



Université
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DEVELOPING THE CARPOOL SYSTEM FOR THE STUDENTS COMMUTING TO SART - TILMAN

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ABSTRACT

The actual climate change problem has become everyone concern. With the purpose of saving the planet, any initiative is welcomed. The environment pollution in dioxide Carbone (CO₂), noise, chemical, etc. is consequence to many sources: industries (power, manufacturing, chemical, etc.), household activities, cars, airplanes, etc. The car comes to the second place just after the industry (Oliver et al., 2013; Toress et al., 2011). Logically, diminishing the number of cars on the road must have a great impact on the reduction of CO₂ production.

The carpooling is one of the policies in travel/ transportation demand management (TDM) which has recently gained great success and good reputation in fighting CO₂ emission and toxic gases like PM₁₀ and NO_x, congestion and noise nuisance from cars by reducing the number of cars on the road. This reduction is the result of sharing rides for commuters in their different trips (Cools et al., 2013; Vanoutrive, 2012). The carpooling service at Sart Tilman (ST) is provided by Taxistop, the transportation operation which has its office, Carpoolplaza, in Walloon province. Carpoolplaza is a free online database where commuters can find a match (Toress et al., 2011). This online platform does not take any responsibility in commuter trips and it does not pay any particular attention on students' mobility. Using programming software (Matlab), spatial data analysis software (ArcGIS) and statistic data analysis (SAS), this thesis models the carpool system that fit ST students' community.

The carpool groups of five commuters each were produced and mapped respectively to their specific quarters. The factors including gender, financial need and time saving was identified to encourage carpooling at ST. These results are justified by the change of the community behaviour, especially the scientific community, which understands their responsibility to protect the environment and fights the climate change by reducing single occupancy vehicles (SOV) use, consequently CO₂ emission, and shift to the ride sharing mode.

Keywords: *Carpool system, CO₂ emission, Congestion, TDM policy, Matlab programming, Shortest path, Logistic regression, Sart – Tilman Students' community.*

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List of Abbreviations

ATM	Alternative Transportation Mode
CO2	Dioxide Carbone
CS	Carpool System
CHU	Centre Hospitalier Universitaire
HOV	High Occupancy Vehicle
ICEDD	Institut de Conseil et d'Études en développement Durable
ICT	Information and Communications Technology
LRA	Logistic Regression Analysis
OD	Origin-Destination
SAS	Statistic Analysis Software
ST	Sart - Tilman
SOV	Single Occupancy Vehicles
TDM	Transportation Demand Management
ULg	University of Liège
UK	United Kingdom
USA	United States of America
VMT	Vehicle Miles Travelled
VM	Virtual Machine
WGS	World Geodetic System

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The rapid increase in demography together with increase in need of transportation means has made auto mobile manufactures to increase their production and prosper their business. This situation which seems to be of great happiness to auto mobile operators is at the same occasion source to problems related to congestion, energy resources, noise nuisance, and climate change. The predictions by the Transportation Research Board have shown that by the year 2030, the number of vehicles will reach 2 billion (Transportation Research Board, 2008). Considering the Belgium situation, the higher number of commuters uses the car for their daily trip. The statistics from the 2001 Belgian Census confirmed that in Belgium 6.1% (203 024 commuters) commutes as a car passenger, 66.1% as a car driver, 6.5% uses the bicycle, 6.0% is a rail user, 6.2% uses regional public transport (bus, tram or metro) while other modes have a share below 5.0% (Vanoutrive et al., 2012). From the above numbers, we deduce that 72.2% of Belgian workforce commutes using a car. Moreover, the population in the South of the country, especially in the former industrial east-west part of Belgium which contains cities like Charleroi and Liège less densely populated (Vanoutrive et al., 2012), commuters in this part of the country have larger average commuting distances. The larger commuting distances together with more commuters using a car in their daily trips, it is obvious that problems related to congestion, environment pollution by CO₂ emission from cars are the main problems of transportation in this area. Consequently, commuters are experiencing present and future travel cost such as fluctuating fuel costs related to the ebb and flow of global energy markets, traffic congestion, environmental concerns, and longer commute times.

The average of carpool users as alternative form of transportation in Belgium and over the world is still to its lower level. Carpooling as TDM policy is not competing very well with other dominant form of vehicle use. For example, carpool mode share in the year 2000 in the United States was 12%. This compares with 5% for transit, and 76% for SOV trips. Recent data for Canada suggest that by 2006, 7.7% of commuters were traveling as passengers as carpooler (Vanoutrive et al., 2012). 6.1% of carpoolers compares with 72.2% of solo car users remains insignificant to tackle the TDM related problems. The limited historical mode share data in Belgium indicates that the proportion of passenger travel years ago, was lower

than recent statistics. This change in commutes mode is resulted in policy makers, planners, and commuters becoming increasingly aware of, and interested in, alternative transport options for commuting. ST is a natural reserve of more than 760ha, located around 10km far from the centre of Liège, in Belgium (Torres et al., 2011). The commuting related challenges described earlier may not be seen at the first site at Liège, but it is certain that financial related problems and congestion during peak hours are the main challenges related to transportation at Liège which houses a larger community of University of Liège (ULg) and whose majority commutes to ST. (Cools et al., 2013) confirms that the financial motives and necessity are the main triggers for students to carpool. He also added that the fact of maintaining the alcohol limit only to the driver play an important role when carpooling is considered for the student group. The Government of Belgium together with the province of Liège are developing and studying the integration of a sustainable TDM in the region (Torres et al., 2011). The Government encourages commuters to explore different commuter options like carpooling, transit, cycling, walking etc. The transportation operator, Taxistop with its office Carpoolplaza, at Liège proposes carpool service to the community. This online service does not guarantee security to the commuters after match (Torres et al., 2011). Since people are aware for their safety, this situation discourages many to carpooling. It is difficult to convince travellers carpooling unless their security is guaranteed. Furthermore, carpool users are very needful regarding other transportation aspects such as comfort, commute times, schedule flexibility, etc.

This thesis is concerned with designing a structured carpool system that fit the need of students commuting to ST and examine its sustainability. The carpool system proposed in this research, is a long term commute system that differ from ridesharing, which implies occasional shared travel that takes place on a single ride basis. However, some of ridesharing literature has been used and mentioned throughout the thesis.

1.2 CARPOOLING

1.2.1 DEFINITION

The literature proposes many definitions of carpooling. In this research, the following definition was adopted: carpooling is the sharing of rides in a private vehicle among two or more individuals (Cools et al., 2013). It involves the use of one person's private vehicle to carry one or more fellow passengers. The carpool group can share one or many member's car according to the level of ownership of cars of that particular group.

Carpooling is the easiest and most common ridesharing arrangement. It usually consists of two to five persons (according to the location) commuting in the same vehicle. Different arrangements are adopted during carpooling. In one hand, carpoolers share driving and other travel related responsibilities. In the other hand, one person in the group does all the driving and is reimbursed for mileage by his or her riders.

The driver may pick up passengers from their home or the passengers may find a way to get to the driver's home at a specified time or they may meet at a particular location. In this study, the carpool driver must pick up and drop off passengers to their home from the ST site. In case of many cars in a carpool group, the members must organize among themselves as to who is to drive on which day or which vehicle to use, and so forth. Preferably, carpool groups members would alternate driving and vehicles on a daily or weekly basis, or any other basis they prefer.

1.2.2 CHALLENGES

Many factors related to the weakening in carpooling have been found in the literature. In this study we focus on the following factors that increase private car use and decline the shared trips:

Increase in car ownership

Generally, the majority of the costs of owning a car are allocated to the purchase and maintenance of the car. The fuel costs are relatively small portion of the car ownership. Researchers believe there is a strong correlation between the number of vehicles a household owns and vehicles miles travelled by each household. Because income and car ownership are strongly related (as higher income people are more likely to own more cars), they do not feel

the weight of the fuel costs since it still relatively low compared to the other fixed costs related to the car ownership. Consequently, this category of people do not understand the need of savings on travel cost. Thus, as vehicle ownership rates have increased, carpooling and the use of public transportation has decreased.

Demography

The demographic factor is very important in carpooling studies. The way people are located on a given geographic area, both with the household composition, impact highly the carpool formation and use in that area. At the same time as car ownership has increased, household size has decreased leading to reduced opportunities for household based carpools. Researchers suggest that household based carpools are one – third to three – quarters of all carpooling. As household size decreases, carpooling rates decrease because there are less in household options for carpooling (Teal, 1987).

Moreover, increased suburbanization and dispersed land use settlement patterns have also contributed to the decrease in carpooling. Because work trip carpools are destination oriented, they are most successful in employment areas with a high number of employees and/or a high density employee settlement at the point of origin (Teal, 1987).

Researchers have found that carpool formation and use is particularly sensitive to individual compositional characteristics (e.g. gender, age and income), residential spatial context (the accessibility of an individual to be matched to other carpool users), mobility status (number of household automobiles) and the attitudes toward cost, the environment, and the value of time.

Attitudes and travel behaviour

The urbanisation has been always accompanied with a fundamental change in travel. In the area where destinations and activities centres are broadly dispersed, it becomes difficult for carpooling. The individual attitudes were identified as an explanatory variable for why people choose to carpool or not to do so (Giuliano et al., 1990).

Carpooling requires more travel time in order to pick up the other carpool members (for external carpooling in opposition to household carpooling) and this induces conflicting schedules (Giuliano et al., 1990). Although carpools are more spatially flexible and less time consuming than public transit options, they are often perceived to be more time consuming because of the need to pick up and deliver members which can lead to concerns about becoming involved with and dependent on strangers (Teal, 1987). Solo drivers find

carpooling less convenient due to schedule rigidity or because of irregular shift hour work location. Commuters may also be less likely to shift their mode choice when they have established habits and associate carpooling with a loss of privacy and independence, particularly if they need a vehicle during the workday (Teal, 1987).

The other stressful issue related to carpooling is how to build trust among commuters. The internet with its social media are nowadays exploited for establishing that environment of trust between carpoolers. The social media enables people to build trust, establish norms, and form social networks, which can then promote shared community objectives, for example carpooling. Researchers in that field have approved the capacity of social media to help in overcoming the obstacles to carpooling. The high levels of trust could help decrease the fear of getting into a stranger's car. Additionally, the difficulties in finding suitable matches are decreased, since the social media connect many potential carpoolers.

1.2.3. ADVANTAGES

Carpooling has a dominant voluntary aspect. The sense of responsibility such as protecting the environment by reducing CO2 emissions and decrease congestion are the main habits that commuters must have. To be successful, carpooling requires coordination, cooperation and flexibility from participants. The following are the benefits of carpooling for both the community and the environment.

- Carpooling reduces the costs involved in repetitive or long distance driving.
- It reduces the stress to commute and allows someone to relax, read, or even work while commuting.
- Carpooling enables some families to cut back to one car or to do without a car at all.
- If someone do not have a car or do not drive, carpooling allows him to consider jobs throughout the area.
- Carpooling can provide new friendships and company for commuting.
- Carpooling reduces air pollution and traffic congestion.
- Carpooling helps to combat rising traffic congestion, by filling the extra seats in the car, there are fewer drivers and therefore fewer cars crowding the roads.

1.2.4 CARPOOLING THROUGH HISTORY

Carpooling is, by definition, car journeys with arrangements so that more than one person can travel in a car. This can be done either for commuting or for occasional long journeys. This can happen spontaneously. For example if two colleagues find out they live not far from each other and decide to go to work together. Or carpooling can be achieved by using specialized tools to find people to share a ride with. An example of such tools are websites such as www.carpooling.fr where users can post offers and ride requests for others to see (Corentin, 2012-2013).

However, the definition of carpooling varies within the literature and is conceptualized in this research as the sharing of transportation to school in a private vehicle with other students. Alongside these definitions, there exist different types of carpoolers. Teal (1987) outlined three types of carpoolers:

- (1) Household carpoolers;
- (2) External carpoolers who share driving responsibilities; and
- (3) Carpool riders who do contribute the use of their vehicle to the pool and therefore they only ride (technically rideshare participants).

Based on the nature of the carpool system (CS) that is under study in this research, we notice that it belongs to the second carpool group.

Interest in carpooling has ebbed and flowed over time, unlike SOV use, which has grown consistently, and non-linearly, during the post-World War II era. Carpooling appears to come into focus as a possible mode choice, receiving widespread attention from the public and policy makers in times of favourable exogenous conditions (e.g., high fuel prices, or fuel shortages) (Soltys, 2009).

UK work on car sharing in the late 1970s and early 1980s was rather downbeat about the potential for car sharing. Meanwhile, Rahman (1993), has reviewed corresponding experience in the USA. He also highlights that, although car sharing was first introduced in the mid-1960s, it only became of mainstream interest during the 1973 oil crisis (Cairns et al., 2004).

Car club membership in Switzerland has been growing rapidly since the mid-1990s. Membership growth has been helped by the various car clubs joining forces to form a national organisation, Mobility CarSharing Switzerland, and by initiatives such as a combined season ticket marketed with Swiss Railways (Cairns et al., 2004).

In 1990 the number of members of car clubs in Switzerland stood at about 500 (similar to numbers in the UK in 2002). By 1997 it had increased to more than twenty times this figure, and by 2003 it had grown more than a hundred, fold to 58,000 members (Cairns et al., 2004).

Growth has also been rapid in Germany, although there the pattern has been slightly different, with a number of car clubs in existence. The German umbrella association for car clubs reported a total membership of 55,200 in 2001, following growth of over 20% a year for several years. Membership was conservatively estimated to reach over 200,000 people by 2010 (Cairns et al., 2004).

Car clubs in North America took off in the late 1990s, and Shaheen et al. (2002) reported that by mid-2002, US car clubs had between them approximately 11,500 members, and Canadian car clubs reported a total of 5065 members. By winter 2003/04, the Carplus newsletter reported that US car clubs in 8 cities served by the three main players (Zipcar, Flexcar and City Carshare) had over 30,000 members. Communauto in Québec (Canada) had grown to over 3000 members in 7 years, and Zipcar in Boston attracted an impressive 4000 members in its first 3 years (Cairns et al., 2004).

The 2008 increase in fuel prices, along with general economic factors in 2008-2009, undoubtedly increased the load factor for all modes. People shifted to carpools, vanpools, and transit to save on fuel costs and cope with a sluggish economy. Similarly, it is likely that carpool/vanpool programs would have relatively high cost effectiveness, for similar reasons: low cost to implement, savings in motor vehicle operating costs, and co-benefits from reduced congestion and infrastructure costs (C. J. Burbank et al., 2009).

In summary, the carpooling, as opposed to going to work or to school alone in one's car, offers several benefits. These benefits can be financial, environmental, and social or can simply be the reduction of the number of cars on the roads (section 1.2.3).

The financial benefits are obvious, if two people share a car for a journey, they also share the fuel costs. For frequent journeys, being able to reduce the costs can be very interesting. The environmental benefits are linked to pollution generated cars. The most known effect on the environment of driving a car is the CO₂ emission. CO₂ contributes to global warming. If more than one people ride in a car, the number of cars needed by those people is reduced, and so is the threat to the environment. Social benefits depend on people. Some will prefer to be alone while commuting. On the other hand, for some, travelling in a car with someone else

driving is an occasion to take a nap during their trip. For others who prefer to talk with their trip companions, being with other people in the car can be a way to enjoy the trip. The last benefit is obvious: every person riding in a car with someone else reduces the number of cars doing the journey by one. This means that there will be less cars on the road, which reduces the probability of congestion. Reducing the number of cars on the road can also make the trip faster and less stressful for the driver (Corentin, 2012-2013).

The people most likely to benefit from carpooling are lower income households with no car, or struggling to run a car; households where the only car is used for the daily commutes, leaving others with no access to a car; less mobile or less active people, e.g. elderly or disabled people; people setting up a small business; and those seeking employment (Cairns et al., 2004).

1.3 RESEARCH OBJECTIVES

Taken into consideration with a global view on environment and transportation related issues pointed out earlier in the above statements, furthermore, considering the present tangible panic caused by the climate change, the change in behaviour of earth planet habitant in different fields with the aim of saving the planet has been observed. In the transportation field, the commuters are conscientious and aware of the issues related to CO₂ gas emission and they are looking for transportation alternative means that can either reduce or better stop that CO₂ emission. Thus, it is apparent that this is a crucial point in time for carpool related research as alternative in TDM. The carpool system will not only tackle the environment related problems, but it will also solve the problems of congestion, noise nuisance, long commuting time, etc.

This research focuses on the carpool formation and its applicability on student's community that commutes to ST as a TDM initiative. The three objectives of this research are:

1. To study the Carpool formation by grouping students commuting to ST at the same faculty and coming either from the same quarter or neighbour quarters. Afterward, simulation is made to view the model and its applicability to the students commuting to ST from different quarters of Liège.

2. To apply programming, engineering and statistics software like Matlab, ArcGIS and SAS in Carpool formation and modelling. Moreover, analysing Carpool influencing factors using software. The use of software such as Matlab in this thesis is an innovative approach in Carpool system formation and open other perspectives for Carpool developers willing to apply new technologies.
3. Finally, analysing Carpool influencing factors like demographic, spatial and temporal factors. The conclusion on significant and insignificant factors will be made after the logistic regression analysis (LRA) of SAS software.

The research objectives are accomplished using data from students commuting to ST satisfaction questionnaire survey of 2013 together with the students' database of 2014 detailing their addresses and faculties. The questionnaire detailing the transportation modes used by students of the ULg commuting to ST, their schedules and satisfaction about the commuting modes was done by the faculty of applied science. The work is intended to contribute to the study of CS that fit the student's community that commute to the ST site by experiencing software applications in Carpool formation, simulation and analysing different factors influencing the Carpool formation and sustainability. In other words, this thesis bridges an important gap between ordinary CS and a CS conceived especially for students commuting to ST as an alternative transportation mode (ATM). Contributions to practice are intended to shed light on improving Carpooling initiative, with a view to enhancing access to sustainable transport options in the Liège area.

1.4 STRUCTURE OF THE THESIS

This thesis is split into six main chapters. The introduction has provided the summary of all the thesis and outlined the research objectives and description of the carpool system. Following the introduction, Chapter 2 provides a review of the relevant literature. The study area, students' activities analysis and the proposed carpool mode are described in Chapter 3. Chapter 4 presents the theory development and the methodology used to analyse data. The application of the methodology and findings are presented in Chapter 5. Lastly, the conclusion is presented in Chapter 6 along with recommendations for improving mobility and carpooling, moreover a new door for the future research is opened.

