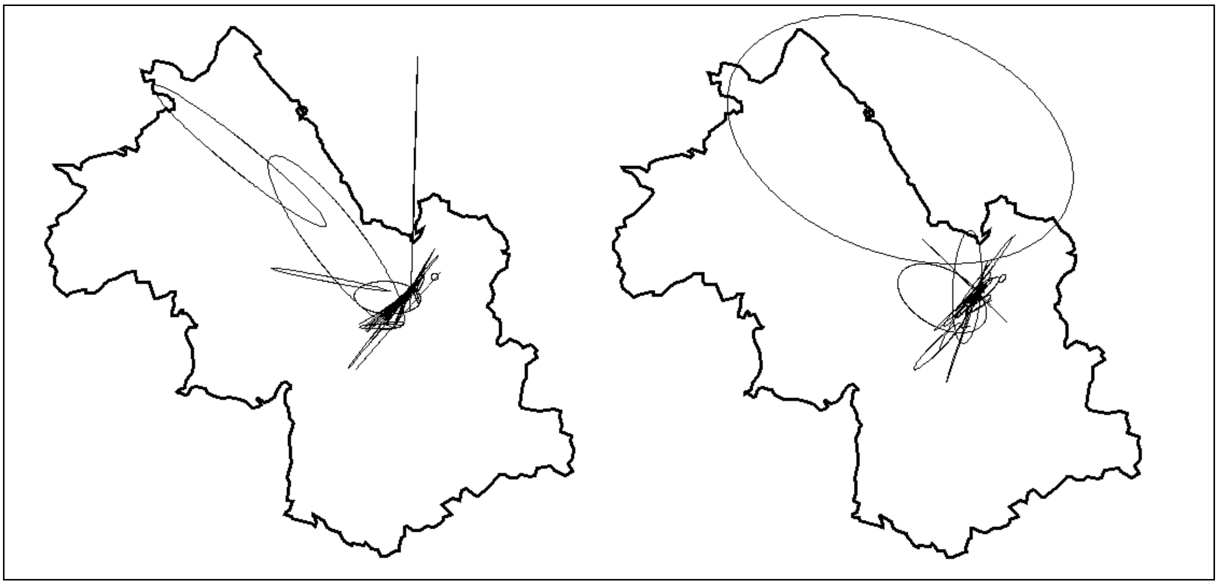

Figure 4.8 Weighted SDE's for Friday (left) and Saturday (right).

Table 4.10 ANOVA results for weighted size (area) according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1409497,126	3	469832,375	1,968	0,122
Within groups	29361196,764	123	238708,917		
Total	30770693,890	126			

Table 4.11 ANOVA results for weighted fullness according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,285	3	0,095	3,298	0,023
Within groups	3,547	123	0,029		
Total	3,832	126			

The analysis of the weighted SDE continued with an ANOVA calculated on size (area) of the activity-spaces and day of the week. The results from the ANOVA test area shown in table 4.10. The analysis is not significant. With a value of 0,122 it does not fall within this limit and can not therefore be considered as statistically significant. A look at the graphical presentation of the ellipses (see figure 4.7 and figure 4.8) indicates somewhat of a difference in size (area) though this is related to the larger, and fewer, ellipses. The overall trend among the standard deviational ellipses is that they do resemble each other over the different days. Extending the look a bit further, an ANOVA was calculated on fullness of the activity-spaces and day of the week. Table 4.11 presents the results from the ANOVA test. The analysis is significant. A P-value of 0,023 it falls within the statistical significant level of > 0,05. Looking at the visualization of the ellipses reveal some differences between the days, especially between the first few days and Saturday. However, it is hard to determine the significance visually but it does give some “feel” for the statistical result. One more variables have been analyzed: work status (whether individuals work or not), to see if this could be an explanatory variable. The results of ANOVA calculated on size (area) according to work status for weighted SDE are not significant. The results are presented in table 4.12. ANOVA was also run for fullness according to work status, table 4.13 show the results. The analysis was significant with a P-value of 0,006 it falls well within the 95 % confidence limit. Figure 4.9 illustrates the differences between the groups. The working groups ellipses seem to be more elongated than for the other group and can be verified by looking at mean values is made (see table 4.14).

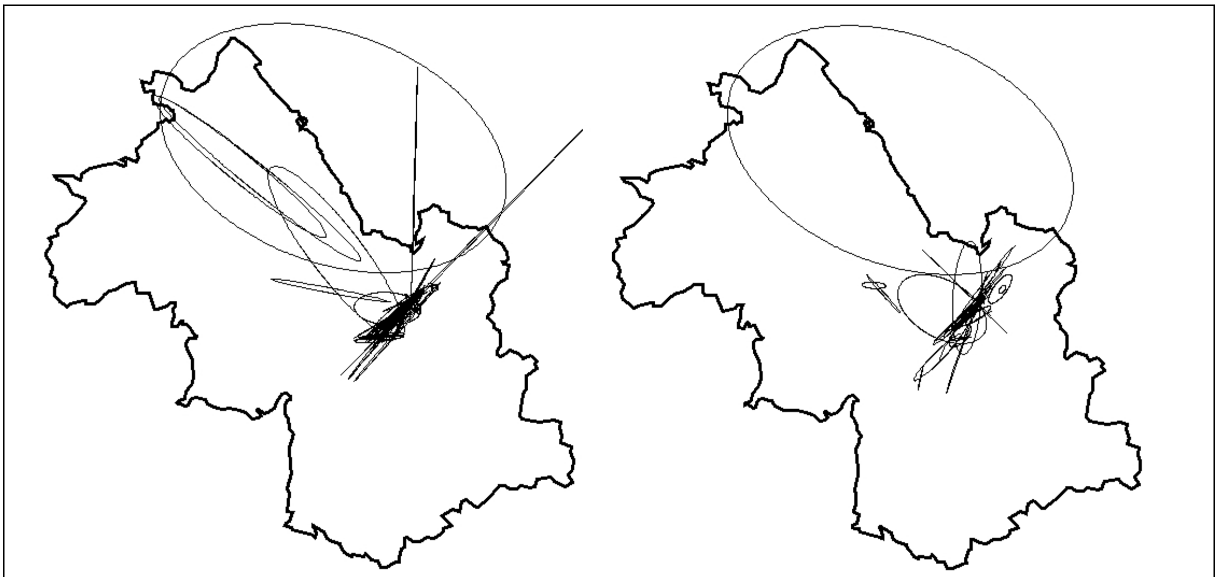

Figure 4.9 Weighted SDE’s for working people (left) and non-working people (right).

Table 4.12 ANOVA results for weighted size (area) according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	40036,376	1	40036,376	0,163	0,687
Within groups	30730657,5	125	245845,260		
Total	30770693,9	126			

Table 4.13 ANOVA results for weighted fullness according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,230	1	0,230	7,977	0,006
Within groups	3,602	125	2,882E-02		
Total	3,832	126			

Table 4.14 Mean values.

