MASTER

Shopping in an Australian mall
modeling pedestrian behavior in retail areas

Peeters, F.A.C.M.

Award date:
2008

Disclaimer
This document contains a student thesis (bachelor's or master's), as authored by a student at Eindhoven University of Technology. Student theses are made available in the TU/e repository upon obtaining the required degree. The grade received is not published on the document as presented in the repository. The required complexity or quality of research of student theses may vary by program, and the required minimum study period may vary in duration.

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
Shopping in an Australian mall

Modeling pedestrian behavior in retail areas

F.A.C.M. Peeters • July 2008
Eindhoven, University of Technology

A model to simulate individual route choice behavior of pedestrians in shopping malls.
Colofon

F.A.C.M. Peeters
Graduate student
Urban Design and Planning

Supervisors:
Dr. A.L.W. Borgers
Dr. ir. A.D.A.M. Kemperman
Prof. dr. H.J.P. Timmermans


This thesis is part of the R&D certificate program of the Master Design Decision and Support Systems (DDS).

Eindhoven University of Technology, the Netherlands
Department of Architecture, Building and Planning

August 2008
Preface

I want to take this opportunity to thank ir. A.W.J. Borgers and dr.ir. A.D.A.M. Kemperman of the Eindhoven University of Technology for supporting me during my graduation process and for providing me with essential information involving all the topics in this study. Without their help I would not have been able to finish the project in the way I did. Of course I want to thank R. G. V. Baker from the University of New England (Australia) for putting the data at our disposal and providing the necessary information about the shopping mall. The data collected in Armidale CBD made this research possible in the first place. Furthermore, I want to thank P.J.H.J. van der Waerden for the help with the computer software called TransCAD. It gave me the possibility to perform the necessary analyses and visualizations.

Finally, I would like to wish you a pleasant time reading this report.

Eindhoven, the 20 of August 2008.

F.A.C.M. Peeters
Summary

The way people move through shopping areas has important implications for architects, investors, retailers and government. Therefore, pedestrian behavior is often a motive for research. Most researchers focus either on behavior in relation to pedestrian environment or behavior in relation to retail characteristics. Planning pedestrian environments requires assumptions about how pedestrians will respond to characteristics of the environment. But, planning retail areas require also insights in how pedestrians respond to characteristics of shopping malls and their tenant mix. This research will look at both environmental aspects and retail aspects of pedestrian behavior.

At the Eindhoven University of Technology a model was developed and tested for this type of pedestrian behavior. Judith van Wijk (2003)\(^1\) used this model to predict pedestrian behavior in the city centre of Eindhoven and several years later (2005) the same model was tested on the city centre of Maastricht (Deckers 2005)\(^2\). In both cases the model was able to re-predict the observed behavior, although it was not exact. Therefore, it is interesting to test the validity of this model to predict pedestrian behavior in a foreign case.

A literature review provided insights in two main aspects of pedestrian behavior: pedestrian environment and tenant mix. Based on findings in the literature, four hypotheses were formulated. Next, the shopping area subject to this study was analyzed to acquire insights in this particular case. Subsequently, the collected data of 1995 (provided by the University of New England, Armidale) was used to analyze observed behavior. Here, the hypotheses were evaluated. Finally, the model was applied to two situations: the mall in 1995 and the mall in 2008. The model is used to re-predict observed behavior of 1995 and simulate the behavior of 2008.

The data for this study was collected in the main shopping center of Armidale, New South Wales (Australia). Eleven students of the university of New England (Australia) were instructed to follow pedestrians entering the shopping mall unobtrusively, draw their route through the shopping area on a map, and denote each shop entered. The observation of a pedestrian finished when the pedestrian returned to his/her car. Pedestrians were observed on 11, 14, 16 and 18 November 1995. In total 148 pedestrians were followed. In favor of the descriptive analysis, 145 were useful. The routes of only 99 respondents were used for the model.

The value of this data is of great importance for testing the model on this particular case. Whereas in previous studies people were asked to redraw their shopping routes and in this case people were followed. It is likely to get a more reliable result of the observed behavior and the descriptive analysis. But the great disadvantage of the available data is the low number of observed respondents. Especially for the use of the model (simulation) it is both a small research area and a low number of observed routes. Despite the low number of observed pedestrians, the collected data provided important information about pedestrian behavior in the shopping mall of Armidale.

Two characteristics of pedestrian movement are of vital importance when looking at the observed behavior in this research. First, the phenomenon of walking the shortest route possible clarifies the observed behavior. Especially the facet describing the tendency of pedestrians to stay close to their starting point can be used to explain the outcomes of the descriptive analysis. Secondly, the first visited branch provides interesting results. The Department store (Kmart) is not in favor when looking at the distribution of visited branches of all respondents. But when looking at the first visited branch, the Department store plays a bigger role. And, most people who visited this store, parked their car nearby. A lot of shops

---

decrease in their portion of visited branch when looking at the first visit. Combining this outcome with the phenomenon of 'nearby parking', it is likely to assume that this department store functions as a key tenant in the shopping mall. But there are more 'candidates' for the role of key tenant. In the Food branch a similar conclusion can be drawn for the supermarket Woolworths.

The most visited branch is Food, Followed by Remain (services). Analyzing the first visited branches shows interesting differences. On general, the branch Fashion comes in third place of most visited branches, but people certainly do not visit this branch firstly. They prefer to visit the branches Food and Remain (services) first.

In the descriptive analysis, the hypotheses were evaluated with the available data. Two out of four hypotheses can be qualified as true, one needs to be rejected, and one can not be evaluated with the available data. Further research is necessary to evaluate these hypotheses more accurately.

In favor of the modeling technique, the shopping mall is translated into a network of links. These links represent the street segments and choice alternatives a pedestrian has when walking around. The characteristics of the mall (pedestrian environment and tenant mix) were then translated into a series of variables. These variables are based upon recent studies at the Eindhoven University of Technology (Deckers 2005; van Wijk 2003). They can be categorized into five groups: distance, route history, length of sight, tenant mix and accessibility, and physical characteristics. The multinomial logit model is used to estimate the required parameters of the defined variables.

In order to apply the model developed at the Eindhoven University of Technology a couple of modifications were needed. Some variables were modified in order to match the situation of the shopping mall of Armidale. However, new variables were added representing the different (sub)areas of the study area as defined earlier in this study. This set of variables determines whether a pedestrian has a preference for a certain area when parked at one of the three car parks. The variables have been estimated in three phases. In each phase variables are modified or added, started with the original set of variables from recent studies (Deckers 2005; van Wijk 2003). Doing this, insights in the effect of the variables and their parameters have been acquired. It turned out that modifying and adding variables was useful to improve the performance of the model (rho² increasing from 0.29 to 0.31).

Despite the fact that the data set was relative small, the outcomes of the multinomial logit model are satisfactory. A interesting set of variables is defined which helped to predict pedestrian behavior. The process of estimating the parameters resulted in a defined model which was used to simulate pedestrian behavior in the shopping mall of Armidale.

Monte Carlo simulation is used to simulate pedestrian behavior in the shopping mall of Armidale. The model with modified and new variables was capable of re-predicting observed pedestrian behavior of 1995. The situation of 2008 was a challenge to cope with because the shopping mall has changed a lot during the past 13 years. However, the model is applied to this new situation as best as possible. The model did not produce link loadings that are likely to represent counted numbers of pedestrians. Therefore, the model was modified to try to solve the encountered problems. Firstly, some variables were adjusted and parameters re-estimated and secondly, the network of the 2008 situation was adjusted. These modifications resulted in more likely link loadings. But still, the results are questionable. As a result, the simulation of 1995 was satisfactorily but some questions related to the simulation of the situation of 2008 are still unanswered.

Although the differences between this case and previous ones are relative big, the results of the model are in line with previous studies. Thus it can be concluded that the model is applicable in different (foreign) cases, although fine-tuning should be considered. The modified and added variables were useful to model pedestrian behavior. Thus further development, which has been done in this study, turned out to be valuable for this case.

# Table of contents

Preface ................................................................................................................. 2  
Summary .............................................................................................................. 3  
Table of contents ................................................................................................. 5  

1. Introduction ........................................................................................................ 9  
1.1 Background and motives .................................................................................. 11  
1.2 Objective and problem definition .................................................................... 12  
1.3 Research method .............................................................................................. 13  
1.5 Case description ............................................................................................... 15  
1.5 Report structure ............................................................................................... 17  

2. Literature review ................................................................................................. 19  
2.1 Types of shopping malls .................................................................................... 21  
2.1.2 Types of shoppers ......................................................................................... 23  
2.1.3 Shortest route possible .................................................................................. 24  
2.1.4 Walking patterns ............................................................................................ 26  
2.1.5 Conclusion ..................................................................................................... 28  
2.1 Pedestrian environment ...................................................................................... 21  
2.2 Tenant mix ......................................................................................................... 30  
2.2.1 Branches ...................................................................................................... 30  
2.2.2 Tenant types .................................................................................................. 31  
2.2.3 Allocation principles ...................................................................................... 33  
2.2.4 Conclusion ..................................................................................................... 35  
2.3 Modeling techniques .......................................................................................... 38  
2.3.1 Detailed spatial level ...................................................................................... 38  
2.3.2 Higher spatial level ......................................................................................... 40  
2.3.3 Route choice behavior model ......................................................................... 40  
2.3.4 Conclusion ..................................................................................................... 41  
2.4 Conclusion ......................................................................................................... 42  

3. Shopping mall Armidale ...................................................................................... 43  
3.1 Situation ............................................................................................................ 45  
3.2 Shopping mall Beardy Street ............................................................................. 47  
3.2.1 Physical characteristics ............................................................................... 47  
3.2.2 Retail characteristics ...................................................................................... 53
Appendices ................................................................. 133
Appendix 1 'shop categorization'................................................................. 134
Appendix 2 'shop location' ..................................................................... 137
Appendix 3 'data collection' ..................................................................... 138
Appendix 4 'coding scheme' ................................................................... 139
Appendix 5 'observation 2008' ............................................................. 140
Table of contents
1. Introduction

The introduction will give an overview of this study. First, reasons to study pedestrian behavior in retail areas are given. Secondly, the objective and problem definition, the research method and a short description of the case study are described. At the end of this chapter, the organization of the report is provided.

Figure 1.1: The Queen Victoria building in Sydney, Australia
The building was built in 1898 to replace the original Sydney Markets. Later, it accommodated a concert hall, which eventually became the City Library. In 1984, it was completely refurbished as a shopping centre, with more than 200 shops.
1. Introduction
1.1 Background and motives

The way people move through public spaces has important implications for architects, investors, retailers and government. The need to understand the mechanism of choice has prompted microscale and laboratory-based research on exploratory spatial behavior within walking districts (Zacharias, 2001). Pedestrian behavior is often a motive for research. Most researchers focuses either on behavior in relation to pedestrian environment or behavior in relation to retail characteristics. Planning pedestrian environments requires assumptions about how pedestrians will respond to characteristics of the environment (Zacharias, 2001). But, planning retail areas requires also insights in how pedestrians respond to characteristics of shopping malls and their tenant mix. Only few studies discuss both aspects of retail areas. This research will look at both environmental aspects and retail aspects of pedestrian behavior.

Studies of shopping behavior have provided a number of useful findings; however most of this research is based upon face-to-face interviews, which is predicated upon the assumption that respondents can recall their shopping experiences. There is, however, an enormous amount of literature on human memory that is based on observation and proves the opposite (Brown, 1992). Therefore, a more reliable result could be accomplished. In comparison to other research, in this study we analyze what people do, not why they do so (Brown, 1992). Over the last decades spatial interaction and spatial choice models of varying degrees of sophistication have been used to describe consumer shopping behavior and predict the likely impact of (planned) retail change on such behavior. Models have been used for determining the optimal location of new stores or shopping centers, determining the optimal size of a new store at a given location, and examining the likely impacts, in terms of market shares or sales volumes, of retail planning proposals on existing shopping centers (Timmermans, Borgers and van der Waerden 1992).

At the Eindhoven University of Technology a model was developed and tested for this type of pedestrian behavior. Judith van Wijk (2003) used this model to predict pedestrian behavior in the city centre of Eindhoven and several years later (2005) the same model was tested on the city centre of Maastricht (Deckers 2005). In both cases the model was able to re-predict the observed behavior, although it was not exact. Therefore, it would be interesting to test the validity on a foreign case. The data for this study was collected in the main shopping center of Armidale, New South Wales (Australia). There are some differences and similarities between this case and the previous ones. First of all this case is in Australia, while the other were in the Netherlands (differs in both geographical and cultural aspects). Second, the cities of Eindhoven and Maastricht are bigger than the city of Armidale: in sequence 209,702, 119,033 and 21,660 inhabitants (Gemeente Eindhoven 2007; Gemeente Maastricht 2008; Armidale Dumaresq Council 2008). The case used in this research is also located in the centre of a city, even though the characteristics of this particular shopping centre correspond with peripheral Dutch shopping centers (See chapter 3: 'Shopping mall Armidale). Finally, the data in this research is collected by following people. In Eindhoven and Maastricht, the people were asked to recall their itinerary of the route they walked. In this research, the data received from the University of New England can be used for analyzing what people do, not why the do it.

Due to these differences this case is worthwhile to investigate.

The question then is; can the model be applied in an Australian shopping area?
1.2 Objective and problem definition

In order to predict effects of changing the existing structure of the shopping mall, insights in the behavior of pedestrians are necessary. The model developed at the Eindhoven University of Technology is not fully tested yet. As mentioned before, this case provides an interesting opportunity to test the model in a new type of shopping mall in another country. If the model performs well, we can generate results of pedestrian movement in new situations (scenarios). Insights can be gained in pedestrian behavior in retail areas, looking at aspects of both the (spatial) environment and the characteristics of the retail supply. Given the background and motives, the objective can be defined as follows:

The aim of this research is to develop (apply and test) a model to predict pedestrian behavior in an Australian retail area, and acquire insights in specific aspects of an Australian mall (looking at aspects of the pedestrian environment and tenant mix).

Given this aim of research and the background and motives the following research question can be formulated:

Is it possible to predict pedestrian behavior on a micro-level in an Australian case, based on aspects of the pedestrian environment and tenant mix, in order to describe consumer shopping behavior and predict the likely impact of (planned) retail change in the existing structure?

In order to answer this question, a research framework is defined in the next section and data is obtained from the University of New England, Armidale, and used to model pedestrian movement. First, hypotheses are formulated based on an evaluation of previous research. Next the shopping mall will be described to obtain characteristics of both pedestrian environment and retail aspects. Subsequently, descriptive analyses provide insights in pedestrian movement and therefore confirm or rebut these hypotheses in this particular case. Finally these insights will be used to draw up the model developed at the Eindhoven University of Technology and predict pedestrian behavior in the shopping mall of Armidale. Insights in effects of changes in the existing structure are generated by formulating scenarios.
1.3 Research method

Verschuren en Doorewaard (2007) advise to develop a research framework in order to structure a research. Figure 1.2 illustrates this framework. A science-based design is taken to investigate pedestrian behavior in retail areas. This science-based design is the entire body of intellectually thought, analytic, partly formal, and partly empirical knowledge for the design process (Simon 1996). The research framework is based upon this science-based approach. The blocks on the left hand side are the various sources of information for the research, with the top left blocks representing the existing intellectual thoughts and formal knowledge. These are used to form a theoretical framework. The bottom left blocks represent the case study which provided empirical data of pedestrian behavior in a shopping mall. The data used in this study were already collected during an empirical observation in 1995. The theoretical framework and the pedestrian behavior in practice are the results of the first phase. Next, the results are translated in both hypotheses and data (GIS) in order to analyze and diagnose. Finally these insights will help to model and predict pedestrian movement in the shopping mall in Armidale, Australia.
In order to answer the research question a research method is established. Figure 1.3 is a schematic representation of this method. This research starts with a literature review. Some hypotheses are formulated, found in reported research. The recent research done at Eindhoven University of Technology is discussed in order to evaluate the use of the model in different cases. Next, the shopping mall in Armidale is analyzed in respect to the two formulated aspects of pedestrian behavior (pedestrian environment and tenant mix). Next, the observed behavior is analyzed by a descriptive method. The data collected in 1995 will be used to test the formulated hypotheses. The results and conclusions will be summarized in the conclusion of chapter 4 ‘Observed behavior’. Finally, the model developed at Eindhoven University of Technology is used to predict pedestrian behavior in the shopping mall of Armidale. This all ends with a conclusion and recommendations. Here, the comparison with the results of earlier research is evaluated.

Figure 1.3: Research method
1.5 Case description

As mentioned before, the case study involves a shopping mall in the Central Business District (CBD) of Armidale, Australia (see figure 1.4). The data is collected in the retail area around Beardy Street, the oldest street in Armidale (S. Scott 2007) (see figure 1.5). Started as a street with a couple of local shops, the CBD has grown to a – partially open air, partially indoor – shopping mall. At the time of the data collection (1995), the mall had characteristics of a peripheral Dutch shopping mall. A retail area with sufficient parking space, shops in all retail branches and some leisure functions. Despite the historical development of Beardy Street, the shopping mall is a planned urban area. In contrast with most Dutch shopping areas, where an organic development took place.

The studied part of the CBD of Armidale has three parking lots, and three main shopping areas. For a more detailed description of the Armidale shopping mall, see chapter 3 ‘Shopping mall Armidale’. To each car park, a number of students were allocated. They observed pedestrians by following them around and writing down if the respondent entered shops. The observation of a pedestrian finished when the pedestrian returned to his/her car. All information regarding one observed pedestrian was drawn and noted on a sheet of paper. Furthermore, some characteristics (gender and age) of the pedestrian were collected. The data of this survey will be used in this research to obtain insights in pedestrian behavior in the Armidale mall, and to test the model developed in Eindhoven.

As mentioned before, this research will take both pedestrian environmental and retail characteristics into account. These two aspects will be summarized in chapter 3 ‘Shopping mall Armidale’. Before doing so, the literature review (chapter 2) will look at aspects of the pedestrian environment and retail characteristics (which will be brought back to one dominant aspect, namely tenant mix).

Anno 2008, the Armidale shopping mall has grown with several extensions of new shopping areas. At this moment, a new shopping area is added to the mall. It is an indoor mall with several important anchor stores (e.g. Big-W: a department store), owned by a world wide real estate investor known as "Centro". Besides, two big supermarkets (Woolworths and Coles) are re-located outside the research area. With these developments, there is a move away from a public space surrounded by shops to a private space surrounded by shops (a planned indoor shopping mall) (S. Scott 2007). Therefore, the mall which started as a shop on Beardy Street has developed to a shopping mall with American standards. However, this research will focus on the data collected in 1995 and therefore will use the physical characteristics of the mall at that time. Afterwards, the new situation will be used to try to simulate the new situation.
1. Introduction

Figure 1.4: City of Armidale; square represents shopping mall
(source: www.armidale.info; Edited by F. Peeters)

Figure 1.5: Shopping mall area subject to this research
1.5 Report structure

The structure of this report represents the different phases of this research: the introduction, the theoretical analysis phase, the case orientation phase, the descriptive analysis phase, the modeling phase, and the conclusions and recommendations (see figure 1.6 on the next page).

The first section describes several aspects of pedestrian behavior in retail areas and how to model these, all based on literature research. Both pedestrian environment and tenant mix of shopping malls (in general) are discussed. Next, the Armidale shopping mall will be analyzed to get insight in the retail and spatial characteristics of this specific mall. The third section provides descriptive analyses after the data collection and preparation has been described. Next, the used model is described and applied. A simulation of pedestrian behavior will take place. Finally, this report will end with a conclusion and some recommendations.
Introduction

1. Introduction

Literature
- Pedestrian behavior
  - Pedestrian environment
  - Hypotheses
- Modeling techniques
  - Hypothesizes

Shopping mall
- Situation
  - Shopping mall
  - Beaudy Street
- Physical characteristics
- Retail characteristics

Observed behavior
- Data collection
- Data preparation
- Descriptive analysis

The model
- The used model
  - Theory
  - Network
  - Variables
  - Data '95
  - Parameters
  - Model validation

Simulation
- Monte Carlo simulation
- Simulation '95
- Simulation '68

Conclusion
- Checking hypotheses
- Conclusion

Conclusion and recommendations

Figure 1.6: Report structure
2. Literature review

First, the relevant literature on pedestrian behavior in shopping areas is summarized. The summary is organized into two subsections; pedestrian behavior in the context of the (physical) environment and pedestrian behavior in relation to tenant mix (see figure 2.2). Next, attention will be given to models of pedestrian movement in general. The model used in this research will be described in detail and applied to the observed data in chapter 5 'The model'. This literature review is done to formulate some hypotheses which will be tested with the available data. Therefore, this chapter will end with a conclusion where hypotheses of pedestrian behavior are listed.

Figure 2.1: The dome of the Melbourne Central shopping centre in Melbourne, Australia
The Melbourne Central shopping centre is located in the heart of the city. A historical tower forms the focal point of the mall. The Coop's Shot tower was built in 1890. It was saved from demolition in 1973 and incorporated into an 84m high conical glass roof.
2. Literature review

Figure 2.2: Chapter structure
2.1 Pedestrian environment

People walk in predictable ways through the built environment. Planning these environments requires assumptions about how pedestrians will respond to characteristics of the environment as they consider their walking itineraries. As a consequence, most research interest in public environments focuses on behavior in relation to those characteristics. According to Zacharias (2001), relational models that place the pedestrian space within the network of spaces have proven useful in relating layout to the volume of activity. Earlier research at Eindhoven, University of technology emphasizes this statement (van Wijk 2003; Deckers 2005; and Smeets 2005).

In this paragraph this pedestrian environment will be discussed. What conditions of the environment influence the behavior of pedestrians. And what kind of behavior is most common in certain situations?

The pedestrian environment is split up in order to get insight in the different aspects. First, the environment itself and it participants are described: types of mails and types of shoppers. Next, the principle of economy of movement behavior (shortest route possible) will be defined. This paragraph will deal with two aspects: distance and choice behavior. And finally, the phenomenon of walking patterns is described. This section will end with a conclusion with relevant hypotheses in favor of the descriptive analysis further on.

2.1.1 Types of shopping malls

There are three basic location types of retail facilities: the isolated store, the unplanned business district and the planned shopping centre (Bruwer 1997). The first originated retail areas can be defined as isolated stores in the city which evolved to unplanned business districts. Most of current downtown shopping areas in the Netherlands are of this type. Looking at planned shopping malls, a distinction of three types can be made: the open air mall, the covered walkways mall and the closed shopping mall.

The open air mall is closest related to the retail areas which evolved along streets in the city centre. When the first planned open air malls were introduced, usually single level, they were elegantly landscaped and restrained in design. These planned public spaces were pedestrianised. A disadvantage of an open air mall is the influence of the weather conditions. In order to get maximum profit for the tenants, the climatic conditions should be ideal and may not influence the shopping duration (Keith, 1989).

Then the covered walkways were introduced and provided a sheltered area from shop to shop. These may be provided by setting back the shop frontages behind the main building face of upper storey’s or by some form of canopy. These covered walkways provided the pedestrians with shelter from rain and protected the goods against solar damage. Finally, a closed mall can be distinguished. As an indoor retail area where the public can enjoy comfortable environmental conditions. The shopping centre becomes a retreat where strolling, window shopping, enjoying refreshments and other leisure facilities become possible. This type of centre is a highly serviced and technically appointed complex, the design, planning and servicing of the mall being integral to the scheme. All of these malls range in size from a small specialist or neighborhood utility centre to a vast many-acre project. And there are many retail areas which can be defined as composite malls: a combination of these types of malls (Keith, 1989).
The closed mall is off course the most ideal situation to maximize the tenants revenue. By excluding all the possible negative conditions, like the weather, and therefore creating a comfortable environment, this type of mall is a retail area where people tend to stay the longest. Although, this does not mean that open air malls will not function as well as a closed mall. In areas where the weather conditions are nice throughout the year, an open mall provides the comfort of the sun. On the contrary, too much sun (and relating high temperatures) will result in an unpleasant shop environment. In short, it depends on the particular situation (N. K. Scott 1989). In closed malls, it is more and more about combining shopping with recreation; it is described with the term leisure. Project developers ensure a perfect and pleasant environment where people can stay all day in order to get the maximum revenue. The closed mall has the most exaggerated examples of leisure shopping throughout the world. Some even have rollercoaster’s inside the shopping mall to entertain the visitors (e.g. the Mall of America in Bloomington, Minnesota and the Times square shopping centre in Kuala Lumpur, Malaysia). These physical characteristics of a shopping mall affect the walking behavior of a pedestrian. Zacharias (2001) declares that it is reasonable to assume that aesthetic aspects of a shopping mall (visual environment) in some way have an impact on behavior, although he emphasizes that the known relationships remain at a fairly generalized level.