CHAPTER 2. CARPOOLING THROUGH LITERATURE

This chapter reviews the literature on carpooling. The section focuses on findings of researches on the following topics: Section 2.1 discusses TDM which studies the carpool as alternative model in transportation field. The section 2.2 offers more details on the requirements for carpool formation, where carpool groups formation and trip definition are explained. Section 2.3 outlines factors that encourage and discourage carpooling. Section 2.4 outlines how Information and Communications Technology (ICT) impacts and benefits on carpool formation and use. Lastly, section 2.5 summarizes and concludes the main findings of the literature review.

2.1 TRANSPORTATION DEMAND MANAGEMENT (TDM)

The policy initiatives are needed to improve the efficiency of the urban transport and solve its complexity. The rapid urbanisation and expansion of cities requires TDM which deals with the population movement operational improvements by improving transit infrastructures and mitigates transportation effects on the environment (e.g., air and noise pollution, and energy conservation).

In the year 1999, Meyer identified three types of TDM (Soltys, 2009):

- The first creates and promotes alternative transportation options to increase occupancy in vehicles;
- The second changes the amount of travel, particularly travel during peak hours through the use of incentives; and
- Third, eliminates the need for physical travel altogether (e.g., telecommuting)

Carpooling is associated with the first and the second type of TDM (creating alternative transportation options to increase occupancy in vehicles and changing the amount of travel, particularly travel during peak hours). This alternative does not need construction of new infrastructures compared to others like cycling and working. It uses existing transportation infrastructures with the goals of reducing monetary and environmental costs of commuting. Moreover, the carpooling as a TDM strategy fits the current needs of urban transport

developers and ecologists. The multifaceted use of carpooling brings this mode at the first rank in solving transportation related issues such as CO₂ emission that causes global climate change, air and noise pollution, congestion, etc.

Although nowadays carpooling has encountered many success in solving issues mentioned above, it has been subject to many critics by authors and scientists. Some authors like Teal in 1987 and Ferguson in 1997 have critiqued the usefulness of carpooling as a TDM (Soltys, 2009). Additionally, with the aim of criticizing ridesharing, Meyer (1999) showed that ridesharing's impact as a TDM strategy is limited compared to other initiatives. He found that several strategies were more successful than ridesharing in reducing vehicle miles travelled (VMT): employer trip reduction, improvements to transit, parking pricing, congestion pricing, telecommuting, and land use planning (Soltys, 2009). Likely, ridesharing slightly differs from carpooling. However, problems related to the ridesharing may affect as well carpooling. Reason why, though carpooling does not require more infrastructures, it needs more studies before its implementation and ability in organisation.

2.2 CARPOOLING FORMATION

The carpool main challenge is located at its formation and organisation steps (Section 2.1). The flexibility of schedules makes more difficult to match commuters (Cools et al., 2013). Furthermore, Sally, et al., 2004 discovered that commuters fear for their safety and privacy to carpooling with unknown persons. Thus, this attitude creates a barrier to carpool success.

2.2.1 GROUPING

The fundamental carpool process is the formation of carpool groups, in other words, matching commuters. The commuters (driver and passengers) match is not a random event. Some factors like the commuters' origins, destinations, schedules, ages, activities, etc. must guide that formation. In the research on the carpool behaviour conducted in Flanders, Belgium, by Cools et al., 2013, it has been found in students group, that the students are pleased by the initiatives taken by their colleges. Thus, it is easier for the students or workers to participate in activities initiated by their colleagues or coordinated by their respective institutions. Furthermore, Cools (2013) continues on confirming that one of the most prevalent initiatives is to compose groups based on the students' origin. This leads to

matching college-hours and facilitates carpooling to a large extent. Next, He also emphasizes on the use of new technologies (internet) in groups formation by approving that a database to which potential carpoolers can subscribe is considered to be a very good idea, given that individual privacy is safeguarded. Afterward, Cools (2013) recommends the use of initiatives such as competitions and gadgets in persuading students to change their travel behaviour. Finally He concludes that ride sharing with total strangers seems to be a no-go, but carpooling with fellow-students or members of the same sports club is more feasible (even if the partner is not known in person).

2.2.2 TRIP DEFINITION

In carpool, the trip is defined as the distance vector from the centroid of the origin to the centroid of the destination (end point) and back again to the origin (starting point). In our case, the strip will be considered as the distance made by carpoolers, from commuters address centroid to their faculty, and back to their home.

2.3 FACTORS THAT AFFECT CARPOOLING

The section discusses factors that affect carpooling. The authors attempt to classify factors related directly to the commuters (demographics, mode choice and preferences, financial situation, mobility constraint, attitudes, etc.), or to the availability and accessibility to the transport means (public transport or private car) which constitute spatial factors, and finally to the commuters activities scheduling and commuting time (temporal factors).

Since carpooling does not require additional infrastructures to those already in use by other transportation modes, the key factors for the success to carpooling are those related to the commuters. The change in commuting behaviour is the primary key to the carpool formation and use (Cools et al., 2013; Soltys, 2009). The factors mentioned above must be examine with a particular attention on norms and social characteristics of the community where the carpool implementation is going to take place. It is important to consider the context in which commuters make their decision and understand their behaviour. Obviously, every community has specific attitudes associated to the spatial and temporal factors which is different to another given community. Consequently, the carpool studies conducted on both communities must also be different and the carpool system applied to the first will certainly differ from the

one applied to the second, no matter the similarities of both societies. Thus, the success of the carpool system will be channelled by the quality of the study of factors that impact carpooling in a specific area, period and community.

2.3.1 FACTORS THAT ENCOURAGE CARPOOLING

This section has been divided in three parts: the part discusses literature on factors related to the commuters (demographics, mode choice, financial situation, mobility constraint, attitudes, activities, etc.), accessibility and vehicle availability effect on carpooling is detailed in the second part, the third part deals with the scheduling and commuting time. However, all the above listed factors will not be examined. The selection of these factors was guided by the weightiness they may have on carpooling considering the characteristics and needs of the community (students commuting to ST) studied in this research.

Commuters related factors

The role of gender in the carpool formation process and use has been widely discussed in the literature. Researchers like Johnston (1992) and Camstra (1996) demonstrated that females had shorter commuting times than males. That result was associated to the poor accessibility of the females to the vehicle (Soltys, 2009). The discussion around the difference of commuting time between females and males has controversial opinions in the literature, and authors do not have the same point of view on that topic. For example, Rietvald et al., 1999 and Kwan, 2000 have found that females had longer commuting times than males (Soltys, 2009). According to Kwan (2000), full time employed females had longer commutes than males, although males were more chance to have sufficient income to use a vehicle to commute (Soltys, 2009).

Many literature on impacts of gender on carpooling attempts to explain this difference in carpooling between females and males by household responsibilities of females compared to that of males. Because females generally perform larger domestic responsibilities such as shopping and childcare, they tend to have shorter commutes than males. This result can be justified by the shorter distances between some infrastructures like shops and schools that attract more females' activities. Camstra (1996) concluded that females have shorter commutes not only because of vehicle access constraints, but also because of household responsibilities that make females had higher value of time than males (Soltys, 2009).

Ferguson (1995) found that households' income played an important role in making decision to carpool (Soltys, 2009). In the research conducted in Flanders, Belgium, Cools et al. (2013) found that lower income groups such as students were more likely to begin carpooling because of their financial and their age (for students). Many other researches like Levin (1982), Tischer and Dobson (1979), found that students joined a carpool mainly because of financial motivation. Giuliano (1992) added that the decision to carpool depended more on cost saving than on other factors like time savings.

Soltys (2009) also discovered that age was also a determinant in the choice to begin carpooling. In their research, Cools et al. (2013) and Soltys (2009) demonstrated that young commuters were most likely to engage in carpooling compared with other transport modes.

Furthermore, some authors found that carpooling mostly occurs over longer distances (Cools et al., 2013). This is due to the higher cost of SOV that is easily noticeable on longer commutes.

However, although many authors found that gender and cost to be of higher significance on carpool formation and use than other demographic factors, some researchers criticized their findings. Baldassre et al. (1998) and Ferguson (1995) acknowledged that vehicle availability and educational attainment were more influential in the choice to carpool than other characteristics like gender.

Accessibility and vehicle availability (spatial factors)

The accessibility and availability of a vehicle has two completely parallel effects on carpool formation. On one hand, some researchers have found the vehicle availability to encourage carpooling. Cools et al. (2013) found that, the fact that many students do not have access to their household cars discourages this group to carpooling, since a car is needed to commute. Thus, the car is a primary condition to form a carpool group (section 4.3.1).

Torres et al. (2011) discussed on the difference of carpooling between females and males. He showed that the main reason was the less accessibility on a vehicle for females due to their lower income compared to males. On the other hand, car ownership reduces the chance to carpooling. The increase in schedule flexibility due to car ownership make more difficult to set up commuting times (pick and drop). In addition, the increase in car ownership also increase travel alone attitude (Torres et al., 2011), which attitude break the carpool formation process.

Scheduling and commuting time (temporal factors)

The commuters' activities schedules are great challenge to the carpool formation and use. However, when the schedules are arranged to encourage carpooling, it becomes an important trigger to the carpool formation and use. Torres et al. (2011) suggested that companies could organize they employees' schedules to encourage them carpooling. He found that the percentage of employees carpooling could largely increase if 30 minutes to 1 hour were added to the work start time and cut back to the end of the day. Thus, this situation would increase the chance to the employees to match their commuting time and encourage carpooling at the same time. According to the commuting time, almost the entire literature approve its positive effect on carpooling. The chance to carpooling increases as the commuting time increases (Cools et al., 2013).

2.3.2 FACTORS THAT DISCOURAGE CARPOOLING

The need for independence, incompatible work schedules, lack of convenience and flexibility, additional time needed to pick up and drop each rider, incompatibility with short distance commuting, lack of promotional campaigns including parking and other facilities are generally perceived to be barriers to carpool.

Andrey et al. (2004) found scheduling issues, problems related to the transport of items, and mobility during the work days are the main factors discouraging carpooling. In the same viewpoint with Andrey et al. (2004), Van Vugt et al. (1996) also found that many people were unable to carpool due to scheduling issues. The researchers found that the advantages of using high occupancy vehicle (HOV) lanes did neither solve the carpooling problems nor promote its uses. More researchers stressed on the problem additional commuting time and distance. Levin (1982), concluded that additional time needed to pick up and meet each rider discouraged commuters to carpooling. In addition, he stressed the complexity of solving the problem of incompatibility with short distance commuting. We cannot conclude this section without talking about commuters attitudes and promoting carpool as an alternative mode in TDM. Andrey et al. (2004), after they had explored the role of social norms in travel decision making, concluded that psycho social barriers to mode change were as important as the practical barriers. Cools et al. (2013), concluded on the students group that *'students usually do not lead much structuralized lives and therefore are very often not able to make and come up to appointments very strictly. The students are not familiar with any of the promotional*

campaigns of the government. This may be one of the reasons why carpooling is not very popular with this group' (Cools et al., 2013, p. 8).

2.4. INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) AND CARPOOL

The carpool formation and use is changing with time. The way our grandparents were carpooling is totally different to the situation we are facing nowadays. The modern world with its technologies have change the way people are carpooling. This section discusses the literature on how ICT impact on carpool. Some researchers like Resnick (2004) and Winter and Nittel (2006) found little impact of the ICT on the carpool formation, their research concluded that the ridesharing was closely associated with social convention rather than with technological innovation (Soltys, 2009). Furthermore, other researchers found less realistic the application of new technologies on carpool formation success. Pessimistic conclusion on impact of ICT on carpooling are found in some literature like Hall and Qureshi (1997) who concluded that web-based carpool applications were theoretically viable, but their utility appeared limited in real world as there was little evidence of people finding success in matching through internet.

However, many literature recognized the huge impact of the ICT on carpool formation and use. The ride match study conducted by Dailey and Meyers (1999) found that as more users are registered, there is an increase in carpool formation. This finding would be explained by the following theory: as the pool of users becomes larger, the diversity of commuting routes, and commuter demographics is likely to increase, and the chance of finding a suitable match is likely to increase too. Dailey and Meyers' work suggests that a small carpool program may have little impact initially, but over time, as the number of commuters becomes larger, the program's impact may increase. Additionally, Calvo et al. (2004), concluded that technology played an important role in carpool creation. Their study was conducted in Europe, and concluded that ICT based solutions worked well, but the researchers presented little empirical evidence to substantiate their observations (Soltys, 2009).

2.5. LITERATURE REVIEW SUMMARY AND CONCLUSIONS

The literature review on carpooling has examined commuters' related factors, spatial and temporal factors affecting carpool formation and use. The factors encouraging carpooling were identified with a particular consideration of the commuters' gender, household income, age, car ownership, schedules and commuting time.

Concerning the socio-demographic effects on carpooling behaviour, literature highlights only a limited influence of the gender. The studies have found that females are more likely to have the intention to switch to carpooling. Notwithstanding, carpooling is more common among commuters with lower incomes and among younger age groups. The lower car ownership rates and vehicle availability of these commuters are the most important factors influencing carpool outcomes. With respect to spatial determinants, the degree of urbanization and proximity to carpool lots does not seem to play a role. Nonetheless, proximity of carpool matches and longer travel distances to work appear to have a stimulating effect on carpooling. Concerning the temporal dimension, especially a fixed work schedule increases the likelihood of carpooling. With reference to attitudinal effects, several researchers suggest that attitudinal factors are more important in describing carpooling behaviour than socio-demographic variables.

The carpooling discouraging factors include the need for independence, incompatible work schedules, lack of convenience and flexibility, additional time needed to pick up and drop each rider, incompatibility with short distance commuting, lack of promotional campaigns including parking and other facilities.

Generally, the literature suggests that SOV travel is more preferred and successful for short commutes than the carpooling, since it increases commuting time due to the picking up and dropping of process of other members of the carpool. In the case of longer commutes, this SOV advantage is less important and commuters are more attracted to cost savings by carpooling.

The impacts of the ICT on carpooling were also examined. The researchers have different opinions on the effect of ICT and its uses on carpool formation and use. The ICT must solve

the complex issue of matching carpoolers by creating a platform that will easily match riders by creating a larger pool which increases the chance to find a matching rider.

The commuters' attitude behaviour was found to be an important factor that affect carpooling. The change in commuting behaviour is needed to ensure the carpool success.

The literature does not consider many issues whereas there are many other factors that may influence both carpool formation and use. Because carpooling seems to be a multifaceted process, its study requires also complex methods.

This thesis attempts to design a carpool system that fit the need of students commuting to ST. During the whole research, processes like creating carpool groups and defining the shortest path using Matlab, mapping using ArcGIS and logistic regression analysis in SAS will be used to answer the main research question: **which algorithms can be used to develop a carpool system for students commuting to ST?**

Chapter 3 presents details on the study area, students' activity analysis and the proposed carpool model.

CHAPTER 3. STUDY AREA, ACTIVITY ANALYSIS AND CARPOOL PROPOSED MODEL

The TDM of Liège need to emphasise on carpooling aimed to solve different problems related to transportation. Since carpooling has shown many advantages as an important alternative mode choice, this research aims to contribute to the field of TDM by studying the applicability of a carpool system that fit the need of the students commuting to ST. The study also analyse the factors that will affect the system either by encouraging or discouraging the commuters to carpooling. The literature review (Chapter 2) of this thesis discussed existing commuting modes with a special interest on sustainable transportation alternatives like carpooling, walking, and cycling. The chapter explained the formation of the carpool system and shows the factors that encourage and discourage commuters to carpooling. In this section (Section 2.3), the study covers demographic, spatial and behavioural factors that affect carpool formation.

This chapter describes the area and students' daily activities analysed in this thesis. Section 3.1 introduces the study area, the road network and different access to the site of ST. Section 3.2 discusses the students' activities: commute mode and schedule. Finally, the section 3.3 describes the carpool mode proposed for the ST students' community which fit their need considering their daily activities.

3.1 STUDY AREA

ST is a natural reserve more than 760ha large, located on a hill around 10km far from the centre of Liège, in Belgium. ST houses three major centres of activity: the Campus du Sart-Tilman of Université de Liège, the Centre Hospitalier Universitaire (CHU) of Liège and the scientific park « Liège Science Park » (Figure 3.1) (ICEDD, 2004).

These centres of activity generate a large number of trips. In particular, more than 20,000 people are daily commuting to ST. Among these centres of activity, the University Campus is the one attracting a larger amount of people (Torres et al., 2011). This thesis is interested in the University Campus and the Centre Hospitalier Universitaire where faculties are located, which faculties attract students for study purpose.

Aerial photography width: 724 pixels x height: 807pixels



Figure 3.1 View of the ST site (source: https://www.ulg.ac.be/cms/a_16385/fr/sart-tilman)

The accessibility of ST site is made easy due to the important traffic lanes network (Figure 3.2): Aachen (E40), Anvers (E313), Bruxelles (E40), Maastricht (E25), Luxembourg (E25) and Namur (E42) are the main lanes which serve the site (ICEDD, 2004).

The ST site has three main entry points from the following streets:

- Condroz,
- Colonster, and
- The Marche-en-Famenne Street (ICEDD, 2004).



Figure 3.2 Road accesses to ST (Source: ICEDD, 2004)

The access to the place from Liège's centre must be realized by bus or by car, being the latter the most used mean of transport (Torres et al., 2011).

However, ST accessibility and the trips that are generated are problematic in general.

The main problem regarding the ST site accessibility using the car is indeed the parking. Although there are many parking zones, they do not satisfy the highly demand in some locations. Some locations on the site have serious issues related to inappropriate car parking alongside the road (Figure 3.3). Thus, this situation needs an urgent solution. Furthermore, there are some parking zones which have exceeded their capacity, mainly those located near the Faculty of Medicine (Torres et al., 2011). It is obvious that parking must be constructed in

some zones, but the issue is that the whole site cannot be transformed into a giantess parking with the purpose of responding to that problem.

Therefore, the need of studying other transportation alternatives in order to solve this problem of parking must be a priority.



Figure 3.3 parkings alongside the road (Source: ICEDD, 2004)

The CS as transportation alternative does not need specific structures. The existing structures that other commuting modes use can serve for carpool as well. However, some structures at ST site must be rehabilitated. For example some bus stop in wood structures are very old and need rehabilitation (Figure 3.4) as well as some street connexions need lighting.