Variable	Mean*
Working – weighted	0,10495782
Non working – weighted	0,19436309

** Mean ranges between 0 (=straight line) and 1 (=full circle)*

4.3 Standard Distance

The data sample for the standard distance measure consists of 150 activity-spaces out of a total of 156 activity-spaces. The standard distance requires only two points (in this case locations) to be calculated, whereas the SDE requires three. This is an obvious advantage since a higher number of the total data will be included in the analysis. Four of the 156 activity-spaces have been exempted from the analysis since they did not have enough required points. Furthermore, two other activity-spaces have been deleted and exempt from the analysis, since they represent two extreme values and are not representative for the data as a whole. Both the non-weighted and the weighted activity-spaces are affected by this. Of the 150 activity-spaces, 84 belong to women and 66 belong to men.

4.3.1 Non-weighted standard distance

The second type of analysis performed on the data was the standard distance. The standard distance provides a single measure which shows the distribution around the mean centre. Table 4.15 presents the results of the ANOVA calculated on standard distance and gender. The analysis is not significant. A P-value of 0,711 is too large and does not fall within the statistically significant level of > 0,05. The visual analysis of the standard distance, as shown in figure 4.10 supports this: most of the circles (which are the graphical representations of the standard distance value) are clustered similarly in space, with the exceptions of some larger circles. An ANOVA calculated on the standard distance and day of the week was examined next. Table 4.16 presents the results of the ANOVA test. The analysis is not significant. A P-value of 0,331 is too large to be within the statistical significance level (> 0,05). Figure 4.11 and figure 4.12 shows the graphical representation of the standard distance according to day. The visual interpretation shows no real difference between the days: the bulk of the circles are similar in size and within the same region. ANOVA was also calculated on standard distance according to work status. The result is presented in table 4.17 and is not significant.

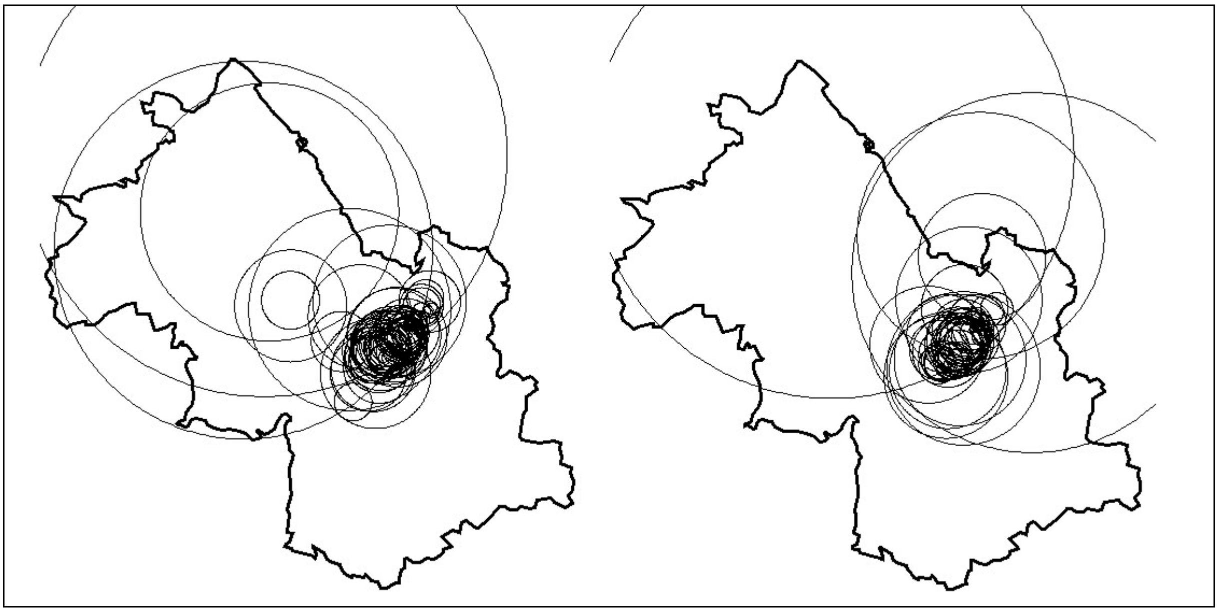

Figure 4.10 Non-weighted Standard distance (presented as circles) for females (left) and males (right).

Table 4.15 ANOVA results for non-weighted standard distance according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	11029942,256	1	11029942,256	0,138	0,711
Within groups	11824997684,504	148	9898633,003		
Total	11836027626,759	149			

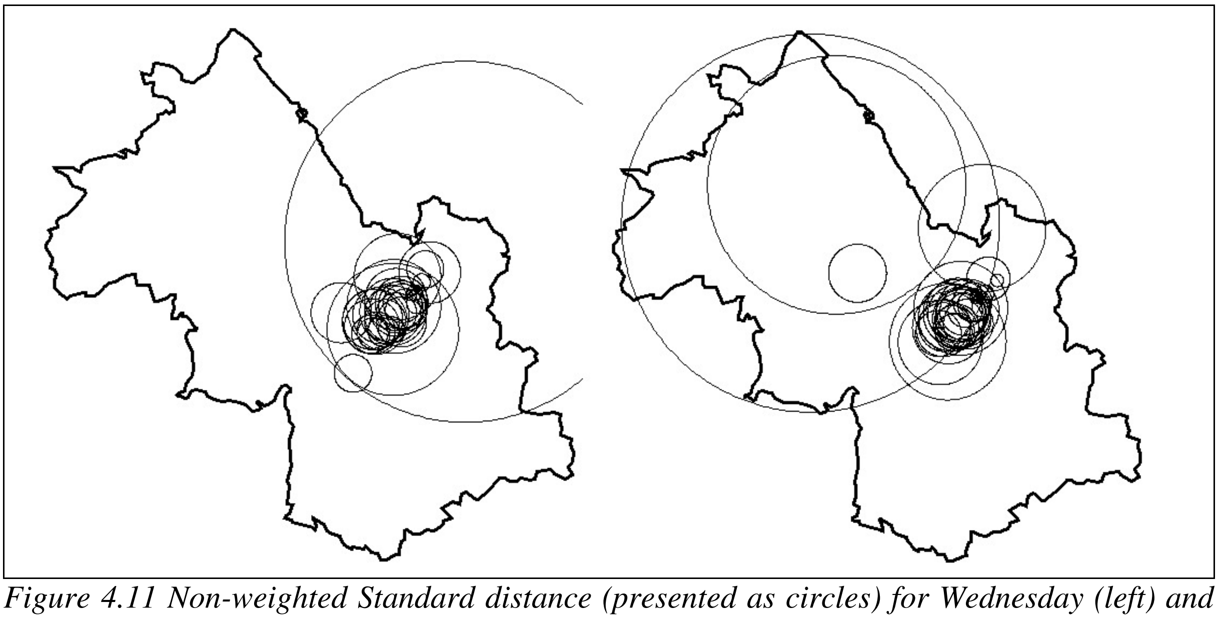

Figure 4.11 Non-weighted Standard distance (presented as circles) for Wednesday (left) and Thursday (right).