In 2004, Sander van Bodegraven described the relation between the design of a shopping mall and the emotions and behavior it provokes. He researched the approach and avoid behavior of respondents towards different design attributes. He discovered that the behavior is subject to many influences. These influences are both based upon the individual as upon the environment (even the weather). People differ in their approach and avoid behavior towards (different) design stimulus. There are too many attributes that influences the behavior and therefore the ideal shopping centre can not be predicted based upon a combination of design characteristics (Bodegraven 2004). Nevertheless, he defined some attributes that are (more or less) responsible for some kind of approach behavior. First, dark (warmer) colors attract more than lighter colors; second, wide streets (segments) attract more than smaller streets; the presence of art provokes approach behavior; and finally the presence of greenery attract people. The last mentioned attribute also comes forward in other
research done at the Eindhoven, University of Technology. Which design characteristics of retail areas contribute to a positive appreciation of public space, was the subject of this research. It emphasizes that greenery attracts people. The report concludes that greenery 'invites' to enter the public area, it gave an appreciation towards the design of retail areas (Berg, Mulders and Peeters 2006).

As a result, it is clear that types of shopping malls influences the pedestrian behavior. But based upon literature, it turns out to be very difficult to clarify which attributes are responsible for which behavior. Unfortunately there are no explicit rules of thumb known on this subject.

2.1.2 Types of shoppers

Off course, an important characteristic of pedestrian behavior is the pedestrian himself. Besides the general characteristic of pedestrians (e.g. gender and age), another distinction can be made: pedestrians in retail areas represent a particular type of pedestrian behavior. It is possible to determine a classification in types of shoppers.

There are three groups of shopping individuals: goal-directed shoppers, pure entertainment seekers and those who do both (Eastlick et al. 1998; Bellenger et al. 1977; Zacharias, 2001). Goal-directed shoppers (economic shoppers) have an itinerary already made up in their mind. Therefore, the shortest route will be chosen to accomplish their goal. Pure entertainment seekers (recreational shoppers) will have the most amount of impulse visits during their shopping trip. Their shopping route will be less explanatory. Finally, those who do both form the major part of the shopping individuals and their shopping behavior will possess both grounds of route choices (Brown 1992).

There are results in literature which emphasize this statement. Zacharias (2001) states that researchers generally agree that pure entertainment seekers constitute a small proportion of the visitors, whereas those engaging in multiple activities now constitute the majority. In a study of 1,200 individuals in six malls in the United States, shopping behavior was only a part of a larger set of intentions and activities. Visits to shopping areas without buying plans, together with visits to look at goods that might be purchased but only in the future, constituted 62 percent of all trips, whereas those visits with a definite buying intention made up the remainder (Bloch et al. 1991). These findings confirm the impulse behavior of many pedestrians discovered in previous studies (Cobb and Hoyer 1986).

Leung (2007) also claims a possible split in consuming behavior. It appears, considering the results of an efficiency index analysis, that there are economic shoppers (goal-directed) and non-economic shoppers (recreational) to distinguish. The economic shoppers are the largest group (60%). He also discovers a difference between Eindhoven and Maastricht (both Dutch cities), the shoppers in Maastricht seem to be a little bit more economic in their shopping behavior (Leung 2007).

Unfortunately, these conclusions of both researches are not comparable. Pure entertainment seekers will probably not be economic shoppers. What can be said is that probably most shoppers are economic in their behavior and engage in multiple activities.

Mulders (2008) performed a research in the field of choice behavior of entry points at an inner city shopping area. The research focused on the influences of several characteristics (the transfer facilities on one hand and the accessibility of the destinations in the shopping centre on the other), on the (combined) choice for a particular transfer facility and accompanying entry point. One aspect of his research was the type of shoppers and their preferences according to car parks. He discovered that goal directed shoppers have a greater preference for car parks in or near the city centre and a short distance between this car park and entry point, then recreational shoppers. These so-called 'run shoppers' will endeavor to
2. Literature review

be as close as possible to their goal in order to do some efficient shopping. In contrast, so-called ‘fun shoppers’ do not want to take the effort to find the best parking spot: they park their car at the most logical location considering their origin. They also accept a higher parking charge than ‘run shoppers’

2.1.3 Shortest route possible

The first interesting aspect of pedestrian behavior in the context of the direct environment is the phenomenon that people tend to take the shortest route possible. In order to get some facts around this subject, the aspect distance and the aspect choice movement is discussed.

Distance

Walking distances play an important role in pedestrian behavior. Therefore, the walking patterns in local retail areas have been studied by several researchers to determine acceptable walking distances. These distances that people are willing to walk to destinations for shops follow a regular pattern locally, even though average distances may vary considerably from city to city. Pushkarev and Zupan (1975) report several results on walking distances in different cities. The average walking distances in central London were more than 800 meters, in midtown New York City 524 meters and those in downtown Edmonton were only 265 meters. Zacharias (2001) establishes that local variations are not obviously related to age, sex or even mobility impairment.

According to Deckers (2005) pedestrians in Maastricht (a Dutch city) tend to stay close to their starting point. She does not give a direct reason for this behavior but one could conclude that this is because of people's tendency towards walking short distances. Hence, there were not any reasons to believe that the interesting stores were only located at these entry points. Moreover, on different entry points people stay in the direct surroundings of their starting point. This means that the point of entrance in a retail area is of high importance.

Walking distances of shoppers not only depends on the pedestrian environment. Tenant placement is an important aspect in this context. Stephen Brown (1992) states that both tenant placement and the science of space management is significant. But he also mentions the fact that this last aspect of walking distances is still very much in its infancy. Whereas the intra-centre location of outlets remains heavily reliant upon the ‘received wisdom’ of the shopping centre industry. This wisdom of space and retail management is not based upon scientific research and therefore it is only possible to summarize some ‘rules of thumb’. These rules of thumb involve mostly the tenant mix and types, while it seems that people’s behavior is more influenced by these aspects, rather than by the environment itself (Brown, 1992). This interesting enumeration of the rules of thumb is provided in section 2.3.3 ‘allocation principles’. Tenant placement can also be reviewed in the context of entry points (parking lots) and the location of certain shops. Van der Waerden, Borgers and Timmermans (1998) studied the relationship between the location of supermarkets and other stores and the locations of parking lots. They used a hierarchical logit model of parking lot and store choice behavior to gain insights into these effects. At the level of the supermarkets the estimated model performs very well. It is less accurate at the level of parking lots but still performs satisfactory.

For now, the only conclusion one could draw, based upon literature, is the fact that walking distances do play a significant role in pedestrian behavior. But there is no general description of what this distance aspect of pedestrian behavior would be. What can be said is that it mostly depends on the location, instead of age, gender, et cetera.
Choice movement
An interesting situation of taking the shortest route possible is the moment when pedestrians approach an intersection. Choice behavior at intersections will affect the efficiency of their (planned or unplanned) itinerary. In this context, choice behavior seems to have some general rules of thumb.

Recent research emphasizes the behavior of pedestrians to take the shortest route possible. Consider figure 2.7. An example is illustrated with a traditional four-path crossing, and a 90-degree angle on each arm of the intersection. When people come to this moment of choice, they approach generally on the right side of the path. The most economical choice is to turn right, unless they desire to go straight. When people have a destination that requires a left turn, they move to the left of the path before reaching the intersection and then turn left (most economical way to move). On the other hand, when approaching on the left, the most economical way is left unless they want to go straight. Since people tend to walk on the right, most pedestrians are on the right when they come to a choice point and consequently turn right (Bitgood en Dukes, 2006).

Melton (1935), Yoshioka (1942) and Weiss and Boutourline (1963) report a preponderance of right turning behavior in art museum galleries and exhibition halls in New York. In Melton’s (1935) results, 70 to 80% of the visitors turn right as they enter the gallery. An important aspect of this research is the fact that the entrance door was centered in the hall and the visitors had to choose to turn left or right and there were no objects in the middle to pull visitors towards the middle or give any direction. Specific information about whether visitors were on the left or right side of the path is not provided in this research. Yoshioka (1942) discovers varying turning percentages as he looks at a more complex setting than that of Melton (1935). He observed the right-turn bias of Melton for one exhibition hall (Hall of Man, New York) but refutes the right turning dominance for another (Hall of Medicine, New York). He explains the lack of right turning in the Hall of Medicine by the attraction of eye-catching exhibits on the left. The results at the Hall of Man are also arguable: exhibition displays were arranged in such a way, that they attracted people towards the right. Weiss & Boutourline (1963) concludes two interesting aspects of choice movement. Just like Melton, they report a right turning dominance in a museum setting. But they also observe a tendency of visitors to circulate in a counterclockwise direction, depending on the design of the exhibit and the design of the entire hall (Bitgood en Dukes 2006).

Despite the fact that Weiss & Boutourline (1963) did not give an explanation for this behavior pattern, again a right turn bias came forward (since circulating counterclockwise demands a right turn start). These researches show us that the reality is more complex if more aspects of the environment come along (salient object attraction).
Bitgood and Dukes (2006) put Taylor's (1986) research forward as an example of economy of movement behavior. At the Steinhart Aquarium in San Francisco, Taylor observes a predominately right hand turn of visitors at a 'T'-intersection at the beginning of the tour. Taylor also reports that visitors were reluctant to backtrack to see all of the exhibits. Bitgood and Dukes also interpreted behavior results of research by Deans, et al. (1987) as an application of economy of movement. In this case the visitors at the Reid Park Zoo were not observed but interviewed. They were asked to retrace their circulation route. Right turning and counterclockwise circulation were drawn the most. But more remarkable was the fact that people stuck to the main 'circle' path in the floor plan. Connecting paths with inner circles were rarely used. People tend to take the route with the fewest steps, according to Bitgood and Dukes (2006). Bitgood and Dukes seem to forget that this research is predicated upon the assumption that respondents can recall their itinerary. However, visitors may have drawn the main route because they attach significance to this part of their trip and 'forget' they also took some connecting paths.

Other reports rebut these findings on right turning behavior. Parsons and Loomis (1973), for example, reported that 60% did not turn right. This setting was also more complex than those studied by Melton. He attributes the opposite results to the attraction of "landmark exhibits". Besides, they found different pedestrian flow patterns when the museum was crowded. In this case it is likely that a path of least resistance is the most economical way to move, instead of the shortest path (Bitgood, 2006). Bitgood, Hines, et al. (1992) also underline the shading context of right turning hypotheses. They did not find any proof of visitors turning right. Several exhibitions were part of the research, and not one pointed out a certain pattern of right turning dominance. Although the circulation patterns of the visitors changed from one setting to another, there was also no strong tendency to circulate in a counterclockwise direction. Although, looking at the location where visitors remained the most, interesting results came forward. In three out of four exhibitions, visitors mostly remained on the left wall after they entered (respectively 70%, 60% and 56%). Bitgood, Hines, et al. (1992) attribute these results of direction of traffic flow to the architectural characteristics of the Anniston Museum of National History (where the exhibitions took place) and the layout of exhibit displays. The most important architectural characteristic was the left oriented entrance (along the left wall). In addition, it is important to note that there was only one entrance and exit (the same door). Other reports only emphasize the right turning dominance. Shettel (1976), for example reports the opposite as mentioned above. Seventy three percent of the visitors entered at the right side of an exhibition and most stayed on that side. One-side viewing is a common observation in museum exhibitions and is also explained by economy of movement, according to Bitgood (2006). Unfortunately, Shettel does not mention whether there was also a left door alternative. Therefore, these two findings are not entirely comparable.

2.1.4 Walking patterns

From a retail perspective, there is a need to describe the movement patterns and to relate them to the designed environment (Zacharias 2001). In the literature, there are different researches about this subject. They all conclude that people walk certain patterns but 'standard' walking patterns do not exist. Therefore, they do not describe walking patterns in detail but do make judgments on different aspects in this context. A couple of these conclusions on walking patterns are described here.
According to Zacharias (2001) investigations in environmental factors is the result of relative stability in these walking patterns. He claims that people do walk in certain patterns. There are three aspects that contribute to certain behavior of shoppers. First of all, shoppers experience a variety of ‘sensations’ related to comfort and stimulation: the direct environment makes it more or less comfortable to remain in the public space (sit or engage some activity). The type of sensations depend strongly upon the particular public environment, therefore every case is a different one. Next, the quantity of people and visual display play an important role for people to walk in certain patterns. Moderate crowding is both attractive and dissuasive and visual display is also not perceived indifferently by people. But there is another aspect responsible for the more or less unpredictable character of walking patterns. Shoppers make judgments about the places they intend to visit before they have arrived. They also make a series of decisions while navigating through the environment (Zacharias 2001).

Unfortunately their is no ‘guide’ with rules of thumb to define these walking patterns, as told by Zacharias (2003). There is a reason why. A walking pattern is the result of a series of choices based upon even more factors in the environment and the individual himself. These factors are both of an physical environment- and tenant mix-nature. In short, walking patterns are very complex phenomena if you want to know what is responsible for the chosen itineraries. On the other hand, defining what people do is in this case much easier than why people do certain things. In order get insight in these walking patterns two types models can be defined: relational- and metric models (these will be described in section 2.5 ‘modeling techniques’ of this chapter.

There is a lot of information available about how people tend to walk, but in detail it is still a mystery. For example, Smeets (2005) demonstrates that people do walk in patterns. The research took place in downtown Antwerpen (Belgium) and consisted of street segments, each with three zones. Two zones along the shops and one in the middle. People tended to stay in one zone because of street furniture which divided the street into these three zones. But, does this mean that in each case and each environment street furniture will guide people along certain zones? Probably not, several aspects such as street width, size and shape of furniture, type of street / city exert influence on walking patterns. There is simply not a general rule of thumb because each case is different.

The entry and exit points of a retail area are two of the most important aspects in generating circulation patterns. Davies and Bennison (1977) discover a major change in a patronage pattern at key tenants and local streets in Newcastle as a result of a subway opening. Even shoppers who visit the shopping mall on a regular basis will visit different parts of a retail area, depending on their entry and exit point on a particular visit (Zacharias 1997).
2.1.5 Conclusion

In order to get insight in the pedestrian environment, it is split up to get some insights in the relevant different aspects. First a short glance at the environment itself was given. Next, the users of this space and their differences were summarized. Then, an important characteristic (and one of the few researchers are sure about) of these shoppers is described: the economy of movement behavior. Finally, the phenomenon of walking patterns was described.

First the main conclusions are summarized. These conclusions will result in a couple of hypotheses found in the literature. Only hypothesizes that can be tested with the available data in this particular research are summarized.

There are three basic location types of retail facilities: the isolated store, the unplanned business district and the planned shopping centre (Bruwer 1997). Looking at these planned shopping malls, a distinction of three types can be made: the open air mall, the covered walkways mall and the closed shopping mall. The way a shopping mall is build influences the pedestrian behavior. But there are (too) many aspects both within the design and other environmental characteristics (even the weather that affect pedestrian behavior).

By research the required knowledge is gathered to understand the underlying mechanism that affect behavioral response. But, every built environment is different and emerges different choice movements and therefore it is not an easy job. Researches mention the tendency of shoppers to walk in certain patterns, but no reports prove this phenomenon in general. Therefore it turns out to be very difficult to clarify which attributes are responsible for what behavior. There is a lot of information available about how people tend to walk, but in detail it is still a mystery. This does not mean that there is nothing to be said on this subject. Preceding sections showed us that some characteristics of the pedestrian environment do clarify behavioral response.

Literature claims a possible split in consuming behavior. There are three groups of shopping individuals: goal-directed shoppers, pure entertainment seekers and those who do both (Eastlick et al. 1998; Bellenger et al. 1977; Zacharias, 2001). Goal-directed shoppers (economic shoppers) have an itinerary already made up in their mind. Pure entertainment seekers (recreational shoppers) will have the most amount of impulse visits during their shopping trip. Finally, those who do both form the major part of the shopping individuals and their shopping behavior will possess both grounds of route choices (Brown 1992). The shopping route of goal-directed shoppers is easier to understand. The other two are a bit more complex due to the many sensations of the environment these shoppers are affected by. In other words, the goal-directed shopper will not be easily distracted by impulses from the retail environment, in contrast to the other two types.

There is one interesting aspect related to these goal-directed shoppers. They tend to take the shortest route possible in order to be as efficient as possible. This is one of the few aspects of behavior that can be scientifically proven. Leung (2007) claims, considering an efficiency index analysis, that non-economic shoppers (recreational) are less efficient in their shopping routes and therefore not eager to take the shortest route possible. Mulders (2008) emphasizes this tendency of goal-directed shoppers to take the shortest route possible. In this case it is the shortest route form car park to entry point. In contrast, so-called ‘fun shoppers’ do not want to take the effort to find the best parking spot: they park their car at the most logical location considering their origin. They also accept a higher parking charge than ‘run shoppers’.

Once, the car is parked and the retail area is entered, shoppers tend to stay close to their entry point (Deckers, 2005). She does not give an specific explanation for this phenomenon, but it seems like the same reason as mentioned before: walking short distances. Especially because the observations that on different entry points people stay in the direct
surroundings of their starting point. This phenomenon will be translated in a hypothesis in favor of the descriptive analysis further on.

Another example of the economic movement of pedestrians is choice behavior at intersections. In this context, choice behavior seems to have some general rules of thumb. According to Bitgood and Dukes (2006), Melton (1935), Yoshioka (1942), Weiss and Boutourline (1963) and Shettel (1976), pedestrians who approach an intersection will choose the most economical direction. For instance, if a person walks on the right side of a street, the direction which represents the shortest route possible will be chosen: straight ahead or a right turn. Research of Bitgood and Dukes proves that most people in this situation will act in this way. Going left in this case is a significant inferior option. This choice behavior emphasizes again the will of pedestrians to take the shortest route possible. There is also some literature on this matter that rebut this assumption of economic behavior. Parsons and Loomis (1973), discovered that most people went straight ahead or left (instead of right). But, an interesting matter comes forward in the further description of this research. When the museum was crowded, different pedestrian flows were observed. It is likely that a path of least resistance is the most economical way to move, instead of the shortest path (Bitgood, 2006). In the end, it is inevitable to state that people take the shortest route possible.

The investigations in influences of the environmental factors related to pedestrian behavior is the result of the belief that people do walk in patterns. Zacharias (2001) claims that people do walk in certain patterns. Smeets (2005) demonstrates with her research this assumption. People tended to stay in one zone because of street furniture which divided the street into three zones. Interesting about this matter is the question if it counts for more locations/situations. Therefore, this phenomenon will be translated in a hypothesis in favor of the descriptive analysis further on.

But predicting these patterns, instead of observing them, is a lot harder. Everyone can 'guess' what people will do based upon experience from yourself as a person or as a retail developer. And in most cases these guesses predict pretty good. But to set up a guide based upon scientific facts seems almost impossible due to differences in location, situation, trends, culture etcetera. Walking patterns are very complex phenomena due to a series of choices based upon even more factors in the environment and the individual himself. Zacharias (2001) postulates that the experience of space, architecture, activity, sound, and light has a cumulative effect on the desire to remain and to return. Such places will become associated with certain social characteristics and will affect joining behavior.

In favor of the analytic phase of the observed behavior in this research, a couple of hypotheses are defined. Only those hypotheses that can be tested with the available data are summarized.

The formulated hypotheses are:

- **Pedestrians tend to stay close to their starting point** (Deckers, 2005).

- **The allocation of street furniture influences walking patterns** (Smeets, 2005).
2.2 Tenant mix

The way people walk around a retail area is strongly determined by the allocation of the shops. For instance, Smeets (2005) identifies a relationship between the itinerary of shoppers and the location of shops. As mentioned before, people tended to stay in one zone because of street furniture which divided the street into three zones. Smeets (2005) discovered that 50% of all switching between zones had shop location reasons. There is more evidence to suggest that variety in tenant mix at malls will influence shopping behavior. Wakefield and Baker declare that it influences consumers' shopping center choice, frequency of visit, and shopping center image and even will avert the leakage of valuable expenditures form the local economy through so-called 'outshopping' (Timothy 2005). It all demonstrates that pedestrian behavior is not only based upon the environment itself, but also upon the shops and especially their location. Therefore this section is will discuss this second important aspect of pedestrian behavior: tenant mix. "Tenant mix refers to the combination of business establishments occupying space in a shopping centre to form an assemblage that produces optimum sales, rents, service to the community and financiability of the shopping centre venture" (Abratt et al., 1985; Kaylin, 1973).

First the two ingredients of an optimal tenant mix are described: the branches (line of business) and the tenant types. Finally the allocation principles are presented, which define the tenant mix. This section will end with a conclusion with relevant hypothizes in favor of the descriptive analysis further on.

2.2.1 Branches

Branches is a common used classification in retail literature. It is based upon the most logical interpretation of the line of business of a shop. The great advantage of doing this, is to group the large amount of shops into several main groups which represent each type of shop. There are many ways to define branches. Table 2.1 shows the branches which are defined in earlier research of modeling pedestrian behavior at Eindhoven University of Technology (van Wijk 2003; Deckers 2005). Since the model (which will be used later on in this research) uses a categorization of branches and van Wijk (2003) and Deckers (2005) already used the model with a certain branch classification, the defined branches in these studies are used. The chosen classification of branches is:

<table>
<thead>
<tr>
<th>Branches</th>
<th>Shops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>supermarkets, bakeries, butchers, green shops, etc.</td>
</tr>
<tr>
<td>Fashion</td>
<td>clothing, bags, accessories, etc.</td>
</tr>
<tr>
<td>Shoes</td>
<td>shoes</td>
</tr>
<tr>
<td>Personal care</td>
<td>pharmacies, barber shops, pedicures, etc.</td>
</tr>
<tr>
<td>Home products</td>
<td>furniture, garden appliances, etc.</td>
</tr>
<tr>
<td>Electrical appliances</td>
<td>washing machines, tv's, stereos, etc.</td>
</tr>
<tr>
<td>Books and magazines</td>
<td>book stores, news agencies, etc.</td>
</tr>
<tr>
<td>Music and video</td>
<td>music stores, videogames, etc.</td>
</tr>
<tr>
<td>Department store</td>
<td>large department stores</td>
</tr>
<tr>
<td>Other retail</td>
<td>gifts, toys, sewing, outdoor, sport shops, etc.</td>
</tr>
<tr>
<td>Bars and restaurants</td>
<td>catering industry, fast food, chocolate, donuts, etc.</td>
</tr>
<tr>
<td>Remain (services)</td>
<td>real estate agencies, hotels, dentists, security, toilets, etc.</td>
</tr>
</tbody>
</table>
Recent research at Eindhoven University of Technology shows that department stores are by far the most visited branch. Therefore, it forms the most essential component of a shopping trip. Approximately 90% of the respondents visited at least one Department store. Twenty percent of all respondents visited more than one Department store during their shopping trip (Leung 2007). According to Leung (2007), the branches Bars and restaurants, Shoes and Fashion have the highest amount of so called ‘impulse-visits’. The results of research in Eindhoven and Maastricht (both are two medium-sized Dutch cities) shows that 60% of the visits of these branches are impulse-visits. The branches Shoes and Fashion were often visited more than once during a shopping trip.

Deckers (2005) postulates in her research that the branches ‘Fashion’ and ‘Department store’ attract the most shoppers. She discovers that most people visit these two branches during their itineraries.

The success of a shopping centre depends on the success of the tenants. The number of visiting consumers and their consuming behavior is therefore of vital importance. A very successful store brings a lot of pedestrian flows about.

### 2.2.2 Tenant types

Besides an classification of the shops in branches, shops can be categorized in types of tenants. In this case, we do not look at the merchandise a shop offers but the way consumers act towards a particular tenant.

The types can be defined as follows: key tenants, satellite tenants and purpose tenants. A key tenant generates the greatest amount of customer patronage. Studies in tenant mix have proven the existence of ‘attractor stores’ or key tenants, which bring pedestrian flows about from one key tenant to another (Sim & Ru Way, 1989). It thus has the potential to be situated independently and it attracts patronage from beyond the primary zone of the trade area (Abratt, Fourie and Pitt 1985). Purpose tenants are stores which are planned to visit (Leung 2007). This store functions (like the key tenant) independently. Finally, satellite tenants are the remaining stores. These stores do not generate pedestrian traffic and are more or less dependent on ‘passer-by’ patronage. These stores have the highest amount of impulse visits (Abratt, Fourie and Pitt 1985).

Two types of tenants can be pointed out because of allocation: tenants who depend on a ‘hot’ location and tenants who need a certain amount of pedestrian flow. In other words, tenants, searching for aspects such as accessibility and visibility (key tenants) and tenants searching for aspects such as compatibility and synergy between stores (satellite tenants). For these, relative location is of great importance (Sim & Ru Way, 1989). The third tenant (purpose tenant) is not location dependent, since people know where to find them.

The previous part described the necessary types of tenants to constitute a tenant mix. But how does this ‘mix’ look like? The anchor stores largely determines the character and profile of the centre and provides most of the visibility needed to attract customers (Bruwer 1997).

In physical configuration, anchor stores are normally located as far from each other as possible to maximize the amount of traffic from one anchor to another (Brown 1992). They do not depend on other stores but on their location. Departments stores, supermarkets and national chain stores are the best examples and attract all kind of shoppers.

Purpose stores are shops which customers plan to visit. Therefore, the number of impulse visits is considerable fewer than other shops (in contrast to key tenants). Thus spillover effects are low. Shops representing this type are banks and a variety of services, such as real estate agencies, employment agencies, hairdressers etc. and attract goal-directed shoppers.
Purpose stores do not require prominent locations within the shopping mall, since most people know where to find them (Leung 2007).