Figure 3.4 wooden bus stop

3.2 ACTIVITY ANALYSIS

3.2.1 STUDENTS COMMUTE MODE

Car

The majority of students commuting to ST comes from the District of Liège. Considering the road network aspect, accessing the ST site by car is easier (ICEDD, 2004). Unfortunately, the majority of students do not use the car to commute to ST site.

Bus

The students constitute the main social group that uses more the public transport. If we compare the results of the survey of 2004 and those obtained in 2010, we see a decrease in the percentage of students who use the car as a transport mode to access the ST site while the percentage of bus users is high (Torres et al., 2011). Different buses serve the ST Site: lines 48 (Opera-Guillemins-Sart Tilman University-CHU), 58 (Opera-Standard-University-CHU-

Boncelles), 2 (and 32) (Opera Seraing- Boncelles-Sart Tilman) and 25 (Angleur-Opera-Ougrée Boncelles-Sart Tilman).

The main lines providing the majority of service are 48 ST line and the line 58 (ICEDD, 2004). Moreover, given that the buses do not serve on Saturdays, Sundays and during public holidays (ICEDD, 2004) when they have to work on weekends

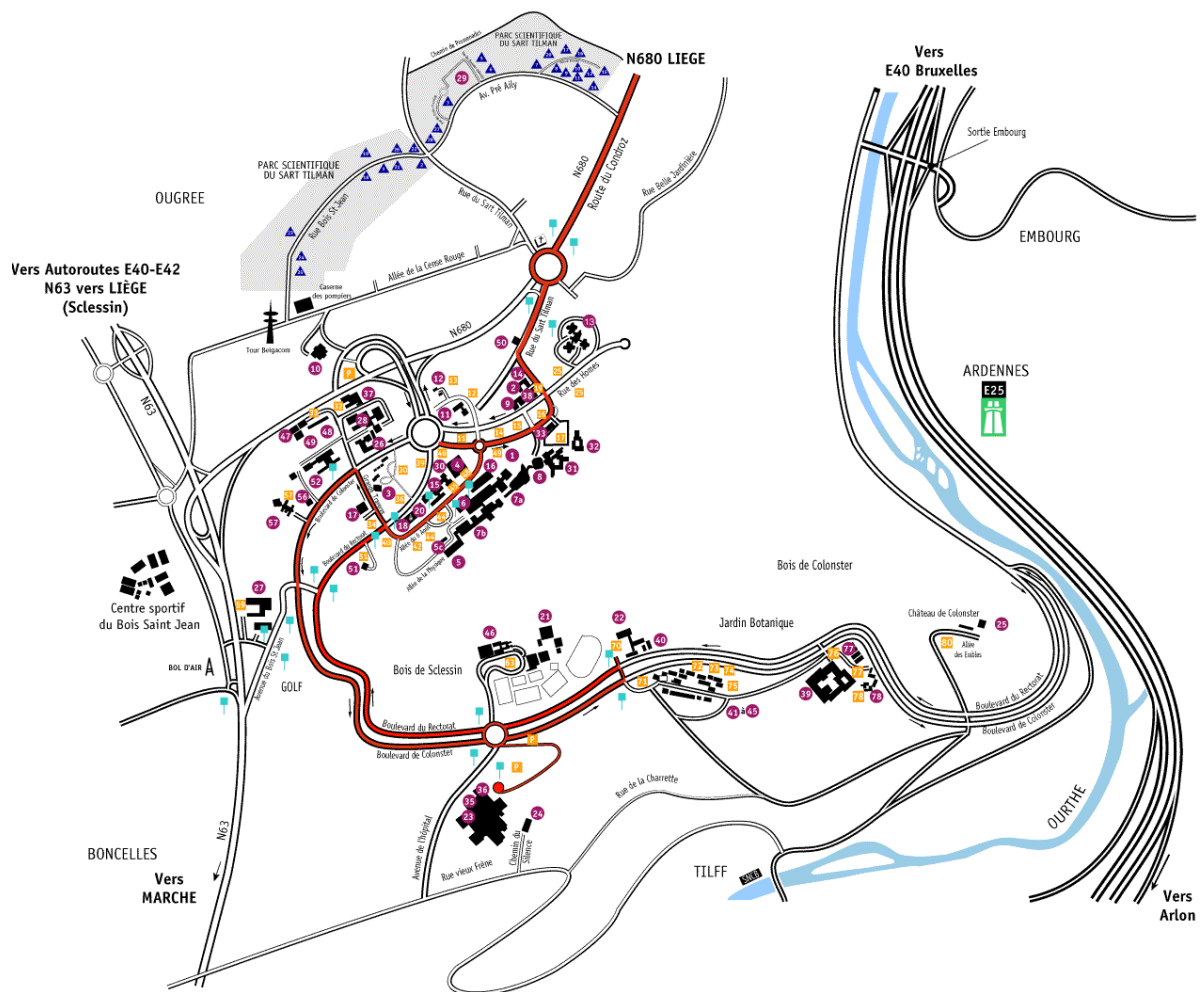


Figure 3.2.1.1 Bus line 48 at ST site

(Source: <http://www2.ulg.ac.be/acces/plans/bus/STbus48-det.html>)

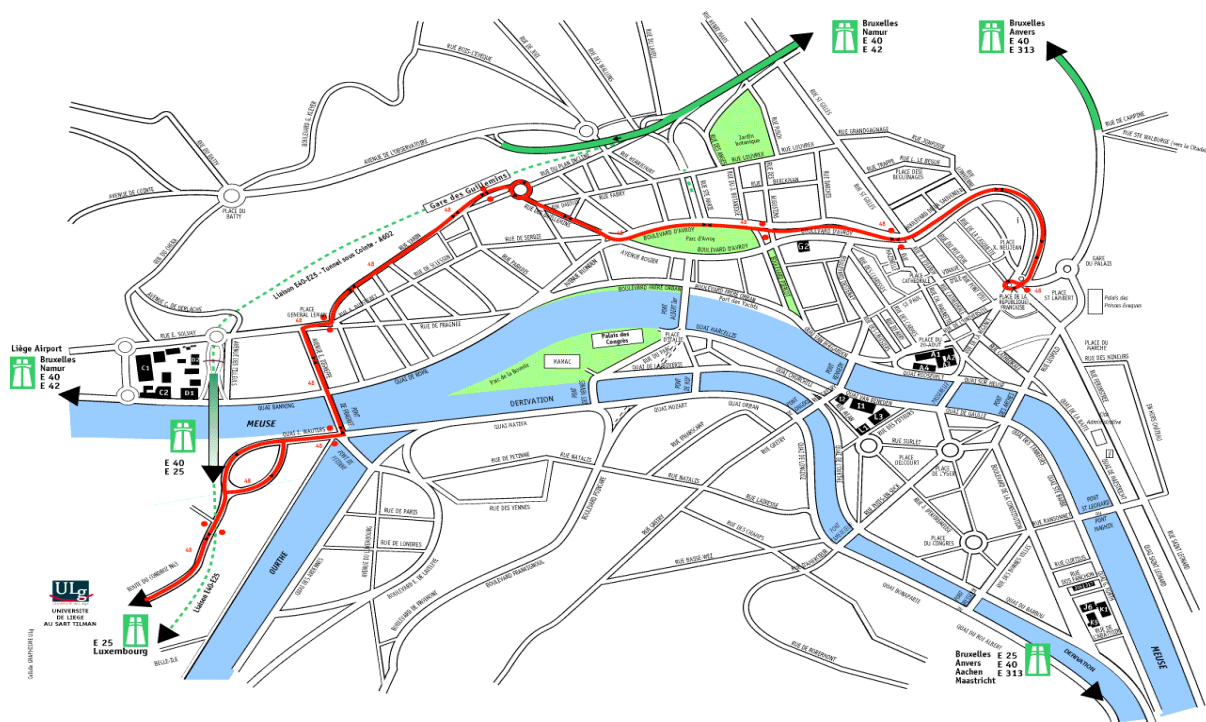


Figure 3.2.1.2 Bus line 48 in centre Liege

(Source: <http://www2.ulg.ac.be/acces/plans/bus/bus48-det.html>)

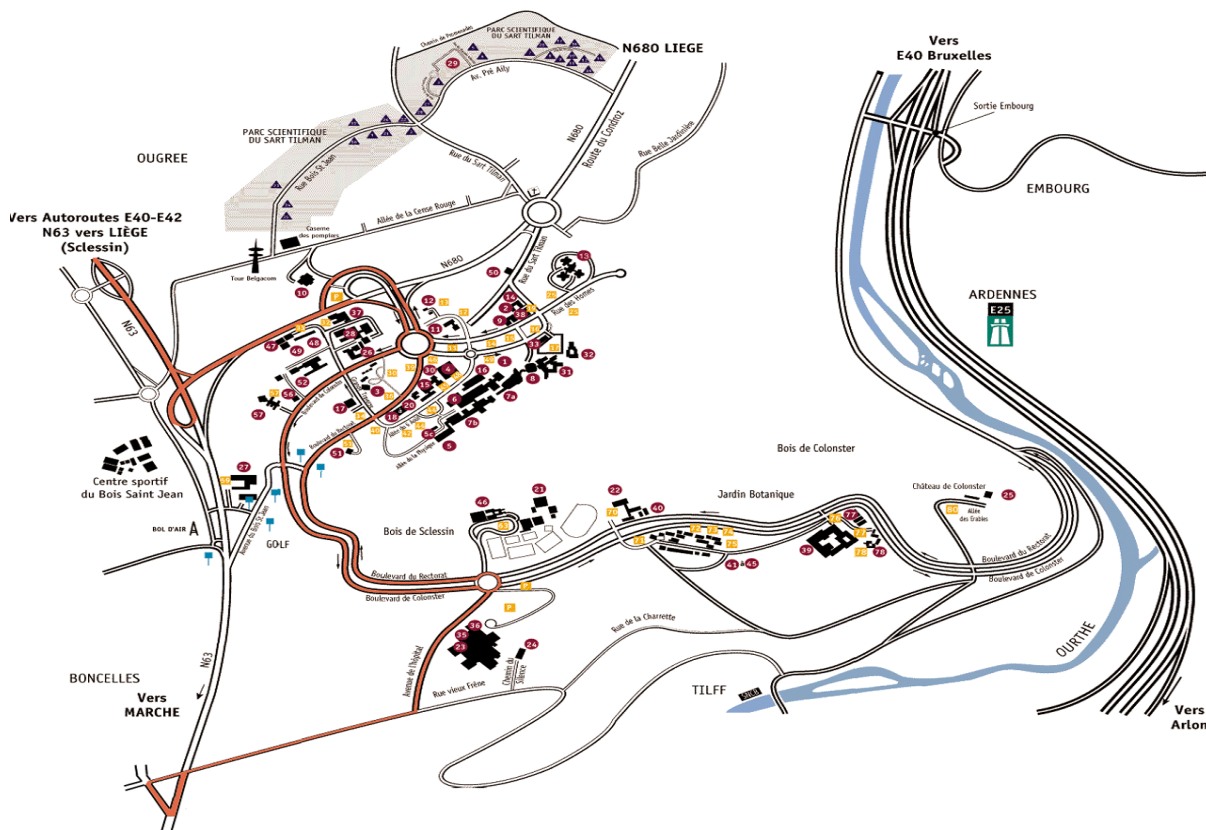


Figure 3.2.1.3 Bus line 58 at ST site

(<http://www2.ulg.ac.be/acces/plans/bus/STbus58-det.html>)

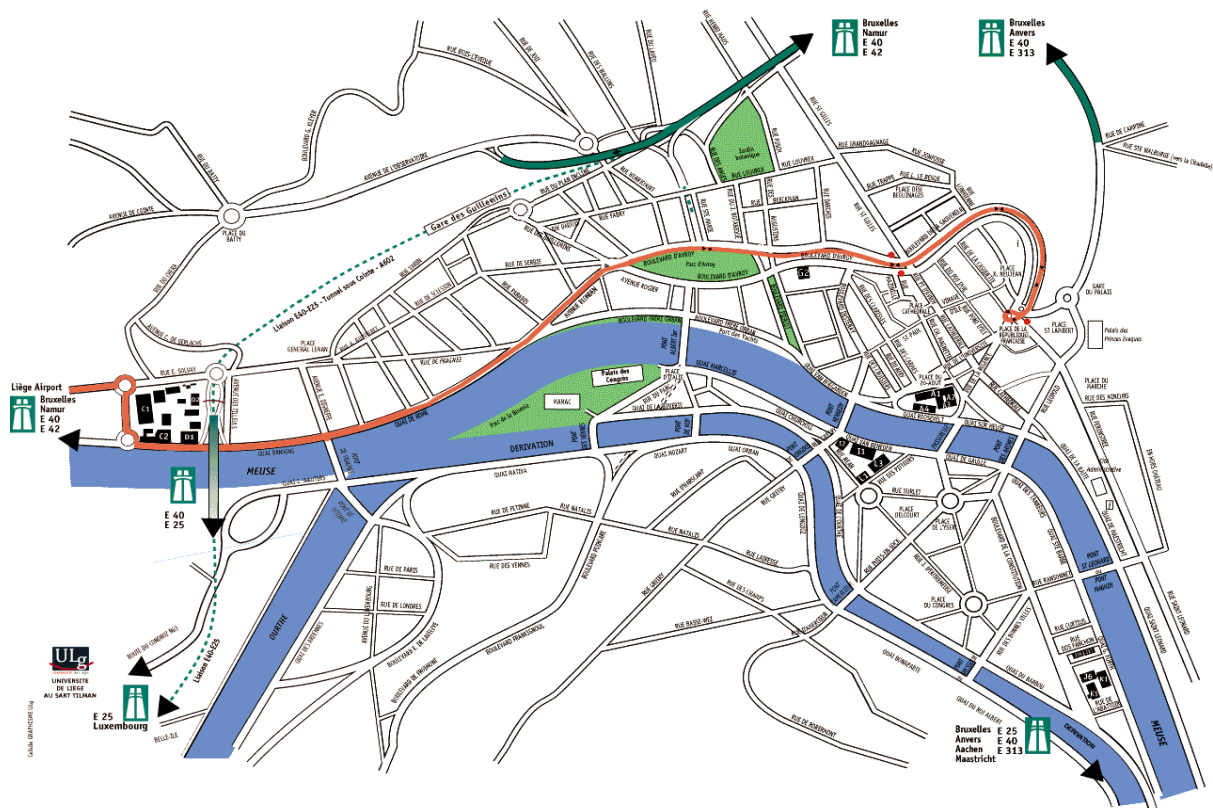


Figure 3.2.1.4 Bus line 58 in centre Liège (<http://www2.ulg.ac.be/acces/plans/bus/bus58-det.html>)

Train

The ST site is not served by the train. The train is not an attractive option given the lack of bus connections between the stations and the site. It is therefore the Liège-Guillemins station, the important railway junction which is the main station serving the site. The bus connections from that station to the ST site have high frequency (8 buses per hour) and a travel time of about 30 minutes (ICEDD, 2004).

Cycling and walking

ST is a site located in a wooded area, located on the heights of Liège about ten kilometers south of downtown, at the top of the valleys of the Ourthe and Meuse. The site includes more than 760ha area, most of which are woodland and hosts private nature reserve of ST, which is approved to be the most extensive in Walloon (Torres et al., 2011).

The bike accessing to ST site is not easy: the geographic characteristic (slopes) of the site and the non-secured paths toward the site make this transport means more difficult and sometimes dangerous. Since walking is considered as viable alternative in a 2 km radius around a site, obviously it does not present a significant potential to reach the ST site. The advantage of walking is the possibility it offers the students to connect the site to the village of ST where

restaurants are located. Walking appears primarily as a way to reach its destination from bus stops. Definitely, the car is the means of transport, students can use to reach more easily the ST from different origins, except the centre of Liege. From this place, the bus service is considered to be good. That assessment must, however, be modulated according to the location considered. Note however, that the accessibility of the ST site is distinct from that on the site itself. Indeed, it is difficult to go to ST by soft modes (cycling or walking), however it is easier to go biking or walking once on the site. Therefore, it should be analysed through surveys the importance of trips made on the same site in order to define the potential of these modes in terms of modal shift and alternative.

Carpool

The organization of carpooling system available on the ST is made in partnership with Taxistop who has a central carpool office at the Walloon Region, Carpoolplaza. Carpoolplaza is an online database that provides free access and the ability to find the right carpool match for commuting to work. However, the smooth progress of such transport organized by Carpoolplaza users takes place entirely on their own responsibility (Torres et al., 2011). The students commuting to ST do not use this carpool system and the majority are not even informed on the existence of this organization.

Carpooling is the alternative mode choice preferred by most respondents, followed by the option “no alternative” and, further, the bus. It would, therefore, be necessary to encourage this mode of transport in order to satisfy the interests which respondents showed (Torres et al., 2011).

After analyses the mobility and accessibility to the ST site, one can conclude that the main problems to solve are: Information and insufficient promotion of alternative modes of transport, especially carpooling.

3.2.2 SCHEDULE

According to the studies done in 2004, more than 50% of people commuting to ST make between 2 and 20km from home to the site. The majority of the ULg community lives in the province of Liège and does not spend more than an hour to commute to ST site.

At morning time, 70% of ST students arrive to the site between 8h00 and 9h00 with a particular peak hour at 8h30 (56%). They generally start leaving the site in the afternoon at

12h00 and 13h30 and 56% among them leave at 12h30. The course start in the afternoon at 13h30 and others at 14h00. Two peak hours are observed at this period: the first at 13h30 (44%) and the second at 14h00 (25%). The course take end in the evening at 17h00 and 18h00. At this time interval three peak hours occur: first at 17h00 (16%), second at 17h30 (26%) and third at 18h00 (17%) (Torres et al., 2011). From the data above, we notice that congestion occurs on roads to ST during those peak hours. Consequently, public transport are full and with less comfort on these specific moments. During weekend, this schedule changes but students still commuting to ST for study or other academic activities including sports, seminars, etc.

The student schedule is not uniform for all students and this is the main challenge for carpool groups' formation since those commuters who need to carpooling must have the same schedule or a schedule which is favourable for all carpool group members. This issue of schedule and formation of groups will be discussed in the following chapter section 4.3.1.

3.3. CARPOOL PROPOSED MODE

The rise in the production of auto mobility is expected to intensify problems with congestion, energy resources, and climate change (Soltys K. A, 2009). Thus, solutions must be found to tackle these problems. The CS is among emerging alternatives solutions in TDM.