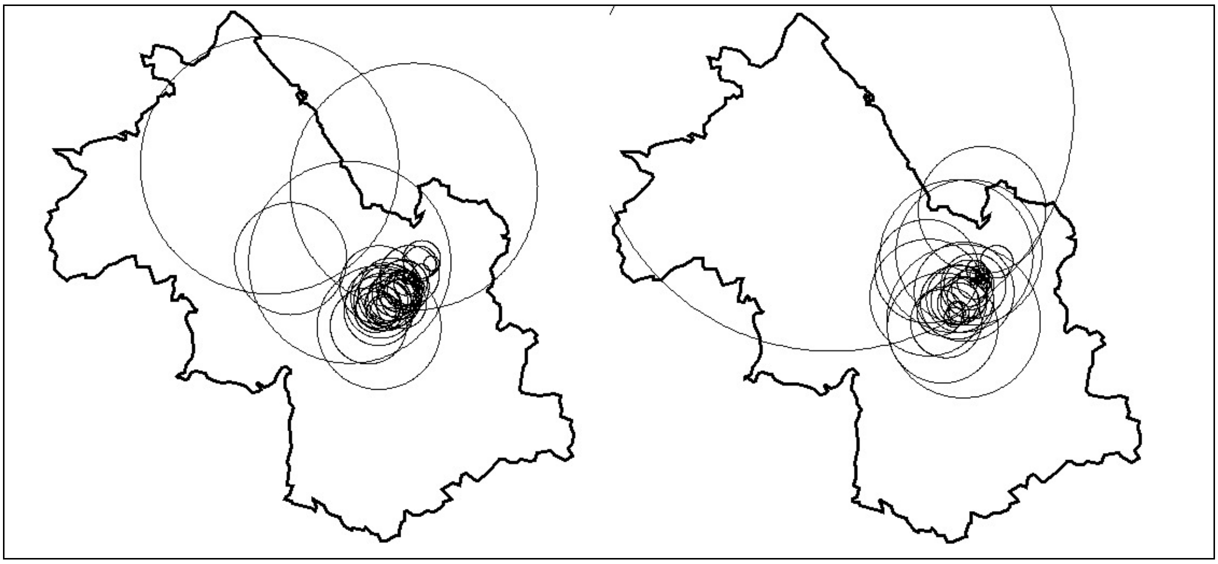

Figure 4.12 Non-weighted Standard distance (presented as circles) for Friday (left) and Saturday (right).

Table 4.16 ANOVA results for non-weighted standard distance according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	273424769,838	3	91141589,946	1,151	0,331
Within groups	11562602856,921	146	79195909,979		
Total	11836027626,795	149			

Table 4.17 ANOVA results for non-weighted standard distance according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	23946103,3	1	23946103,3	0,296	0,587
Within groups	1,196E+10	148	80786641,4		
Total	1,198E+10	149			

4.3.2 Weighted standard distance

A weighted standard distance analysis was also carried out. The results of the ANOVA calculated on weighted standard distance and gender are presented in table 4.18. The analysis is not significant with a P-value of 0,773. The graphical presentation of the standard distance can be found in figure 4.13 and support the statistical results. There are some differences between the genders standard distance circles although they are few. There exists a concentration of circles around the same area, which represent a fairy homogeneous result. To conclude, an ANOVA calculated on the standard distance and day of the week were performed next. Table 4.19 shows the ANOVA results, which include a P-value of 0,251. The analysis is therefore not significant. Figure 4.14 and figure 4.15 shows the standard distance graphically and depicts no real difference between the days. Saturday is more dispersed than the other days, however the main concentration can be found around the same area for all the days. ANOVA were also run on weighed standard distance according to work status. The result is presented in table 4.20 and is not significant. However, in relation to the other weighted standard distance analyses, work status asserts more over the standard distance value.

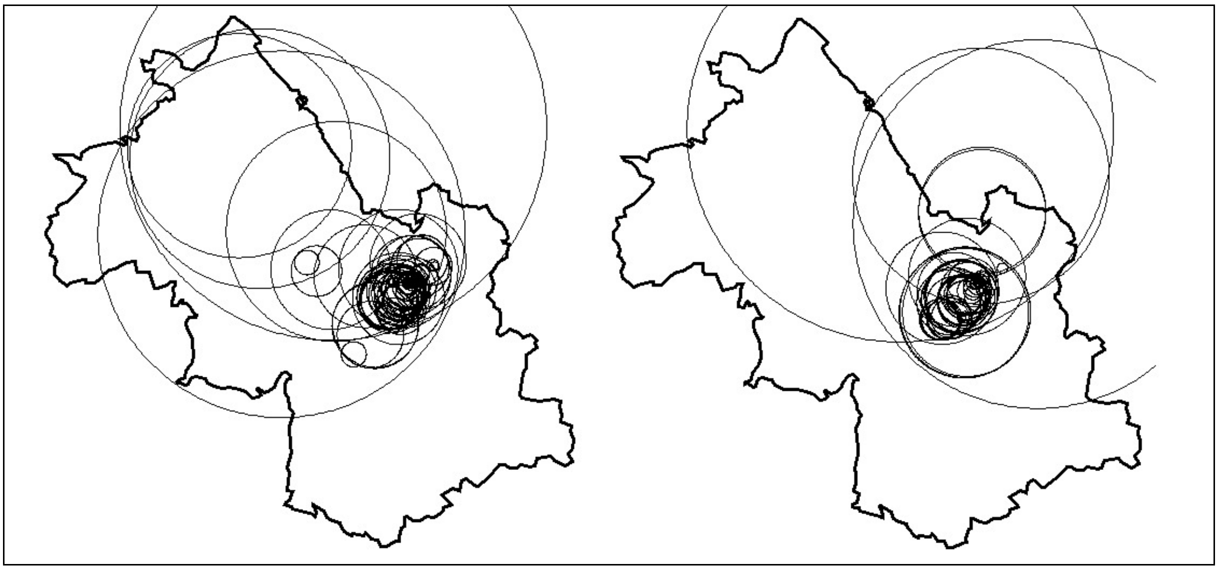

Figure 4.13 Weighted standard distance (presented as circles) for females (left) and males (right).

Table 4.18 Weighted ANOVA results for weighted standard distance according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	5951253,025	1	5951253,025	0,084	0,773
Within groups	10523437285,530	148	71104305,983		
Total	10529388538,555	149			

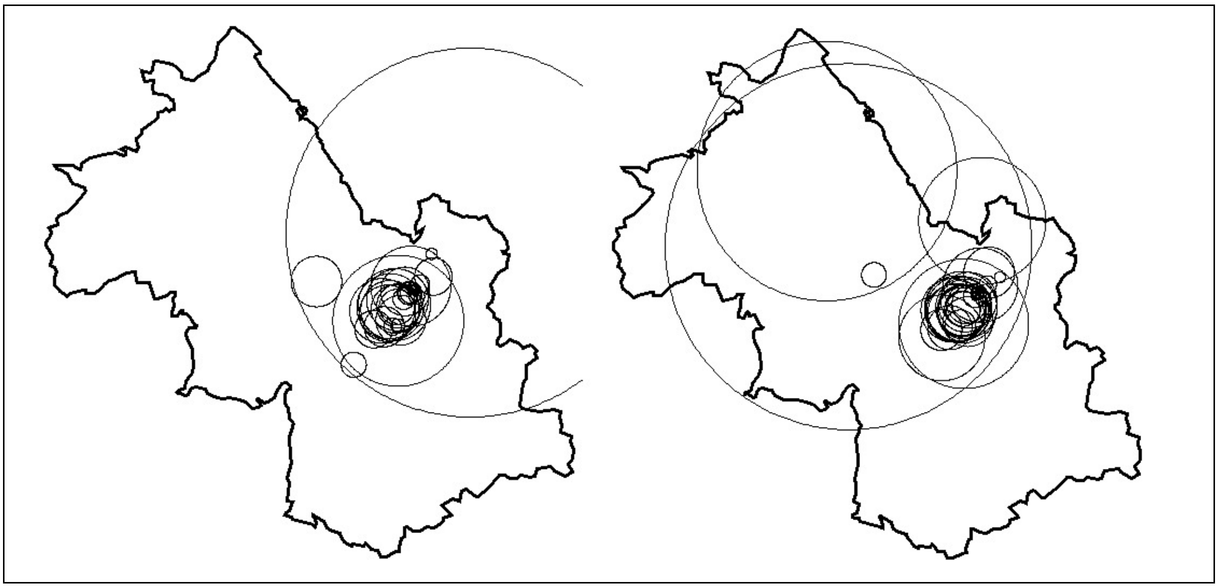

Figure 4.14 Weighted standard distance (presented as circles) for Wednesday (left) and Thursday (right).