When using these categories, one should realize that some stores are both key and purpose tenants (e.g. a shopper who planned a visit to a big supermarket). A key tenant like McDonalds for instance could also function as a satellite store along a pedestrian flow. Table 2.2 gives an overview of the tenant types, their main characteristics (positive means that it possesses this characteristic), the shopping behavior they provoke and finally a couple of examples.

<table>
<thead>
<tr>
<th>Type</th>
<th>Generating patronage</th>
<th>Impulse visits</th>
<th>Dependent on location</th>
<th>Dependent on other stores</th>
<th>Shopping behavior</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key tenant</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
<td>All types of shoppers</td>
<td>Department stores, supermarkets and national chain stores</td>
</tr>
<tr>
<td>Purpose tenant</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Goal-directed shoppers</td>
<td>Banks, real estate agencies, employment agencies, hairdressers</td>
</tr>
<tr>
<td>Satellite tenant</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Entertainment shoppers</td>
<td>Small food stores, all kind of independent (local) traders, bars en restaurants.</td>
</tr>
</tbody>
</table>
2.2.3 Allocation principles

To enhance the ideal location of the tenant types, strategies of allocating stores in a shopping mall are necessary. But, different branches have different characteristics and therefore different demands for mall allocation. In the literature, several general guidelines come forward according this allocation problem. First, the retail compatibility in general is described. Next, the clustering of shops is discussed. Finally, a couple of guidelines, based upon literature and the discussed aspects, are summarized in order to define some allocation principles.

Retail compatibility

Nelson claims: ‘two compatible businesses located in close proximity will show an increase in business volume directly proportionate to the incidence of total consumer interchange between them, inversely proportionate to the ration of business volume of the larger store to that of the smaller store and directly proportionate to the sum of the ratios of purposeful purchasing to total purchasing in each of the two stores’ (Nelson, 1958). In other words, two businesses that are compatible will do better side by side, other things being equal. The literature according this issue is divers. Brown proclaims a physical configuration, where anchor stores are located as far from each other as possible to maximize the amount of traffic from one anchor to another (Brown 1992). The first approach is from the concerned stores point a view, the second from the satellite stores point a view (which depend on pedestrian flows generated form the key tenants). Thus, as a tenant you will search for a location near a compatible business. But as a shopping centre developer, you will look for an ideal tenant mix which will result in making compromises and considerations concerning the total tenant balance in a shopping mall.

Although a synergy can be pointed out, there are certain factors which can reduce this interchange between two compatible stores. The pedestrian flow can be interrupted by dead spots in which shoppers lose interest in going further (e.g. vacant stores or other non-shopping functions along the route). Next, physical breaks and cross traffic can end a shoppers itinerary (e.g. elevators, sharp turns and crossovers). Shopping centre sections which are identified with hazard, noise and unsightliness congested areas are a fourth reason of pedestrian flow interruption (Abratt, Fourie and Pitt 1985).

In Japan, Kita, et al. (1996) found that local shops within a 200- to 400-meter radius of a shopping center benefited more from the presence of the shopping center than any other spatial location factor. In Eindhoven, the opening of a shopping center contributed to the overall growth in business in the city center without taking away trade from existing street-level shops (Teklenburg, Timmermans and Borgers 1994). In general, such pedestrian distributions are highly related to layout and the distribution of land uses (Zacharias 2003). In contrast, a shopping center may contribute to local business decline because the generated walking patterns tend to concentrate the movements along certain channels, leaving others relatively unvisited (Zacharias 2001).
Clustering
Clustering is probably one of the most recognized planning principles in urban retail (Leung 2007; Timothy 2005). Clustering can be defined as grouping similar tenants (e.g. a number of shops in the fashion branch) in order to benefit from each others presence.

Retail developers use clustering so that merchants can take advantage of consumers’ multi-purpose shopping tendencies. A mall should offer store balance and tenant variety. According to Wakefield and Baker (1998) these malls generate excitement and offer conveniently compared product offerings, which will attract more shoppers (Timothy 2005). Timothy also declares that the idea of clustering becomes a benefit in multi-store shopping centers. By locating close to direct competitors, consumers can compare prices, products and services better, which is an important motive for visiting shopping malls (instead of a local store).

Clustering of stores is not a rare phenomenon. For instance, grouping fashion stores or (fast food) restaurants is often used by retail developers. As mentioned before, clustering is often based upon branches, but developers are creative in shaping these clusters since a cluster can be based upon exclusivity, store type, bargain stores or brand-related stores. In the literature, a lot has been written about this subject, but there is only a small amount of empirical proof whether shops should be clustered or not (Brown 1992).

Leung (2007) researched the shopping behavior described in visiting patterns by means of “branch visiting combinations”. He did both a cluster- and a branch matrix analysis to determine possible recurring shop visiting patterns. The cluster methodology groups observations according to similarities in variables. The branch matrix shows the amount of respondents visiting a particular combination of shops. The results of the shopping itineraries of the respondents were with both types of analysis the same. It was difficult to see obvious patterns but there are some to distinguish: it turns out that a visit to a department store is combined with a visit of another department store. Although, there was a remarkable distinction between the two cities. In Maastricht, there were much more department store visits during one shopping trip. In contrast to Eindhoven, in this city the two department stores are located next to each other. It could be possible that department stores exploit from each others closeness. Furthermore, a department store visit is often combined with a visit to the branches: Fashion, Books and magazines, Music and video, Bars and restaurants, Food and Other retail. In other words, it is difficult to define visiting patterns but when a respondent combines a visit, it is probably with a department store (Leung 2007). Finally, Leung (2007) discovered another interesting phenomenon of shopping behavior in the cities of Eindhoven and Maastricht. The branch Personal care provokes a high level of clustering. This means that respondents tended to visit a shop from the same branch (Personal care) nearby.
A second aspect of the retail setting is the venue in which a cluster of shops is located. The geographical setting is very important but is rarely subject of research. Timothy (2005) mentions a few authors who have examined this aspect in rural regions and historic urban quarters. Jansen-Verbeke et al. noted that shopping areas in central urban districts, with their physical characteristics (e.g. historic buildings, sidewalk cafes and bars), are considered to be highly attractive places that lead to a leisure mindset to many shoppers (Timothy 2005).

**General guidelines**
In an early stage of the development of a shopping mall, the tenant mix is determined. The literature mentions several guidelines how to ‘fill in’ these tenant spaces. The allocation of tenants should reckon with these rules of thumb (Gruen 1973, Beddington 1982, Abratt et al., 1985, Lewis 1987, Sim & Way 1989, Brown 1992):

- place anchor stores at opposite ends of the mall and line the intervening space with smaller outlets;
- ensure that the main entrances and anchor stores are sufficiently far apart to pull shoppers past the satellite shops;
- avoid cul-de-sac if possible (they inhibit the free flow of customers);
- place services outlets on the side malls, close to the entrances and exits;
- keep conflicting shops apart;
- achieve an even distribution of shoppers in multi-level centers through judicious placement of escalators and eating facilities and the manipulation of the floor at which shoppers enter the complex.
2.2.4 Conclusion

There are two ways to classify shops in a certain shopping centre: according to branch and according to tenant type. The classification in branches is useful to analyze the available data in this research and to use in the model further on. In regards to branches, there are many classifications of shops possible. In favor of the analysis and model further on in this research, the classification in branches of recent research (of the same model) is chosen. The chosen classification of branches is:

Table 2.3: Defined branches

<table>
<thead>
<tr>
<th>Branch:</th>
<th>Shops:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>supermarkets, bakeries, butchers, green shops, etc.</td>
</tr>
<tr>
<td>Fashion</td>
<td>clothing, bags, accessories, etc.</td>
</tr>
<tr>
<td>Shoes</td>
<td>shoes</td>
</tr>
<tr>
<td>Personal care</td>
<td>pharmacies, barber shops, pedicures, etc.</td>
</tr>
<tr>
<td>Home products</td>
<td>furniture, garden appliances, etc.</td>
</tr>
<tr>
<td>Electrical appliances</td>
<td>washing machines, tv's, stereos, etc.</td>
</tr>
<tr>
<td>Books and magazines</td>
<td>book stores, news agencies, etc.</td>
</tr>
<tr>
<td>Music and video</td>
<td>music stores, videogames, etc.</td>
</tr>
<tr>
<td>Department store</td>
<td>large department stores</td>
</tr>
<tr>
<td>Other retail</td>
<td>gift s, toys, sewing, outdoor, sport shops, etc.</td>
</tr>
<tr>
<td>Bars and restaurants</td>
<td>catering industry, fast food, chocolate, donuts, etc.</td>
</tr>
<tr>
<td>Remain (services)</td>
<td>real estate agencies, hotels, dentists, security, toilets, etc.</td>
</tr>
</tbody>
</table>

Leung (2007) and Deckers (2005) both described a certain preference of shoppers to visit the branches 'Fashion' and 'Department store'. Both researchers take a different point of view, but conclude more or less the same visiting pattern of branches. Therefore, this aspect of pedestrians' behavior of visiting these two branches will be translated in a hypothesis in favor of the descriptive analysis further on.

Besides branches, shops can be distinguished by tenant types. There are three types of tenants: key-, satellite- and purpose tenants. The classification in tenant types and allocation principles are used to clarify what tenant mix means.

Figure 2.10 shows a schematic representation of allocation principles of the three defined tenant types. It shows how an ideal shopping centre should look like according to tenant types. In other words it describes (partly) the tenant mix. The other part that determines the tenant mix is branches. The kind of branches and how many in each type is represented. Thus, within the defined tenant types, different branches can be defined. Good examples of key tenants from different branches are Mc Donalds (restaurant) and Kmart (department store). Brown states that the best examples of key tenants are department stores, supermarkets and national chain stores (Brown 1992). In favor of the analytic phase of the observed behavior in this research, this attribute of key tenants is translated in one hypothesis. Due to the available information in this research, the department store is chosen as a possible key tenant in the shopping mall.

The biggest arrow in figure 2.10 represents the main (biggest) pedestrian flow generated by the key tenants. The (relative smaller) satellite tenant benefits from this pedestrian flow. Therefore, both tenants depend on a 'hot' location within the mall: the key tenant needs an accessible and visible spot (near the entry/exit of the mall), whereas the satellite tenant needs a spot combatable with the main pedestrian flow (synergy along the biggest arrow) in order to gain 'passer-by' patronage. Finally, the purpose tenant functions, just as key tenants, independently but, in contrast with key tenants, is not location dependent.
In favor of the analytic phase of the observed behavior in this research, a couple of hypotheses are defined. Only those hypotheses that can be tested with the available data are summarized.

The formulated hypotheses are:

- *Department stores fulfill the role of key tenant in a shopping mall* (Bruwer, 1997; Brown, 1992).

- *The branches 'Fashion' and 'Department store' attract most shoppers* (Deckers, 2005; Leung, 2007).
2.3 Modeling techniques

Over the last three decades spatial interaction and spatial choice models varying degrees of sophistication have been employed widely by both academics and practitioners to describe consumer shopping behavior and predict the likely impact of (planned) retail change on such behavior.

Each model is developed for particular reasons and specific conditions of data collection and data use. Developed models can be used to assess the effects of design decisions at a detailed level or at the level of urban districts. They can be used to predict individual pedestrian movement or look at pedestrian volumes in general (flows). Therefore, this literature review will discuss the most important models according to their usage scale. First, the models to predict pedestrian volumes are described. The most recent models on this subject are based upon an individual (microscopic) approach of pedestrian behavior, but serve a flow-characterized result. Next, the most common models strive to predict individual behavior (mostly in evacuation situations) are described. Subsequently, models to predict pedestrian behavior at different spatial levels come up for discussion. These models consist of a aggregate and individual scale. Finally, the model developed at Eindhoven University of Technology (used in this research) is briefly described. The detailed description and operationalization of this model is described in chapter 5 'The model'. This section will end with a conclusion which acts as a brief overview of the discussed models.

2.3.1 Detailed spatial level

A number of simulation tools have been developed to predict pedestrian flows in the planning and design of public pedestrian facilities, such as airports, public stations and shopping malls.

The social force model suggests a new interpretation of pedestrian behavior. The motion of pedestrians can be described as if they would be subject to so-called 'social forces'. They are the measure for the internal motivations of individuals to perform certain movements. Pedestrians behave in a way as if they would be subject to an acceleration force and to repulsive forces describing the reaction to borders and other pedestrians (Helbing and Molnár, 1998a).

In this model for predicting individual pedestrian behavior three groups of 'force' terms are essential: a term which represents the acceleration towards the desired velocity of motion; next, several terms which are responsible for keeping the pedestrian at a certain distance to other pedestrians and borders; finally, a term which models the attractive effects.

Helbing and Molnár (1998b) simulated two examples in urban planning: lanes and narrow passages. Figure 2.11 shows the result of the simulated walking patterns of pedestrians in a lane that is 10 m wide and 50 m long. The white circles represent pedestrians who walk in the opposite direction to the black circles defined pedestrians. The computational output shows four walkways. Figure 2.12 represents a narrow passage. The circles represent opposite
directions as in the lanes example. Here, the output shows that if a pedestrian passes a narrow passage, other pedestrians will follow his lead and pedestrians with an opposite desired direction have to wait. The diameter represents the velocity of motion. According to Helbing and Molnár (1998b), this social force model simulates the self-organization of several observed collective effects of pedestrian behavior realistically (Helbing and Molnár, 1998b).

There are several so called cellular automata models. These models are capable of a detailed modeling of pedestrian behavior. In contrast to other models, these models do not focus on behavior of pedestrians to avoid other pedestrians and objects. These models focus on the interaction of the environment on the level of route choice behavior. For instance, the influence of shops are important. A grid is used to model pedestrian behavior and aspects such as walking speed and a set of local characteristics are used (Deckers 2005).

PEDROUTE and PAXPORT (developed by the Halcrow group) and the SimPed model (developed by Holland Railconsult and Delft University of Technology) are examples of models which have been applied with success to assist in the evaluation and optimization of designs of new or existing walking environments (Hoogendoorn 2003). A recent model to predict pedestrian flows is the simulation tool NOMAD (developed at the Transportation and Traffic Engineering Section of the Delft University of Technology). This microscopic model is based on the assumption that pedestrians can be described by optimal predictive feedback controllers with a limited prediction horizon. It consists of two mutually dependent models: a top-level model which predicts pedestrian activity scheduling, activity area choice, and route choice in public spaces and a down-level model which describes the walking behavior. An important aspect of the model is that the routes are continuous curves in space and time, rather than an ordered set of links (complete free route choice) (see figure 2.13). Besides, pedestrians can choose between multiple activity areas where to perform their activities. Knowledge of the pedestrian flow characteristics and of the walking behavior that constitutes the flow is required to evaluate pedestrian flows.

The planned activities of the pedestrians forms an important role, these determine the actions of the pedestrians. Therefore, there are two major aspects in the activity pattern: a set of activities (e.g. buying a ticket) and the areas where these activities can be performed (e.g. ticket counter). The model determines the most likely areas where the activities will be performed, and the most likely routes between them. The route modeling is based upon several aspects. The main term is the assumption that pedestrians will take the shortest route possible. If this route is congested, a pedestrian will avoid it and take an alternative route available. Likewise, when a pedestrian encounters with other pedestrians or obstacles, he or she will take an alternative route (shortest form that point on). Finally, it is possible to define preferred walking areas (e.g. shopping windows) and specific kinds of walking infrastructure (e.g. escalators). The modeling is based upon empirical facts and theory on pedestrian behavior. The calibration of the model parameters is done using a microscopic
approach, the model results have been compared to observed microscopic pedestrian behavior (determined by video) and adjusted where needed. Besides, the user can vary several inputs in the model (Hoogendoorn 2003).

What is remarkable is the development stage: there is already a simple application in use to model and evaluate real-life studies. Their research is now aimed at further fine-tuning the model, including a user-friendly interface for input generation and output viewing.

2.3.2 Higher spatial level

In the literature, individual route choice is generally indicating that each individual is assumed to decide on his own and to optimize his personal satisfaction. Each individual has his own perception of the (objective) situation on which the pedestrian’s personal decision is based. The decision process thus consists of two main parts, that is predicting the formation and composition of individuals’ choice sets (choice set formation) and predicting the probability that an alternative belonging to an individuals’ choice set will actually be chosen (choice modeling) (Arentze & Timmermans 2004).

A model to assess the effect of larger retail and parking facilities on pedestrian volumes was developed by Sandahl and Percivall in 1972. This model is one of the first models for predicting pedestrian behavior and was applied in a Swedish town. They observed a number of pedestrians on defined links of the central area network and regressed these against the characteristics of the links (parking facilities, retail floor space, accessibility by bus, centrality of the link in the network, number of street stalls and seating places). In Manhattan, Puskarev and Zupan (1975) did similar research: they related pedestrian counts on block sectors to building floor space, walkway area and proximity to transit facilities. Hillier et al (1993) regressed observed pedestrian behavior on links, using characteristics of these links. This model is in line with the approach of Sandahl and Percivall (1972).

2.3.3 Route choice behavior model

A route choice behavior model, developed at Eindhoven University of Technology, proposes an approach at the level of links in a network. The pedestrian behavior is represented in a route from link to link (in a predefined network). The pedestrians enter the retail area near parking facilities, bus stops, train stations, etc. Their shopping purposes are unknown. From each current link in the network, the pedestrian has a couple of alternative links to choose from (see figure 2.14). This procedure will continue until the pedestrian leaves the area at the same point (entry-link is exit-link) (Smeets 2005).

The main principles of this model are:
- pedestrians move away from the entry point, later on, they return to their entry point to leave the shopping area;
- pedestrians are attracted by street segments offering attractive retail supply;
- all street segments consists of characteristics defined in a set of variables.

Deckers (2005) used this model to predict pedestrian behavior in Maastricht. Because this was not the first usage of the model, she had the opportunity to compare the application and outcomes of the model with an earlier report (a research executed in Eindhoven by van Wijk in 2003). Deckers (2005) concluded that the route choice behavior model is not generally...
applicable to all types of situations (retail areas). To make the developed model work she had to add some variables in order to fit the model to the new situation. Furthermore, the different types of businesses had to be joined in a different way. The estimated variables were different whereas the variables of Eindhoven have different influence on the route choice behavior than those in Maastricht. Deckers allocates this incapability of the model to the physical differences of both cities. However, the results of both studies do not differ that much after all. This model will be described in more detail in chapter 5 ‘The model’.

### 2.3.4 Conclusion

The modeling techniques, found in the literature, were discussed shortly according to their usage scale. Developed models can be used to assess the effects of design decisions at a detailed level or at the level of urban districts. They can be used to predict individual pedestrian movement or look at pedestrian volumes in general (flows). Several models predict pedestrian behavior at different spatial levels. These models consist of a aggregate and individual scale. Figure 2.15 summarizes the discussed models in this literature review. The overview of the modeling techniques is indicative: the models can be explained in different ways. The figure shows that models are spread out throughout their usage field. Each model focuses on different aspects of pedestrian behavior and results in different ways to visualize simulated pedestrian behavior. There are models which try to model pedestrian behavior on the entire spatial scale but results in a less specific result. Depending on the available data and the desirable results, a model can be chosen. The model used in this study (Individual route choice behavior) focuses on individual behavior on the level of links in a network (representing a shopping area).

![Diagram of modeling techniques](image-url)

**Figure 2.15: Overview of modeling techniques discussed in this research**
2.4 Conclusion

In the conclusions of the different sections of this chapter, four hypotheses came forward. These hypotheses are based upon findings on pedestrian behavior in literature. The pedestrian behavior is split up in two aspects which influence the behavior: pedestrian environment and tenant mix.

Another annotation has to be made: these hypotheses are not the focus of this research. It is simple based upon literature and will be tested in the descriptive analysis. Further research is necessary to evaluate these hypotheses more accurately. But, in the context of this research it is a nice opportunity to check these assumptions. Next, the hypotheses are formulated with care: it must be possible to test them with the available data in this research.

The formulated hypotheses are:

- “Department stores fulfill the role of key tenant in a shopping mall.” (Bruwer, 1997; Brown, 1992).
- “Pedestrians tend to stay close to their starting point.” (Deckers, 2005).
- The branches ‘Fashion’ and ‘Department store’ attract most shoppers (Deckers, 2005; Leung, 2007).
- “The allocation of street furniture influences walking patterns.” (Smeets, 2005).

These hypotheses will be used in chapter 4 ‘Observed behavior’. The results (and the conclusions on this matter) of the descriptive analysis are utilized as a test of these hypotheses. This is evaluated in the conclusion of the concerning chapter.
3. Shopping mall Armidale

Before analyzing the data, the shopping mall will be described. First, the situation of the shopping mall is addressed. Next, the spatial characteristics will be analyzed on two scales: the situation as a whole and the shopping mall of Armidale in particular. The shopping mall characteristics are split up in two main sections: the physical- and the retail characteristics (see figure 3.2). This chapter ends with some concluding remarks.

Figure 3.1: Shopping mall Armidale, Australia
This picture is taken from the main square towards the indoor shopping centre. The historical building is preserved and its tower forms a small landmark within the mall.
Figure 3.2: Chapter structure
3.1 Situation

Armidale is located in the Australian state of New South Wales, in the south-east region of the country. It lies about midway between Sydney and Brisbane (figure 3.3). Armidale has about 21,660 inhabitants, was established in 1849 and has its own university (Armidale Dumaresq Council, 2008) (see figures 3.4 and 3.5 for an impression of Armidale). Because of Australia’s relative young urban development (1788: first colonial settlements), Armidale is a relative ‘old’ city. The old buildings around Beardy Street (today’s Armidale shopping mall) remind the shoppers of the ‘old’ days (see figure 3.6). The area was at first explored by John Oxley, who named it after Armidale on the Isle of Skye in Scotland. As you can see, this man was not good at spelling. Oxley recommended this area for cattle breeding and soon small farms settled. The town was then established to provide a market and administration for the farms. A gold rush in the 1850’s ensued and it’s prosperity enlarged the town rapidly. The gold mining settlement of Hillgrove, about 40 km east of Armidale was the site of Australia’s first hydroelectric scheme. Remains are still visible today (Armidale Dumaresq Council, 2008). Armidale is the town known as the home of the famous captain Thunderbolt (the notorious outlaw Fred Ward), who caused trouble in this region in the 1860’s. Locals compare this guy with the famous murderer Ned Kelly, but probably only because of a tourist’s attraction.

In short, Armidale is a small town with regional relevance due to the university. The university was founded in 1938, at first as an outpost of the University of Sydney, but later it became independent (1954). Since then, the rural market town changed into a “city of great culture and diversity” (Encarta Winkler Prins 2007).
Figure 3.4: Armidale, NSW, Australia (source: Google Earth)

Figure 3.5: Armidale overview (source: http://en.wikipedia.org/wiki/Armidale)

Figure 3.6: Buildings dating from the earlier settlements. Clockwise: the court house, the shopping mall, the post office and the university.
3.2 Shopping mall Beardy Street

The shopping mall area subject to this research is located at the central business district (CBD) of Armidale. We start to look at the physical characteristics of the mall such as location, spatial characteristics and some other interesting attributes of the mall. Then, the retail characteristics are described in order to get some information about the amount of shops, the diversity of the tenant mix and about specific tenant types located in the area. Unless it is specifically mentioned, the mall of 1996 will be subject of discussion (when the data collection took place).

3.2.1 Physical characteristics

Since the data collection in 1996, the CBD of Armidale and especially the shopping mall has changed. The observation in 1996 did not cover the whole shopping mall. In order to give an overview, the different situations are explained briefly.

In Figure 3.7 left the shopping mall anno 1996 is pointed out. The shops are concentrated around the (oldest) main street of Armidale: Beardy Street. The shops are situated towards this main street.

The shopping mall area subject to this research is pointed out in figure 3.8. This area is surrounded by the three most important car parks of the CBD of Armidale (figure 3.8; left). This area is also the most visited part of the shopping mall (in 1996) due to its pedestrian area (a car free square) and the location of the most important shops.

Figure 3.7 right shows the layout of today's shopping mall. One new shopping centre in the north east (called Centro), an expansion of the formerly western side of the shopping mall (called Armidale Plaza) and finally an individually located establishment of the supermarket 'Coles' at the northeast of the CBD of Armidale.
3. Shopping mall Armidale

Figure 3.7: left Shopping mall Armidale CBD anno 1996 (source: Google Earth)
right Shopping mall Armidale CBD anno 2008 (source: Google Earth)

Figure 3.8: left Shopping mall Armidale CBD anno 1996, subject to research (source: Google Earth)
right Shopping mall Armidale CBD anno 1996, subject to research
Layout

As shown in figure 3.9, the shopping mall can be divided by three streets (Dangar Street, Moore Street and Beardy Street) in three (sub) areas (A, B and C). As cars are moving around on these streets, they may cause a barrier effect on the shopping behavior, which is an interesting subject for the analysis. It would not be surprising that this barrier effect will contribute to the earlier mentioned hypothesis that pedestrians stay close to their starting point, which is one of the car parks in one of the three (sub) areas. The names of these parking facilities refer to the most ‘dominant’ store in that area: Kmart, Woolworths and Commonwealth bank (two department stores and a bank). Kmart car park is the largest one and is connected to both areas 'A' and 'B'.