One single definition of carpooling does not exist. Furthermore, the terms carpooling, ridesharing and car-sharing may or may not be used interchangeably. In the broadest sense of the word, ridesharing exists when two or more trips are executed simultaneously, in a single vehicle (Vanoutrive et al., 2012). In this research, we prefer to use the term carpooling since it stresses the formation of a pool, which emphasise on the relatively stable arrangement between commuters (driver and passengers). We will not use the term car-sharing since this is regularly understood as a service in which a car can be booked by persons who only occasionally need a 'rental' car for e.g. their weekly trip to the supermarket (Vanoutrive et al., 2012).

The literature outlines three types of carpool: (1) the household carpool, for household members; (2) external carpool, for commuters who share driving responsibilities; and (3)

flexible carpool, where riders are picked at random places and contribute to the trip expenses. Based on the nature of transportation issues and the characteristics of the community under examination in this research, the studied carpool within this thesis belongs to the second carpool group listed above.

Comparing with less flexible transportation systems such as public transport, carpool formation and use is a challenging alternative mode to develop given the issues of schedule matching and the potential increase in commute time associated with passenger pickup and drop off.

In order to free carpooling from rigid schedules and preplanning, just-in-time carpooling allows a large member base of passengers and drivers to be matched with each other automatically and instantly, allowing for on-the-spot arrangement of rides. The internet, a mobile phone call or text message, and other modern technologies initiate an automatic process in which drivers and passengers are matched to carpooling wherever and whenever they need it, without the scheduling constraints of traditional carpooling (Massaro D. W, 2009).

CHAPTER 4. THEORY DEVELOPMENT AND METHODOLOGY

4.1 HYPOTHESES

The behavioural motivations, cost, demographic, and environment variables influence the decision to carpool. The expectation of this research is that cost and availability of a vehicle will be primary motivations underlying the decision of students commuting to ST to start carpooling. This research demonstrates that, from responses of students commuting to ST, some algorithms and process can be used to develop a sustainable carpool system model that fits the needs of ST Students Community:

- First, the groups must be formed with a maximum of five commuters per group,
- Second, a centroid for each group has to be created to represent the average position of each commuter of the group,
- Third, the previous formed groups and centroids together with faculties are presented on the map for visualization,
- Fourth, the Euclidian distance between the centroid and the faculty is calculated.
- Then, the shortest paths from centroids to the corresponding faculty, on the road network is calculated,
- Finally, the LRA showing if the likelihood to carpool is successful by considering different predictor variables that impact the model formation and use.

4.2 DATA SOURCES

The necessary information used in this research were the questionnaire from the faculty of applied science of the ULg; the students database, the road network and the quarters of Liege shapefiles from the faculty of Science of ULg. For this thesis, we did not conduct a questionnaire survey due to budgetary and time constraints. Thus, we omit any critics on how the questionnaire was prepared and the way the survey was done. However, the filtration process was done to fit the needs of our research. The questionnaire used in the research contains some students' personal information such as postal codes address, and monthly

transport budget. Reason why these information will be kept secret for the respect of their privacy.

4.3 DATA ANALYSIS AND TREATMENT

The data used in this research are of two types. The first data are few and complete and the second data are numerous but incomplete. The reason why we used two kinds of data is that even though the first data were complete, after data filtration we remained with a sample of few students to decide if the formed carpool groups are adequate. Then the use of the second data helps with simulations about the increasing of the number of students who have a car and see if the carpool groups will increase.

The analysis of the carpooling research is discussed under five headings: grouping (Section 4.3.1), centroids (Section 4.3.2), geocoding (Section 4.3.3), mapping (Section 4.3.4), and logistic regression (Section 4.3.5). The grouping section explains how the carpool groups were formed and different constraints used for that formation. The centroids section discusses on how the average positions of students were calculated. The explanations on the transformation of respondents' postal codes address into geographic coordinates in geocoding section. The mapping section explains how the respondents and faculty locations, centroids, and roads network were mapped. Finally, the LRA was designed to address the study's primary research question: what factors influence carpool formation and use? The discussion of the logistic regression analysis includes a list of the predictor variables used in the model.

4.3.1 GROUPING

The grouping process done in Matlab software, reads and treats excel files (xlsx) data which are quantitative (numbers: ndata) and qualitative data (text). Firstly we treated the quarters: Liege has 27 quarters. The program will search the unique quarters and calculate the occurrence numbers of every quarter (number of persons leaving each quarter). The following table shows every quarter and the number of respondents in each quarter:

Amercoeur	5
Angleur	53
Bois-de-Breux	1
Bressoux	7
Burenville	3
Centre	178
Chênée	10
Cointe	16
Droixhe	1
Glain	1
Grivegnée	15
Guillemins	48
Jupille	9
Kinkempois	3

Laveu	18
Longdoz	8
Nord	14
Outremeuse	29
Rocourt	3
Sart-Tilman	17
Sclessin	7
St-Laurent	5
Ste-Marguerite	10
Ste-Walburge	20
Thier-à-Liège	1
Vennes	19
Wandre	6

Table 4.3.1.1 27 quarters of Liege with respondents of each quarter

It is remarkable that too many students live in the centre quarter mainly because it is where it's found almost all activities, shops etc. Obviously, this may also be the most populated quarter since the population need the same facilities.

The figure below show the quarters of Liege (our study zone).

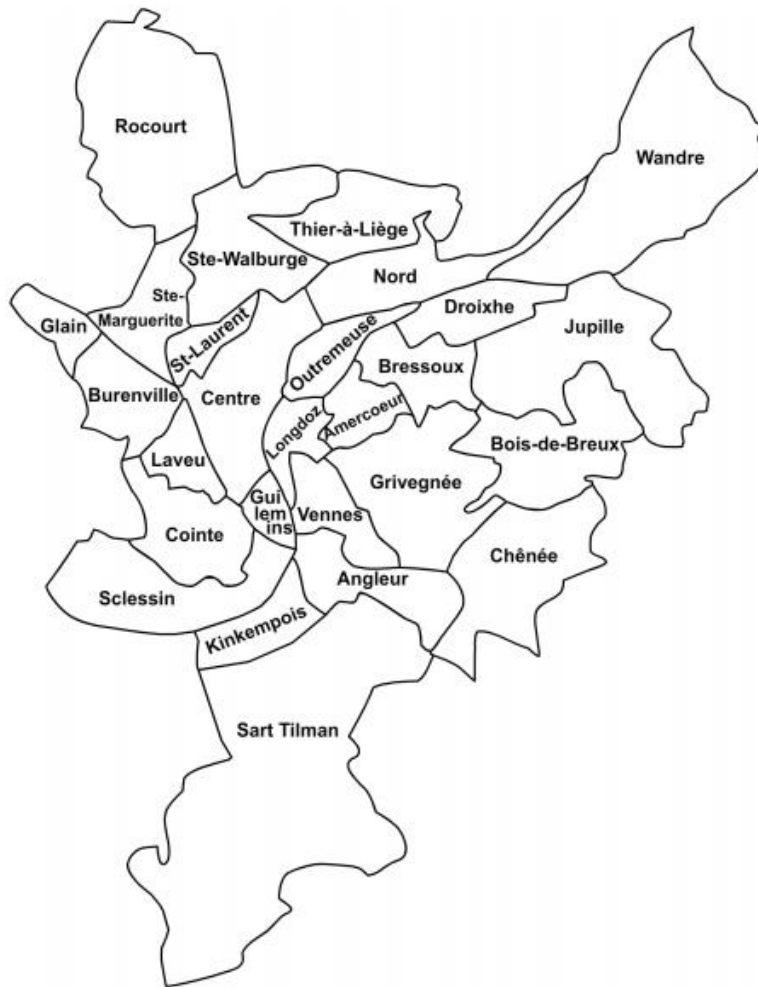


Figure 4.3.1.1 27 quarters of Liege

Second, we treated the faculties to see all the students' faculties. The faculties are 10:

Faculty	Id
Architecture	1
Droit - Science politique - Ecole	
Criminologie	2
HEC – Ecole de gestion	3
Medecine	4
Médecine Vétérinaire	5
Philosophie et Lettres	6
Philosophie et Lettres	6
Psychologie et Sciences de l'Education	7
Institut des Sciences humains et sociales	8
Sciences	9
Sciences appliquées	10

Table 4.3.1.2 10 faculties of University of Liege (ULg)

The faculties 7 and 8 ("Psychologie et Sciences de l'Education" and "Institut des Sciences humains et sociales") are neighbours and are represented as one point on the map.

Finally, we treated the cars to see the available cars in the data.

Formation of Groups

After extracting and treating the quarters, faculties and available cars in the data, the formation of the carpool groups with the first data is done using deterministic constraints and with the second data it is done with probabilistic together with deterministic constraints because we did simulations. The groups are formed depending on the following constraints:

- Groups of maximum 5 students and minimum 1 student,
- At least one student in the group has a car,
- The students are going to the same faculty,
- The students are from the same quarter or in the neighbour quarter,
- Distance optimization: in order to choose the next person in the group, the programming is done so that it will choose the nearest student as we have each one's address coordinates.

When the first four constraints are fulfilled the program will choose the next person in optimizing (minimizing) the distance so that it will not choose the students everywhere so far with one's quarter while it could choose the nearest ones.

This is a general Matlab code and if the data change, like we are using other data, the groups will also change depending on the quality of the data. Having two types of data, the first data which are few are used in all treatments because they are complete and the second data are used for simulation and will help to explain and interpret the theory about group formation.

4.3.2 CENTROIDS

Centroid or the geometric centre of two dimensional region is the average position of all the points in the shape. Here, it will be the average position of the students of the formed group.

They are calculated either in matlab using the function below:

```
function [x] = Search_Centroid(Distt)
N_C = length(Distt(:,1));
x(1,1) = (sum(Distt(1:end,1)))/(N_C);
x(1,2) = (sum(Distt(1:end,2)))/(N_C);
end;
```

or in ArcGis using the feature envelop to polygon, multipoint or multiline:

- ArcToolbox, features, point to line: creates groups' lines which link all points that contributed in group formation, a step before the envelop polygon.
- Feature envelop to polygon: takes the capable bounding box, we took the envelop polygon and the calculated centroids are in the middle of the bounding box. The results are in chapter 5 (sections 5.3.4). This method has limitations: it calculates the centroids exactly in the middle of the bounding box. If we had used for example a convex hull, each point in the region is assigned a weight or coefficient alpha in such a way that the coefficients are all non-negative and sum to one, and these weights are used to compute a weighted average of the points. If it was a weighted centroid method, the centroids will tend to go where many points that are contributing in the calculation of the centroids are. The weighted centroid will use the points' intensities in the region as weights in the centroid calculation. In the non-weighted centroid, all points in the region get equal weight.
- Then as we used the capable bounding box, the feature to point, gives the group centroid.

4.3.3 GEOCODING

Geocoding is a process of affecting at the postal codes addresses the geographic coordinates (latitude, longitude). When the data filtration was finished, we remained of a sample of data that are used in the treatments. In those data, each has its address and the addresses have been geocoded using "Batch geocodeur".

Batch Geocodeur is an online tool "The Google Geocoding API": the following website address was used, <http://www.batchgeocodeur.mapjnz.com/>. The geocoding is realized in WGS 84 (World Geodetic System 1984) in (lat, long). These coordinates in the WGS 84 system are transformed in Belgian Lambert 72 system because we are operating in the Belgian coordinates system. After geocoding the geocoded addresses are copied in excel tabular and they will be imported in ArcGIS for mapping. The accuracy goes from 1 to 8: if it is 8, the geocoding is successful. It found the correct, exact number of the house in the street. If it is 6, it is in the exact street but not on the exact number of house. When the accuracy decreases it means that the geocoding was not successful and maybe the address was not correct.

4.3.4 MAPPING

The mapping is done using ArcGIS. After geocoding and Matlab treatments, some requests to complete the treatments are done in ArcGIS and we represented the results on the map.

- For the first data, the following requests are done:
 - importing the geocoded students addresses,
 - importing the geocoded faculties addresses,
 - transformation of coordinates,
 - importing the Matlab output, formed groups,
 - join between addresses table and formed groups in Matlab,
 - calculate groups' centroids,
 - represent the centroids and the faculties,
 - calculating the distance (Euclidian distance) from each centroid to their faculty,
 - calculating the shortest paths on the road network using spatial analyst form each centroid to the corresponding faculty,
- For the second data: we did the same first 6 requests as we did for the first data.

4.3.5 LOGISTIC REGRESSION

The Logistic Regression Analysis (LRA) is a statistic common and popular technique for describing how a binary dependent variable is associated with a set of explanatory (independent) variables. The LRA is performed using many software according to the researcher preferences and objectives. In this research, the LRA developed by the SAS software was used. SAS is a statistic software which is leading the current market of statistical analysis research. The SAS University Edition which was used in this work, is a free version of SAS designed especially for student's researches.

The predictor variables used in the model were selected from the satisfaction survey questionnaire conducted by the Faculty of Applied Sciences of the ULg. The dependant variable is concerned with carpooling preference opinion status of the respondents at the time when the survey was conducted. This variable is made up of two responses: ready to carpooling for everyday home to study trip as either driver or passenger at the time of

sampling, and not ready to carpooling for everyday home to study trip as either driver or passenger at the time of sampling.

The block entry logistic regression model was specified and estimated to explore the determinants (the predictor variables) of carpool formation and sustainability. The figure 4.2.3.1 shows the framework of factors that impact carpool formation and use. It was developed using information from the literature.

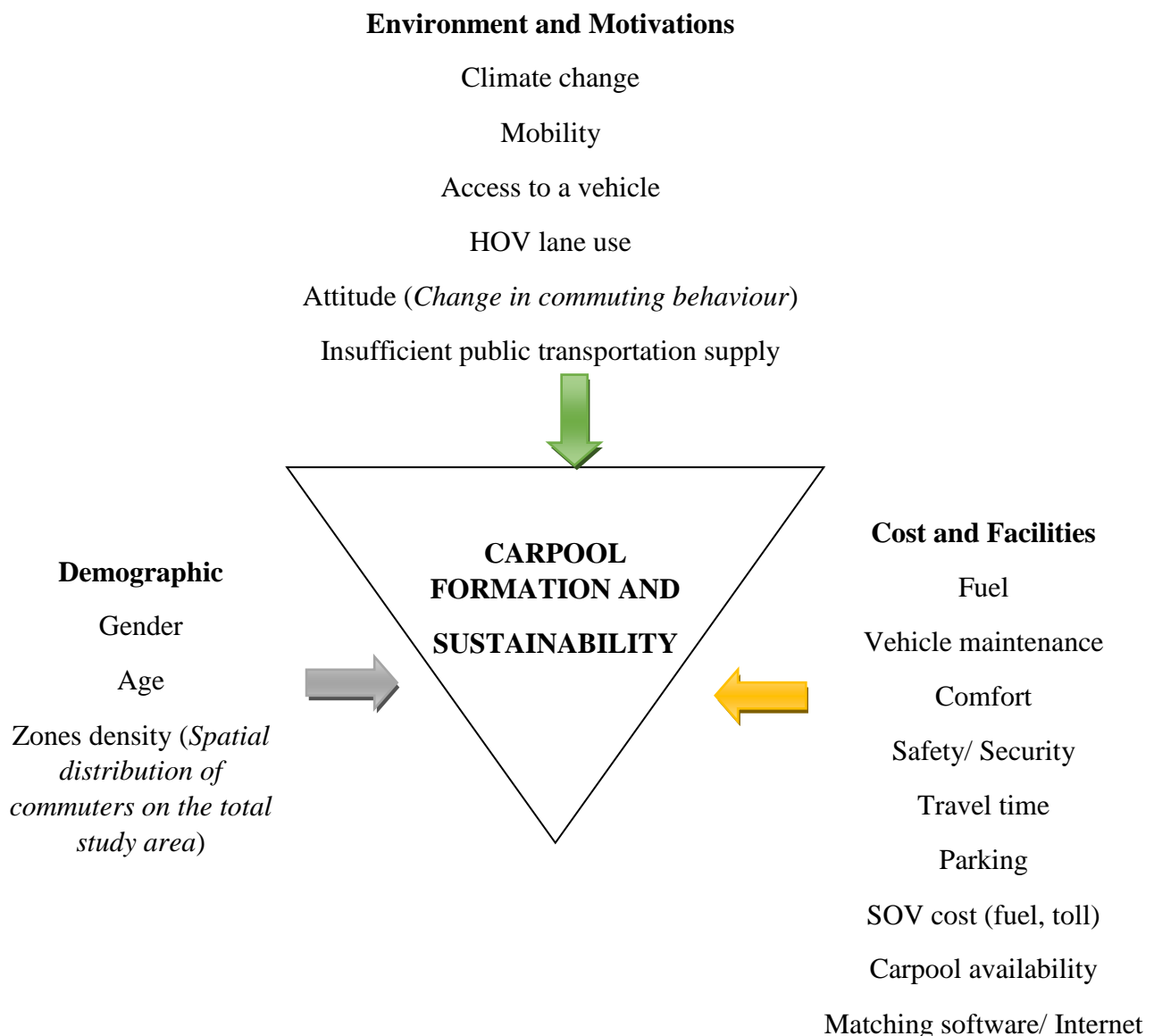


Figure 4.3.5.1 Framework for Carpool Formation and Sustainability

Only 19 predictor variables were selected and used in our model to assess their impact on the carpool formation and sustainability. The main constraint that influenced the predictor

variables selection was the data availability. Some variables listed in Figure 4.3.5.1 were not considered in this work due to that scarcity of data. The only predictor variables considered in this study are listed in Table 4.3.5.1, explained with more details in Section 4.2.3.1 and identified in bold typeface in the Framework for Carpool Formation and Sustainability (Figure 4.3.5.1). The predictor variables are divided into three groups (Figure 4.3.5.1): demographic, environment and motivations, and cost and facilities.