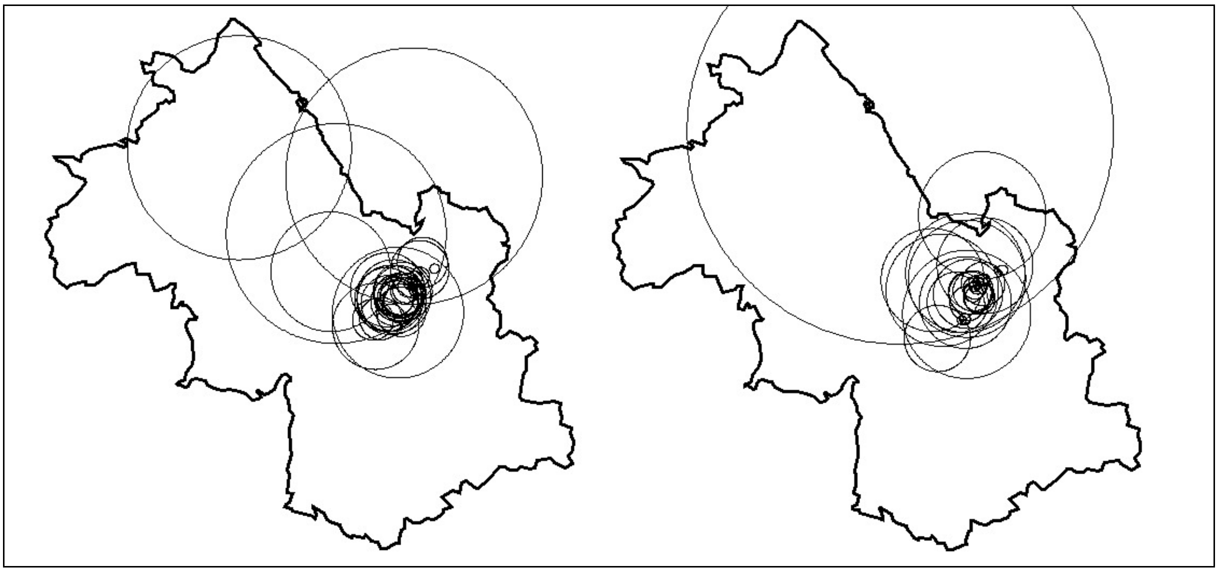

Figure 4.15 Weighted standard distance (presented as circles) for Friday (left) and Saturday (right).

Table 4.19 ANOVA results for weighted standard distance according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	290430754,460	3	96810251,487	1,380	0,251
Within groups	10238957784,095	146	70129847,836		
Total	10529388538,555	149			

Table 4.20 ANOVA results for weighted standard distance according to work status.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	164405500	1	164405500	2,059	0,153
Within groups	1,82E+10	148	79837591,4		
Total	1,198E+10	149			

4.4 Daily Potential Path Area (DPPA)

The analyses of the DPPA have been carried out through the use of the ANOVA test to see if there is a difference in potential mobility between gender and between days. There are a total of 156 DPPA's (one for each day per respondent). The DPPA's are constructed by adding all the PPA's together for a person per day. However, due to technical computation power, or rather the lack of it, not all PPA's have been calculated. This applies to all PPA's that exceeds 30 minutes in time and have resulted in a loss of data. A total of 115 DPPA's have been used in the analyses and 41 DPPA's are missing. This is a loss of 26,3 %, which rather large. Of the 115 DPPA's, 62 belong to women and 53 belong to men. An example of two DPPA's for two different people are given in figure 4.16 and figure 4.17. The DPPA for female U1 (figure 4.16) is a lot smaller than the DPPA for male U2 (figure 4.17) which is her husband. As the DPPA is the sum of all the different PPA's during the day for an individual, it shows the potential area an individual could visit. In the case for individual U1 and U2, the difference in size of DPPA is large. The size (area) of the DPPA is a variable that will be used to test whether there is a difference of potential mobility according to gender and according to day. Another variable is *n* of total kilometre of routes within the DPPA. This measure is an indication of mobility within the DPPA; the more kilometres within the DPPA, the greater

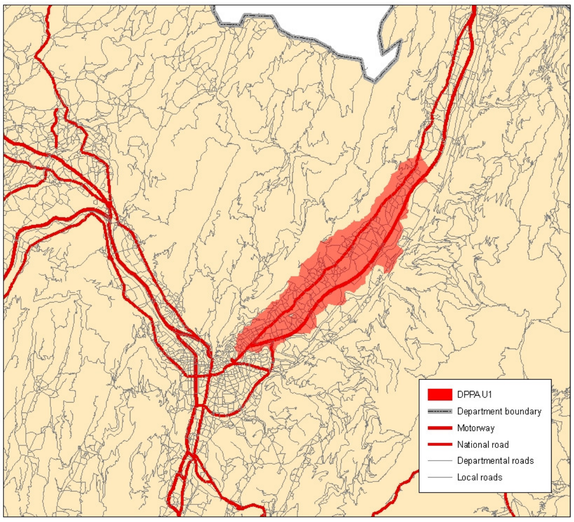

Figure 4.16 DPPA for female U1.

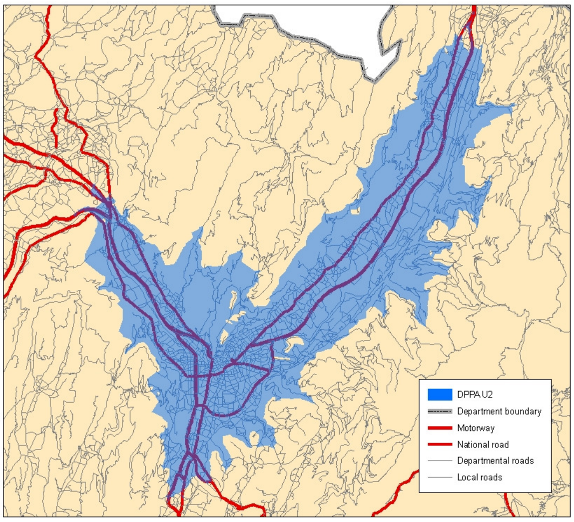

Figure 4.17 DPPA for male U2.

potential mobility within the DPPA (for example, two DPPA's with the same size but covering to different areas, could have a difference in *n* total kilometres). Table 4.21 shows the results of the ANOVA calculated on size (area) and gender. As can be seen by the P-value of 0,606, the analysis is not significant. The next ANOVA performed was calculated on size (area) and day of the week. The result is in table 4.22. The analysis is not significant with a P-value of 0,141. Table 4.23 shows the ANOVA results calculated on total kilometre and gender. A P-value of 0,503 indicates that the analysis is not significant. Table 4.24 presents the results of the ANOVA calculated on total kilometre and day of the week. The analysis is not significant with a P-value of 0,231.