There are also clear distinctions between the three (sub)areas while area A is an indoor shopping mall with sidewalks along the streets, area B consists of sidewalks with two passages to the car park and area C is a pedestrian (car-free) square with opportunities to sit down and go to an outdoor café.

As already has come forward, there is also a distinction possible in three different types of shopping streets (see figure 3.10):

1. sidewalks along streets for motorized traffic;
2. open air pedestrian area (car-free square);
3. indoor shopping arcade (pedestrian area).

The last two are related to the (earlier mentioned) division in areas, whereas area B is mainly an open air pedestrian area and area A is mainly an indoor shopping arcade. The sidewalks along streets are spread throughout the shopping center. These characteristics of shopping streets may be relevant in understanding pedestrian behavior.
Figure 3.9: 3 Areas

Figure 3.10: 3 types of shopping street
The indoor shopping mall (area A) is a relatively old building. And with its small turret it functions as a small landmark in the shopping mall (see figure 3.12). The entries are decorated with stained glass windows above the sliding doors (see figure 3.13). Adjacent to this (sub) area, is the biggest car park (148 places) of the shopping mall located (Kmart car park). This area is a pedestrian area and completely indoors, therefore it can be defined as an indoor shopping arcade. All shops are introvert oriented.

Area B is mostly extravert oriented, which means that most shops are facing the street. Sidewalks along this street make it possible for pedestrians to stroll along these shops. There are two covered passages towards the car park at the rear (Woolworths car park) with shops along the route. These passages can be seen as so called arcades. Two shops are located at the car park. These shops are a bit isolated and can probably be defined as purpose stores (see the subsection 'types of tenants' in the next paragraph and the literature review). This area also houses historical buildings from the earlier days of Armidale. Today these buildings accommodate retail. This area can be seen as a mixture of different types of buildings and various types of facades.

Area C represents the image of the city centre of Armidale. This is the main square and if one wants to start shopping or have a cup of coffee, one should start here. This car free zone is a pleasant environment to stroll and visit some shops. In contrast to area A, this pedestrian area is outdoors. It contains two indoor passages and one outdoor passage. The first two are comparable with the passages in area B. But the last mentioned one has no shops and is therefore only for the sake of getting to the car park in the rear.

As mentioned before, these three areas are divided by three roads. The roads are quite crowded and therefore some pedestrian crossings are situated in the retail area. There are two important locations on this matter: the intersection of Beardy Street and Dangar Street and the crossing on Beardy Street which connects area A and B. The crossing is situated slightly to the right of the indoor mall entrance of area A (see figure 3.11; 1). therefore pedestrians have to take a longer route if they want to walk along the crossing facility. Probably most people will take the shortest route and thus not use the crossing. The crossings around the intersection will maximize the chance that people will walk along the facades instead of walking in the middle of the square (see figure 3.11; 2).

Figure 3.14 through 3.21 show an impression of the different areas within the mall.
Figure 3.14: The passage to the Woolworths car park (area B)

Figure 3.15: The inside oriented shopping arcade (area A)

Figure 3.16: The walkways along the car free square (area C)

Figure 3.17: The indoor shopping arcade (area A)

Figure 3.18: The outdoor passage without shops (area C)

Figure 3.19: Historical building (area B)

Figure 3.20: The intersection of Beardy street and Dangar street

Figure 3.21: The crossing at Beardy street, between area A and B
3.2.2 Retail characteristics

Shops
The shopping mall has 142 shops. Areas 'A' en 'C' contain most shops (figure 3.22). The total m² floor area of each cluster of shops (area A, B and C) is presented in figure 3.23. With 41 % of the shops, area C offers the major part of the available shops. Area C represents also the largest floor space (m²) of the shopping mall. Although area A has clearly more shops than area B (37% over 22 %), area B matches almost the same amount of floor space as area A. This means the shops in area B are a bit bigger than the shops in A. In this last one two big stores (Coles and Kmart) are located, but a lot small ones as well. In contrast to area B which has mostly middle-sized stores and one big store (Woolworths). Thus, area C has relatively a lot of small shops; even without a large shop, it still represents the largest amount of floor space.

Branches
The shops are categorized in retail branches, in favor of a well-ordered analysis (table 3.1). The used classification is based upon defined branches found in literature and corresponds with the most logical interpretation of the line of business of a shop (see 2.2.1 'Branches'). Most retail branches in the table are commonly used in retail literature. Remarkable for this shopping mall is the great amount of sewing related shops. These are subsumed under the branch 'Other retail'. Besides, a lot of chemists and medical care shops are present in the mall. These, and other related shops are subsumed under the branch 'Personal care'. Appendix 1 gives a more detailed overview of the shops and categorization of the shops. Appendix 2 shows the map of the shopping mall with the shop locations.

The shop categorization is made in such a way, that the defined branches correspond with the categorization used in other studies related to this subject. In this way, the branches can be easily implemented in the model developed at Eindhoven University of Technology.

The colors correspond with the figures and charts later on. The codes are added in favor of the descriptive analyses later on.

<table>
<thead>
<tr>
<th>Table 3.1: The defined branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch</td>
</tr>
<tr>
<td>Food</td>
</tr>
<tr>
<td>Fashion</td>
</tr>
<tr>
<td>Shoes</td>
</tr>
<tr>
<td>Personal Care</td>
</tr>
<tr>
<td>Books and magazines</td>
</tr>
<tr>
<td>Electrical Appliance</td>
</tr>
<tr>
<td>Books</td>
</tr>
<tr>
<td>Department store</td>
</tr>
<tr>
<td>Other retail</td>
</tr>
<tr>
<td>Restaurants</td>
</tr>
<tr>
<td>Remain (services)</td>
</tr>
</tbody>
</table>

The total: 142 Shops

Figure 3.22: Number of shops by area

Total: 71,458

Figure 3.23: Floor space (m²) of shops by area
Figure 3.24 provides an overview of the distribution of the branches in the shopping mall. Figure 3.25 shows the spatial distribution of the branches in the mall. These two figures show that the available shops are well spread throughout the defined branches. Likewise, the branches are evenly spread out throughout the floor plan of the shopping mall. This means that there are no obvious clusters of branches definable in the shopping mall of Armidale CBD. What you do see is that the branches seek each others nearness: in most cases a certain shop has a neighbor in the same branch (see figure 3.25). Which is often subject in retail literature (see chapter 2).

Figure 3.24: Non-spatial distribution of branches in the shopping mall

Figure 3.25: Spatial distribution of branches in the shopping mall.
**Types of tenants**

As mentioned before there are three types of tenants: key-, satellite- and purpose tenants. In the descriptive analyses, an attempt will be made to identify these types in order to get some information about the tenant mix of the shopping mall. Now, a few interesting tenants will be highlighted who play an important role in the retail business.

There are three large tenants showing up on the floor plan: Woolworths, Coles and Kmart. These company names are well known tenants by the Australian people and there are many stores around Australia (especially Coles which can be found in almost any middle-sized to large town). The supermarket Coles and the department store Kmart are located inside the indoor arcade (area A) (see figure 3.27), the supermarket Woolworths is located at the side of Beardy Street (see figure 3.28). All these tenants are well accessible from the car park. It is not surprising that these stores are the main stores in the shopping center which attract the most customers. In other words, these stores can probably be defined as so-called key tenants which play an important role in the shopping mall layout.

Subsequently, the post office is an important tenant in the shopping mall (see figure 3.29). Despite the fact that it is accommodated in a historical building it is also a frequently visited service by locals. This post office is located in the pedestrianised part of Beardy Street. This shop is categorized within the branch Remain (Services).

Satellite tenants are difficult to describe while they are mostly the remainder of the shops in a shopping mall. Therefore it is not necessary to identify these tenant types.

Purpose tenants are easier to identify and Armidale mall has a couple. But whereas these shops are often located outside the shopping mall and in this case outside the research area, it is also not handy to identify these tenant types. But a couple can be pointed out near the car parks. A couple of shops are located outside the shopping mall, near the car park. They are situated just within the borders of the research area. One shop, for example, is an outdoor necessities shop, often a shop with characteristics of a purpose store while people do not need these articles on a daily base and this shop does not offer small merchandise (see figure 3.30). People know where to find these kinds of stores if they need these items.
3. Shopping mall Armidale

Figure 3.27: The Kmart in Armidale CBD
Figure 3.28: The Woolworths in Armidale CBD
Figure 3.29: The post office of Armidale
Figure 3.30: An 'isolated' shop at the Woolworths car park
3.3 Conclusion

In order to explain the characteristics of the shopping mall in Armidale, this section is divided into two parts: the physical- and the retail-characteristics. Looking at the plan of the shopping mall, three areas can be distinguished. These areas are separated by a pedestrian ´barrier´: roads. Next the shopping mall has three types of street segments: sidewalks along streets; open air pedestrian area; and an indoor shopping arcade.

The relevant physical- and retail characteristics are summarized by area (see figure 3.9 of section 3.2.1. 'Physical characteristics').

**Area A**
This area can be defined as an indoor shopping arcade. The shops are introvert oriented. Except for the sidewalks along the building, it is fully indoors and car free. It houses two of the three (likely) key tenants of the shopping mall: Coles and Kmart (respectively a large supermarket and a large department store; both large chain stores in Australia). Thus, it is likely that this area will attract a lot of people. Despite these large stores, there us a large number of smaller ones.

**Area B**
In contrast with area A, this area is an extravert oriented part of the shopping mall. It consists of sidewalks along a (busy) road and can be seen as a retail area which has evolved from some isolated stores to a part of an shopping mall. There are two covered passages towards the car park in the back. These passages are pure functional, since they can not be defined as indoor shopping arcades. Area B has the smallest amount of shops, but on average the shops are bigger than in area A. The biggest shop is the supermarket ‘Woolworths’, a big chain store in Australia. This supermarket will probably attract a lot of people.

**Area C**
Area C is the biggest area in the shopping mall. It is not surprising that it contains the most number of shops and it offers the major part of floor space of the shopping mall. However, it does not house any plausible key tenants. Nevertheless, it is an important area within the shopping mall: it forms the biggest pedestrian area in the mall and offers a nice square for pedestrian to stroll along the shops. Most stores are extravert oriented and most parts are outdoors.

This area has the potential to provide a context where people could walk along a certain route (walking pattern). Along the two facades on the square, two zones can be distinguished which could function as two main routes for the pedestrians. Trees and street furniture provide the opportunity for pedestrians to stay in these zones. As mentioned before, this physical characteristic is translated into a hypothesis, which can be tested with the available data in the descriptive analysis.
3. Shopping mall Armidale
4. Observed behavior

In this chapter, the data regarding observed shopping behavior in the Armidale mall will be described. The data were collected by students of the University of New England Armidale, Australia. First, the data collection will be described followed by the data preparation. Next, the results of the descriptive analyses will be presented using different aspects (see figure 4.2). Finally, this chapter will end with a conclusion where the earlier formulated hypotheses are confirmed or rejected.

Figure 4.1: Queen Victoria Market in Melbourne, Australia
Opened in 1878, the Queen Victoria Market is Melbourne’s shopping Mecca. This 19th century market is a historic landmark, tourist attraction and an institution for all Melburnians.
4. Observed behavior

Figure 4.2: Chapter structure
4.1 Data collection

Data on pedestrian shopping behavior was collected by students. Eleven students were instructed to follow pedestrians entering the shopping mall unobtrusively, draw their route through the shopping area on a map, and denote each shop entered. For each shop that was entered by the pedestrian being followed, the time of entering and leaving the shop had to be denoted, as well as whether something was bought by the pedestrian. To each car park, a number of students were allocated. The observation of a pedestrian finished when the pedestrian returned to his/her car. The observation of a pedestrian was ceased when the pedestrian stayed more than 60 minutes in a shop. Sometimes, a student lost track of a pedestrian, in which case the observation ceased as well. In addition to the observed behavior, the gender and age of the pedestrian were registered. All information regarding one observed pedestrian was drawn and noted on a sheet of paper (see appendix 3). Pedestrians were observed on November 11, 14, 16 and 18, 1995.
4. Observed behavior
4.2 Data preparation

To get insight into the collected data, a preparation is necessary. Therefore, a network was designed to store the routes and branches that were determined to describe the types of shop visited.

In order to store and analyze the data, a geographical information system (GIS) is used. In this project, the GIS-package TransCAD is used. To store routes in a GIS, a network is established. This network forms the base for further research in this project. The principle of the network is shown below. For each type of shopping street, a specific network is operationalized, based on the three principles discussed before. The streets in the shopping mall are formed as lines representing the sidewalks. Diagonal lines and lines perpendicular to the sidewalks represent possibilities to cross the street (figure 4.3; a). The network that represents the pedestrian district which runs up Beardy Street is shown in figure 4.3; b. In this network, the position of street furniture and other obstacles is taken into consideration. Finally, the indoor shopping arcade is represented by just one central line with opportunities to enter the shops (figure 4.3; c). Figure 4.4 shows the entire network for the study area.

To analyze the data, both GIS- and statistical software will be used. Therefore a unique key-variable is used to link both datasets. Detailed information about the datasets can be found in appendix 4.
Figure 4.4: Network
4.3 **Descriptive analysis**

In this section, the respondents and their shopping behavior will be described. First, the number of respondents and their general characteristics will be discussed. In the following subsections, the respondents' shopping behavior will be analyzed. The analyses are brought to a conclusion in the final subsection.

The analyses will be differentiated regarding the characteristics of the respondents. Table 4.1 shows the structure of this section: each row represents an aspect of the respondent, which will be described by the characteristics in the columns. The following paragraphs discuss these aspects by row. But first, this chapter will start with a general description of the characteristics of the observed respondents.

**Table 4.1: Descriptive analyses matrix**

<table>
<thead>
<tr>
<th>All Respondents</th>
<th>Walking patterns</th>
<th>Car park</th>
<th>Average shopping time</th>
<th>Visited branches</th>
<th>First visited branch</th>
<th>Distance</th>
<th>Number of visited shops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
</tr>
<tr>
<td>Age</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
</tr>
<tr>
<td>Starting point</td>
<td>!(!)</td>
<td>x</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
<td>!(!)</td>
</tr>
</tbody>
</table>

\(\checkmark\) = discussed  
\(x\) = pointless to discuss
4.3.1 Characteristics of the respondents

In total, 148 pedestrians were observed. However, only 145 respondents provided useful data for this research. 115 of them are female, 28 male. Some observations concern a couple of a male and a female (see figure 4.5).

Regarding age, a major part of the respondents is 'middle-aged' (see figure 4.6). For eight cases, age is missing, these do not take part in the age related analyses.

Looking at the observed men, all ages are quite equally represented. Although, female respondents are dominated by the age group of 30-59 (figure 4.7).

Not all respondents returned to their start location. Only 107 (out of 145) had finished their routes and 38 were lost, out of sight or stayed too long in a shop. These respondents do take part in this analysis if it is not a problem for the results of the analysis.

![Figure 4.5: Respondents by gender](image)

![Figure 4.6: Respondents by age](image)

![Figure 4.7: Age by gender](image)
4.3.2 All respondents

In this subsection all respondents will be subject to a short analysis of the defined characteristics (see table 4.1). It starts with the entry point of the pedestrians: the three car parks, and will end with the number of visited shops.

Figure 4.8 shows the walking patterns of all respondents. For this figure, the established network is used (see section 4.2 'Data preparation'). Although a lot of walked routes are visualized, some main walking patterns can be distinguished. Three are two points of interest. First, along the facades of the square (figure 4.8; box a) a walking pattern appears. Most people walk along the edges of the square, instead of crossing it. As mentioned in chapter 3 'Shopping mall Armidale', there are trees and street furniture which could provoke two walking patterns along the facades. It seems that this is the case. It is not that remarkable because people want to see the shop windows and are guided by these street elements. Another interesting pattern can be pointed out. There are two main routes to cross the road between the entry of the shopping arcade in area A and the passage in B. When people want to go from area A to area B (and vice versa), they have two options. They take the shortest route by crossing the street in a diagonal line, or they can take the longer route using the crossing facility. Figure 4.8; box b shows that both routes are in favor but a bit more people choose the shortest route (diagonal).

Figure 4.9 shows that the largest group of respondents (54%) starts at Kmart. This car park has the biggest capacity, which may be a reason for choosing this car park. The commonwealth bank car park is the smallest car park, thus it is not surprising that this starting point is not chosen as much (6%).

The average time spent in the shopping mall is 25 minutes. Figure 4.10 shows a total overview of shopping time by all respondents. The range is well spread between 1 and 94 minutes of shopping.

Figure 4.11 provides an overview of the branches visited by the respondents. Food is the most visited branch (24%), followed by Remain (services) (20%). The branches Fashion and Other retail come in third place (in sequence 11% and 12%). The Department store (7%) does not attract many visitors as expected (see section 2.3 'Tenant mix').

The pie chart in figures 4.12 shows the first visited branch by a respondent. Again, Food and Remain (services) are the most visited branches. But now they even represent a bigger portion of the visited branches (in sequence 31% and 29%). In contrast with the overall visited branches, department store comes in the third place as first visited branch. Thus, when people visit the department store, they probably do this at the beginning of their itinerary. What is remarkable is the outcome of the fashion branch, only 1% visits this branch first. Most people do visit a fashion store, but most visitors do not schedule this visit in the beginning of their shopping trip.

The average distance pedestrians walked in the shopping mall is 565 meters. In relation to the dimensions of the shopping mall, this is about the width of the mall.

The average number of visited shops is 2.66. This is not much. But do not forget, this is a relative small shopping mall (especially for Australian standards) in a relative small town. This could be the reason that people do not shop for hours and visit a lot of shops as they would do in big shopping malls.
4. Observed behavior

Figure 4.8: Walking patterns of all respondents

Figure 4.9: Starting point of all respondents

Figure 4.10: Shopping time of all respondents
Figure 4.11: Distribution visited branches

Figure 4.12: Distribution first visited branches
4. Observed behavior
4.3.3 Gender

In this subsection the gender of the respondents will be the base of the analysis. Unfortunately, only 28 men were observed in the data collection. Therefore, this analysis is not that useful. Nevertheless, all aspects on this subject are investigated. The same order of determined characteristics as in the subsection ‘all respondents’, will be applied to this analysis.

The walking patterns of both men and women are illustrated in the network (figure 4.13). Due to the small number of observed men (28), the figure of the walking patterns of men does not show any main walking patterns (all equally thin lines). Figure 4.13, showing the walking patterns of women, corresponds to the figure of all respondents shown before (figure 4.8). Therefore, the distinction between men and women does not show any supplementary information on this subject.

Both men and women choose the Kmart car park most frequently (54%, see figure 4.14). But there are relatively more men than women who choose the commonwealth car park (23% over 15%). Women are more in favor of Woolworths (32%).

The average shopping time for men (24 minutes) is approximately equal to the average shopping time of women (25 minutes). The average shopping time of all respondents is 25 minutes.

In figure 4.15 the 100% stacked column shows the branches visited by gender. The Food and Remain (services) are the most visited branches. The column which represents the male gender shows a different distribution over the available branches than earlier showed in the pie chart of all respondents on this subject. The branch Fashion especially differs across gender: females visit more Fashion stores than men. Men visit more shops in the branch Books and magazines. This branch is now of a greater importance than it was in the results of all respondents.

Most men make their first stop at a shop in the Food- or Remain (services) branch (figure 4.16). Interesting is the outcome of the Other retail branch. In relation with the overall visited branches, the third visited branch switches from Books and magazines to Other retail. The column of first visited branches of women shows two interesting aspects (figure 4.16). First, the department store plays a bigger role when choosing the first branch (21%). And secondly, the branch Fashion decreases when it comes to a first visited branch instead of an overall view. As seen before, the fashion shops do not attract many visitors on their first stop in the shopping centre (2% for women, 0% for men). The remainder first visited branches of the women are more or less equally distributed.

The average distance women walk during their shopping trip is a bit less than the average of all respondents. Men walk a bit more. There is nothing noteworthy about this result (see figure 4.17).

Men visit a bit fewer shops than women (in sequence 2,44 and 2,67 shops). One guy visited 15 shops, which is a lot. Because of the low amount of respondents (especially men), this respondent is eliminated from the analyses.
4. Observed behavior

Figure 4.13: Walking patterns by gender

Figure 4.14: Starting point by gender

Figure 4.15: Visited branches by gender
Figure 4.16: First visited branches by gender

Figure 4.17: Average distance by gender
4. Observed behavior
4.3.4 Age

This subsection discusses the age of the respondents. The low number of observed elderly should be taking into account (21). For eight respondents, age is missing; they are left out in this analysis. Again, the characteristics, which will now be discussed relative to age will be in the same order.

The figures 4.18; a through 4.18; c show the walking patterns by age. Due to the fact that most respondents fall in the category of middle aged (30-59), this figure corresponds with the walking pattern of all respondents (see also figure 4.8). There is nothing noteworthy to report here.

But looking at the distribution over the available car parks, middle-aged people appear to choose the Woolworths car park more often. There is no explicit explanation for this phenomenon. The commonwealth bank car park shows a rather equal share for the three age groups (figure 4.19). The differences between the young and old visitor groups are rather small.

Middle-aged shoppers spend on average 27 minutes in the shopping mall. This is three minutes above the average of all respondents. Elderly need only 18 minutes to shop in the mall. This is probably not because they are fast in shopping, but they do not visit a lot of shops. The younger people (age 0-29) are with 23 minutes quite close to the average time of all respondents.

Figure 4.20 presents the different branches visited per age group. It shows that the elderly prefer to visit the Food branch. In the media branch, they visited mainly the news agencies. The young visitors seem to be more interested in Other retail than the middle aged and (even more, the) elderly. They also visit the Books and magazines branch quite often. Fashion and Department stores are relatively popular among the young- and middle aged visitors. There seem to be a few trends: the probability of visiting a bar/restaurant or the Other retail branch decreases with increasing age, while the probability of visiting a Food- or Remain (services) branch increases with age.

Respondents aged 60 and over, mainly visit the food branch first (figure 4.21). And as in previous analyses, Fashion is not a popular first visited branch. The other first visited branches are in line with previous outcomes. But there is one remarkable outcome in the results in the age of 60+: they visit relative much shops in the Electrical appliances branch. Something you would not expect. But again, the relative few respondents (especially in the age category of 60+) could give unreliable results.

For the first time the average distance shows an interesting result: there is a well spread outcome on this matter. Elderly only walk about 300 meters instead of the average of 565 meters of all respondents. The middle aged group is responsible for the longer routes, on average 646 meter. This is all in line with expextations (figure 4.22).

The outcomes of the average number of visited shops by age are in line with the average walked distances and the average shopping time by age. The elderly, who only walk about 300 meters and spend only 18 minutes in the shopping mall, visit only 1,71 shops. The young shoppers and the middle aged shoppers are in line with the average (in sequence 2,51 and 2,69).
4. Observed behavior

Figure 4.18; a: Walking patterns by age

Figure 4.18; b: Walking patterns by age

Figure 4.18; c: Walking patterns by age
Figure 4.19: Starting points by age

Figure 4.20: Visited branches by age
4. Observed behavior

Figure 4.21: First visited branches by age

Figure 4.22: Average distance by age
4.3.5 Starting point

This subsection divides the respondents in three groups, according to their starting point (car park). The characteristic ‘car park’ is in this matter pointless to discuss (see table 4.1).

There is a certain relationship between car park and the area of shops visited. People, who parked their car at Woolworth’s (30%), visit the adjacent area (B) and walk on to area A (see figure 4.23; a). People from the commonwealth bank car park (16%) tend to stay within the same area (C) (figure 4.23; b). Many respondents who started their shopping route at Kmart car park (54%) spread out over the study area (4.23; c). But most of them visited at least the Kmart and/or Coles (respectively a department store and supermarket). Thus, it is possible to identify some walking patterns, starting from each car park. The Commonwealth bank car park is relatively small, and probably most people have a single purpose shopping visit in mind in this area. From this car park, there are two options to enter the shopping mall, but most people enter the shopping area via the west-entrance (figure 4.23; b; thick line). People who parked at Woolworth’s also have two choices. Most people who choose the indoor shopping arcade (thick line on the right in figure 4.23; a) continue their route towards area A. Finally, the car park at Kmart gives people a number of choices which has it’s effect on the results: people spread out and mainly visit both area A and C. This car park is much larger; therefore people will probably choose this location for parking place availability instead of accessibility of shops (see figure 4.23; c).

The average shopping time differs slightly per car park. People who parked their car at the Kmart car park, stay three minutes longer than the average respondent. Furthermore, there is nothing noteworthy to mention on this subject.

The 100% stacked columns in figure 4.24 shows the differences of visited branches by starting point. The large amount of visits to the branch Remain (services) by people who parked their car at the Commonwealth Bank car park catches the eye. And looking at the previous findings, it is quite understandable. Most shops in the branch Remain (services) are located in area C (adjacent to the Commonwealth Bank car park). And most people starting at Commonwealth Bank car park, visit area C. Therefore, it is not surprising that this branch is visited frequently. Another interesting outcome is the portion represented by the Food branch in the ‘Woolworths column’. As you can see a lot of people visit this branch, when parked at the Woolworths car park. This is also in line with the expectations. After all, the big supermarket Woolworths is located in the adjacent area and it is likely that people who want to visit this supermarket park their car in the adjacent car park. Finally, people who started at the Kmart car park visit all kind of shops in all kind of branches. But the branch Department store is more visited than this branch is by people from other car parks. There is only one department store in the shopping mall and it is located in area A, adjacent to the Kmart car park. This is a third example of a possible relationship between car park and visited branch.