Nº	Predictor Variables	Description	Source
Dependent variable			
<i>Cost and Facilities</i>			
1	carpl-dr&pas	Ready to use carpool as driver or passenger	Survey data
Independent variables			
<i>Demographic</i>			
2	sexmf	Gender M/F	Survey data
3	age	Age	Survey data
<i>Motivations (Current commute mode)</i>			
4	satmmode-car	Satisfied with the commonly transport mode used-car as main mode	Survey data
5	satmmode-bus	Satisfied with the commonly transport mode used-bus as main mode	Survey data
6	satmmode-train	Satisfied with the commonly transport mode used-train as main mode	Survey data
7	r-bus	Ready to use more the bus	Survey data
8	r-train	Ready to use more the train	Survey data
9	r-bike	Ready to use more the bike	Survey data
10	r-foot	Ready to use more the foot	Survey data
11	mtransport-car	Have you change the main transport mode to car	Survey data
<i>Cost and Facilities (Spatial)</i>			
12	car-own	car ownership	Survey data
13	car-stilman	Do you use your car at Sart Tilman site	Survey data

14	mbudget	Transport monthly budget	Survey data
15	lfar-stilman	Live far from Sart-Tilman	Survey data
16	lisoplace	Live in isolated place	Survey data
17	lsafety	Lack of safety	Survey data
18	ndemand	No carpool demand	Survey data
19	noffer	No carpool offer	Survey data

Table 4.3.5.1 The 19 Predictor Variables selected for the LRA

Parameter estimates

The logistic regression model considered in this work takes the form:

$$\text{logit}(\pi) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k;$$

where $\text{logit}(\pi)$ is the natural log of the ratio of forming and using a carpool (π) to not doing so ($1 - \pi$), or the natural log of the odds of successfully forming and using a carpool; α is the regression constant; and β_k the parameter estimates associated with K independent variables, X (Cools et al., 2013).

The SAS University Edition always works in virtual machine. This research uses Oracle VM Virtual Box as virtual machine to run the SAS University Edition program. The sharing folder is created and serves as a link between both the real and the virtual machine. All SAS files must be contained in that sharing folder.

The logistic regression in SAS is performed by the PROC LOGISTIC procedure. The syntax of PROC LOGISTIC, as used in the context of this research, is as follows:

```
proc logistic data = < file name>;
where < event> in (0,1);
class < variables> (ref = '1') / param = ref;
model <event> (event = '1') = <variables> / selection = stepwise slentry = 0.05
slstay = 0.05 details;
run;
```

Only individuals for whom the response is known are includes in the WHERE statement.

The CLASS statement allows for parameterization of categorical variables.

In the MODEL statement, the dependent variable is specified on the left side of the equals sign, and the independent variables (both continuous and categorical) are specified on the right.

The selection of main effects is done at the end of the MODEL statement by the stepwise approaches. This mode of selection allow variables to be added or removed in the model according entry and exit criteria specified. In the stepwise section, the method of selection is specified in (SELECTION =), and the p-value criteria for entry into (SLENTY =) and exit from the model into (SLSTAY =).

Predictor variables explanation

Demographic variables

The gender and age independent variables were both extracted from the survey questionnaire. The gender variable was constructed in binary for where male was coded as 0, and female as 1 (reference group). From the literature review (Chapter 2), it is expected that females will less carpool than males with a little impact of the age on the carpool formation and use. The unsuccessfulness of the females group to carpooling might be resulted to scheduling conflicts due to household responsibilities (Chapter 2). Thus, according to the literature, females carpool on shorter commutes and fail to carpool over longer distances. The responses that failed to provide gender (dichotomous response i.e. 0 or 1) information were excluded from the model, while the average age was added on missing age (continuous) responses. This process of replacing missing values in the age responses helped not having many responses excluded from the model.

Motivations

The mode choice is mostly influenced by commuters' motivations as well as cost issues. Some important motivations that impact the mode choice are: travel time and cost, flexibility and comfort, personality traits and attitudes, and the newly emerge issue of environment. Many motivations listed above are not included in the framework of this carpool research due to data constraints. Each motivation variable used in this research is detailed below: 1) respondents were asked if they were satisfied with the commonly transport mode they use at the time of survey. For the car, bus, and train users, the response category was of level three (Yes, No, and Uncertain).

2) Respondents were asked if they were ready to use the bus, train, bike, and foot. The response was also of level three (Yes, No, and Uncertain). Finally 3) respondents were asked

if they have changed the main transport mode to car. The response was of level three (Yes, No, and Uncertain) (See section 5.4: Logistic regression results).

Cost and facilities

The cost and facilities variables were extracted from the questionnaire as other variables listed above. This variables include: ready to use carpool as driver or as passenger, car ownership, if the respondent uses the car at the ST site, transport monthly budget, live far from ST, live in isolated place, lack of safety, no car demand, and no car offer.

Ready to use carpool as driver or as passenger

The dependent variable is special for this research since all other variables (independent) are associated to this variable to model the carpool. The respondents were asked if they were ready to carpool as driver or passenger. The two responses, both for respondents willing to carpool as drivers and those willing to carpool as passengers, were combined to give one dependent variable. This binary variable was coded 1 for Yes and 0 for No. The SAS software, by default, analyses the model for the no occurring of the event. In the MODEL statement, it must be specified that the model have to be design for the event to occur. In this research, the probability of using the carpool as driver or passenger was taken as reference and specified in the MODEL statement in (EVENT = '1').

Car ownership

Many students use the car to commute from home to study trip. It is obvious that having a car will increase the odds to carpool, but there are three scenarios that occur with this variable: 1) many students use household cars to commute (Cools et al., 2013). This situation has a negative impact of the carpool formation and use because the student has no authority on the car and cannot use it regularly. 2) When many students have access to the car, it results in solo-automobile usage of the car. The car owner does not easily see the need of sharing ride and has more and more flexible schedule that make the sharing of rides with others. 3) The third scenario makes the carpool formation and use more difficult as well as the two previous situations mentioned above. One may think that when many students have no access to the car may motivate them to share ride. Unfortunately, we cannot share something we do not possess. At least one carpool group member must own a car to share. In this research, the car must hold 5 commuters to be shared in the carpool group.

The car ownership variable has three responses: Yes, No, and Uncertain. The uncertain response was added to fill the missing information on car ownership, otherwise, the SAS program would have excluded the respondents from the model.

If the respondent uses the car at the ST site

The use of a car at ST site may result in parking management related issues. The parking availability in many places at ST has become a huge concern at a level where some roads on the site have been blocked to serve as parking (Chapter 2). The lack of parking may discourage solo-automobile users and encourage them to carpool. To encourage car users to carpool, some measures need to be taken by the administration of the ST site: parking payment for private car users and free parking for carpool users may positively impact on carpool formation and use.

The 'if the respondent uses the car at the ST site' variable has three responses. Yes, No, and Uncertain. The uncertain response was added to fill the missing information to avoid the exclusion of the respondents from the model.

Monthly transport budget

The cost of transportation is an important factor in TDM. The financial aspect of the transportation mode impact on the success of the mode. The students use carpool generally for financial reasons (Cools et al., 2013). Comparing to the active groups, students do not have a good monthly income to afford a private car. Some expenses such as fuel, car maintenance, tolls, are far huge comparing to many students monthly income. The missing values for the monthly transport budget were added as an average since the budget is a continuous variable.

Live far from ST

It is expected that a high number of potential carpoolers lives far from their destination (Cools et al., 2013). In this research, more students live near the ST site and do not commute for longer distances. This situation increases the female respondents' likelihood of carpooling compared to male respondents according to the literature (Chapter 2). The 'live far from ST' is a binary variable and was coded 1 for Yes and 0 for No response.

Live in isolated place

The variable has a significant effect on carpool formation and use. Living in isolated place increases the distance between respondents, thus it increases the time required to pick and drop them to their locations. This binary variable is expected to decrease the likelihood of carpooling. It was coded 1 for Yes and 0 for No.

Lack of safety

The commuters' safety is an important factor that has to be considered during carpool modelling. One may find more difficult to travel with a completely unknown person in a private car. The lack of safety in carpool trip organisation is among the main factors for carpool failure (Cools et al., 2013). However, in this research, the CS is designed for ST students' community. Among the constraints for forming the carpool group, students in the same group must commute to the same faculty. Thus, commuters feel more secured when carpooling with colleagues and friends. Consequently, it is expected that, in this research, this variable will have less impact on carpool formation and use. The response for this variable was coded 1 for Yes and 0 for No.

No car demand, and no car offer

The response for these variables was dominated by the Yes (1) answer (no car demand, and no car offer). This situation is due to the lack of a carpool platform organised especially for ST students. Moreover, the lack of information and spots on CS makes these variables more significant and impact negatively on the carpool formation and use. This research will contribute on the outset and design of a carpool system adapted to the ST students' community.

4.4 DATA LIMITATIONS

This section discusses the limitations of the data used in this research. The questionnaire and the shapefiles used in this research were given by the faculty of science and applied Sciences of the ULg. We had no control over the originality and clarity of the questionnaire. Missing information and both unclear questions and responses can lead to errors and confusions. The limited spatial, commute mode, motivation, and sometimes demographic information available were a larger problem. Many important information were omitted by respondents.

At this stage, it is difficult to understand the reason why the respondents have left some questions without responses.

Data filtration

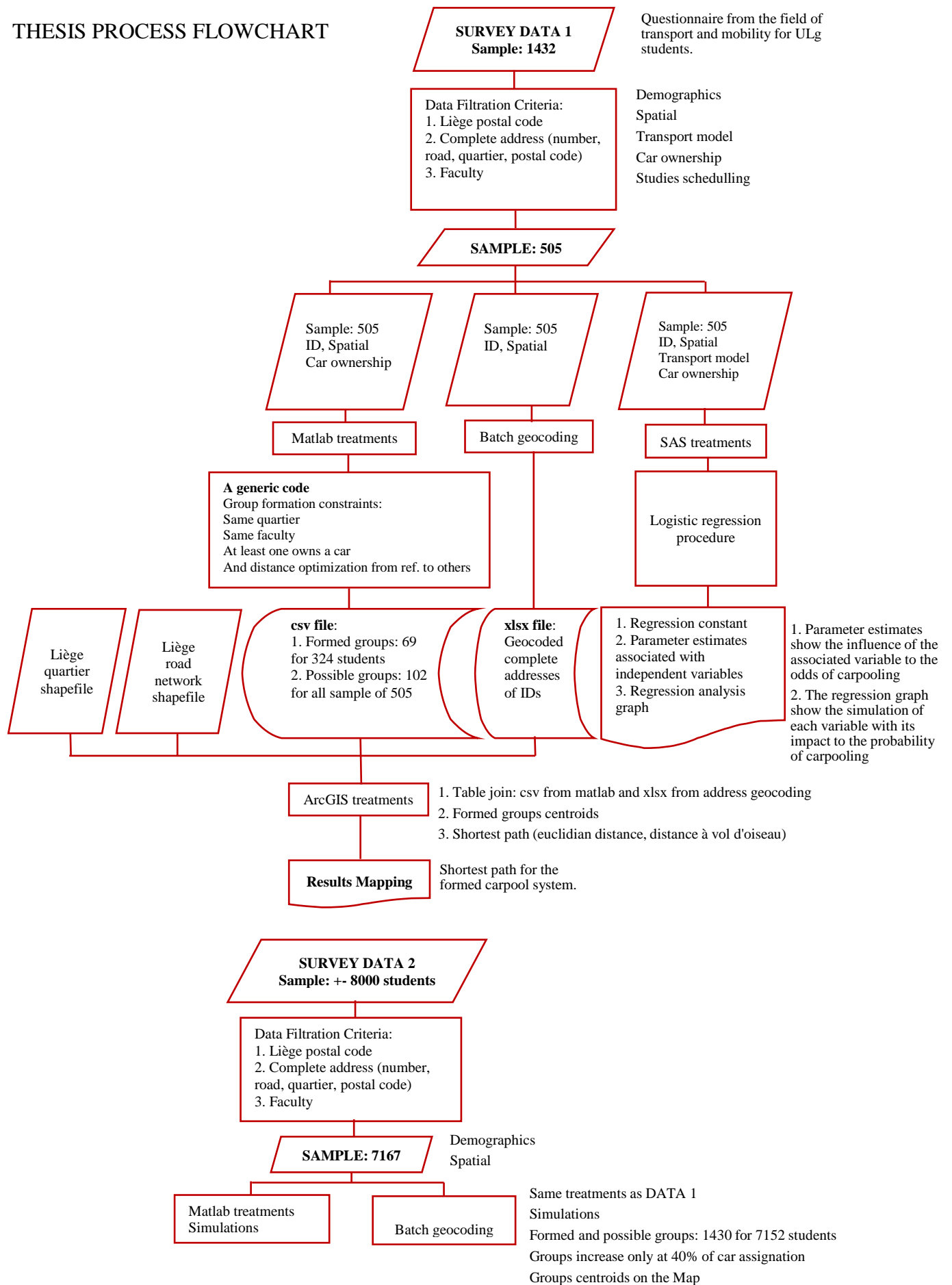
The filtration of data was done, and the process concerned of excluding those respondents who omitted important information for formation groups (respondent postal address and faculty), and for LRA (demographic, motivation, and cost). The filtration process has reduced substantially the number of respondents who may have participated in the model design.

The data filtration discussed in this section should highly impact on the findings of the research. Fortunately, some missing data were replaced by average values and the analysis did not seriously altered.

4.5 CONCLUDING COMMENTS

This chapter described the four steps the study used to analyse carpool formation process for students commuting to ST: geocoding, grouping and formation of centroids, mapping, and the logistic regression. Geocoding process changes the respondents' postal codes address to geographic coordinates (latitude and longitude). The maximum of five respondents were considered for each carpool group formation. Five main constraint guided the formation of the carpool groups (section 4.3.1). The centroid, which is the average position of the students of each formed group, was calculated for all groups. It can be calculated either in Matlab or in ArcGis. The mapping done in ArcGis, helps to visualise students' location, carpool formed groups, those groups' centroids and faculties. Then we did some requests in ArcGis (like join, calculating the bounding box, polygons, calculating the centroids of the formed groups, and calculating the distance between each group centroid and its corresponding faculty). LRA was selected to improve our understanding of what leads to achievement in carpooling through analysis of the impact of demographic, motivations, and cost variables on carpool formation and use. Below there is the flowchart which summarises all processes followed to achieve the results. The next chapter presents the results of the analyses and processes outlined above.

THESIS PROCESS FLOWCHART



CHAPTER 5. APPLICATION, FINDINGS AND VALIDATION

This Chapter discusses in details different results of the research, on carpool groups formation, geocodification process, mapping, and LRA. Lastly, the summary of the Chapter is presented.

5.1 CARPOOL GROUPS

DATA 1

After filtration, it remained a sample of 507 students but 505 only can be treated because the 2 did not have IDs (identifications). After the matlab programming, the formed groups were 69 within which the 56th and 66th were groups of only one student.

ID	Faculty	Quarter	Car	Group
2936166709	1	25	2	1
2936124413	1	22	1	1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1
2936624610	1	8	2	2
2935916182	1	6	1	2
2936069124	1	6	1	2
2936221325	1	6	1	2
2938038622	1	6	1	2
2937174561	1	12	2	3
2939994377	1	12	2	3
2939244170	1	12	2	3
2936096266	1	2	1	3
2938439534	1	6	1	3
2935672255	2	2	2	4
2939304866	2	7	1	4
2938101368	2	12	1	4
2939008852	2	12	1	4
2935948836	2	23	1	4

Table 5.1.1 Carpool groups

In this table, there are some (4 groups) of the results (normally 69 groups). The first column shows the students IDs, the second shows their faculties (10 faculties as shown in the part

4.3.), the third column shows their quarters (27 quarters) and lastly the fourth column shows each one's group: 2 means that the person has a car and 1 means the person doesn't have a car. The first person that the program chooses is a reference person and that one must have a car. The zeros (0) explain that the program could choose the persons in the group but it didn't find anyone responding to all the constraints to form a group of five persons. But if for example the data change and are some that respond to all the constraints, the program will complete and replace the zeros with the correct attributes.

DATA 2

The same process are done but the data didn't have any information about the students that have a car. The use of deterministic and probabilistic constraints helps in programming for these second data. While in first data we had a sample of 505 students for treatments and among them, only 104 has a car it gives the percentage of 20.6 students that have a car. This percentage rounded down (20%) is used for first simulation. Then the next simulations are found by multiplying by 2, 3 and 4 to see if there will be the change in group formation and conclude about the carpool system.

After the data filtration, using the same criteria of data filtration like in the first data, these second data remained with a sample of 7152 students which is a good sample for taking a decision about the CS for the ST students.

The programming used the normal distribution $N(\mu, \sigma)$ to represent the real valued random variables whose distribution are not known, because we didn't know which one among the 7152 students has a car.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where μ is the mean and σ is the standard deviation

If $\mu=0$ and $\sigma=1$, we have a standard normal distribution $N(1,0)$. The random variable (car assignation) with that distribution is a normal deviate (normally distributed). Then the distribution is called the standard normal distribution (0,1) which we used here in the programming where 0 stands for the persons who do not have a car and 1 stands for the persons that have a car.

Following is the example of Matlab code for car assignation:

```
% Car treatment
```

```

Np = 4; % car percentage
XP = zeros(1,Np);
XG = [];
XP0 = 20.6; % initial percentage

for kp=1:Np

    XP(kp) = XP0*kp;
    N1 = length(ndata);%size of quantitative data

    N2V = floor(XP(kp)*N1/100);
    N2E = N1-N2V;
    % Generating cars
    VTI = [ones(N2V,1);zeros(N2E,1)];
    VT = VTI(randperm(N1)); % generating cars randomly

% Grouping IDs of people having the vehicle

for k=1:N1
    for j=1:length(voituresUniques)
        tj = (voituresUniques(j,1)==VT(k));
        if tj==1
            M3(k,j) = ndata(k,1);
            Mc = sparse(M3); %output groups of individuals who have a vehicle
            break
        end
    end
end
end
end

```

The complete code about forming groups is found in the appendices of this thesis.

After randomly assigning the cars to students, firstly with 20%, secondly with 40%, thirdly with 60% and lastly with 80%; the formed groups with the first percentage of car assignation are 1125 groups. Then with the second percentage of assignation of car, the Matlab programming formed 1430 groups. With the next percentage assignation, the number of groups did not change because the sample of the data we have is of 7152 respondents and in each group we have a maximum of 5 students. After 40% of car group assignation, the number of groups remain the same (1430 groups).

The formation of groups in the carpool system, based on this simulations will depend on the data to be treated and the maximum number of the person in the group. If the number diminish (2 or 3 members only in the group), the groups will change.

ID	Faculty	Quarter	Car	Group
8093	1	2	2	1
17276	1	2	2	1
11603	1	2	2	1
5632	1	11	2	1
9780	1	11	2	1
8834	1	14	2	2
8989	1	14	1	2
6315	1	12	2	2
8280	1	12	2	2
10318	1	12	2	2
9511	1	4	2	3
12183	1	4	2	3
12639	1	4	2	3
9449	1	4	1	3

Table 5.1.2 Example of Carpool groups with the second type of the data (first 3 formed groups among 1430 groups).

The figure below show the variability of the formed groups.