Table 4.21 ANOVA results for size (area) according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	2541,351	1	2541,351	0,268	0,606
Within groups	1070908,435	113	9477,066		
Total	1073449,786	114			

Table 4.22 ANOVA results for size (area) according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	51293,348	3	17097,783	1,857	0,141
Within groups	1022156,438	111	9208,617		
Total	1073449,786	114			

Table 4.23 ANOVA results for total kilometre according to gender.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	72483,337	1	72483,337	0,451	0,503
Within groups	18147960,9	113	160601,424		
Total	18220444,2	114			

Table 4.24 ANOVA results for total kilometre according to day.

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	688817,308	3	229605,769	1,454	0,231
Within groups	17531626,9	111	157942,585		
Total	18220444,2	114			

5. CONCLUSIONS

5.1 Introduction

This research has been looking into the daily mobility of people living in metropolitan Grenoble, France. The perspective on mobility has been that the activities of people's daily life are the underlying causes to their travel. Daily mobility of people's life could be studied in different ways; however, the main interest here has been to study mobility by looking at gender, different days of the week, and whether people work or not. Data from fairly homogeneous respondents relating to socio-economic characteristics and life situation have been used in this purpose. Both the observed realized travel and the potential mobility have been under the eye of the researcher.

5.2 Observed mobility

The observed mobility in people's daily life have been analyzed and studied through the use of the Standard Deviational Ellipse (SDE) and the standard distance measures. Both non-weighted and weighted analyses have been made. An analysis of variance (ANOVA) has been applied to the results to asses if gender, day of week, and work status can explain differences in activity-space. Activity-space has been represented through measures derived from the SDE (area and fullness) and the standard distance. A summary of the ANOVA results from the analyses and their significance follows in table 5.1 and table 5.2:

*Table 5.1 ANOVA results of statistical significance of SDE.**

	Dependent variables	
Independent variables	AREA	FULLNESS
GENDER	No	No
GENDER - WEIGHTED	No	No
DAY OF WEEK	No	No
DAY OF WEEK - WEIGHTED	No	Yes
WORK STATUS	No	Yes
WORK STATUS - WEIGHTED	No	Yes

** Cells indicate whether the means of the dependent variables were statistically significant at the 95 % or better confidence level.*

*Table 5.2 ANOVA results of statistical significance of standard distance.**

	Dependent variables
Independent variables	STANDARD DISTANCE
GENDER	No
GENDER - WEIGHTED	No
DAY OF WEEK	No
DAY OF WEEK - WEIGHTED	No
WORK STATUS	No
WORK STATUS - WEIGHTED	No

** Cells indicate whether the means of the dependent variables were statistically significant at the 95 % or better confidence level.*

By looking at the summary of the analysis results in table 5.1 and table 5.2 conclusions can be drawn. Both the non-weighted and weighted analysis results of SDE and standard distance show that gender is not significant to explain differences in activity-space i.e. neither the variable area or fullness indicates any differences between the genders (see Appendix C, D, and E for a full summary of the ANOVA results). Day of week is far more explanatory of differences in activity-space than gender. However, the overall results for all the day of week analyses indicate that neither day of week is significant enough to explain difference in activity-space. This is true with the exception of weighted SDE and fullness. This means that when time spent at each location is accounted for, day of week impacts the fullness of the ellipse (and thus the activity-space). These initial results prompted an extension of the analysis with one more variable: work status. Using the measures derived from SDE (area and fullness) ANOVA has been applied to assess further explanatory variables. The results showed clearly that work status can explain differences of fullness in activity-space. Both the non-weighted and the weighted analysis are within the 95 % confidence level. A comparison of the mean values of work status according to fullness where done to asses the visual analysis, which suggested that ellipses are more elongated when people are working, whereas the areas stay relatively alike. The results (see table 4.17) supports this suggestion. An ANOVA test was also performed with work status and standard distance. The results from the standard distance do not show any statistical significance. This can be explained by the fact the standard distance does not capture the potential skewness of the data.

The aim of the research was to answer questions regarding the daily mobility of people and whether or not gender and/or day of week influence the activity-space. The hypothesis put forward states that females will have a significant different activity-space than males. It further elaborates that the activity-spaces will be significantly different between different days of the week. Even though earlier studies have been somewhat contradictory regarding mobility and differences between the genders, the hypothesis is backed by the notion of, here in France, children up to the age of 11 have a free day on Wednesday and that females traditionally have taken care of the child/children. This should then be visible in the data used. Four conclusions can be made regarding the statistical analyses of the activity-space and the sample data used in the research:

1) You can not explain any differences in activity-space by gender (i.e. gender does not influence the area or the fullness of the standard deviational ellipses, nor the standard distance);
2) Day of week is explanatory for differences in activity-space (as represented by fullness) if duration at each location is accounted for (i.e. weighted analysis). However, the explanatory power of day of week does not extend any further.
3) Work status is explanatory for differences in activity-space (as represented by fullness), both non-weighted and weighted.
4) The activity-spaces are more elongated during the days when people are working then during the days when they are free; however, they stay very alike in terms of area.

The hypothesis put forward concerning gender can't be verified at all. Concerning the day of week, the hypothesis can't be verified without modification i.e. it is only when time spent at each location are accounted for that day of week becomes explanatory for fullness (i.e. the shape) of the ellipse. However, through the extended analysis, the research found that work status is explanatory of differences in activity-space. This applies to the fullness of the ellipses, not to the area which doesn't show any real difference. This indicate that people undertake longer journeys the days they are working and that their activities are more likely to be in the immediate surrounding of their route between home and work (and hence more elongated), whereas during the days people are free, trips are more spread out but no as long (and hence more circular).

5.3 Potential mobility

The potential mobility of people has been analyzed through the concept and measure of daily potential path area. This is the area an individual potentially can reach according to their activity schedule and routine activities. It is the underlying activities (i.e. whether or not activities are *fixed* or *flexible*) that govern the restrictions or possibilities resulting in the potential path area. The analysis of the daily potential path area is dependent on the road network and how it has been modelled. In this case, many assumptions regarding the attributes of the network have been made due to lack of information. Furthermore, due to the lack of computational power, many daily potential path areas have been excluded from the analysis. All these remarks make it necessary to be cautious of any conclusions drawn. An analysis of variance (ANOVA) has been applied to the results to asses if gender and day of week influence the daily potential path area. A summary of the ANOVA results from the analyses and their significance follows in table 5.3 (see Appendix F for a full summary of the ANOVA results):

*Table 5.3 ANOVA results of statistical significance of DPPA.**

	Dependent variables	
Independent variables	AREA	TOTAL KM
GENDER	No	No
DAY OF WEEK	No	No

** Cells indicate whether the means of the dependent variables were statistically significant at the 95 % or better confidence level.*

The aim of the research regarding the potential mobility was to answer questions whether or not gender and/or day of week influence the daily potential path area. The results leave no doubt to what conclusions that can be drawn:

1) You can not explain any differences in DPPA by gender (i.e. gender does not influence the area or total kilometre of the DPPA);
2) You can not explain any difference in DPPA by day of week (i.e. day of week does not influence the area or total kilometre of the DPPA).