Figure 4.25 shows the first visit related to the chosen parking facility. Previous assumptions about the visited branches of respondents and their starting point are now emphasized. When people park at the commonwealth Bank car park, almost 70% first visits a shop in the Remain (services) branch. Therefore, it is clear that the car park and the adjacent area do relate in some way. Secondly, 25% of the people who parked at Woolworths, first visit a shop in the Food branch. It is likely to assume that this would be the big supermarket Woolworths. Parking at Kmart is more diverse in comparison with the other two car parks. This is not surprising as people who started at Kmart also physically spread out through the shopping mall (see also section 4.3.3 ‘All respondents’). As seen before, the branch Department store plays a bigger role in the Kmart column, than it does in the other two. It is
likely that people who want to visit the (only) department store, park their car in the adjacent car park (Kmart's).
There are no differences between walked distances of the respondents categorized by starting point (see figure 4.26). They all walk, more or less, the average distance.
The number of shops visited of the respondents, ordered by each car park, lies around the average of 2,66 shops.

Figure 4.23; a: Woolworths car park

Figure 4.23; b: Commonwealth car park
Figure 4.23: Kmart car park

Figure 4.24: Visited branch by starting point
4. Observed behavior

Figure 4.35: First visited branch by starting point

Figure 4.36: Average distance by starting point
4.3.6 Conclusion

This conclusion will summarize all relevant outcomes of the descriptive analysis in order to accept or reject the formulated hypotheses. The overview and evaluation of these hypotheses will be described in the next section: the final conclusion of this chapter.

First of all, the collected data consisted of 148 observed pedestrians. Only 145 are used in the descriptive analysis. Next, most respondents were female and middle aged. Therefore, one should be careful when interpreting the results and drawing conclusions.

The average time spent in the shopping mall is 25 minutes. During this time, shoppers walk an average of 565 meters and visit an average of 2.66 shops. This is not much. But do not forget, this is a relative small shopping mall (especially for Australian standards) in a relative small town. Considering age, we found interesting outcomes. Elderly spend considerably less time (18 minutes) during their shopping trip and walk shorter distances (300 meters). This is in line with the number of shops they visit: 1.71. Note: there were only 21 respondents in the age category of 60+.

The most visited branch is Food (24%), followed by Remain (services) (20%). Department store (7%) does not play an important role regarding the number of visits, in contrast to the assumption made before (see section 2.3 ‘Tenant mix’).

Analyzing the visited branches shows interesting results. It turns out that the branch Fashion comes in third place when all visits are evaluated. But people certainly not visit this branch firstly. They prefer to visit the branches Food and Remain (services) first. The Department store plays a role when it comes to the first visited shop.

The descriptive analysis described, using several approaches, more or less the same phenomenon related to walking patterns. The observed pedestrian behavior is clearly related to the (sub)area and the car park the shopper has chosen to start the shopping trip. In other words, the analysis where the data is categorized by starting point shows some interesting results regarding walking patterns. Two characteristics of pedestrian movement are of vital importance when looking at the observed behavior in this research.

First, the phenomenon of walking the shortest route possible (as described in section 2.2.3 of this report) clarifies the observed behavior. Especially the tendency of pedestrians to stay close to their starting point can be used to explain the outcomes of the descriptive analysis. The visualization of the walking patterns of all respondents sorted by car park (literally) shows us this phenomenon. Figures 4.27; a through 4.27; c combine two aspects of the descriptive analysis: the distribution of the pedestrians who first visited a certain branch and the location of the shops within the shopping center. These figures visualize the tendency of pedestrians to stay close to their starting point. For example, 86% of the respondents who visited the Department store first, parked their car in the adjacent Kmart car park (figure 4.27; c). It is likely to assume that car park and a first visit to a certain location of a shop are related.

In this percept, the definition of the key tenants in this shopping mall becomes relevant. As mentioned before, most people who visited the department store (Kmart), parked their car nearby. Next, this department store is not in favor when looking at the distribution of the branches visited by all respondents. But when looking at the first visited branch, the Department store plays a more important role. Combining this outcome with the phenomenon of ‘nearby parking’, it is likely to assume that this department store functions as a key tenant in the shopping mall. But there are more ‘candidates’ for the role of key tenant. In the Food branch a similar conclusion can be drawn. The Food branch is one of the most visited branches in the mall. Forty-two percent of the respondents who first visited a Food branch, parked at Kmart’s (figure 4.27; a). Another 46% parked at Woolworth’s. Figure
4. Observed behavior

4.27. a shows the locations of the shops in this branch. Most shops in the Food branch are located in area A and B. The Kmart- and Woolworths car parks are the adjacent locations to park the car. Thus a similar conclusion can be drawn. Knowing that two big supermarkets are located in these areas (Coles in area A and Woolworths in area B), strengthen this assumption even more.

Figure 4.27; a

Figure 4.27; b

Figure 4.27; c
4.4 Conclusion

Despite the low number of observed pedestrians, the collected data provided a lot of information about pedestrian behavior in the shopping mall of Armidale. In order to manage this data, a data preparation was necessary. This data preparation consisted of building a network to visualize the walking patterns and to code the data in favor of the descriptive analysis.

Earlier in this research two aspects of pedestrian behavior were defined: pedestrian environment and tenant mix. These two aspects were examined in the literature research. Next, these aspects were used to describe the shopping mall in Armidale. The literature review was done with the intention to formulate some hypotheses which could be evaluated with the available data. Thus, the formulated hypotheses are a result of the interpretation of pedestrian behavior considering two aspects: pedestrian environment and tenant mix.

Below are the formulated hypotheses in summary. According to the descriptive analysis, the first one can be qualified as ‘true’. Although other branches in the shopping mall of Armidale probably also fulfill a role as key tenant. This is not surprising because most shopping malls consist of more than one key tenant in order to generate pedestrian flows (Sim & Ru Way 1989).

The second hypothesis can also be qualified as ‘true’. This phenomenon was observed multiple times in the outcomes of different aspects in the descriptive analysis. This is likely the most trustworthy statement on this subject.

The branches ‘Fashion’ and ‘Department store’ do not attract the most shoppers in the shopping mall of Armidale. The branches Remain (services) and Food do instead. Therefore, this hypotheses is not true for this particular case (probably because of the relative small size of the shopping center).

And finally, the last hypotheses turned out to be the most difficult to prove with the available data. Further research is necessary to state something on this matter. But, based upon the findings, there is no reason to reject this hypothesis. There are reasons to belief this statement could be true.

✓ “Department stores fulfill the role of key tenant in a shopping mall.” (Bruwer, 1997; Brown, 1992).

✓ “Pedestrians tend to stay close to their starting point.” (Deckers, 2005).

✗ The branches ‘Fashion’ and ‘Department store’ attract most shoppers (Deckers, 2005; Leung, 2007).

4. Observed behavior
5. The model

There are many models for predicting pedestrian behavior. This study will use the still popular multinomial logit model to predict pedestrian behavior in the shopping mall of Armidale CBD. The aim of this research is to test this particular model on an Australian case and check if it is possible to predict pedestrian behavior. In contrast to most models, which apply to microscopic and grid-based behavior, this model predicts pedestrian behavior at the level of links in downtown retail areas.

This chapter is divided into two main sections: The multinomial logit model and the Monte Carlo simulation (see figure 5.1). Each section will start with a short general description of the used method. The first section will describe the results of estimating the parameters. The second section will describe the results of the simulation of two situations (1995 and 2008). This chapter ends with a conclusion.

Figure 5.1: Drive through in Cairns, Australia
A drive through express in Cairns, Australia. This 'shop' is open twenty four seven and accessible by car.
5. The model

Multinomial logit model
- Theory (assumptions)
- Variables
- Data 1995
- Parameters
- Validation

Monte Carlo simulation
- Theory
- Simulation situation '95
- Parameters model 1
- Predicted behavior
- Simulation situation '08
- Parameters model 2
- Predicted behavior
- Conclusion

Figure 5.1: Chapter structure
5.1 The model

As mentioned in chapter 2 ‘Literature review’, there are many models to predict pedestrian behavior. Due to the background and motives of this research, the model developed at the Eindhoven University of Technology is chosen (see chapter 1 ‘Introduction’ for the motivation). This model consists of two main sections: the multinomial logit model and Monte Carlo simulation.

The multinomial logit model is used to estimate the probability an alternative (link) is chosen and is described in detail in this section. It is chosen because it is one of the best known and most frequently applied in studies of spatial shopping behavior (Timmermans, Borgers and van der Waerden 1992).

First the theory behind this model is explained. Next, the variables are summarized which represent the two main characteristics of pedestrian behavior: pedestrian environment and tenant mix. These variables are also used in earlier studies of the model developed at Eindhoven University of Technology. Some of these variables are modified for this particular case and there are new variables added. These variables will be discussed separately. The original variables are described in section 5.1.2 ‘Variables’ and the modified and new variables are described in the concerning sections of the parameters. In the next section, the data collected in 1995 will shortly be discussed in this context. In order to explain observed behavior, the parameters of the variables are estimated. To test and evaluate the added and new variables, three sets of variables are used to re-predict observed behavior: the ‘original model’, the ‘model with modified variables’ and the ‘model with modified and new variables’. Therefore the results of the multinomial logit model are discussed in three sections: the parameters of the original model, of the model with modified variables and of the model with modified and new variables. Finally, a model validation will evaluate these three models.

5.1.1 Theory

The main principle of this model is the individual choice behavior of a pedestrian on each link in the network. On every link (which resembles a street segment) a pedestrian chooses one of the alternatives to continue his/her route (see figure 5.2). This set of alternatives on each link is called a choice set. Besides all the available alternatives, a choice set also contains a possible stop alternative. This stop alternative is only part of the set of alternatives when the current link is adjacent to or on a ‘start’-link. The final itinerary of a pedestrian is established by this sequence of individual choices made on each link. It starts and ends at one of the car parks in the area (van Wijk 2003; Deckers 2005).

![Figure 5.2: Schematic representation of choosing alternatives.](image)

Assumptions

The model involves several assumptions towards choice behavior in general. First, this model assumes that the final goal of a pedestrian is unknown. As a result no visitor can be defined as a goal-directed shopper, all shoppers are intended to stroll and shop without having an itinerary made up in their mind. A second important assumption is related to the starting
point of a pedestrian's trip. They start and end their route at a car park in the research area. This entry point is part of the defined network (a link) (see section 5.1.2 'Network') and is located at the edge of the network.

When an individual \(i\) is located at a certain link, he/she has a number of alternatives \(j\) to choose from. These alternatives together are defined as a choice set \((C_i)\) of individual \(i\). Each alternative consists of several characteristics \(k\) (both physical and retail characteristics). In what extent a characteristic \(k\) of alternative \(j\) scores for a particular individual \(i\), is annotated with \(x_{ik}\). This score represents a part of the utility of each alternative for each individual. This score is weighted by a parameter \(B_k\). The structural utility \((V_{ij})\) a alternative \(j\) has for an individual \(i\) can be derived from equation 1:

\[
V_{ij} = \sum_k B_k x_{ik}
\]  

(1)

The structural utility \((V_{ij})\) is the sum of weighted characteristics of alternative \(j\). There is a second component that makes up the final utility of an alternative. This part of the model assumes that individuals have different preferences and retain characteristics differently. Subsequently, the utility of an alternative is not constant over time for a particular individual. Therefore a so called 'random'-component \(\varepsilon_{ij}\) is integrated to take these differences between individuals and moments in time into account. This component also corrects possible observation and possible model specification errors.

These described two components (a structural part and a random part) result in a final utility \((U_{ij})\) of one alternative (see figure 5.3). In formula:

\[
U_{ij} = V_{ij} + \varepsilon_{ij}
\]  

(2)

Finally, a individual will choose the alternative with the biggest utility. But due to the 'random'-component \(\varepsilon_{ij}\) (which describes the differences between individuals) it is not obvious what alternative has the biggest utility. By assuming an independent and identically double exponential distribution for the error terms, the probability a particular alternative will be chosen can be derived from the equitation below:

\[
P(j|i,C) = \frac{\exp(V_{ij})}{\sum_m \exp(V_{jm})}, \text{ for all } j,m \in C_i
\]  

(3)

\(P(j|i,C)\) represents the probability an individual \(i\) chooses alternative \(j\) from the set of alternatives. \(P(j|i,C)\) is equal to the probability the final utility of alternative \(j\) for individual \(i\) (which is \(U_{ij}\)) is bigger than the final utility \((U_{jm})\) of all other alternatives in the choice set \((C_i)\) of this individual. Equations 1-3 are known as the multinominal logit model ((Domencich and McFadden 1975; Lerman and Ben-Akiva, 1987)).

The probability an alternative is chosen increases when the structural utility \(V_{ij}\) of this alternative increases or the structural utility of another alternative decreases. The probability an alternative is chosen does not depend on the absolute value of the utility of this alternative. It depends on the differences between the utilities of the available alternatives. In other words, the ratio between the probabilities of two alternatives only depends on the difference between the utilities of these alternatives \((V_{ij} - V_{jm})\).

Figure 5.3 shows a schematic representation of the working of the model.
Parameters
A route can be translated into a series of choices the pedestrian made at each link (consisting of two junctions with several alternatives). The variables determine the choice of a pedestrian (e.g. an alternative is located in a car free zone which people may prefer over other types of streets). Each variable is multiplied by a parameter which represents the influence the variable has on the route choice behavior. These parameters influence the utility of an alternative negatively or positively, and finally it will influence the probability a utility is chosen.

Based upon this approach, the parameters of the variables are statistically estimated with an optimization algorithm. In this study, the software package Limdep (REF toevoegen) has been used. This program uses a file in which all choice sets are listed. Based upon this file, the program estimates the parameters of each variable in order to re-predict the observed behavior in the best possible way. The model tries to estimate the parameters in such a way that the log-likelihood is as high as possible. In other words, the higher the log likelihood, the better the model re-predicts the observed behavior.

Parameters which do not differ significant from zero shall be removed from the model.

Model validation
Finally, a model validation is necessary to determine if the model is capable of re-predicting observed behavior. To do this, the log-likelihood function is used. \( \rho^2 \) is a derivative from this function; it represents how good the model re-predicts the observed behavior. It shows to what extent the log-likelihood of the estimated model differs from the zero-model. The zero-model is the model where all parameters are set to zero. This means that the probabilities each alternative is chosen is equal to \( 1/j \), where \( j \) is the number of alternatives. In other words, the probabilities of all alternatives are equal (Hendriks and Ottens 1997; van Wijk 2003). Usually, \( \rho^2 \) lies between zero and one. The closer to one, the better the model is. Literature claims that a \( \rho^2 > 0.2 \) reflects an acceptable model (Hendriks and Ottens 1997; van Wijk 2003). When this value turns zero, the model is not better than the zero-model, which means that every choice could be based upon a random selection. In formula, \( \rho^2 \) is:

\[
\rho^2 = 1 - \frac{LL(\beta)}{LL(o)}
\]  

where \( LL(\beta) \) is the log likelihood of the model with estimated parameters and \( LL(o) \) is the likelihood of the zero-model.
5.1.2 Network

This model is based upon the link to link principle. Therefore, the situation of the shopping mall has to be translated into a network of links. The observed routes of the pedestrians are then translated into this network. Subsequently, the network is used to visualize the pedestrian behavior into intensities of the links (street segments).

As seen in chapter 4 ‘Observed behavior’, a network is established in order to visualize observed pedestrian behavior (see figure 5.4). This network is not suitable for this model; it is too detailed. The network used before has many nodes to facilitate links to shops. The nodes in the network underlying the model should represent intersections, and the links between the nodes street segments. Therefore, a more simple network is defined based upon the existing network. This new network is established with the insights gathered in the descriptive analyses in chapter 4 ‘Observed behavior’. In short, the most walked routes are represented in the new network. Besides this, important choice moments in shopping routes have been taken into account. From now on, the new network in figure 5.5 will be used.

All the links in the network have physical characteristics. For each link all relevant characteristics are annotated. These characteristics define the variables for each link. The characteristics are gathered during the data collection, the descriptive analysis and during the visit of the shopping mall in 2008 (see also chapter 1 ‘Introduction’ and section 5.2.2 ‘Situation 2008’ of this chapter). Some of the most interesting network links (with their characteristics) will be summarized here briefly.

Figure 5.4: Network in favor of the descriptive analysis

Figure 5.5: Network in favor of the model
5.1.3 Variables

Each link in the network has several characteristics. These characteristics are translated into variables. Supposedly, the choice of a pedestrian to enter an adjacent link depends on these variables. The variables used in earlier studies of this model are summarized in this section. These variables can be categorized in five categories: distance, route history, length of sight, tenant mix and accessibility, and physical characteristics. It is discussed according this categorization.

Some variables are modified and some new variables are added in favor of this particular case. These variables will be discussed in their relevant 'parameter' sections of this chapter.

Distance
An important variable is ‘Dist’. The distance traversed from the starting link until the current link is denoted by ‘Distbeg’. The shortest distance via the alternative link to the starting position is denoted by ‘distend’. The model assumes that at the start of a route a pedestrian wants to move away from his starting point. After T meters (‘T’ is an average threshold that has to be estimated), the pedestrian wants to return to the starting point. The variable ‘dist’ is determined as follows:

\[
dist = \text{distend} \times [1 - (\text{distbeg}/T)]
\]

This variable has a positive value as long as ‘Distbeg’ is shorter than the threshold ‘T’ and is negative if it is longer than ‘T’. Therefore, a positive parameter is expected for this variable.

Sometimes, pedestrians turn around in a certain link. In other words, he/she leaves the link where he entered it. Therefore, a variable ‘Return’ is introduced. If an alternative implies a return, the value of ‘Return’ will be equal to one and zero otherwise. As pedestrians are expected to dislike turning around in a link, the parameter of this variable should be negative. However, if a pedestrian is far away from his starting point, the resistance to turn around may decrease, which is operationalized by the variable ‘Disret’. This value of this variable is equal to the reciprocal of the shortest distance from the current link to the starting link. If ‘Return’ is equal to zero, ‘Disret’ is equal to zero by definition.

Finally, the variable ‘Stopdis’ represents the possibility to finish a route. If a pedestrian comes near his starting point he has the opportunity to end his route. Only if the alternative link is the starting link or adjacent to the starting link, the pedestrian may decide to stop. ‘Stopdis’ measures the traversed distance until the current link. If the pedestrian walked a long distance, the probability the pedestrian stops is likely to increase. Therefore, a positive sign for the corresponding parameter is expected. If a pedestrian (accidentally) approaches his entry link at an early stage, he will probably continue his trip. To summarize, the variables related to distance are:

- Dist
- Disret
- Return
- Stopdis

Route history
Apart from distance effects, variables related to route history are defined. These three variables (‘Before1’, ‘Before2’ and ‘Before3’) all describe whether a link has been passed before during the trip. ‘Before1’ indicates whether the alternative link has been passed before once (if yes, ‘Before1’ is one, zero otherwise). ‘Before2’ and ‘Before3’ indicate whether
an alternative link has been passed two or three times before respectively. It is likely that pedestrians do not like passing twice the same link. In this case the parameter for this variable should be negative. However, it is possible that people prefer to walk back to the entry link the same way they walked to their current position. In this case, passing a link for a second time induces no negative impact, while passing a third or fourth time could do so. Thus, the history is described by three separate variables:

- Before1
- Before2
- Before3

**Length of sight**

It is assumed that pedestrians like street segments with a view. Therefore, links that belong to long, straight streets may be preferred over links without a view. A group of variables is defined to implement this phenomenon. In terms of the model this means that if a link is part of a long straight line of connected links, the link is probably preferred over links in a short line. These links situated along the same line, represents the 'length of sight'. But there are also relatively long links which could function as a length of sight. The model deals with this aspect. Even if a long link is not connected in a straight line to other links, the value of this variable can be relatively high. Four versions of the length of sight have been defined. 'Dsight1' represents the length of sight in both directions; 'Dsight2' the length of sight in both directions, but only for pedestrianized links; 'Dsight3' and 'Dsight4' are defined similarly, but the length is only measured in the walking direction. The variables are:

- Dsight1
- Dsight2
- Dsight3
- Dsight4

**Tenant mix and accessibility**

An important characteristic of the alternatives is the supply and configuration of the present shops. In a retail area the attractiveness of a certain (sub)area is determined by the presence and number of certain shops. People will tend to walk towards (sub)areas where the shopping supply is significant. This is split up in two aspects. First the shopping supply is of importance: if the number (floor space) of shops increases, the tendency of pedestrians to walk towards this area increases. Second, the accessibility of shops within the network is assumed to be important: if an alternative link gives better access to a lot of shops, this alternative will probably be more attractive.

The variable is split up in a number of branches (see also section 2.3.1. 'Branches'). Next, these variables are merged into groups. For instance, the branches Fashion and Shoes are jointed into 'ShopsF'. This turned out to be necessary in order to get significant parameters. The used branches in the defined variables are:

- ShopsP (Food and Personal care)
- ShopsF (Fashion and Shoes)
- ShopsH (Home products and Electrical appliances)
- ShopsO (Books and magazines, Music and video and Other retail)
- Shops10 (Departments stores)
- Shops11 (Bars and restaurants)
- Shops12 (Remain, services)

The last two variables do not represent shops but these types of outlets might influence route choice behavior as well. The supply and accessibility for a particular type (branch) of shops is equal to the floor space of these shops in a link divided by the distance to that link.
from the current link, summed over all links. Supply in the current link is divided by half the length of this link.

Physical characteristics
Finally, there are a series of variables representing the physical characteristics of the links. Some of these variables are already mentioned in section 5.1.2 'Network' of this chapter. Some variables describe the environment of a link, for instance 'Pedestr' refers to a car free link. And some refer to a particular function or characteristic of the link itself, for instance 'Cross' means that the link is a crossing. The variables are:

- Façade
- Square
- Road
- Other
- Water
- Pedestr
- Pedcar
- Mixed
- Footpath
- Indoor
- Trshops
- Cross
- Elevin
- Elevout

5.1.4 Data 1995
As mentioned before, 148 pedestrians were followed during their shopping trip in the shopping mall of Armidale (Australia). 145 pedestrians were useful for the descriptive analysis. However, 46 people did not return to the starting point: they were lost during the observations or were in a store for more than 60 minutes. Because the model assumes a pedestrian starts and ends at the same location, these pedestrians can not be used in the model, so only 99 pedestrians are useful to estimate the parameters of in the model. Figure 5.6 shows a visualization of these 99 observed routes.

Figure 5.6: Observed behavior
5.1.5 Parameters original model

First the original configured model of recent research in Eindhoven and Maastricht will be used to estimate the parameters of the relevant variables. The variables as listed in section 5.1.2 ‘Variables’ are used. These variables have not been modified and directly applied to this situation (after adapting them to this case).

Not all available variables have been used in this case. There are two reasons why. First, given the relative small number of observed routes, the software used to estimate the multinomial logit model is not able to estimate too many variables. It simply does not find an optimal solution. And if it finds a solution, many parameters are insignificant. Secondly, some variables do not play a role in this particular situation (e.g. water: there is no water in Armidale CBD). A process of testing and evaluating parameter estimates resulted in a set of selected variables. Although some parameters are not significant, they are kept in the model because they are somehow related to another variable. For instance, the variables which represent the presence or absence of vehicles (in sequence, ‘Mixed’ and ‘Pedestr’) are both used in the model despite the fact one of them is not significant.

**Results**

Table 5.1 shows the outcomes of the multinomial logit model. The first column lists the variables, the second column a short description of this variable, the next column the estimated value for the concerned parameter and the last column shows the significance of the parameter.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
<th>significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopdis</td>
<td>possibility to finish a route</td>
<td>0.0026</td>
<td>0.0000</td>
</tr>
<tr>
<td>Return</td>
<td>turning around in a link</td>
<td>-2.4938</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dist</td>
<td>distance traversed from starting link until current link</td>
<td>0.0048</td>
<td>0.0000</td>
</tr>
<tr>
<td>Before2</td>
<td>a link has been passed before once</td>
<td>1.2433</td>
<td>0.0000</td>
</tr>
<tr>
<td>Disht2</td>
<td>length of sight in both directions of pedestrianized links</td>
<td>0.0055</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsP</td>
<td>food and personal care</td>
<td>-0.00006</td>
<td>0.6810</td>
</tr>
<tr>
<td>ShopsF</td>
<td>fashion and shoes</td>
<td>0.0012</td>
<td>0.0016</td>
</tr>
<tr>
<td>ShopsH</td>
<td>home products and electrical appliances</td>
<td>0.0036</td>
<td>0.0002</td>
</tr>
<tr>
<td>ShopsO</td>
<td>books and magazines, music and video and other retail</td>
<td>0.0000</td>
<td>0.9844</td>
</tr>
<tr>
<td>Shops10</td>
<td>departments stores</td>
<td>0.0026</td>
<td>0.0000</td>
</tr>
<tr>
<td>Shops11</td>
<td>bars and restaurants</td>
<td>0.0027</td>
<td>0.0016</td>
</tr>
<tr>
<td>Shops12</td>
<td>remain, services</td>
<td>-0.0003</td>
<td>0.3366</td>
</tr>
<tr>
<td>Indoor</td>
<td>an indoor link</td>
<td>-0.0432</td>
<td>0.7471</td>
</tr>
<tr>
<td>Mixed</td>
<td>pedestrians and cars share this area</td>
<td>-0.8672</td>
<td>0.0345</td>
</tr>
<tr>
<td>Pedestr</td>
<td>a car free link</td>
<td>0.1434</td>
<td>0.5161</td>
</tr>
<tr>
<td>Cross</td>
<td>link crossing a street</td>
<td>-0.7685</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
As table 5.1 shows, still five variables are not significant: 'ShopsP', 'ShopsO', 'Shops12', 'Indoor' and 'Pedestr'. According to this set of variables there is not an obvious explanation for this result; probably the small number of observations causes the insignificances. The model validation shows a Rho² of 0.29 (see section 5.1.8 'Model validation').