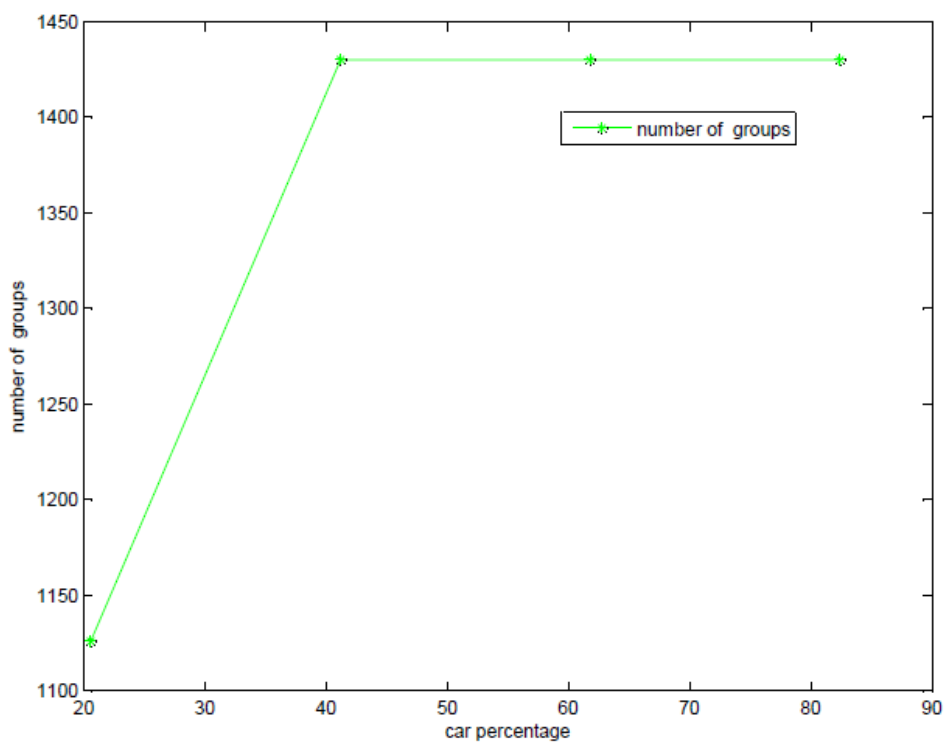


Figure 5.1.1 Matlab Plot for the formed groups based on the second type of data in simulations.

5.2 GEOCODIFICATION PROCESS

The geocoding uses a batch geocodur as explained in chapter 4, there you copy the complete addresses: address, postal code, city and country; you validate your data; start geocoding

process and then recuperate your geocodification results that can also be represented on google map. This process is done for both the data 1 data 2 and faculties. The results from geocoding are imported in ArcMap and the addresses are represented as points in a shapefile. As said in chapter 4, there are much concentration in the centre quarter and this for the first and second data.

Scale: 1/50,000

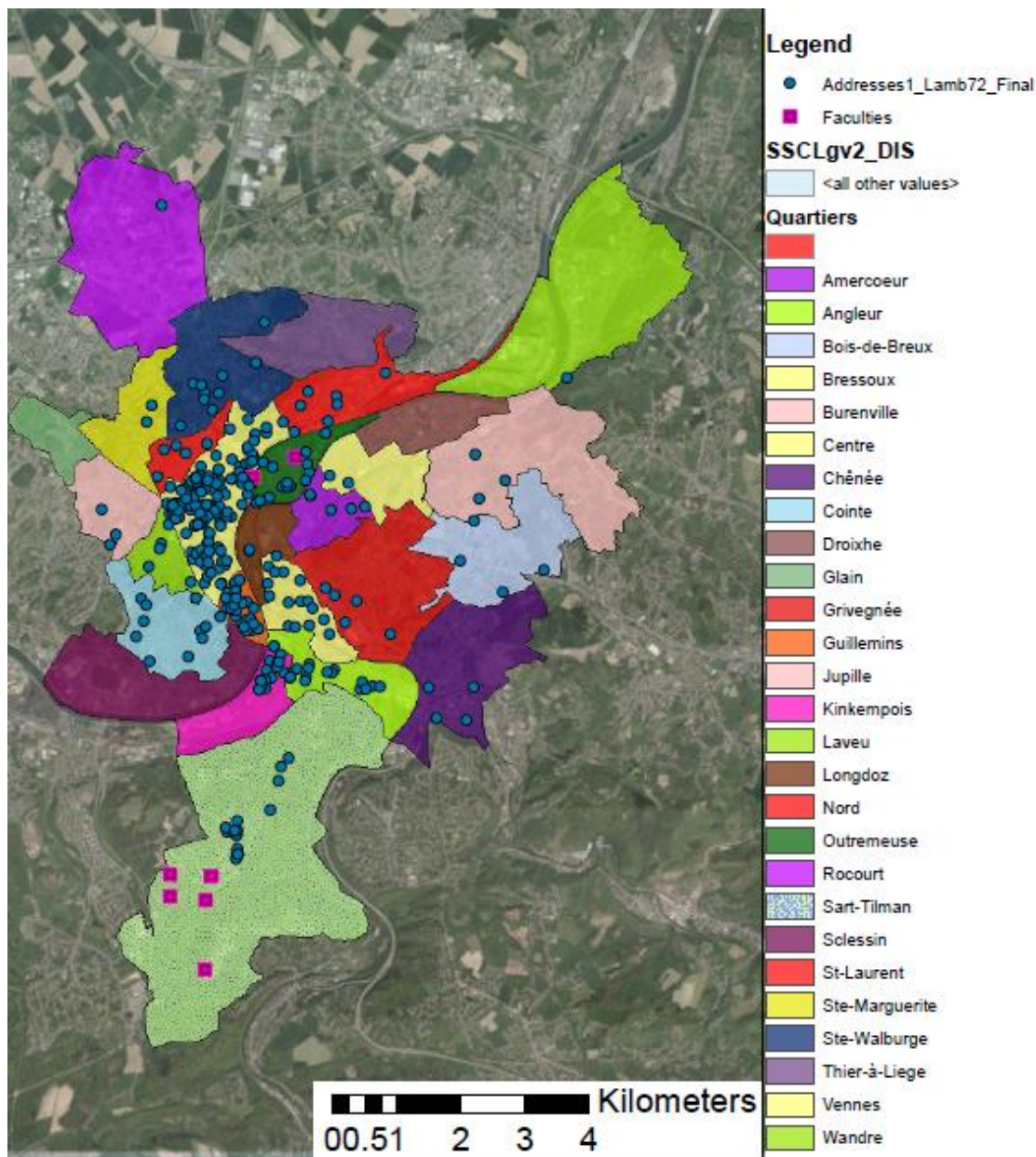


Figure 5.2.1 Data 1 (505 respondents) and faculties geocoding results

In round blue colour, are points representing the students' addresses in the Lambert 72 coordinate system (Addresses1_Lamb72_Final), and in square pink colour are points representing the faculties' addresses in Liege for the first data.

Scale: 1/50,000

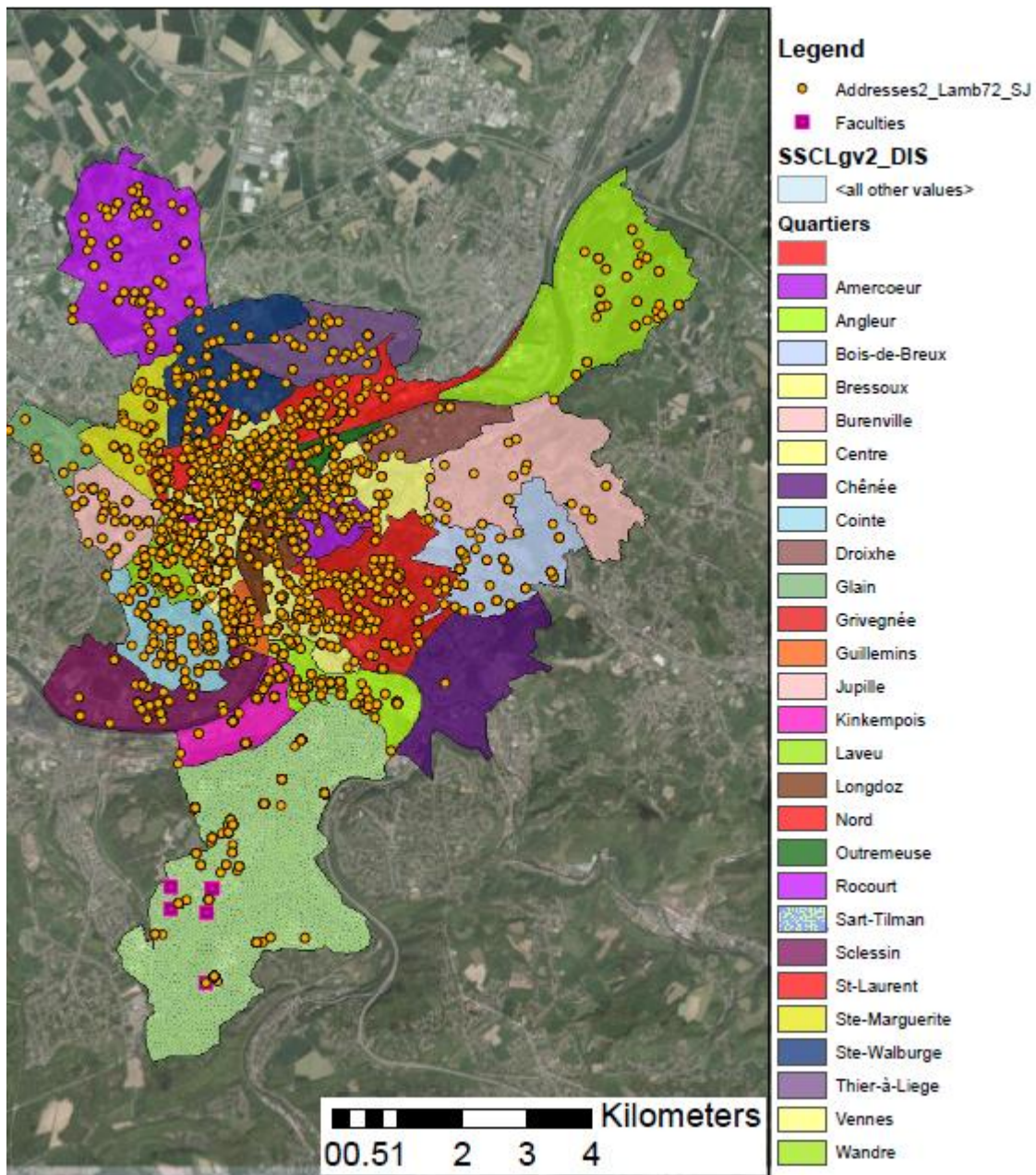


Figure 5.2.2 Data 2 (7152 respondents) and faculties geocoding results

In round electron gold colour are points representing the students' addresses in the Lambert 72 coordinate system (Addresses2_Lamb72_SJ), and in square pink colour are points representing the faculties' addresses in Liege for the second data.

5.3 MAPPING RESULTS OF THE CARPOOL SYSTEM WITH THE FIRST DATA

In this part, all treatments are done only for the data 1 (first data), the second data are only used for simulations. The mapping of the CS is done in five steps: first the importing and representation of the formed groups, then calculate groups' lines and groups' polygons (bounding boxes) which is used to calculate groups' centroids and lastly calculating and representing the shortest paths from every group's centroid to the faculty where each group has to go.

5.3.1. Formed Groups

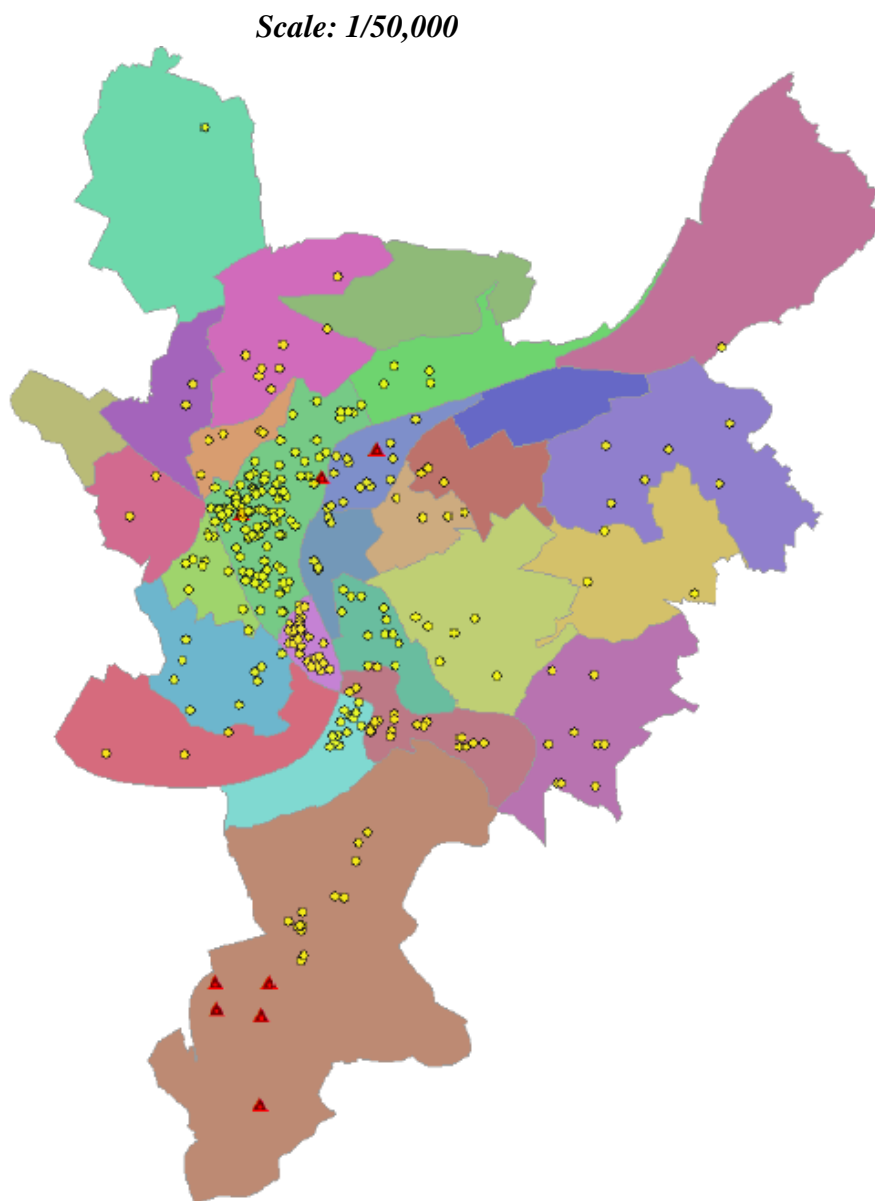


Figure 5.3.1.1 the representation of the formed groups (origins) and the faculties (destination).

The Matlab programming gave 69 groups, which are for only the 324 respondents among the sample of 505 respondents.

Scale: 1/50,000

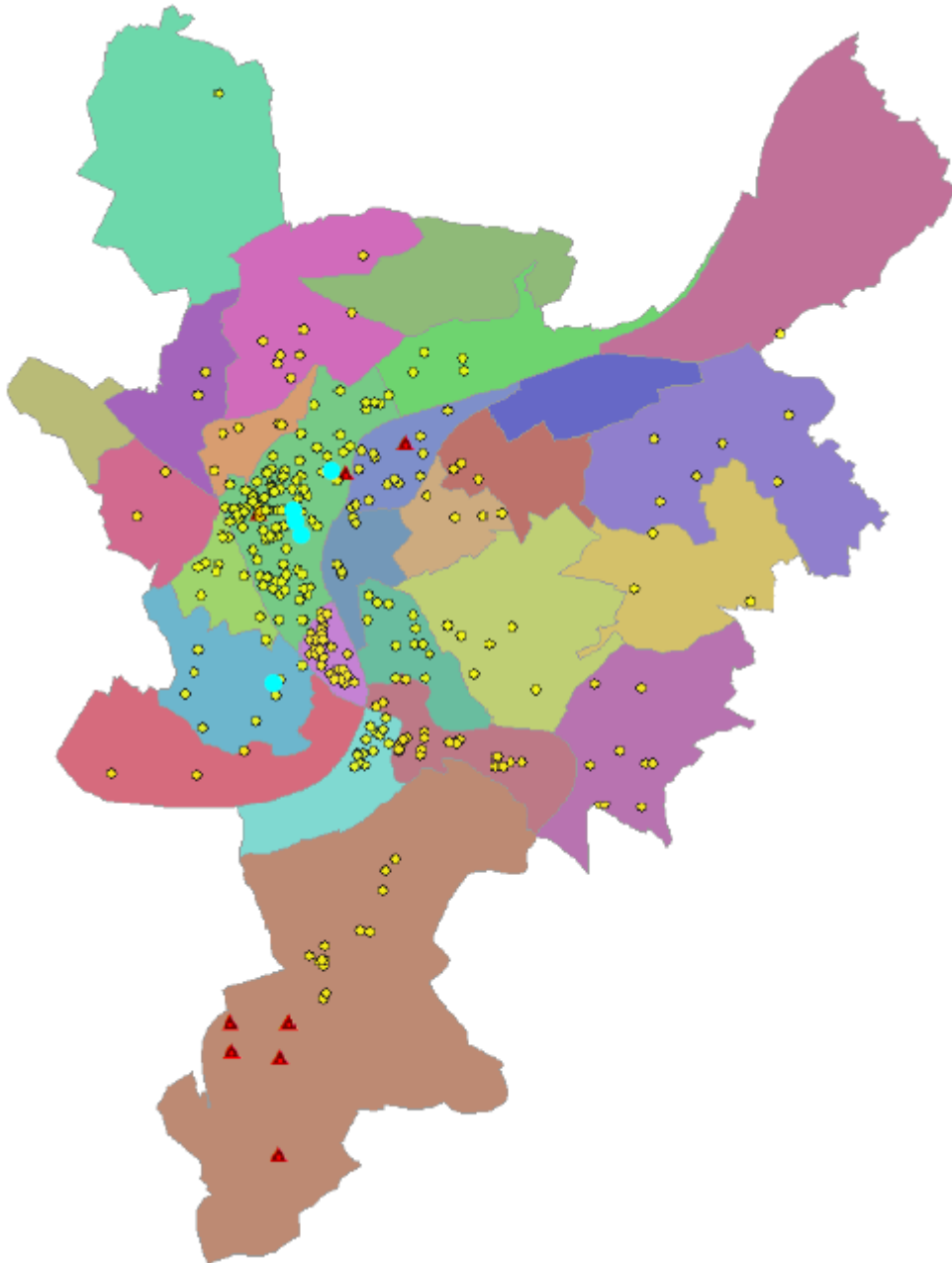


Figure 5.3.1.2 Example of the formed group number 2 of 5 students, in visible big blue dots.