The analysis of potential mobility needs to be extended further to include more variables. More detailed data and of better quality also needs to be included to assure that results and conclusion can be reliable. One thing to remember is that potential mobility is this research only "scrape at the surface" of its use in mobility research. Potential mobility is often studied in the context of accessibility e.g. how different groups in society has access to different kinds of opportunities e.g. work, primary care etc. Knowing the potential mobility of people, the activities they could potentially participate in, and knowing how the metropolitan context look like (e.g. public transport etc.) could have large implications in how planning policies are formed and decided upon. This kind of research would aspire to find out how potential mobility looks like for different groups in the society, how different planning scenarios could affect their routine activities, and how this in turn would affect their mobility pattern and accessibility to/usage of different activities. The potential mobility could be a link to better understand the effects of growth and urban sprawl of cities and metropolitan areas.

5.4 Future research

Mobility issues in metropolitan regions all over the world are always a current subject. It could be put in the context of accessibility, environment problems as well as issues of transport planning. All of these issues are related to each other and of importance. The results and conclusions presented above could be developed further into more specific research questions as mentioned above. Furthermore, a main interest would also be to include a considerable larger sample and from a much more heterogeneous data pool. It would also be of interest to test more variables to see if there are other determining factors of activity-space than day of week and work status. Considering the methodology, the SDE proved to be a good statistical measure of activity-space, more so than standard distance which lacks the influence of skewness in the data. Since the SDE is a statistical measure calculated in abstract space, no real world attributes are considered. However, results derived from SDE could possibly point out the right direction for future research. Mobility research adapting an activity-based approach (more or less all studies nowadays) has also started to include ICT (information and communication technologies) and how these impacts the activities people undertake in their daily life. Since many of these activities directly or indirectly replace and/or supplement other activities (e.g. shopping online, studying online) and thus might alter the time-space trajectories of individuals (e.g. instead of going to the university a student have the choice to stay at home or somewhere else and participate in classes online and thus alter a trajectory that might've taken place), ICT is sure enough a component to include in future mobility studies. Another example of future research, which has been touched upon in this study, is potential mobility. Research concerning potential mobility is a very interesting subject. It has only been briefly introduced in this study, but could, and should, be developed further and used in accessibility context as well as other domains. An example could be studying children and their spatial choice to and from school (this is an accessibility research put in another type of context). The implementation of mobility research in a GIS has given the opportunity to explore the potential mobility through tailor made models using already available geoprocessing tools. This is an area where further development and exploration should be done regarding potential mobility and its implications. Putting a "potential" in front of mobility does indeed promise exciting times.

REFERENCES

André, M. and Hammarstöm, U. (2000) ”Driving Speed in Europé for Pollutants Emissions Estimation”, Transportation Research Part D 5, pp. 321-335.

Bachi, R. (1963) “Standard Distance Measures and Related Methods for Spatial Analysis” in LeBeau, J. L. (1987) “The Methods and Measures of Centrography and the Spatial Dynamics of Rape”, Journal of Quantitative Criminology, Vol:3, pp. 125-141.

Banister, D. (2008) “The Sustainable Mobility Paradigm”, Transport Policy, Vol: 15, pp. 73-80.

Buliung, R. and Kanaroglou, P. S. (2006) “A GIS Toolkit for Exploring Geographies of Household Activity/Travel Behaviour”, Journal of Transport Geography, Vol: 14, pp. 35-51.

Cayer-Barrioz, E. (2004) “La Mobilite Quotidienne des Familles du Moyen Grèsivaudan”, Université Joseph Fourier, Institut de Géographie Alpine.

Casas, I. (2007) “Social Exclusion and the Disabled: An Accessibility Approach”, The Professional Geographer, Vol: 59:4, pp. 463-477.

Dorothy, S. T. (2006) “Should We Abandon Activity Type Analysis? Redefining Activities by Their Salient Attributes”, Transportation, Vol: 33, pp. 517-536

Frihida, A., Marceau, D. and Thériault, M. (2002) “Spatio-Temporal Object-Oriented Data Model for Disaggregate Travel Behaviour”, Transactions in GIS, Vol: 6:3, pp. 277-294.

Golledge , R. G. and Stimson, R. J. (1997) “Spatial Behaviour”, The Guilford Press, New York / London in Schönfelder, S. and Axhausen, K. W. (2002) “Measuring the Size and Structure of Human Activity Spaces – The Longitudinal Perspective”, Arbeitsbericht Verkehrs- und Raumplanung 135.

Kim, H-M. and Kwan, M-P. (2003) “Space-time Accessibility Measures: A Geocomputational Algorithm with a Focus on the Feasible Opportunity Set and Possible Activity Duration”, Journal of Geographical Systems, Vol: 5:71, pp. 71-91.

Kwan, M-P. (2004) “GIS Methods in Time-Geographic Research: Geocomputation and Geovisualization of Human Activity Pattern”, Geografiska Annaler, Vol: 86B:4, pp. 267-280.

LeBeau, J. L. (1987) “The Methods and Measures of Centrography and the Spatial Dynamics of Rape”, Journal of Quantitative Criminology, Vol:3, pp. 125-141.

Lefever, D. W. (1926) “Measuring Geographic Concentration by Means of the Standard Deviational Ellipse”, The American Journal of Sociology, Vol: 32:1, pp. 88-94.

Lee, J. and Wong, W-S (2000) “GIS and Statistical Analysis with ArcView”, New York John Wiley & Sons, US.

Lenntorp, B. (1999) “Time-Geography - At the End of Its Beginning”, GeoJournal, Vol:48, pp. 155-158.

Lenntorp, B. (2004) “Path, Prism, Project, Pocket and Population: An Introduction”, Geografiska Annaler, Vol: 86B:4, pp. 223- 226.

McNally, M. G. (2000) “The Activity-Based Approach”, Institute of Transportation Studies and Department of Civil and Environmental Engineering, University of California, Irvine, California, USA.

Miller, H. J. (2001) “What About People in Geographical Information Science?”, Department of Geography, University of Utah, USA

Miller, H. J. (2004) “Activities in Space and Time”, in Stopher, P., Button, K., Haynes, K. and Hensher, D. (eds.) Handbook of Transport 5: Transport Geography and Spatial Systems, Pergamon/Elsevier Science.

Neutens, T., Witlox, F. and Demaeyer, P. (2007) “Individual Accessibility and Travel Possibilities: A Literature Review on Time Geography”, Ejtir, Vol: 4, pp. 335-353

Newsome, T., Walcott, W. A. and Smith, P. (1998) “Urban Activity Spaces: Illustrations and Applications of a Conceptual Model for Integrating the Time and Space Dimensions”, Transportation, Vol: 25, pp. 357-377.