Looking at the values of the parameters some interesting results should be mentioned.

- The distance related variables are as expected. 'Stopdis' and 'Dist' are both positive, the way they should be. And the parameter of the 'Return' variable is negative, also as assumed;
- 'Before1' is positive, which means that this variable contributes in a positive way to the probability the concerning alternative (a link which has been passed before) will be chosen. This and has been found before in the studies in Eindhoven and Maastricht (van Wijk 2003; Deckers 2005);
- 'Dsigth2' is positive which means that people prefer walking through pedestrianized links with a long sight. This represents the phenomenon of people who tend to walk straight ahead (length of sight) instead of turning corners and people’s preference of connected links over links in a short line;
- 'ShopsP' and 'Shops12' have negative parameters. This means that these branches (in sequence, Food and Personal care and Remain, services) have a negative influence on walking towards these types of shops. 'ShopsP' was also negative in the studies of Eindhoven and Maastricht but 'Shops12' was only negative in the study of Eindhoven;
- it is no surprise that the variables 'Mixed' and 'Pedestr' are negative and positive: they are each others opposites. The other types of links (see subsection 'Physical characteristics' of section 5.1.3 'Variables'), these are set to zero. 'Mixed' refers to an area where cars and pedestrians share their space. 'Pedestr' refers to a car free area;
- what is surprising is the negative parameter of 'Indoor'. Apparently people prefer shopping outdoor. It is not as expected, but apparently, Australian people like to shop outdoor;
- finally, 'Cross' is negative. This means that people do not prefer to cross the street. They avoid these links and chose other links which do not cross a street. This is in line with expectations.
5.1.6 Parameters model 1 (modified variables)

In the previous section, the results showed some interesting outcomes, but too many variables were insignificant. Therefore some of the original variables are modified in order to improve the model. Note that the previously presented variables are already adapted to the case of the Armidale shopping mall. Now a couple of variables are modified.

First the modified variables are described, next the results of this model are presented.

**Modified variables**

The original variables which are modified are 'Cross' and 'Mixed'. These variables turned out not to be suitable for this particular case. In order to improve the model, these variables are modified. The variable 'Cross' defines whether a link crosses a street. The left image in figure 5.9 shows the locations where people cross streets in the shopping mall of Armidale. These links are based upon routes respondents followed to cross a street (see figure 5.7). Some of these locations are crosswalks with pedestrian facilities (see figure 5.8). Despite this distinction in types of crossings, the defined variable 'Cross' involves both a crossing with and without pedestrian facilities.

In order to improve the model this original variable is split up in two new variables: 'Cross' and 'Crossp'. One variable regards the situation where people cross a street without pedestrian facilities ('Cross'), and one variable regards the situation where crosswalks are situated. The right image in figure 5.9 shows the two variables applied to the relevant links: red links represent crossings without facilities ('Cross') and green links represent crossings with facilities ('Crossp').
In the original set of variables, there were several variables related to the type of area a link is located in. The variables 'Mixed' and 'Pedestr' are used in this case. 'Mixed' represents areas where pedestrians and cars share the public space (figure 5.10). This means that both can use this area and neither pedestrians or cars have their own (sub)area. The (original) variable 'Parking' defines the links located in parking lots (figure 5.11). As can be seen, these two types of areas are more or less the same in this particular case.

The image on the left in figure 5.12 shows the links located in the 'Mixed'-area (green) and the 'Parking'-area (red). As shown, the number of both types of links is rather small. Therefore these two variables are merged into one new variable 'Mixed'. From now on, the 'Mixed'-variable represents both the mixed and the parking areas.
Results
Table 5.2 shows the outcomes of the multinomial logit model. The first column lists the variables, the second column a short description of this variable, the next column the estimated value for the concerned parameter and the last column shows the significance of the parameter.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
<th>significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopdis</td>
<td>possibility to finish a route</td>
<td>0.0021</td>
<td>0.0000</td>
</tr>
<tr>
<td>Return</td>
<td>turning around in a link</td>
<td>-2.5110</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dist</td>
<td>distance traversed from starting link until current link</td>
<td>0.0052</td>
<td>0.0000</td>
</tr>
<tr>
<td>Before1</td>
<td>a link has been passed before once</td>
<td>1.2241</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dsight2</td>
<td>length of sight in both directions of pedestrianized links</td>
<td>0.0059</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsP</td>
<td>food and personal care</td>
<td>-0.0004</td>
<td>0.7815</td>
</tr>
<tr>
<td>ShopsF</td>
<td>fashion and shoes</td>
<td>0.0013</td>
<td>0.0018</td>
</tr>
<tr>
<td>ShopsH</td>
<td>home products and electrical appliances</td>
<td>0.0037</td>
<td>0.0003</td>
</tr>
<tr>
<td>ShopsO</td>
<td>books and magazines, music and video and other retail</td>
<td>0.0002</td>
<td>0.6993</td>
</tr>
<tr>
<td>Shops10</td>
<td>departments stores</td>
<td>0.0026</td>
<td>0.0000</td>
</tr>
<tr>
<td>Shops11</td>
<td>bars and restaurants</td>
<td>0.0028</td>
<td>0.0089</td>
</tr>
<tr>
<td>Shops12</td>
<td>remain, services</td>
<td>-0.0007</td>
<td>0.0202</td>
</tr>
<tr>
<td>Indoor</td>
<td>an indoor link</td>
<td>-0.5389</td>
<td>0.0039</td>
</tr>
<tr>
<td>Mixed</td>
<td>pedestrians and cars share this area</td>
<td>-0.6874</td>
<td>0.0000</td>
</tr>
<tr>
<td>Pedestr</td>
<td>a car free link</td>
<td>0.3137</td>
<td>0.1928</td>
</tr>
<tr>
<td>Cross</td>
<td>link crossing a street without pedestrian facilities</td>
<td>-0.8989</td>
<td>0.0000</td>
</tr>
<tr>
<td>Crossp</td>
<td>crosswalk</td>
<td>0.3985</td>
<td>0.0253</td>
</tr>
</tbody>
</table>

Table 5.2 shows the results using the variables of the original model with the modified variables. Now, only three instead of five parameters are insignificant: ShopsP', 'ShopsO', and 'Pedestr'. It turns out that because of the modified variables, the model is better capable of estimating the parameters in order to re-predict the observed behavior. The Rho² is 0.30 (increased) (see section 5.1.8 'Model validation'). During the process of estimating the parameters it appeared that both modified variables 'Mixed' and 'Cross' are necessary in order to generate these results.

Looking at the values of the parameters some interesting results should be mentioned.
- The distance related variables are still significant (0.0000) and all signs of the parameters are still as expected;
- before1 and 'Dsight2' haven't change much: still as expected and significant;
- 'ShopsP' and 'Shops12' are (still) negative parameters. But in contrast to previous model, now 'Shops12' is significant.
- 'Mixed' and 'Pedestr' are still negative and positive: the way they should be according to the expectations. Unfortunately, 'Pedestr' is still insignificant;
• the variable 'Indoor' became significant in this model. And as in the previous results the parameter is negative;
• the most interesting about these results is the modified variable 'Cross'. In previous results of the original model, the variable 'Cross' had a negative parameter. That was in line with the expectations: people do not prefer crossing a street. But now the variable has been split up in a crossing with and without pedestrian facilities, the crosswalk with pedestrian facilities ('Crossp') has become positive. In other words, people prefer a crosswalk over crossing the street without any pedestrian facilities. Both parameters are significant.

5.1.7 Parameters model 2 (modified and new variables)

In the previous section, the model with modified variables showed some interesting outcomes of the parameter estimation. But still three variables were insignificant. Now, a few variables are added trying to improve the model and get these parameters significant. First the new variables are described, next the results of this model are presented.

New variables

In chapter 3 and 4 the layout of the shopping mall and the pedestrian behavior has been described and discussed. The most important aspect on this matter was the subdivision of the shopping mall into three areas which provoked a tendency of people to stay in the adjacent area where they parked their car (tendency of people to stay close to their starting point). This characteristic of the mall and it related behavior is now translated into a new set of variables. Hopefully the parameters of these variables will show the same phenomenon of people staying in the (sub)area where they parked their car (see also the conclusion of chapter 3 and 4).

The expectation is that people have a preference for staying in the adjacent area of their starting point (one of the three car parks). In terms of the model this brings a variable about which measures the distance from an alternative link to each of the three areas. If a pedestrian wants to go to (or stay in) a certain area, this will decrease the distances towards this area (negative parameter).

This possible behavior is represented by a set of nine new variables:

• Area1Po (started at Kmart (Po) and prefers/dislike area 1)
• Area2Po (started at Kmart (Po) and prefers/dislike area 2)
• Area3Po (started at Kmart (Po) and prefers/dislike area 3)
• Area1P1 (started at Woolworths (P1) and prefers/dislike area 1)
• Area2P1 (started at Woolworths (P1) and prefers/dislike area 2)
• Area3P1 (started at Woolworths (P1) and prefers/dislike area 3)
• Area1P2 (started at Commonwealth bank (P2) and prefers/dislike area 1)
• Area2P2 (started at Commonwealth bank (P2) and prefers/dislike area 2)
• Area3P2 (started at Commonwealth bank (P2) and prefers/dislike area 3)

In fact, each variable measures the shortest distance to the corresponding area from the current position. If the pedestrian is already in the area, the distance is set to zero. As the preference for each area may depend on the starting position (car park), car park specific variables were specified. For example, if a pedestrian parked his car at the Kmart car park (Po) and he has a certain preference to stay in or go to area 1, the parameter of 'Area1Po' would be negative. The bigger the value of this parameter the more this pedestrian wants to go to or stay in area 1. Of course, this parameter has to be significant in order to contribute in
re-predicting the observed behavior. The subsequent variables are set up according to the other car parks and areas.

In order to implement these variables into the model, the links in the network must be defined according to these new variables. Figure 5.13 shows the definition of the links on this subject. First each link in the network is defined whether it is located in area 1, 2 or 3 (in sequence red, green and yellow). Next all remaining links are defined as ‘not in an area’ or ‘remain links’ (brown). Besides this categorization, the links which represents the car parks are defined as Po, P1 or P2. These links correspond with the starting links of the respondents.

![Figure 5.13: the defined links according to their (sub)area](image)

Finally, the new variables can be summarized as:

- The shortest distance from alternative x towards area 1, if started at Po
- The shortest distance from alternative x towards area 2, if started at Po
- The shortest distance from alternative x towards area 3, if started at Po
- The shortest distance from alternative x towards area 1, if started at P1
- The shortest distance from alternative x towards area 2, if started at P1
- The shortest distance from alternative x towards area 3, if started at P1
- The shortest distance from alternative x towards area 1, if started at P2
- The shortest distance from alternative x towards area 2, if started at P2
- The shortest distance from alternative x towards area 3, if started at P2
Results

Table 5.3 shows the outcomes of the multinomial logit model. The first column lists the variables, the second column a short description of this variable, the next column the estimated value for the concerned parameter and the last column shows the significance of the parameter.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopdis</td>
<td>possibility to finish a route</td>
<td>0.0015</td>
<td>0.0000</td>
</tr>
<tr>
<td>Return</td>
<td>turning around in a link</td>
<td>-2.5186</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dist</td>
<td>distance traversed from starting link until current link</td>
<td>0.0052</td>
<td>0.0000</td>
</tr>
<tr>
<td>Before1</td>
<td>a link has been passed before once</td>
<td>1.2356</td>
<td>0.0000</td>
</tr>
<tr>
<td>Disht2</td>
<td>length of sight in both directions of pedestrianized links</td>
<td>0.0051</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsP</td>
<td>food and personal care</td>
<td>-0.0002</td>
<td>0.3064</td>
</tr>
<tr>
<td>ShopsF</td>
<td>fashion and shoes</td>
<td>0.0019</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsH</td>
<td>home products and electrical appliances</td>
<td>0.0036</td>
<td>0.0003</td>
</tr>
<tr>
<td>ShopsO</td>
<td>books and magazines, music and video and other retail</td>
<td>0.0005</td>
<td>0.2765</td>
</tr>
<tr>
<td>Shops10</td>
<td>departments stores</td>
<td>0.0031</td>
<td>0.0000</td>
</tr>
<tr>
<td>Shops11</td>
<td>bars and restaurants</td>
<td>0.0025</td>
<td>0.0233</td>
</tr>
<tr>
<td>Shops12</td>
<td>remain, services</td>
<td>-0.0008</td>
<td>0.0092</td>
</tr>
<tr>
<td>Indoor</td>
<td>an indoor link</td>
<td>-0.4810</td>
<td>0.0119</td>
</tr>
<tr>
<td>Mixed</td>
<td>pedestrians and cars share this area</td>
<td>-0.4903</td>
<td>0.0085</td>
</tr>
<tr>
<td>Pedestr</td>
<td>a car free link</td>
<td>0.5118</td>
<td>0.0392</td>
</tr>
<tr>
<td>Cross</td>
<td>link crossing a street without pedestrian facilities</td>
<td>-0.7616</td>
<td>0.0001</td>
</tr>
<tr>
<td>Crossp</td>
<td>crosswalk</td>
<td>0.4185</td>
<td>0.0263</td>
</tr>
<tr>
<td>DeelP0</td>
<td>shortest distance towards area 1, if started at P0</td>
<td>-0.0004</td>
<td>0.0246</td>
</tr>
<tr>
<td>DeelP1</td>
<td>shortest distance towards area 2, if started at P1</td>
<td>-0.0029</td>
<td>0.0156</td>
</tr>
<tr>
<td>DeelP2</td>
<td>shortest distance towards area 3, if started at P0</td>
<td>-0.0008</td>
<td>0.0012</td>
</tr>
<tr>
<td>DeelP3</td>
<td>shortest distance towards area 2, if started at P2</td>
<td>-0.0038</td>
<td>0.0048</td>
</tr>
</tbody>
</table>

Table 5.3 shows the results using the variables of the original model with the modified variables and the new variables. Now, the variable ‘Pedestr’ has a significant parameter in contrast to the insignificant parameters in the previous models. Unfortunately, ‘ShopsP’ and ‘ShopsO’ are still insignificant. These variables will not be excluded from the model. Presumably, these parameters will turn into significant values in case of a bigger dataset. Only the new variables which are significant are shown in the table. Despite the fact some were not significant, still four new variables could be added to the model. Normally adding significant variables does not mean that the model improves. But because ‘Pedestr’ has improved to a significant parameter and ‘ShopsP’ and ‘ShopO’ have become more significant
(although still not enough), it is worthwhile to add these new variables while the model validation shows a Rho$^2$ of 0.3 (increased)(see section 5.1.8 'Model validation').

Furthermore, all variables which were also used in the previous models show more or less the same results. But the results of the new variables are noteworthy. All new variables are significant and have (as expected) negative parameters. Figure 5.14 shows the schematic explanation of these results. First, Area1Po with a negative parameter means that pedestrians who started at Po (Kmart car park) have a preference for area 1. The second new variable shows that the same starting location also brings a preference for area 3 about. In other words, pedestrians starting at Po prefer the adjacent shopping areas (figure 5.14). This phenomenon came also forward in the descriptive analysis of this study. The third variable shows the same behavior. People who started at P1 (Woolworths car park) prefer the adjacent area (2) instead of visiting the other two. In contrast to these two results, the last new variable is not in line with expectations. Pedestrians who started at P2 (Commonwealth Bank car park) prefer visiting area 2 instead of the expected area 3.

![Figure 5.14: the re-predicted behavior according to the new variables](image)

### 5.1.8 Model validation

The parameters of the last mentioned model are acceptable. But to what extent is the model capable of re-predicting the observed behavior? In order to give an answer to this question the 'goodness of fit' is determined (see section 5.1.1 'Theory'). This is reflected in the so-called Rho$^2$. This value lies between 0 and 1. The closer to 1, the better the model is. Literature claims that a Rho$^2$ > 0.2 reflects an acceptable model (Hendriks and Ottens 1997; van Wijk 2003). Table 5.4 shows the Rho$^2$ for each model.

<table>
<thead>
<tr>
<th>Rho$^2$</th>
<th>Original model</th>
<th>Model with modified variables</th>
<th>Model with modified and new variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.29</td>
<td>0.30</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

The Rho$^2$ increases as the modification of the original model continues. All values are > 0.2 which means that all modes are acceptable. Despite the fact that the differences are small, the 'model with modified and new variables' scores best. Knowing that modifications to a model only bring small effects in the Rho$^2$ about, it is a nice result.
5.1.9 Conclusion

In order to simulate pedestrian behavior, a model is used. First the shopping mall is translated into a network of links. These links represent the street segments and choice alternatives a pedestrian has when walking around. The characteristics of the mall (pedestrian environment and tenant mix) are translated into a series of variables. These variables are based upon recent studies at the Eindhoven University of Technology (Deckers 2005; van Wijk 2003). They can be categorized into five groups: distance, route history, length of sight, tenant mix and accessibility, and physical characteristics. Each link is characterized by several variables. Each variable has a parameter which can be used to re-predict the observed behavior. These parameters represent the (part worth) utilities of each variable of each alternative (link). The multinomial logit model is used to estimate these parameters for each variable. When simulating pedestrian behavior in the mall, these utilities determine the probabilities that alternative will be chosen. This will be described in the next section.

The series of available variables is partly modified and even extended with new ones. The variable 'Cross' which represents an opportunity to cross a street has been split up into two new ones: one with and without specific pedestrian facilities (a crosswalk). Another modified variable is 'Mixed'. From now on this variable represents both an area where pedestrians and cars share their space, and parking areas. A set of new variables represent the different (sub)areas as defined earlier in this study. This set of variables determines whether a pedestrian has a preference for a certain area when parked at one of the three car parks.

Estimating the variables has been done in three phases. In each phase variables are modified or added, started with the original set of variables from recent studies (Deckers 2005; van Wijk 2003). Next, modifying and adding variables can be proven worthwhile by compared the results with the original set of variables.

Finally a model validation has been performed in order to evaluate the generated parameters. The rho* is a way to qualify the results in order to determine the quality of the suggested model. Rho* should be at least 0,2. The higher the rho*, the better the model functions (with a maximum of 1).

The outcomes of the multinomial logit model are satisfactorily. An interesting set of variables is defined which will help to predict pedestrian behavior further on. The process of testing and evaluating variables and estimating its parameters, resulted in a model with modified and new variables. The model validation showed also some nice results with a rho* of 0,31, which is satisfactorily. This model will be used to simulate the pedestrian behavior in the shopping mall of Armidale.
5.2 Monte Carlo simulation

In order to predict pedestrian behavior a simulation model is needed. For this, the Monte Carlo simulation method is used. In the previous sections of this chapter, the parameters of several variables have been estimated. These parameters are now used to simulate behavior in the situation of 1995 and 2008. The simulation of the behavior of 1995 is actually re-predicting the observed behavior. Therefore this simulation acts as an evaluation of the model. The simulation of the situation of 2008 can be checked against data that has been collected in 2008. This will be discussed in section 5.2.3 'Simulation 2008'.

Before the results are summarized, a short description of the theory of the used simulation method is provided. Next, the simulation of 1995 is described, followed by the simulation of 2008. Each simulation has a conclusion. This section will be concluded with a summary of the simulation results.

5.2.1 Theory

The Monte Carlo simulation uses the probabilities the alternatives in a choice set will be chosen. The process of selecting an alternative at each link of a route is explained using a (fictional) graph (figure 5.16; b).

For instance, if a choice set contains six alternatives (figure 5.15), the probabilities of choosing each alternative can be listed as showed in figure 5.16; a.

This list could be translated into a graph as showed in figure 5.16; b. All the probabilities are summarized in a cumulative way. Based upon a random choice selection, a number is picked between zero and 1. Supposing the number 0.2 is picked. This number brings the alternative 2 about (see figure 5.16; b). The probability this alternative is picked was defined to be 0.3. For each pedestrian this method continues this process of selecting alternative links to compose a route, given a starting position for the pedestrian. Thus the route is build up form link to link until a stop alternative is chosen and the route ends (always at one of the three starting points).

![Figure 5.15: Choice set](image)

![Figure 5.16: Schematic representation of the Monte Carlo simulation](image)
5.2.2 Simulation 1995

The first simulation is based upon the situation of 1995. The physical and retail characteristics of that time are used to estimate the parameters and these characteristics and parameters form now the base of this simulation. The pedestrian behavior in the shopping mall of Armidale is simulated two times. One time based upon the model with modified variables and one time based on the model with modified and new variables; each with its own parameters.

Simulation model 1 (modified variables)
Figure 5.17 shows the observed behavior of 1995. Figure 5.18 shows the predicted behavior based upon the parameters of the model with modified variables. As can be seen, the differences are minimal. The model re-predicts the observed behavior quite good.

Simulation model 2 (modified and new variables)
Figure 5.19 shows the observed behavior of 1995 again. But in contrast to the previous simulation, figure 5.20 on the right shows now the predicted behavior based upon the parameters of the model with modified and new variables. Again the differences are minimal. Thus, the model re-predicts the observed behavior quite good.


**Conclusion**

Both models re-predict the observed behavior pretty good. Unfortunately, the differences between the results of each model are so small that it is difficult to say which model performs better. Presumably the last model performs better because of the better results on parameter estimation and model validation (see 5.1.8 'Conclusion'). But the presented figures do not show these differences. Therefore two figures are made to visualize the balance of the observed and simulated behavior for each model. These figures show in what extend the simulated behavior differs from the observed behavior. A perfect simulation means a balance value zero. Figure 5.21 and 5.22 show the simulation results of the two models. The red links in the network represent absolute differences between observed and simulated numbers of pedestrians larger than 2000 pedestrians. The green links indicate absolute differences smaller than 2000 pedestrians.

The figure on the right (5.22) has more green links than the one on the left. Model 2 (modified and new variables) has 47 green links (figure 5.21) and model 1 (modified variables) has 33 green links (figure 5.22). This visualizes that model 2 performs better in re-predicting the observed behavior.

**Figure 5.21:** Balance simulated and observed:
Model 1 (modified variables)

**Figure 5.22:** Balance simulated and observed:
Model 2 (modified and new variables)
5.2.3 Simulation 2008

This simulation is based upon the situation of 2008. The physical and retail characteristics of 2008 are used as the base of this simulation. In contrast to the 1995-simulation, this simulation is based upon the parameters of the best working model: the model with modified and new variables. First, the new situation of 2008 is described. Next, the results are visualized and discussed.

Situation

The situation of 2008 has changed a lot compared to 1995. First the shopping mall is a lot bigger. Figure 5.28 shows the shopping mall in 1995, figure 5.29 shows it in 2008. As can be seen the retail area has grown a lot. In thirteen years the shopping mall has grown 1.5 times bigger.

As a result, the number of parking lots has grown too. In 1995 there were 3 main car parks. In 2008 two relatively big car parks have been added and one existing car park is extended (figure 5.30). The concerning car park is the Kmart car park. This car park has tripled its size in 15 years. An overhead car park is built on the original location (see figure 5.23). Subsequently, an underground car park has been added in order to offer sufficient supply of parking facilities (see figure 5.24).

Most of the added shops are in new planned shopping centers. Three have been added over the years: Centro (fig. 5.25), Armidale plaza (fig. 5.26) and Coles (see figure 5.31). Centro and Coles are located outside the research area. Armidale Plaza, however, is partially located inside the research area of this study. A lot of shops are moved to these new shopping centers. The most important changes in retail structure are the removal of two key tenants form the research area: Woolworths and Coles (two big supermarkets). Furthermore, most of all popular shops are now located in these new shopping centers.
Due to the major changes in the shopping mall between 1995 and 2008, the network is modified to fit the present layout. Figure 5.32 shows the new established network. Part 2 and 3 are physically exact the same as in the ‘old’ network (1995), but the tenant mix has been changed. In Part 1, both the network and the supply has changed (the new shopping centre Armidale Plaza). The new shopping center in this area (Armidale Plaza) consist of an indoor shopping arcade. Due to the lack of choice of alternative links, this part of the mall is represented as one long link.