It is seen from the figure above and the table below that the matlab programming was successful, because after choosing the first person who must have a car and which is the reference person, it chooses the next nearest persons to form the group either in the same or the neighbouring quarter and that are going to the same faculty.

FID	Id	Quartier	Lat	Lng	Faculty	Quarter	Car	Group *	x_lamb	y_lamb
3	2936124413	St-Laurent	50.641206	5.556001	1	22	1	1	233975.137	148513
4	2936166709	Ste-Walburge	50.656934	5.578197	1	25	2	1	235516.391	150287.595
0	2935916182	Centre	50.636981	5.568503	1	6	1	2	234866.891	148057.314
1	2936069124	Centre	50.640923	5.574711	1	6	1	2	235298.862	148502.83
5	2936221325	Centre	50.635877	5.568894	1	6	1	2	234896.59	147934.942
6	2936624610	Cointe	50.619512	5.56489	1	8	2	2	234642.66	146110.28
8	2938038622	Centre	50.634471	5.56975	1	6	1	2	234959.666	147779.646
2	2936096266	Angleur	50.598276	5.581684	1	2	1	3	235869.572	143767.723
7	2937174561	Guillemins	50.619476	5.57623	1	12	2	3	235445.137	146119.239
9	2938439534	Centre	50.63027	5.564144	1	6	1	3	234570.593	147305.938
10	2939244170	Guillemins	50.620523	5.57394	1	12	2	3	235281.234	146233.063
11	2939994377	Guillemins	50.619683	5.57771	1	12	2	3	235549.454	146143.955
12	2935672255	Angleur	50.613695	5.594319	2	2	2	4	236735.66	145497.363

◀ ◀ 1 ▶ ▶ (0 out of 324 Selected)

Table 5.3.1.1 Example of the output of the formed groups table.

In this table, there are the students' IDs, their quarters, their address angular coordinates, their faculties, the number of each quarter, the car availability, each one's group and the address coordinates in Lambert 72 coordinate system. The column 8 in this table shows the car availability. It means that the number 2 represents that the person has a car and the number 1 represents the persons who do not have a car. It can be that in the same group more than one person have a car because of the type of the data we have.

5.3.2. Groups' Lines

This process is done in order to convert the groups' points into lines so that it will help in the formation of the next step which is the polygon envelop.

Scale: 1/50,000

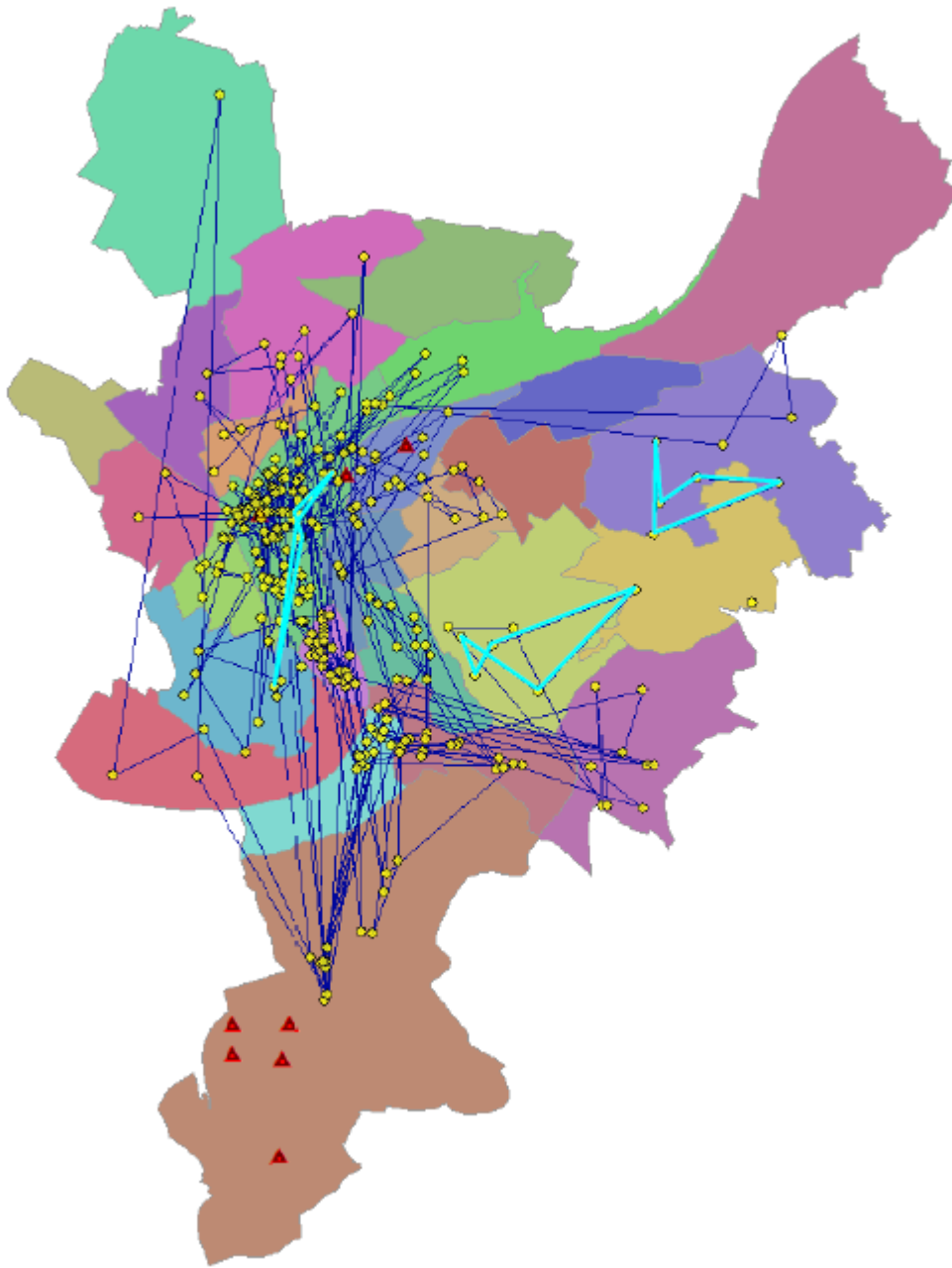


Figure 5.3.2.1 Example of the formed groups' lines with example for the 2nd, 20th and 26th group.

In green colour: at the left it is the group number 2, in the middle the group number 26 and at the right it is the group number 20.

5.3.3. Groups' Polygons, bounding box

It creates the bounding box, in which it is represented the points of every formed group.

Scale: 1/50,000

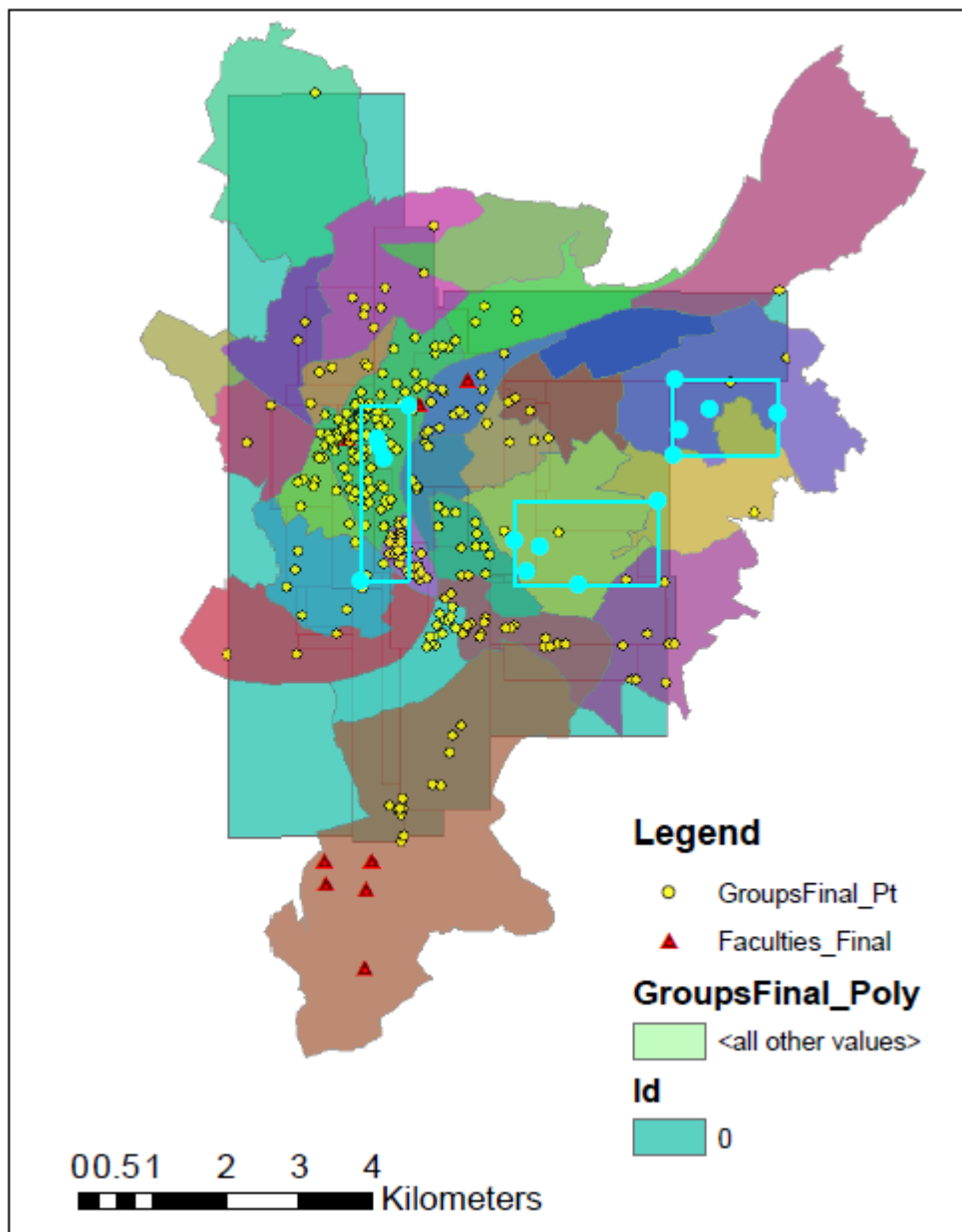


Figure 5.3.3.1 Groups bounding boxes with examples (in green) for the groups 2, 20 and 26.

Starting from the left to the right, group 2, 26 and 20. It is seen that the bounding box is the envelop that cover the formed groups as seen in these three examples of the formed groups.

5.3.4. Groups' Centroids

Scale: 1/50,000

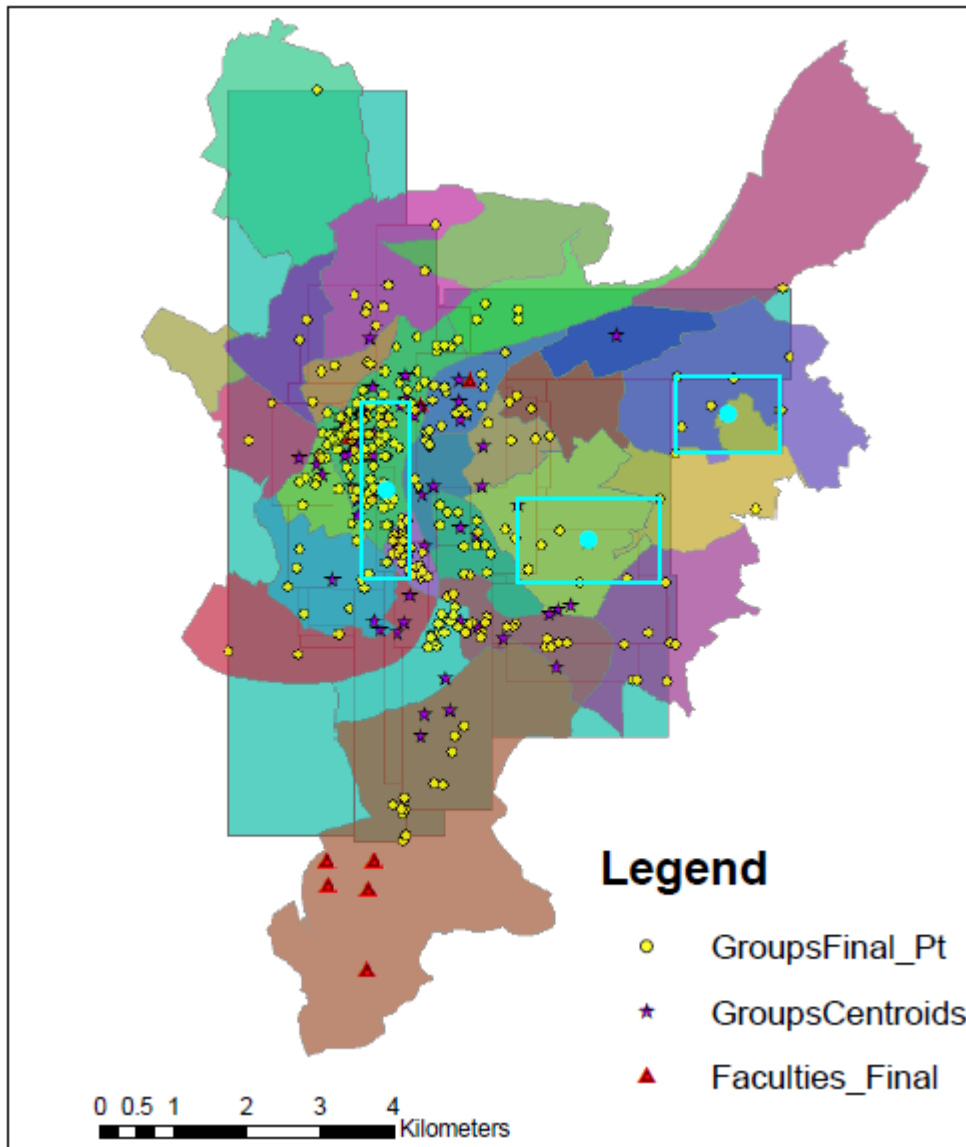


Figure 5.3.4.1 Representation of the calculated groups' centroids with the example of the groups 2nd, 26th and 20th respectively

The calculated centroids are exactly in the centre position of the formed bounding box of every formed group.

5.3.5. Shortest Paths

Scale: 1/50,000

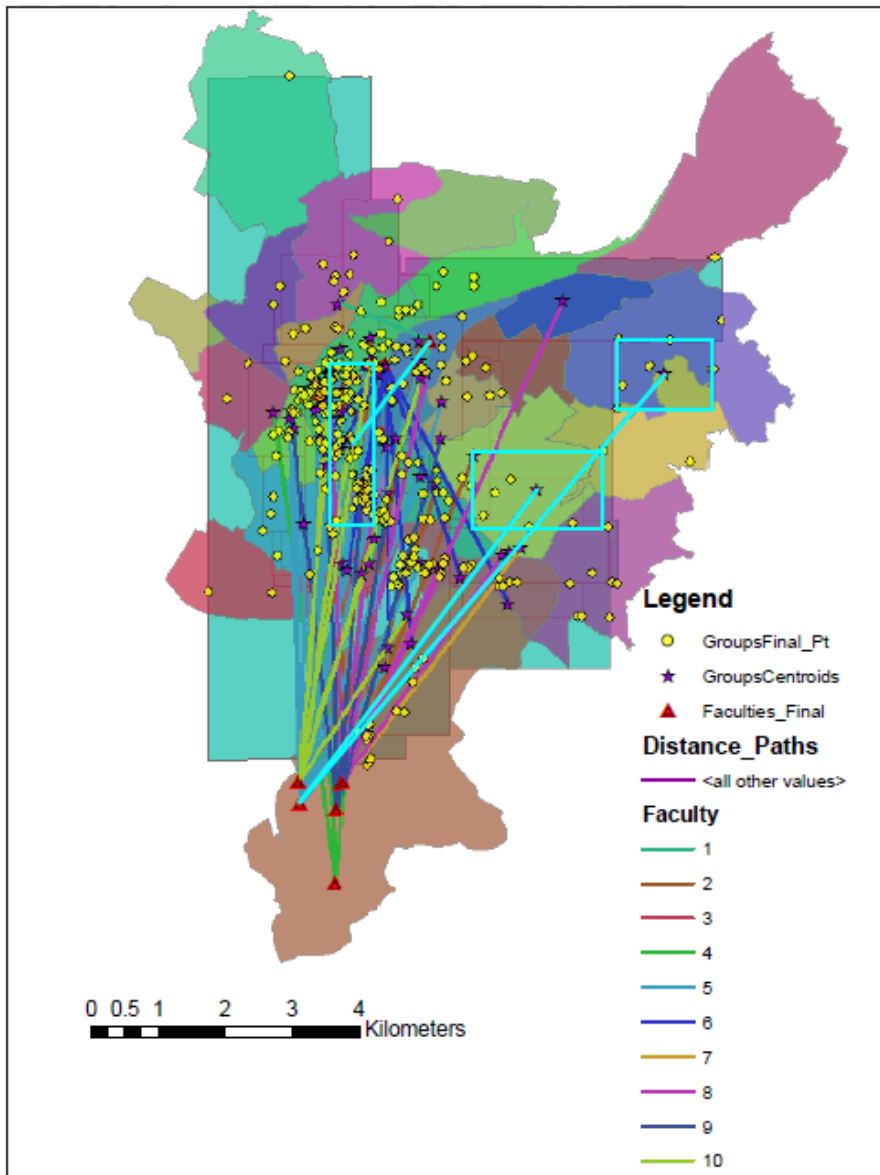


Figure 5.3.5.1 Representation of the distances between every centroid to the faculty where the students from every centroid are going to.

For example here in the figure, for the group 2 the students are coming from the calculated centroid to the faculty 1 (faculty of architecture). For the group 20 and 26, they are coming from their respective calculated centroids to the faculty 5 (faculty of médecine vétérinaire). The smallest distance is of from the centroid of group 10 to the faculty 3 (HEC – Ecole de gestion): **108** meters.