Novák, J. and Sýkora, L. (2007) “Metropolitan Processes in Post-Communist States”, Geografiska Annaler, Vol: 89B:2, pp. 147-167.

Reneland, M. (2002) “GIS Metod för Analys av Tillgänglighet med bil, buss, cykel och gång” Chalmers Tekniska Högskola, Göteborg.

Schönfelder, S. and Axhausen, K. W. (2002) “Measuring the Size and Structure of Human Activity Spaces – The Longitudinal Perspective”, Arbeitsbericht Verkehrs- und Raumplanung 135.

Shaw, S-L. and Wang, D. (2000) “Handling Disaggregate Spatio-Temporal Travel Data in GIS”, GeoInformatica, Vol: 4:2, pp. 161-178.

Sherman, J. E., Spencer, J., Preisser, J., Gesler, W. M. and Arcury, T. A. (2005) “A Suite of Methods for Representing Activity Space in a Healthcare Accessibility Study”, International Journal of Health Geographics, Vol: 4:24.

Shoval, N. and Isaacson, M. (2007) “Sequence Alignment as a Method for Human Activity Analysis in Space and Time”, Annals of the Association of American Geographers, Vol: 97:2, pp. 282-297.

Thériault, M., Claramunt, C. and Villeneuve, P. Y. (1999) “A Spatio-Temporal Taxonomy for the Representation of Spatial Set Behaviours”, Lecture Notes in Computer Science 1678, pp. 1-18.

Turner, T. and Niemeier, D. (1997) “Travel to Work and Household Responsibility: New Evidence”, Transportation, Vol: 24, pp. 397-419.

Vandermissen, M-H. (2006) “Évolution Récente de la Mobilité à Québec : Quén est-il des Différences selon le Genre ? “, Département de gégraphie et Centre de recherché en aménagement et developpement, Université Laval, Québec (QC), Canada

Weber, J. (2003) “Individual Accessibility and Distance from Major Employment Centres: An Examination using Space-Time Measures”, Journal of Geographical Systems, Vol: 5, pp. 51-70.

Weber, J. and Kwan, M-P. (2003) “Evaluating the Effects of Geographic Contexts on Individual Accessibility: A Multilevel Approach”, Urban Geography, Vol: 24, pp. 647-671.

Yu, H. (2006) “Spatio-Temporal GIS Design for Exploring Interactions of Human Activities”, Cartography and Geographic Information Science, Vol: 33:1, pp. 3-19.

Yu, H and Shaw, S-L. (2004) “Representing and Visualizing Travel Diary Data: A Spatio-Temporal GIS Approach”, 2004 ESRI International User Conference, San Diego, CA.

Yuill, R. S. (1971) “The Standard Deviational Ellipse; A Updated Tool for Spatial Description”, Geografiska Annaler, Vol: 53:1, pp. 28-39.

Internet references

Statistics Canada (2001) “Geographic Units: Urban Areas”, http://www12.statcan.ca/english/census01/Products/Reference/dict/geo049.htm, 2008-04-22

University of Regina (2007) “Appendik K, The F-distribution”, uregina.ca/~gingrich/f.pdf

WolframMathWorld (1999-2008) “F-distribution”, http://mathworld.wolfram.com/F-Distribution.html

APPENDIX A: SOCIO-ECONOMIC CHARACTERISTICS OF HOUSEHOLDS

Households (HH) with:	Number of:
Males	17 (17 HH with male and female)
Females	22 (5 HH with females only)
Two-earners	16 (all HH with male and female)
One-earner	6 (5 HH with female only; 1 HH with male and female)
Children	21 (1 HH with 5 children; 7 HH with 3 children; 12 HH with 2 children; 1 HH with 1 child)
No children	1
Cars	22 (1 HH with 3 cars; 20 HH with 2 cars; 1 HH with 1 car)
No cars	0

HH with children in:	
Daycare	1
Primary school	10
Secondary school	1
Primand AND secondary school	7
No answer	2

Age bracket:	Individual characteristics (39 individuals in total):
30-35	2 (1 male; 1 female)
35-40	6 (2 males; 4 females)
40-45	28 (13 males; 15 females)
45-50	3 (1 male; 2 females)

Employment status:	
Full-time	26 (17 males; 9 females)
Part-time	12 (0 males; 12 females)
No employment	1 (0 males; 1 female)

APPENDIX B: ACTIVITY CODES

1. Physiological needs
    - 11. Sleep
        - 111. Sleep
    - 12. Personal care
        - 121. Personal hygiene
        - 122. Dress, undress, prepare
        - 123. Personal care outside home
        - 124. Personal care at home
    - 13. Medical care
        - 131. Medical care at home by yourself
        - 132. Medical care outside home
        - 133. Personal medical care received at home
    - 14. Meals
        - 141. Meals at home by yourself or with a member of the household
        - 142. Meals at work by yourself
        - 143. Meals outside by yourself or with a member of the household
        - 144. Meals at home with friends, neighbours etc except household members
        - 145. Meals at work with colleagues, friends etc
        - 146. Meals outside with friends, neighbours etc except household members
        - 150. Other private activities
        - 151. Other private needs (ex. sex)

2. Professional work and education
    - 21. Professional work
        - 211. Professional work except at home
        - 212. Professional work at home
        - 213. Travel during work
        - 214. Other work related to farmers
    - 22. Other work
        - 221. Participation in a professional activity as a member of the household
        - 222. Other work
    - 23. Non work related activities at work
        - 231. Coffee break, celebrations, other
        - 232. Strikes
        - 233. Various breakdowns
        - 234. Meetings and union activities
    - 24. Searching for employment
        - 241. Searching for employment
    - 25. Professional training
        - 251. Professional training
        - 252. Other activities related to professional training
    - 26. Studies
        - 261. Courses
        - 262. Study duties
        - 263. Time between studies
        - 264. Internship
    - 27. Other training or studies
        - 271. Personal education
        - 272. Other training

3. Household work

- 31. Kitchen
  - 310. Kitchen work - work for associations
  - 311. Preparation and cooking
  - 312. Washing dishes
  - 313. Make the table
  - 314. Baking etc
  - 319. Cooking for another household
- 32. Household
  - 320. Household work - work for associations
  - 321. Washing, cleaning etc
  - 322. Shopping arrangements
  - 329. Household work for another household
- 33. Clothing and house textile
  - 330. Washing, ironing etc
  - 331. Washing textile
  - 332. Ironing
  - 333. Sewing, knitting etc less than ¼ hour
  - 334. Sewing, knitting etc more than ¼ hour
  - 335. Tidying the clothes, preparing your bag
  - 336. Washing, ironing etc for another household
- 34. Other work
  - 340. Other work - work for associations
  - 341. Maintenance of heating and water
  - 342. Make your account
  - 343. Other household related work
  - 344. Moving – non professional
  - 349. Other work for another household
- 35. Purchase of goods
  - 350. Purchase - work for associations
  - 351. Purchase of goods for consummation, shopping
  - 352. Purchase of goods for workshop
  - 353. Purchase of goods for another household
- 36. Administrative services
  - 360. Administrative service - work for associations
  - 361. Use of administrative services, bank services etc
  - 362. Administrative services for another household
- 37. Semi spare time
  - 370. Semi spare time work (gardening, DIY) - work for associations
  - 371. Artistic creations
  - 372. Work on your car
  - 373. DIY
  - 374. Gardening
  - 375. Take care of pets at home
  - 376. Take care of pets outside of home
  - 377. Other household activities
  - 378. Leisure activities for another household