Figure 5.32: The new network
Data
In order to evaluate the results of this simulation, a second data collection took place in February 2008. In contrast to the first data collection in 1995, this time people were not followed. Instead, the number of passers-by is counted on several locations in the research area. Figure 5.33 shows the observed links where the link intensities were observed. Unfortunately, due to a totally new shopping centre (and an old network map), it was not possible to observe in the new shopping centre Armidale Plaza (bottom right of figure 5.33). The results of this observation are enclosed in appendix 5.
These results of the observation in 2008 can be used to compare the observed and simulated link intensities. Although this comparison need not be reliable, it is a nice opportunity to see if there are any similarities between the observed and simulated results.

Figure 5.33: The observed links

Simulation model 2 (modified and new variables)
As mentioned before, the situation has changed over the years. Two aspects of the new situation are probably fatal for the reliability of the simulation of pedestrian behavior.
First, the number of starting points has increased and the new car parks can not be implemented in the current model. The model already estimated contains car park specific parameters (based on a situation with only three car parks). Changing these basic characteristics of the model brings a total different model about and can not be compared to the models defined in the situation of 1995 (although, model 1 ‘modified variables’ could be used in future research). Thus the model as defined before (model 2 with modified and new variables) is used despite the fact that in the new situation one car park is changed and two are added outside the research area. Because the data of 2008 is based upon counting passers-by instead of following people starting at a certain car park, a lot of these passers-by may have started their route somewhere else. Therefore, comparing counted number of passers-by with simulated routes is doubtful. In fact the extra starting points are ignored during the simulation.
Secondly, many shops are added to the retail area outside the research area. And a lot of stores originally located within the research area are moved towards the new shopping centers. This likely affects shopping behavior as well, but the simulation is based upon a situation where these new shopping centers are ignored.
The changed layout of the network is no problem for the model if it stays within certain limits. Actually the model is meant to predict the likely impact of (planned) retail change in the existing structure. The fact that the tenant configuration over the mall has been changed is a nice opportunity to see what the model simulates.
The simulation results can not be used to prove certain pedestrian behavior but it will give likely insights in the effects of changing retail structures. Besides, this case gives a nice
opportunity to test in what extent the model can be used in predicting pedestrian behavior in new situations.

Figure 5.34 shows the result of the Monte Carlo simulation of the new situation, using model 2 (with modified and new variables). It is obvious that this result is not a realistic output. The thick line in the bottom right of the figure is one link in the network (link number 53) and this link is excessively visited by (simulated) pedestrians. It turns out that the chance this link is chosen, is bigger than 99 percent. The model predicts people walking back and forth over this link. There are some possible reasons which could explain this effect. First, link 53 is relative long compared to the other links in the mall. This results in a link with many shops. This causes a very attractive link. For instance a lot of shops in the Food and Fashion branches are represented. On top of this, a Department store is located in this area (a key tenant). Another reason might be that due to the relative small size of the study area, only one department store is available. The parameter estimate for department stores is in fact based on this sole outlet and may have been influenced by other accidental aspects in or near the outlet during data collection in 1995. Although the department store parameter may represent the attractiveness of the department store in 1995 very well, it need not do so for the new department store in the new situation.

Another reason may be that due to the relative small dataset only one ‘Before’-parameter appeared to be significant. As mentioned in section 5.1.2 ‘Variables’, the route history related variables are ‘Before1’, ‘Before2’ and ‘Before3’. But only the variable ‘Before1’ turned out to be significant. The other two variables are not used in the simulation. ‘Before1’ has a positive parameter which means that people want to choose a link they passed before. In the studies of Eindhoven and Maastricht, negative parameters were estimated for ‘Before2’ and ‘Before3’. These negative parameters for visiting a link twice or for the third time could have prevented the effect of walking back and forth to this ultra-attractive link. Finally, one possible cause can be found in the structure of the network. Due to the layout of the new shopping centre, link 53 represents the new passage. Due to the lack of choice within this indoor arcade, the link has become very long link compared to the other links in the network. Presumably, a relative long link in the network can provoke errors in the simulation. In this case, splitting up this link could solve the problem. If this would solve the problem, it indicates the model is sensitive to exceptional long links: a feature that has to be investigated in future research.

Figure 5.34: Simulated behavior in the situation 2008

Figure 5.35 shows the observed number of passers-by and the simulated intensities at each link. The link numbers on the horizontal axe correspond with the numbers in previous showed figure 5.33. As can be seen, the observed and simulated numbers of pedestrians differ considerably. Some link intensities are quite similar, but most counted numbers of
pedestrians are not simulated according to the actual situation of 2008. Considering previous discussion regarding the new situation and using the model in this situation, the result is in line with expectations: it turns out that the model not should be used to predict the simulate pedestrian intensities in the new situation.

![Figure 5.35: The links of the data collection 2008: observed and simulated](image)

**Modifications**

Because of the unrealistic simulation results for the new situation, the model has been modified. First, some parameters are added in order to solve the problem of walking back and forth. These modifications are described in the next subsection 'Step one: optimizing'. Secondly, the relatively long link (number 53) is split up in order to acquire insights in the effects of enclosing relative long links in the network. This second step is described in the subsection 'Step two: Split link 53'. Finally, the new model is used to simulate the pedestrian behavior in the situation of 2008. In order to assess the effects of both modifications, the situation is simulated with and without splitting up link 53.
Step one: optimizing

The optimizing process involves two types of modifications: related to the configuration of the model variables and related to estimating the parameters of the variables.

With regard to the configuration of the model variables, the following modifications have been made:

1. In order to simulate the situation of 2008 (as done in previous simulations), three 'pedestrian feeding links' were added to the network. The reason for this modification of the model is the fact that a car park (starting point) was represented as several starting links. But, in order to simulate pedestrian behavior (fictional) people have to start at one link. The problem is, which link on a starting point? This is why a so called 'pedestrian feeding link' is added to each car park. Simulated pedestrians will start at this link and start their route by choosing one of the original starting links. This represents the situation of the observed pedestrian the best: observed respondents could also choose on what link to start. The length of the 'pedestrian feeding links' is set to a very small, ignorable value.

For each pedestrian, the simulation starts by selecting one of the original starting links from the feeding link. When choosing the second link (from the original starting link), the feeding link could be chosen. As this is very unlikely in reality, this option is excluded from the choice set at this choice moment.

2. A second modification is related to the distances within the shopping mall. 'Disret' represents the distance of the moment of turning back (see section 5.1.3 'Variables'). This variable is defined as follows: 1.0 / distance to start link. This value can get really small due to distance unit of only one meter. Therefore this variable is multiplied with 100 to prevent loss of valuable differences within the outcome of this variable.

3. The relative long link 53 has a lot of adjoining (attractive) shops. To ensure that the model is less sensitive on this matter, the variables of the branch floor areas are adjusted. The defined floor space of a certain branch in an alternative link is now divided by the distance from the current link to the alternative link.

With regard to estimating the parameters of the variables, following modifications have been made:

1. Due to the insignificant parameters of 'Before2' and 'Before3', only 'Before1' is used to simulate the new situation. While these two variables could have prevent the phenomenon of walking back and forth on link 53, an adjustment in the set of variables is made. A new variable called 'Before23' is added. This variable is based upon the variables 'Before2' and 'Before3' and has three options: 0, if the concerning link has been passed once or not at all; 1, if the concerning link has been passed twice; 2, if the concerning link has been passed three times or more. Now, the two variables 'Before2' and 'Before3' are joined into one new.

2. The threshold value in the equation to calculated the value of 'Dist' has been decreased in order to compensate for the fact that pedestrian cannot finish their route in the very beginning of their trip. The threshold value has now been set to 350 meters.

3. The defined floor space of a certain branch is now divided by the distance from the current link to the alternative link. But the concerning variables are combined with variables describing the accessibility of these branches. To keep the ratio between these two variables, the floor space related variables are multiplied by ten. This value is determined after a process of testing and evaluating.
Step two: split link 53
To acquire insights whether the relative long link 53 is the cause of excessive high number of predicted pedestrians in this link, link 53 is split up into three new links. Figure 5.36 shows link 53 in the ‘old’ situation. Figure 5.37 shows the new network. These two networks are both used to simulate two scenarios: model 3 with the original link 53 and model 3 with link 53 split up.
The model

**Parameters model 3**

The parameters have to be estimated again. This time the modifications (step one: optimizing) are applied to the model. Table 5.5 shows the results of estimating the parameters for model 3.

Table 5.5: The results of estimating the parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Value</th>
<th>significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopdis</td>
<td>possibility to finish a route</td>
<td>0.0012</td>
<td>0.0019</td>
</tr>
<tr>
<td>Return</td>
<td>turning around in a link</td>
<td>-2.4823</td>
<td>0.0000</td>
</tr>
<tr>
<td>Dist</td>
<td>distance traversed from starting link until current link</td>
<td>0.0045</td>
<td>0.0000</td>
</tr>
<tr>
<td>Before1</td>
<td>a link has been passed before once</td>
<td>1.0818</td>
<td>0.0000</td>
</tr>
<tr>
<td>Before23</td>
<td>a link has been passed before twice or more</td>
<td>-0.3525</td>
<td>0.3118</td>
</tr>
<tr>
<td>Dsight2</td>
<td>length of sight in both directions of pedestrianized links</td>
<td>0.0053</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsP</td>
<td>food and personal care</td>
<td>0.0122</td>
<td>0.0000</td>
</tr>
<tr>
<td>ShopsF</td>
<td>fashion and shoes</td>
<td>0.0165</td>
<td>0.0041</td>
</tr>
<tr>
<td>ShopsH</td>
<td>home products and electrical appliances</td>
<td>0.0039</td>
<td>0.1988</td>
</tr>
<tr>
<td>ShopsO</td>
<td>books and magazines, music and video and other retail</td>
<td>0.0166</td>
<td>0.0000</td>
</tr>
<tr>
<td>Shops10</td>
<td>departments stores</td>
<td>0.0148</td>
<td>0.0126</td>
</tr>
<tr>
<td>Shops11</td>
<td>bars and restaurants</td>
<td>-0.0045</td>
<td>0.0183</td>
</tr>
<tr>
<td>Indoor</td>
<td>an indoor link</td>
<td>-0.4757</td>
<td>0.0146</td>
</tr>
<tr>
<td>Mixed</td>
<td>pedestrians and cars share this area</td>
<td>-0.5888</td>
<td>0.0037</td>
</tr>
<tr>
<td>Pedestr</td>
<td>a car free link</td>
<td>0.3047</td>
<td>0.2305</td>
</tr>
<tr>
<td>Cross</td>
<td>link crossing a street without pedestrian facilities</td>
<td>-0.8706</td>
<td>0.0000</td>
</tr>
<tr>
<td>Crossp</td>
<td>crosswalk</td>
<td>0.4138</td>
<td>0.0204</td>
</tr>
<tr>
<td>Area1P0</td>
<td>shortest distance towards area 1, if started at P0</td>
<td>-0.0048</td>
<td>0.0054</td>
</tr>
<tr>
<td>Area 3P0</td>
<td>shortest distance towards area 3, if started at P0</td>
<td>-0.0057</td>
<td>0.0000</td>
</tr>
<tr>
<td>Area 2P1</td>
<td>shortest distance towards area 2, if started at P1</td>
<td>-0.0083</td>
<td>0.020</td>
</tr>
<tr>
<td>Area3P1</td>
<td>shortest distance towards area 3, if started at P1</td>
<td>-0.0038</td>
<td>0.0059</td>
</tr>
<tr>
<td>Area 2P2</td>
<td>shortest distance towards area 2, if started at P2</td>
<td>-0.0046</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

The list is expanded with two variables. At first the added variable 'Before23' and secondly the variable 'Area3P1'. The first one is added in order to optimize the model. The second variable is added because this variable becomes significant in this model.

A couple of interesting aspects of estimating these parameters are noteworthy:

- 'Before23' has a positive parameters, whereas 'Before23' has a negative one. This is in line with the expectations based upon recent research in Eindhoven and Maastricht (Deckers 2005; van Wijk 2003). Probably, this variable 'Before23' is capable to
prevent the phenomenon of walking back and forth on link 53. The negative parameter will decline the chance people will pass a link for a second or third time.

- 'ShopsP' has turned into a positive, although very small parameter. This is in line with expectations in general.
- 'Pedestr' has a insignificant parameter. In model 2, it was significant.

Simulation model 3: original link 53

The new series of parameters is used to simulate the situation 2008 with model 3. This model is optimized based upon the insights gained at the simulations with model 2. Figure 5.38 shows the result of the simulation of model 3 with the original link 53. In other words, model 2 is optimized and used on the original network of the situation of 2008 (as defined in the previous simulation).

As can be seen, people do not walk back and forth anymore on link 53. The results on this matter are remarkable good. But now other links in the network have implausible link intensities. Especially on the left part of the shopping area some links are over predicted.

![Figure 5.38: Simulated behavior model 2: link53](image)

Figure 5.38 shows the simulated and observed link intensities. The numbers on the horizontal axis represent the observed links, the horizontal axis the amount of passers by on these links. The differences between the observed and simulated numbers of pedestrians are still very big.

![Figure 5.39: The links of the data collection 2008: observed and simulated](image)
Simulation model 3: link 53 split up

Again, the parameters of model 3 are used to simulate the pedestrian behavior. But this time the relative long link (53) is split up into three links (see figure 5.37 in subsection 'Step two: split link 53').

The new series of parameters is used to simulate the situation 2008 with model 3. Figure 5.40 shows the result of the simulation of model 3 with link 53 split up. The image shows a more realistic result of the predicted pedestrian behavior. Remarkable is that the extreme link loading in the left part of the shopping area (figure 5.38) do not occur in this simulation. In this scenario the only thing that has been changed is the division of link 53 into three links. Thus this result is exclusively addressed to this particular modification of the network. It thus can be concluded that relative long links in the network affect the model performance.

Figure 5.39: Simulated behavior model 2: link 53 split up

Figure 5.41 shows the simulated and observed link intensities. The numbers on the horizontal axis represent the observed links, the horizontal axis the amount of passers by on these links. The differences between the observed and simulated pedestrians are still big.

Figure 5.39: The links of the data collection 2008: observed and simulated
5.2.4 Conclusion

The Monte Carlo simulation is used to simulate the pedestrian behavior in the shopping mall of Armidale. First the situation of 1995 is simulated. The observed behavior is re-predicted in order to test the two defined models. Next the situation of 2008 is simulated to evaluate if the model capable of predicting consumer shopping behavior and acquire insights in the likely impact of (planned) retail change in the existing structure. All simulations are visualized in the constructed network in order to get an overview of the simulated link loadings. Next the simulation of the situation of 2008 is compared to the (second) data collection done in February of 2008. It is an opportunity to evaluate the simulated behavior.

The simulation of the situation of 1995 re-predicted the pedestrian behavior satisfactorily. The simulated behavior, expressed by means of links loadings, matches the original observed link loading reasonably well. As expected (based on the results of the multinomial logit model), model 2 performs better than model 1. Thus, the use of modified and added variables was useful in this case.

The situation of 2008 was a challenge to cope with because the shopping mall has changed a lot during the past thirteen years. However, the model is applied to this new situation as best as possible. Probably this was the main reason that the results of the simulation were not satisfactory. The model did not produce link loadings that are likely to represent counted numbers of pedestrians. Despite the fact that the situation was expected to be difficult to apply with the built model, the model was modified to try to solve the encountered problems. Possible reasons of the defined problems were summarized, which resulted in two aspects of modification of model 2: firstly adjusting some variables and re-estimating parameters, and secondly adjusting the network of the situation of 2008. These modifications resulted in a better result in relation to the defined problems. But unfortunately it did not improve the results as hoped for. The process of testing and evaluating the model resulted in three points of interests:

1. The range of the available data set is likely to be of vital importance for the performance of the model. Assumable, a certain amount of respondents is required in order to estimate the parameters correctly. It turned out that the insignificant parameters of the variables ‘Before2’ and ‘Before3’ are probably the result of a too small data set. This resulted in a phenomenon of walking back and forth on a certain link in the model.

2. It is likely that the retail structure of the shopping mall is responsible for possibly incorrect parameters. For example, the parameter of the branch ‘Department store’ was based on only one shop. It is therefore likely that this parameter does represent the attraction of department stores in general. Therefore, the shopping mall under investigation should preferably possess several shops per branch.

3. The model seems to be sensitive to extreme long links in the network. This is a fragile component of the model and should be investigated in more detail.
5.3 Conclusion

The multinomial logit model is used to estimate the required parameters of the defined variables. Next, Monte Carlo simulation is used to simulate pedestrian behavior in the shopping mall of Armidale. In order to apply the model developed at the Eindhoven University of Technology a couple of modifications were needed. First some variables were modified in order to match the situation of the shopping mall of Armidale (in the phase of estimating the parameters). Next another series of modifications were needed in order to simulate realistic pedestrian behavior for the new situation of 2008.

Model 2 'modified and added variables' was capable of re-predicting the observed pedestrian behavior of 1995. This model has a $r^2$ of 0.31 and can be qualified as 'acceptable'. However, this model was not capable of predicting pedestrian behavior in the situation of 2008 realistically. Modifications of the variables and re-estimating parameters made it possible to improve the working of the model somewhat, although not satisfactorily.

The process of testing and evaluating the model resulted in three points of interests:

1. The size of the available data set (number of observed pedestrians) is likely to be of vital importance for the performance of the model.
2. The shopping mall should contain at least some shops per branch.
3. The model seems to be sensitive for Relative long links in the network.

These aspects likely cause a number of unexpected results when simulating pedestrian behavior for the situation of 2008. However, it should be stressed that the shopping mall of 2008 had changed dramatically and that some changes (e.g. a new parking facility) were ignored in order to apply the model. As a result, the simulation of 1995 was satisfactorily but some questions related to the simulation of the situation of 2008 are still unanswered.
6. Conclusion and recommendations

This chapter will deal with the conclusions and recommendations. Here, an answer to the problem definition is described and whether the objective is achieved. The conclusions are described according to the main subjects in this study. Besides the general conclusions, this chapter will also evaluate the model in relation with the results of previous use of the model (studies in Eindhoven and Maastricht). Finally some recommendations are provided.

Figure 6.1: Cavill Street Mall in Surfers Paradise, Australia
The Gold Coast of Australia is booming. Real estate development is unstoppable in the city of surfers: Surfers Paradise. Cavill street Mall is one of the prominent malls in the city.
6. Conclusion and recommendations
6.1 Objective and problem definition

Chapter 1 ‘Introduction’ of this report described the objective and problem definition of this study. The objective was defined as follows:

The aim of this research is to develop (apply and test) a model to predict pedestrian behavior in an Australian retail area, and acquire insights in specific aspects of an Australian mall (looking at aspects of the pedestrian environment and tenant mix).

Given this aim of research and the background and motives the following research question has been formulated:

Is it possible to predict pedestrian behavior on a micro-level in an Australian case, based on aspects of the pedestrian environment and tenant mix, in order to describe consumer shopping behavior and predict the likely impact of (planned) retail change in the existing structure?

In order to achieve the objective and answer the question as mentioned above, a research method was formulated (see figure 6.2 on the next page). First a literature review provided insights in two main aspects of pedestrian behavior: pedestrian environment and tenant mix. Based on findings in the literature, four hypotheses were formulated. Next, the shopping area subject to this study was analyzed to acquire insights in this particular case. Next, the collected data of 1995 (provided by the University of New England, Armidale) was used to analyze observed behavior. Here, the hypotheses were tested and evaluated. Next, the model was applied to two situations: the mall in 1995 and the mall in 2008. The model is used to re-predict observed behavior of 1995 and simulate the behavior of 2008. Besides the general conclusions, this chapter will also evaluate the model in relation with the results of previous use of the model (studies in Eindhoven and Maastricht).
Figure 6.2: Research method
6.2 Conclusions

The conclusions will be described according to the research method. First the results of the literature review are summarized. Secondly, the used data and research area are evaluated. Next, the results of the descriptive analysis are summarized and the observed behavior is described. Next, the conclusions regarding the model and simulations are described. Finally, these conclusions will be evaluated in order to answer the problem definition and to determine whether the objective of this study is achieved.

6.2.1 Hypotheses

As a result of the literature review, four hypotheses came forward. These are based upon the two defined main aspects of pedestrian behavior in the literature: pedestrian environment and tenant mix. The hypotheses are formulated with care: it must be possible to test them with the available data in this research. The hypotheses are:

- “Department stores fulfill the role of key tenant in a shopping mall.” (Bruwer, 1997; Brown, 1992).
- “Pedestrians tend to stay close to their starting point.” (Deckers, 2005).
- The branches ‘Fashion’ and ‘Department store’ attract most shoppers (Deckers, 2005; Leung, 2007).
- “The allocation of street furniture influence walking patterns.” (Smeets, 2005).

These hypotheses have been tested and evaluated based upon the results of the descriptive analysis of the observed behavior. This will be described in section 6.2.3 ‘Observed behavior’.

6.2.2 Situation and data collection

The case, subject to this study, is a shopping mall in the Central Business District (CBD) of Armidale, Australia. Armidale is a relative small town (21,660 inhabitants) (Armidale Dumaresq Council 2008) and lies about midway between Sydney and Brisbane. The studied part of the CBD of Armidale has three parking lots, and three main shopping areas. The data was collected in the retail area around Beardy street which is the main street of the city centre. Eleven students of the university of new England (Australia) were instructed to follow pedestrians entering the shopping mall unobtrusively, draw their route through the shopping area on a map, and denote each shop entered. The observation of a pedestrian finished when the pedestrian returned to his/her car. Pedestrians were observed on 11, 14, 16 and 18 November 1995. In total 148 pedestrians were followed. In favor of the descriptive analysis, 145 were useful. Only 99 respondents were useful for the model. The value of this data is of great importance for testing the model on this particular case. Whereas in previous studies people were asked to redraw their shopping routes and in this case people were followed. It is likely to get a more reliable result of the observed behavior and the descriptive analysis. But the great disadvantage of the available data is the low
number of observed respondents. Especially for the use of the model (simulation) it is both a small research area and a low number of observed routes (see section 6.2.5 'Simulation'). There are a couple of interesting characteristics of the mall. First, a distinction between different areas can be made. Three areas can be identified, each with a car park, separated by streets. It is likely to assume that these streets will act as barriers in a pedestrian’s shopping route. Subsequently, each area has more or less its own type of shopping street: an indoor shopping arcade, a car free square and an area with sidewalks with shops along the street. Secondly, the tenant mix has two points of interest: the available branches in the mall seek each others nearness: in most cases a certain shop has a neighbor in the same branch; next, the stores Woolworths, Coles and Kmart are most likely the key tenants; whereas Kmart is the only departments store of the mall.

Because the data was collected in 1995, pedestrian behavior is simulated for the situation of 1995 and 2008. The situation of 2008 has changed a lot compared to 1995. First the shopping mall has grown a lot bigger. In 13 years the shopping mall has grown 1.5 times bigger. As a result, the number of parking lots has grown too. In 1995 there were 3 main car parks. In 2008 two relatively big car parks have been added and one existing car park has been extended. The most important changes in retail structure are the removal of two key tenants form the research area: Woolworths and Coles (two big supermarkets). Furthermore, most of all popular shops are now located in these new shopping centers. This made the simulation of the situation of 2008 not easy. Therefore, the results of this simulation are probably not reliable. Nevertheless, an attempt was made to simulate pedestrian behavior under conditions of 2008.

6.2.3 Observed behavior

The collected data consisted of 148 observed pedestrians. Only 145 are used in the descriptive analysis. Most respondents were female and middle aged. Despite the low number of observed pedestrians, the collected data provided a lot of information about pedestrian behavior in the shopping mall of Armidale. In order to analyse this data, a data preparation was necessary. This data preparation consisted of building a network to visualize the walking patterns and to code the data in favor of the descriptive analysis. The average time spent in the shopping mall is 25 minutes. During this time, shoppers walk an average of 565 meters and visit an average of 2.7 shops. Elderly spend considerably less time (18 minutes) during their shopping trip and walk shorter distances (300 meters). This is in line with the number of shops they visit: 1.7.

The most visited branch is Food, Followed by Remain (services). In contrast to the assumption made before, the Department store does not play a big role in visiting shops. Analyzing the first visited branches shows interesting differences. On general, the branch Fashion comes in third place of most visited branches, but people certainly not visit this branch firstly. They prefer to visit the branches Food and Remain (services) first. The branch Department store plays a role when it comes to first visiting a shop. The observed pedestrian behavior is clearly related to the (sub)area and chosen car park the shopper has chosen to start his/her route. In other words, the analysis across starting point shows some interesting results on walking patterns.

Two characteristics of pedestrian movement are of vital importance when looking at the observed behavior in this research. First, the phenomenon of walking the shortest route possible clarifies the observed behavior. Especially the facet describing the tendency of pedestrians to stay close to their starting point can be used to explain the outcomes of the descriptive analysis. The visualization of the walking patterns of all respondents sorted by car park (literally) shows this phenomenon. Secondly, the first visited branch provides
interesting results. The Department store (Kmart) is not in favor when looking at the distribution of visited branches of all respondents. But when looking at the first visited branch, the Department store plays a bigger role. And, most people who visited this store, parked their car nearby. A lot of shops decrease in their portion of visited branch when looking at the first visit. Combining this outcome with the phenomenon of ‘nearby parking’, it is likely to assume that this department store functions as a key tenant in the shopping mall. But there are more ‘candidates’ for the role of key tenant. In the Food branch a similar conclusion can be drawn (supermarket Woolworths).

In the descriptive analysis, the hypotheses were tested with the available data: the approval (√) or rejection (X) of the formulated hypotheses is based upon the conclusions of the descriptive analysis. Further research is necessary to evaluate these hypotheses more accurately.

√  "Department stores fulfill the role of key tenant in a shopping mall."
   (Bruwer, 1997; Brown, 1992).

√  "Pedestrians tend to stay close to their starting point."
   (Deckers, 2005).

X  The branches ‘Fashion’ and ‘Department store’ attract most shoppers
   (Deckers, 2005; Leung, 2007).

√ / ?  "The allocation of street furniture influences walking patterns."
   (Smeets, 2005).

6.2.4 The model of pedestrian behavior

The shopping mall is translated into a network of links. These links represent the street segments and choice alternatives a pedestrian has when walking around. The characteristics of the mall (pedestrian environment and tenant mix) were then translated into a series of variables. These variables are based upon recent studies at the Eindhoven University of Technology (Deckers 2005; van Wijk 2003). They can be categorized into five groups: distance, route history, length of sight, tenant mix and accessibility, and physical characteristics. The multinomial logit model is used to estimate the required parameters of the defined variables.

In order to apply the model developed at the Eindhoven University of Technology a couple of modifications were needed. Some variables were modified in order to match the situation of the shopping mall of Armidale (in the phase of estimating the parameters). However, new variables were added representing the different (sub)areas of the study area as defined earlier in this study. This set of variables determines whether a pedestrian has a preference for a certain area when parked at one of the three car parks.

Estimating the variables has been done in three phases. In each phase variables are modified or added, started with the original set of variables from recent studies (Deckers 2005; van Wijk 2003). Doing this, insights in the effect of the variables and their parameters have been acquired. The parameters showed the following results regarding pedestrian behavior:
**Conclusion and recommendations**

- physical characteristics have a bigger influence on pedestrian behavior than tenant mix (also seen in previous studies);
- people prefer shopping in open air (only seen in this particular case);
- people prefer to cross a street at a crosswalk (with pedestrian facilities) (not been researched in previous studies);
- the branches 'Food' and 'Personal care' have a negative parameter (as seen in previous studies);
- the branches 'Bars and restaurants' has a positive parameter (in contrast to previous research).

It turned out that modifying and adding variables was useful to improve the performance of the model (rho' increasing from 0.29 to 0.31).

Despite the fact that the data set was relative small, the outcomes of the multinomial logit model are satisfactorily. A interesting set of variables is defined which helped to predict pedestrian behavior. The process of estimating the parameters resulted in a defined model which was used to simulate pedestrian behavior in the shopping mall of Armidale.

### 6.2.5 The simulation

Monte Carlo simulation is used to simulate pedestrian behavior in the shopping mall of Armidale. The model with modified and new variables was capable of re-predicting observed pedestrian behavior of 1995. The situation of 2008 was a challenge to cope with because the shopping mall has changed a lot during the past 13 years. However, the model is applied to this new situation as best as possible. The model did not produce link loadings that are likely to represent counted numbers of pedestrians. Therefore, the model was modified to try to solve the encountered problems. Firstly, some variables were adjusted and parameters re-estimated and secondly, the network of the 2008 situation was adjusted. These modifications resulted in more likely link loadings. But still, the results are questionable. The process of testing and evaluating the model resulted in three points of interests:

1. The size of the available data set (number of observed pedestrians) is likely to be of vital importance for the performance of the model (in order to estimate the correct and necessary parameters).
2. The shopping mall should contain at least some shops per branch (in order to estimate correct (and general) parameters).
3. The model seems to be sensitive for relative long links in the network.

As a result, the simulation of 1995 was satisfactorily but some questions related to the simulation of the situation of 2008 are still unanswered.

### 6.2.6 Evaluation

The collected data is used to test a model developed at the Eindhoven University of Technology. Judith van Wijk (2003) used this model to predict pedestrian behavior in the city centre of Eindhoven and two years later (2005) the same model was tested on the city centre of Maastricht (Deckers 2005). Table 6.1 shows the differences between those studies and this one. Although the differences between this case and previous ones are relative big, the results of the model are in line with previous studies. Thus the model seems to be applicable in different (foreign) cases, although fine-tuning should be considered.
Table 6.1: studies compared

<table>
<thead>
<tr>
<th>This study</th>
<th>Previous studies in Eindhoven and Maastricht</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Relative small city</td>
<td>Mid-sized cities</td>
</tr>
<tr>
<td>Shopping mall</td>
<td>Inner-city shopping area</td>
</tr>
<tr>
<td>Data collected by following pedestrians unobtrusively</td>
<td>Data collection by asking pedestrians to recall their route</td>
</tr>
</tbody>
</table>

The modified and added variables were useful to model pedestrian behavior. Thus further development, which has been done in this study, turned out to be valuable for this case. The question is: 'is further development necessary to determine whether more variables need to be modified or added to the model?' In other words: is the model now in its final stage?

The aim of this research was to develop (apply and test) a model to predict pedestrian behavior in an Australian retail area and acquire insights in specific aspects of an Australian mall (looking at aspects of the pedestrian environment and tenant mix). Based upon the conclusions of all subjects in this study, this objective is achieved.

And the problem definition was defined as: is it possible to predict pedestrian behavior on a micro-level scale in an Australian case, based on aspects of pedestrian environment and tenant mix, in order to describe consumer shopping behavior and predict the likely impact of (planned) retail change in the existing structure? Based upon the conclusions of all subjects in this study, this question can be answered positive. Although it was not possible to simulate realistic pedestrian behavior in the situation of 2008. But looking at the context of this present situation it is not surprising this did not work out.
6.3 Recommendations

Based upon the results and the conclusions of this study, a couple of recommendations are formulated in order to improve the model and research on pedestrian behavior in general. The recommendations are:

- Further research could determine whether the use of a small data set is the reason why the simulation of the situation of 2008 did not work properly. Is some minimum quantity of respondents needed for the model?

- Further research could determine whether a relative small research area results in too specific parameters. Is a minimum quantity of shops in a certain branch necessary in order to estimate more general parameters?

- Further research in order to determine whether the amount and types of variables is achieved. Is the model in its final stage?

- Further research to standardize the model. Is it possible to develop a model, based upon previous developments, that can be used in any case (without needing to adjust the variables)?
References

• Kaylin, S.O., 1973, "In depth analysis necessary for shopping centre game," shopping centre world, 46.
Appendices
### Appendix 1 ‘shop categorization’

<table>
<thead>
<tr>
<th>Shop</th>
<th>Branche</th>
<th>Cluster</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRMA</td>
<td>Remain (services)</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Hairdressers</td>
<td>Personal Care</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>House &amp; Garden</td>
<td>Home Products</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>Liquorland</td>
<td>Food</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>Coles</td>
<td>Food</td>
<td>A</td>
<td>6</td>
</tr>
<tr>
<td>Locks</td>
<td>Remain (services)</td>
<td>A</td>
<td>7</td>
</tr>
<tr>
<td>Cameras</td>
<td>Electrical Appliance</td>
<td>A</td>
<td>8</td>
</tr>
<tr>
<td>Health Food</td>
<td>Food</td>
<td>A</td>
<td>9</td>
</tr>
<tr>
<td>Computers</td>
<td>Electrical Appliance</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>Rockmans</td>
<td>Fashion</td>
<td>A</td>
<td>11</td>
</tr>
<tr>
<td>Bakery</td>
<td>Food</td>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>Doughnuts</td>
<td>Food</td>
<td>A</td>
<td>13</td>
</tr>
<tr>
<td>Newsagency</td>
<td>Books and magazines</td>
<td>A</td>
<td>14</td>
</tr>
<tr>
<td>Sewing products / Suzanne Grae</td>
<td>Fashion</td>
<td>A</td>
<td>15</td>
</tr>
<tr>
<td>Kmart</td>
<td>Department store</td>
<td>A</td>
<td>16</td>
</tr>
<tr>
<td>Country Collection</td>
<td>Fashion</td>
<td>A</td>
<td>17</td>
</tr>
<tr>
<td>Toilets</td>
<td>Remain (services)</td>
<td>A</td>
<td>18</td>
</tr>
<tr>
<td>Shoes</td>
<td>Shoes</td>
<td>A</td>
<td>19</td>
</tr>
<tr>
<td>Lowes</td>
<td>Fashion</td>
<td>A</td>
<td>20</td>
</tr>
<tr>
<td>Lingerie</td>
<td>Fashion</td>
<td>A</td>
<td>21</td>
</tr>
<tr>
<td>Medicare</td>
<td>Personal Care</td>
<td>A</td>
<td>22</td>
</tr>
<tr>
<td>Sewing</td>
<td>Other retail</td>
<td>A</td>
<td>23</td>
</tr>
<tr>
<td>Mandarin</td>
<td>Bars and restaurants</td>
<td>A</td>
<td>26</td>
</tr>
<tr>
<td>Dumaresq Shire Council</td>
<td>Remain (services)</td>
<td>A</td>
<td>27</td>
</tr>
<tr>
<td>Hairdressers</td>
<td>Personal Care</td>
<td>A</td>
<td>28</td>
</tr>
<tr>
<td>Sport store</td>
<td>Other retail</td>
<td>A</td>
<td>29</td>
</tr>
<tr>
<td>Fair Dinkum Bargains</td>
<td>Other retail</td>
<td>A</td>
<td>30</td>
</tr>
<tr>
<td>Crafts</td>
<td>Other retail</td>
<td>A</td>
<td>31</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Bars and restaurants</td>
<td>A</td>
<td>32</td>
</tr>
<tr>
<td>Beauty</td>
<td>Personal Care</td>
<td>A</td>
<td>33</td>
</tr>
<tr>
<td>Elly’s</td>
<td>Bars and restaurants</td>
<td>A</td>
<td>34</td>
</tr>
<tr>
<td>Bags</td>
<td>Fashion</td>
<td>A</td>
<td>35</td>
</tr>
<tr>
<td>Manns</td>
<td>Fashion</td>
<td>A</td>
<td>36</td>
</tr>
<tr>
<td>HBF</td>
<td>Personal Care</td>
<td>A</td>
<td>37</td>
</tr>
<tr>
<td>Dress</td>
<td>Fashion</td>
<td>A</td>
<td>38</td>
</tr>
<tr>
<td>Trickoders</td>
<td>Other retail</td>
<td>A</td>
<td>39</td>
</tr>
<tr>
<td>Cafe</td>
<td>Bars and restaurants</td>
<td>A</td>
<td>40</td>
</tr>
<tr>
<td>Mathers</td>
<td>Shoes</td>
<td>A</td>
<td>41</td>
</tr>
<tr>
<td>Deli</td>
<td>Food</td>
<td>A</td>
<td>42</td>
</tr>
<tr>
<td>Chemist</td>
<td>Personal Care</td>
<td>A</td>
<td>43</td>
</tr>
<tr>
<td>Toy World</td>
<td>Other retail</td>
<td>A</td>
<td>44</td>
</tr>
<tr>
<td>Elizabeth Lloyd Jeweller’s</td>
<td>Other retail</td>
<td>A</td>
<td>45</td>
</tr>
<tr>
<td>Margots</td>
<td>Fashion</td>
<td>A</td>
<td>46</td>
</tr>
<tr>
<td>Jeans West</td>
<td>Fashion</td>
<td>A</td>
<td>48</td>
</tr>
<tr>
<td>Ganduria Shoes</td>
<td>Shoes</td>
<td>A</td>
<td>49</td>
</tr>
<tr>
<td>Store Name</td>
<td>Category</td>
<td>Floor</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>---------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Jewelry</td>
<td>Other retail</td>
<td>A 51</td>
<td></td>
</tr>
<tr>
<td>Just Jeans</td>
<td>Fashion</td>
<td>A 52</td>
<td></td>
</tr>
<tr>
<td>Deli</td>
<td>Food</td>
<td>A 53</td>
<td></td>
</tr>
<tr>
<td>Sportsgirl</td>
<td>Other retail</td>
<td>A 54</td>
<td></td>
</tr>
<tr>
<td>Toilets</td>
<td>Remain (services)</td>
<td>A 55</td>
<td></td>
</tr>
<tr>
<td>Crystal Moon</td>
<td>Other retail</td>
<td>C 56</td>
<td></td>
</tr>
<tr>
<td>Bookstore</td>
<td>Books and magazines</td>
<td>C 57</td>
<td></td>
</tr>
<tr>
<td>OPSM</td>
<td>Other retail</td>
<td>C 58</td>
<td></td>
</tr>
<tr>
<td>Dymocks</td>
<td>Books and magazines</td>
<td>C 59</td>
<td></td>
</tr>
<tr>
<td>Cafe Midste</td>
<td>Bars and restaurants</td>
<td>C 60</td>
<td></td>
</tr>
<tr>
<td>Armidale Kids</td>
<td>Fashion</td>
<td>C 61</td>
<td></td>
</tr>
<tr>
<td>Health Food</td>
<td>Food</td>
<td>C 62</td>
<td></td>
</tr>
<tr>
<td>Bakery</td>
<td>Food</td>
<td>C 63</td>
<td></td>
</tr>
<tr>
<td>Savages</td>
<td>Fashion</td>
<td>C 64</td>
<td></td>
</tr>
<tr>
<td>Margots (dress)</td>
<td>Fashion</td>
<td>C 65</td>
<td></td>
</tr>
<tr>
<td>Florista</td>
<td>Other retail</td>
<td>C 66</td>
<td></td>
</tr>
<tr>
<td>Accent</td>
<td>Fashion</td>
<td>C 67</td>
<td></td>
</tr>
<tr>
<td>National Australia Bank</td>
<td>Remain (services)</td>
<td>C 68</td>
<td></td>
</tr>
<tr>
<td>CES Social Security</td>
<td>Remain (services)</td>
<td>C 69</td>
<td></td>
</tr>
<tr>
<td>The Stables</td>
<td>Other retail</td>
<td>C 71</td>
<td></td>
</tr>
<tr>
<td>Fruit Shop</td>
<td>Food</td>
<td>C 72</td>
<td></td>
</tr>
<tr>
<td>Jewellers</td>
<td>Other retail</td>
<td>C 76</td>
<td></td>
</tr>
<tr>
<td>Real Estate</td>
<td>Remain (services)</td>
<td>C 77</td>
<td></td>
</tr>
<tr>
<td>Katies</td>
<td>Fashion</td>
<td>C 78</td>
<td></td>
</tr>
<tr>
<td>St. George</td>
<td>Remain (services)</td>
<td>C 79</td>
<td></td>
</tr>
<tr>
<td>Art Supplies</td>
<td>Other retail</td>
<td>C 80</td>
<td></td>
</tr>
<tr>
<td>Sewing</td>
<td>Other retail</td>
<td>C 81</td>
<td></td>
</tr>
<tr>
<td>Figtree Clothes</td>
<td>Fashion</td>
<td>C 82</td>
<td></td>
</tr>
<tr>
<td>Jade Emporium</td>
<td>Fashion</td>
<td>C 83</td>
<td></td>
</tr>
<tr>
<td>Armidale Post office</td>
<td>Remain (services)</td>
<td>C 84</td>
<td></td>
</tr>
<tr>
<td>Hairdressers</td>
<td>Personal Care</td>
<td>C 86</td>
<td></td>
</tr>
<tr>
<td>Tatts Hotel</td>
<td>Remain (services)</td>
<td>C 88</td>
<td></td>
</tr>
<tr>
<td>Randy</td>
<td>Electrical Appliance</td>
<td>C 89</td>
<td></td>
</tr>
<tr>
<td>Bookstore</td>
<td>Books and magazines</td>
<td>C 90</td>
<td></td>
</tr>
<tr>
<td>Newsagency</td>
<td>Books and magazines</td>
<td>C 91</td>
<td></td>
</tr>
<tr>
<td>Gifts</td>
<td>Other retail</td>
<td>C 92</td>
<td></td>
</tr>
<tr>
<td>Good Vibrations</td>
<td>Music and video</td>
<td>C 93</td>
<td></td>
</tr>
<tr>
<td>Raine &amp; Home</td>
<td>Remain (services)</td>
<td>C 94</td>
<td></td>
</tr>
<tr>
<td>Fuji Photos</td>
<td>Remain (services)</td>
<td>C 95</td>
<td></td>
</tr>
<tr>
<td>Commonwealth bank</td>
<td>Remain (services)</td>
<td>C 96</td>
<td></td>
</tr>
<tr>
<td>Jurys</td>
<td>Fashion</td>
<td>C 97</td>
<td></td>
</tr>
<tr>
<td>Mallums Chemist</td>
<td>Personal Care</td>
<td>C 98</td>
<td></td>
</tr>
<tr>
<td>Advance Bank</td>
<td>Remain (services)</td>
<td>C 99</td>
<td></td>
</tr>
<tr>
<td>HSA Real Estate</td>
<td>Remain (services)</td>
<td>C 100</td>
<td></td>
</tr>
<tr>
<td>HCF</td>
<td>Remain (services)</td>
<td>C 101</td>
<td></td>
</tr>
<tr>
<td>Angus &amp; Robertson</td>
<td>Books and magazines</td>
<td>C 102</td>
<td></td>
</tr>
<tr>
<td>Chemist</td>
<td>Personal Care</td>
<td>C 105</td>
<td></td>
</tr>
<tr>
<td>Fiddlesticks (kids)</td>
<td>Fashion</td>
<td>C 106</td>
<td></td>
</tr>
<tr>
<td>Real Estate</td>
<td>Remain (services)</td>
<td>C 107</td>
<td></td>
</tr>
</tbody>
</table>

Page | 135
<table>
<thead>
<tr>
<th>Business Name</th>
<th>Sector</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England Hotel</td>
<td>Remain (services)</td>
<td>C 108</td>
</tr>
<tr>
<td>Real Estate</td>
<td>Remain (services)</td>
<td>C 109</td>
</tr>
<tr>
<td>N.E. Travel</td>
<td>Remain (services)</td>
<td>C 111</td>
</tr>
<tr>
<td>Music Shop</td>
<td>Music and video</td>
<td>C 113</td>
</tr>
<tr>
<td>Building Corp.</td>
<td>Remain (services)</td>
<td>C 114</td>
</tr>
<tr>
<td>Chinese</td>
<td>Bars and restaurants</td>
<td>C 115</td>
</tr>
<tr>
<td>Chickens</td>
<td>Food</td>
<td>C 116</td>
</tr>
<tr>
<td>Reality World</td>
<td>Remain (services)</td>
<td>C 117</td>
</tr>
<tr>
<td>Barber</td>
<td>Personal Care</td>
<td>B 118</td>
</tr>
<tr>
<td>Retravision</td>
<td>Electrical Appliance</td>
<td>B 120</td>
</tr>
<tr>
<td>Sports Power</td>
<td>Other retail</td>
<td>B 121</td>
</tr>
<tr>
<td>Wilderness shop</td>
<td>Other retail</td>
<td>B 122</td>
</tr>
<tr>
<td>Fruit</td>
<td>Food</td>
<td>B 125</td>
</tr>
<tr>
<td>Chinese</td>
<td>Bars and restaurants</td>
<td>B 126</td>
</tr>
<tr>
<td>Agfa Photos</td>
<td>Remain (services)</td>
<td>B 127</td>
</tr>
<tr>
<td>Jeweller's</td>
<td>Other retail</td>
<td>B 128</td>
</tr>
<tr>
<td>Optometrists</td>
<td>Other retail</td>
<td>B 129</td>
</tr>
<tr>
<td>Bakery</td>
<td>Food</td>
<td>B 131</td>
</tr>
<tr>
<td>Harvey World Travel</td>
<td>Remain (services)</td>
<td>B 132</td>
</tr>
<tr>
<td>Frankling</td>
<td>Food</td>
<td>B 133</td>
</tr>
<tr>
<td>N.E. Credit Union</td>
<td>Remain (services)</td>
<td>B 134</td>
</tr>
<tr>
<td>State bank</td>
<td>Remain (services)</td>
<td>B 136</td>
</tr>
<tr>
<td>Chandlers</td>
<td>Electrical Appliance</td>
<td>B 137</td>
</tr>
<tr>
<td>Dress Shop</td>
<td>Fashion</td>
<td>B 138</td>
</tr>
<tr>
<td>Chemist</td>
<td>Personal Care</td>
<td>B 139</td>
</tr>
<tr>
<td>Jet set travel</td>
<td>Remain (services)</td>
<td>B 140</td>
</tr>
<tr>
<td>N.E. Credit Union</td>
<td>Remain (services)</td>
<td>B 141</td>
</tr>
<tr>
<td>Health Food</td>
<td>Food</td>
<td>B 143</td>
</tr>
<tr>
<td>Laundromat</td>
<td>Remain (services)</td>
<td>B 144</td>
</tr>
<tr>
<td>Beauty Salon</td>
<td>Personal Care</td>
<td>B 145</td>
</tr>
<tr>
<td>Woolworths</td>
<td>Food</td>
<td>B 146</td>
</tr>
<tr>
<td>Krumple Kidskin</td>
<td>Fashion</td>
<td>B 148</td>
</tr>
<tr>
<td>Tall Bamboo</td>
<td>Other retail</td>
<td>B 149</td>
</tr>
<tr>
<td>Oogie</td>
<td>Personal care</td>
<td>B 150</td>
</tr>
<tr>
<td>Take Away</td>
<td>Bars and restaurants</td>
<td>B 151</td>
</tr>
<tr>
<td>Hairdresser</td>
<td>Personal Care</td>
<td>B 152</td>
</tr>
<tr>
<td>Rumours</td>
<td>Bars and restaurants</td>
<td>C 153</td>
</tr>
<tr>
<td>Athlete's Foot</td>
<td>Shoes</td>
<td>C 154</td>
</tr>
<tr>
<td>Library</td>
<td>Remain (services)</td>
<td>C 155</td>
</tr>
<tr>
<td>Cafe</td>
<td>Bars and restaurants</td>
<td>B 156</td>
</tr>
<tr>
<td>Butcher</td>
<td>Food</td>
<td>B 157</td>
</tr>
<tr>
<td>Camping Equipment</td>
<td>Other retail</td>
<td>B 159</td>
</tr>
<tr>
<td>Fosseys</td>
<td>Fashion</td>
<td>A 162</td>
</tr>
<tr>
<td>Crazy Prices</td>
<td>Other retail</td>
<td>B 165</td>
</tr>
</tbody>
</table>
Appendix 2 ‘shop location’

Numbers correspond with the list in appendix 1 ‘shop categorization’.
Appendix 3 ‘data collection’

The map which is used in favor of the data collection
## Appendix 4 ‘coding scheme’

<table>
<thead>
<tr>
<th>Respondent</th>
<th>ID 1-....</th>
</tr>
</thead>
</table>
| Walked route | A01=Sat Morn 11-12-95  
B01=Tues Aftern 12-13-95  
C01=Thurs Aftern 16-11-95  
D01=Sat Morn 18-11-95 |
| Location started | Kmart car park=0  
Woolworths car park=1  
Commonwealth Bank car park=2 |
| Location finished | start point=0  
outflow or leakage=1 |
| Gender | male=0  
female=1  
male and female=2 |
| Age | 0-19=0  
20-29=1  
30-39=2  
40-49=3  
50-59=4  
60-69=5  
70-100=6 |
| Time started | time=H:M  
time=minutes |
| Time started (M) | time=minutes |
| Time Finished | time=H:M  
time=minutes |
| Time finished (M) | time=minutes |
| Total Time | time=minutes |
| Visited shops | ID=1-.... |
| Branch | Food=0  
Fashion =1  
Personal Care=2  
Home products=3  
Electra=4  
Media=5  
Department store=6  
Jewelers and opticians =7  
Spare time products =8  
Bars and restaurants=9  
Services=10  
Financial- and post-services=11  
Bargain=12  
Non-retail=13 |
| Start visiting shop | time=H:M  
time=minutes |
| Start visiting shop (M) | time=minutes |
| Finish visiting shop | time=H:M  
time=minutes |
| Finish visiting shop (M) | time=minutes |
| Total Time Shop | time=minutes |
Appendix 5 ‘observation 2008’

The numbers of the observation locations corresponds with the numbers on the map on the next page.

<table>
<thead>
<tr>
<th>Observation locations</th>
<th>Number of passer-by’s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21-02-08</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>34</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>15</td>
<td>34</td>
</tr>
<tr>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>21</td>
<td>72</td>
</tr>
<tr>
<td>24</td>
<td>116</td>
</tr>
<tr>
<td>25</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observation locations</th>
<th>Number of people</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21-02-08</td>
</tr>
<tr>
<td>1</td>
<td>114</td>
</tr>
<tr>
<td>2</td>
<td>138</td>
</tr>
</tbody>
</table>
The numbers correspond with the observation locations in the table on previous page.