4. Care of other persons

- 41. Care of children
    - 410. Care of children - work for associations
    - 411. Care of children except medical care
    - 412. Medical care of children outside of home
    - 413. Medical care of children at home
    - 414. Other
    - 419. Care of other household children
- 42. Games and instruction for children
    - 420. Games and instruction - work for associations
    - 421. Supervision of homework
    - 422. Conversation with children
    - 423. Games and sports inside
    - 424. Games and sports outside
    - 425. Games and sports for other household children
- 43. Care of adults and medical care
    - 430. Care of adults - work for associations
    - 431. Household help or medical care for adults
    - 432. Care of other household adults

5. Social activities

- 51. Receptions and outings
    - 510. Associated receptions and outings
    - 511. Visits to friends, family etc
    - 512. Receptions of friends, family etc
    - 513. Other outings
- 52. Conversations and other contacts
    - 520. Associated conversations
    - 521. Conversations
    - 522. Private telecommunication
    - 523. Private mail communications
    - 524. Other
    - 529. Voluntary contacts
- 53. Civil, religious and funeral ceremonies
    - 531. Religious practice
    - 532. Cemetery
    - 533. Civil ceremonies
- 54. Civic participation and aid
    - 541. Political activities, voting etc
    - 542. Other associated activities
    - 543. Other aid activities

6. Leisure

- 61. Sport
  - 610. Activities associated with a sport club
  - 611. Physical activities at home
  - 612. Sport activities
- 62. Walk and outdoor activities
  - 621. Activities associated with a club
  - 622. Walks in the garden
  - 623. Fishing and hunting
  - 624. Picking fruits, berries, mushrooms etc
  - 625. Beach, camping activities
- 63. Media
  - 631. Reading SAI
  - 632. Reading books
  - 633. Reading magazines
  - 634. Watching TV
  - 635. Watching video
  - 636. Listening to radio
  - 637. Listening to music
- 64. Thinking, relaxing, doing nothing
  - 641. Thinking, relaxing, doing nothing less than 30 minutes
- 65. Audience at an event
  - 651. Audience at a sport event
  - 652. Audience at other events
  - 653. Cinema
  - 654. Museum, expo etc
- 66. Spending time
  - 661. Practice instrument, theatre, dancing etc
  - 662. Video games, computer games, flipper outside of home
  - 665. Make movies, take photos etc
  - 666. Video games, computer games at home
  - 667. Games
  - 668. Leisure

7. Other

- 710. Other activities not covered here

8. Trips

- 810. Trip goals
- 811. Trips home to work
- 812. Other trips
- 813. Trips related to children
- 819. Trip for other households

9. Time to fill in the travel dairy data

- 911. Time to fill in the travel dairy data

APPENDIX C: NON WEIGHTED ANOVA ANALYSES OF THE STANDARD DEVIATIONAL ELLIPSE

AREA (km²) according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1107,590	1	1107,590	0,004	0,952
Within groups	37298410,490	125	298387,284		
Total	37299518,080	126			

AREA (km²) according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1740133,992	3	580044,664	2,006	0,117
Within groups	35559384,088	123	289100,684		
Total	37299518,080	126			

AREA (km²) according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	59668,326	1	59668,326	0,200	0,655
Within groups	37239849,8	125	297918,798		
Total	37299518,1	126			

FULLNESS according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,000	1	0,000	0,000	0,988
Within groups	3,777	125	0,030		
Total	3,777	126			

FULLNESS according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,185	3	0,062	2,114	0,102
Within groups	3,591	123	0,029		
Total	3,777	126			

FULLNESS according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,187	1	0,187	6,495	0,012
Within groups	3,590	125	2,872E-02		
Total	3,777	126			

APPENDIX D: WEIGHTED ANOVA ANALYSES OF THE STANDARD DEVIATIONAL ELLIPSE

AREA (km²) according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1123,083	1	1123,083	0,005	0,946
Within groups	30769570,806	125	246156,566		
Total	30770693,890	126			

AREA (km²) according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	1409497,126	3	469832,375	1,968	0,122
Within groups	29361196,764	123	238708,917		
Total	30770693,890	126			

AREA (km²) according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	40036,376	1	40036,376	0,163	0,687
Within groups	30730657,5	125	245845,260		
Total	30770693,9	126			

FULLNESS according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,004	1	0,004	0,137	0,712
Within groups	3,828	125	0,031		
Total	3,832	126			

FULLNESS according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,285	3	0,095	3,298	0,023
Within groups	3,547	123	0,029		
Total	3,832	126			

FULLNESS according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	0,230	1	0,230	7,977	0,006
Within groups	3,602	125	2,882E-02		
Total	3,832	126			

APPENDIX E: ANOVA ANALYSES OF THE STANDARD DISTANCE

NON-WEIGHTED

STANDARD DISTANCE according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	11029942,256	1	11029942,256	0,138	0,711
Within groups	11824997684,504	148	9898633,003		
Total	11836027626,759	149			

STANDARD DISTANCE according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	273424769,838	3	91141589,946	1,151	0,331
Within groups	11562602856,921	146	79195909,979		
Total	11836027626,795	149			

STANDARD DISTANCE according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	23946103,3	1	23946103,3	0,296	0,587
Within groups	1,196E+10	148	80786641,4		
Total	1,198E+10	149			

WEIGHTED

STANDARD DISTANCE according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	5951253,025	1	5951253,025	0,084	0,773
Within groups	10523437285,530	148	71104305,983		
Total	10529388538,555	149			

STANDARD DISTANCE according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	290430754,460	3	96810251,487	1,380	0,251
Within groups	10238957784,095	146	70129847,836		
Total	10529388538,555	149			

STANDARD DISTANCE according to WORK STATUS

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	164405500	1	164405500	2,059	0,153
Within groups	1,82E+10	148	79837591,4		
Total	1,198E+10	149			

APPENDIX F: ANOVA ANALYSES OF THE DAILY POTENTIAL PATH AREA

AREA (km²) according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	2541,351	1	2541,351	0,268	0,606
Within groups	1070908,435	113	9477,066		
Total	1073449,786	114			

AREA (km²) according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	51293,348	3	17097,783	1,857	0,141
Within groups	1022156,438	111	9208,617		
Total	1073449,786	114			

TOTAL KM according to GENDER

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	72483,337	1	72483,337	0,451	0,503
Within groups	18147960,9	113	160601,424		
Total	18220444,2	114			

TOTAL KM according to DAY

	Sum of squares	DF	Mean Square	F-ratio	P-value
Between groups	688817,308	3	229605,769	1,454	0,231
Within groups	17531626,9	111	157942,585		
Total	18220444,2	114			

Series from Lund University's Geographical Department

Master Thesis in Geographical Information Science (LUMA-GIS)

1. *Anthony Lawther:* The application of GIS-based binary logistic regression for slope failure susceptibility mapping in the Western Grampian Mountains, Scotland. (2008).
2. *Rickard Hansen:* Daily mobility in Grenoble Metropolitan Region, France. Applied GIS methods in time geographical research. (2008).