The longest distance is of from the centroid of group 20 to the faculty 5 (Médecine Vétérinaire): **8378** meters.

FID	Shape *	Group	x_centro	y_centro	x_fac	y_fac	Faculty	Distance
0	Polyline	1	234745.764	149400.297	236125.041	148836.556	1	1490.037
1	Polyline	2	234970.761	147306.555	236125.041	148836.556	1	1916.576
2	Polyline	3	235220.082	145536.83	236125.041	148836.556	1	3421.57
3	Polyline	4	236771.403	147144.67	234816.187	142302.099	2	5222.391
4	Polyline	5	235951.923	148832.405	234816.187	142302.099	2	6628.333
5	Polyline	6	235248.46	148891.546	234816.187	142302.099	2	6603.611
6	Polyline	7	236213.289	146735.108	234816.187	142302.099	2	4647.953
7	Polyline	8	234589.358	147190.885	234816.187	142302.099	2	4894.045
8	Polyline	9	234802.907	145560.409	234816.187	142302.099	2	3258.337

Table 5.3.5.1 Distances between centroids and faculties

Scale: 1/50,000

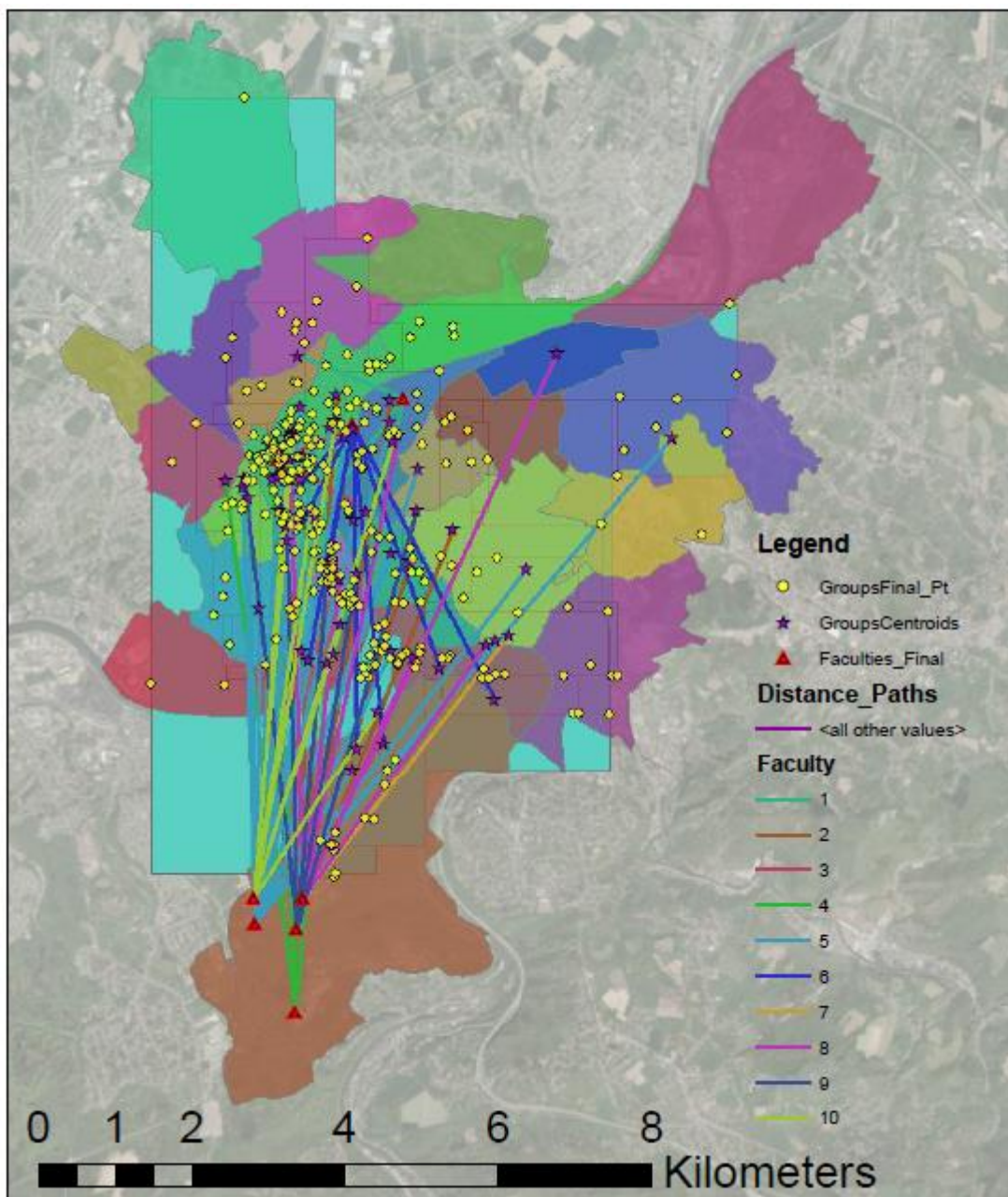


Figure 5.3.5.2 Results mapping of Euclidian distances.

5.3.6. Shortest paths on Liege road network

The shortest (least cost) path is also calculated using ArcGIS. The process consist of building a road between the calculated group's centroid to the group's faculty. Having the Liege road network shapefile, we have to create the network dataset in ArcCatalog: right click on the road shapefile and then create the new network dataset. The network dataset created is called "ReseauRoutierLiege_ND.nd".

Back in ArcMap, we have to add the network dataset. From customize tool and extension, we activated and enabled the network analyst that we will use for the calculation of the shortest paths.

To get the shortest route with the network analyst tool, we selected the new route tool. With that, choose the create network location tool and then choose the origin (point 1) which is the group centroid and the destination (point 2) which is the corresponding group's faculty.

The figure below show the example of the six shortest paths of the groups' centroids number 2, 20, 26, 4, 16 and 60. The lengths are given in the attribute table.

In the illustrated example:

- Route_1: it is the shortest path between the group's centroid number 2 to the faculty Id 1 (Architecture)
- Route_2: it is the shortest path between the group's centroid number 20 to the faculty Id 5 (Médecine Vétérinaire)
- Route_3: it is the shortest path between the group's centroid number 26 to the faculty Id 5 (Médecine Vétérinaire)
- Route_4: it is the shortest path between the group's centroid number 4 to the faculty Id 2 (Droit - Science politique - Ecole Criminologie)
- Route_5: it is the shortest path between the group's centroid number 16 to the faculty Id 4 (Médecine)
- Route_6: it is the shortest path between the group's centroid number 60 to the faculty Id 9 (Sciences)

Scale: 1/50,000

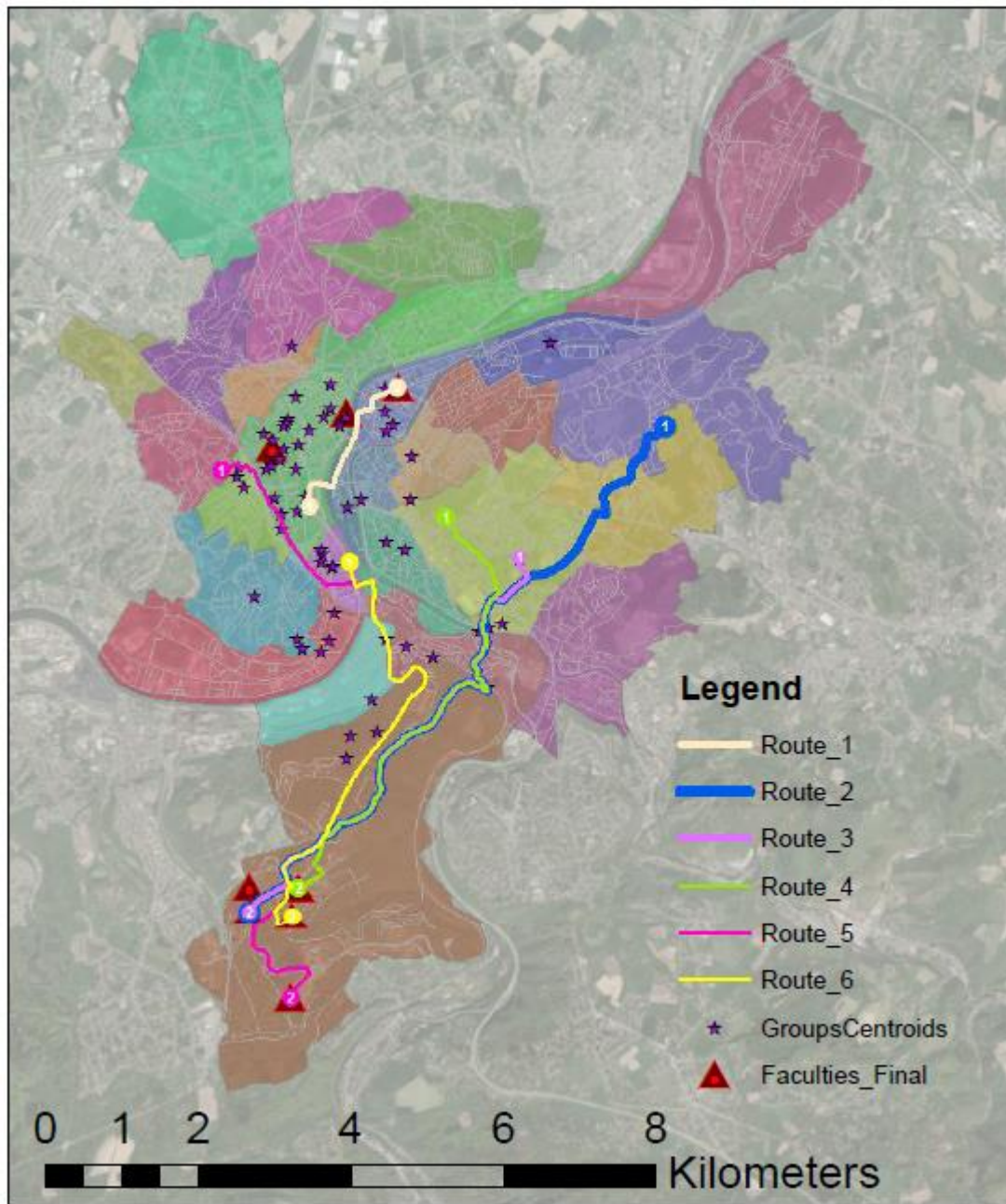


Figure 5.3.6.1 shortest paths examples.

ObjectID	Name	Group's centroid	Faculty	FirstStopID	LastStopID	StopCount	Total_Length on Road Network (meters)	Euclidian Distance (meters)
1	Boulevard	2	1	1	2	2	2348	1917
2	Rue des	20	5	1	2	2	9952	8378
3	Avenue	26	5	1	2	2	7212	5849
4	Avenue	4	2	1	2	2	7060	5222
5	Avenue	16	4	1	2	2	10850	7007
6	Rue des	60	9	1	2	2	6816	4727

Table 5.3.6.1 shortest paths and Euclidean distances between centroids and faculties.

In the example in the table above, the software calculations gave the total length on the road network in meters that is greater compared to the Euclidean distance.

5.4 LOGISTIC REGRESSION RESULTS

Several demographic and special characteristics were tested for significant associations with carpl_dr_pas (Carpooling as driver or passenger).

As the first step in constructing an appropriate model, we identified the significant characteristics and put them all into the model at once. The variable names are described by the comments (*/* comments*/*).

/ Logistic regression model - Sart tilman carpool - Antoinette Marie Reine Nishimwe Thesis */*

proc logistic data=car.stilman;

where carpl_dr_pas in (0,1);

class sexmf (ref='1') satmmode_car (ref='1') satmmode_bus (ref='1') satmmode_train (ref='1') r_bus (ref='1') r_train (ref='1') r_bike (ref='1') r_foot (ref='1') mtransport_car (ref='1') car_own (ref='1') car_stilman (ref='1') / **param**=ref;

model carpl_dr_pas (event='1') =

sexmf */* Gender */*

age */* Age */*

satmmode_car */* Satisfied with the commonly transport mode used-car as main mode */*

satmmode_bus */* Satisfied with the commonly transport mode used-bus as main mode */*

satmmode_train */* Satisfied with the commonly transport mode used-train as main mode */*

r_bus */* Ready to use more the bus */*

r_train */* Ready to use more the train */*

r_bike */* Ready to use more the bike */*

r_foot */* Ready to use more the foot */*

mtransport_car */* Have you change the main transport mode to car*

**/*


```

car_own /* car ownership */
car_stilman /* Do you use your car at sart tilman site */
mbudget /* Transport monthly budget */
lfar_stilman /* Live far from sart-tilman */
lisoplace /* Live in isolated place */
lsafety /* Lack of safety */
ndemand /* No demand */
noffer /* No offer */
vcompl /* Very complicated */
/ selection=stepwise slentry=0.05 slstay=0.05 details;

```

```
run;
```

In the WHERE statement, the standard analytic dataset was subset to include only those students for whom carpl_dr_pas response is known (defined as either 0 or 1). PROC LOGISTIC automatically excludes observations for which the outcome variable or independent variables in the model are missing.

The CLASS statement allows for parameterization of categorical variables via the param=ref option. One can specify the referent group (ref=' ') in parentheses after each variable. It should be noted that the value of the referent group must be placed in quotation marks regardless whether the variable is numeric or character. The variable for gender (sexmf) in the dataset was originally coded as 1 for females and 0 for males. Since the parentheses following sexmf in the CLASS statement specify that the referent group has a value of 1 (female), the logistic regression will model the odds for carpl_dr_pas associated with being male relative to being female. (The variable denoting Satisfied with the commonly transport mode used-car as main mode (satmmode_car) is also included in the class statement because it is a three-level variable, coded as 2 for uncertain, 1 for yes and 0 for no. Since the value of 1 is specified as the referent group in the class statement, PROC LOGISTIC will generate two coefficients for this term: one coefficient for uncertain relative to yes, and another for no relative to yes) etc.

In the MODEL statement, the outcome variable (carpl_dr_pas) is specified on the left side of the equals sign. By default, SAS uses the lesser alphanumeric value of the outcome variable to denote an event occurring. In this analysis, we are interested in modelling when

carpl_dr_pas occurs (rather than when carpl_dr_pas does not occur); however, based on the way the variable is coded, SAS will model carpl_dr_pas=0 as the event. In order to reverse the directionality of the outcome variable, we can specify in parentheses the value that SAS should use as the event (event='1'). By using this syntax, PROC LOGISTIC now models the event as carpl_dr_pas=1. On the right side of the equals sign are the independent variables. All of the independent variables in this model are coded as 1 for yes and 0 for no (2 for uncertain) with the exception of the age and mbudget which are continuous variables.

THE OUTPUT

The first elements generated by the above code is the response profile. The response profile describes how the outcome variable was parameterized. 98 students in our model did not want carpooling while 268 students did. The output then confirms that carpl_dr_pas=1 was modelled as the event (since we specified event='1' in the MODEL statement) (Figure 5.3.1).

Number of Observations Read	366
Number of Observations Used	366

Response Profile		
Ordered Value	carpl_dr_pas	Total Frequency
1	0	98
2	1	268

Probability modeled is carpl_dr_pas='1'.

Table 5.4.1 Response Profile

Next is the class level information that shows how the variables in the CLASS statement were parameterized (Figure 5.3.2).

Class Level Information			
Class	Value	Design Variables	
sexmf	0	1	
	1	0	
satmmode_car	0	1	0
	1	0	0
	2	0	1
satmmode_bus	0	1	0
	1	0	0
	2	0	1
satmmode_train	0	1	0
	1	0	0
	2	0	1
r_bus	0	1	0
	1	0	0
	2	0	1
r_train	0	1	0
	1	0	0
	2	0	1
r_bike	0	1	0
	1	0	0
	2	0	1
r_foot	0	1	0
	1	0	0
	2	0	1
mtransport_car	0	1	0
	1	0	0
	2	0	1
car_own	0	1	0
	1	0	0
	2	0	1
car_stilman	0	1	0
	1	0	0
	2	0	1

Table 5.4.2 Class level information

The following section, analysis of maximum likelihood estimates, where the regression coefficients are estimated.

Analysis of Maximum Likelihood Estimates						
Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-5.5034	1.2274	20.1035	<.0001
satmmode_car	0	1	-0.9004	0.5655	2.5355	0.1113
satmmode_car	2	1	-1.7047	0.5395	9.9833	0.0016
satmmode_bus	0	1	1.1146	0.4726	5.5613	0.0184
satmmode_bus	2	1	-0.6247	0.5364	1.3562	0.2442
lsafety		1	1.7201	0.5055	11.5786	0.0007
vcompl		1	2.5612	0.3139	66.5770	<.0001

Table 5.4.3 Analysis of Maximum Likelihood Estimates

The first parameter, the intercept, represents the predicted value of the logit when all other covariates in the model are equal to 0. Between the columns Parameter and DF (Degree of Freedom), exists an untitled column where variables that appeared in the CLASS statement are indicated. The value in this column denotes the non-referent group. For example satmmode_car, appears twice in the output since it was a three-level variable and the referent group was specified as having a value of 1, PROC LOGISTIC indicates a 0 and 2 to denote the estimates for the uncertain and no values, respectively, relative to the yes value.

The values under the **estimate** column represent the regression coefficients. A value of 0 indicates no association, a positive value indicates increased risk, and a negative value indicates decreased risk. The next column contains the standard errors of the coefficients. The Wald chi-square is equivalent to $(\text{Estimate} / \text{Std Error})^2$. The final column indicates the p-values.

The odds ratios are calculated from exponentiating the coefficients.

Odds Ratio Estimates			
Effect	Point Estimate	95% Wald Confidence Limits	
satmmode_car 0 vs 1	0.439	0.146	1.327
satmmode_car 2 vs 1	0.210	0.072	0.610
satmmode_bus 0 vs 1	2.712	1.058	6.950
satmmode_bus 2 vs 1	0.563	0.196	1.620
lfar_stilman	0.541	0.260	1.124
lsafety	5.439	1.989	14.876
vcompl	14.870	7.724	28.629

Table 5.4.4 the Odds Ratio Estimates

MAIN EFFECTS

Different significance levels for entry and exit criteria were specified. In our model, we chose a stepwise selection method, with an entry and exit criteria of 0.05. We specified the method of selection (selection=), and the p-value criteria for entry into (slentry=) and exit from (slstay=) the model.

At the very end of the output, the variable selection steps for the final model are summarized. The output summarizes the order in which the variables were added and removed and the corresponding p-values. For our model, a total of 5 variables, which are significant variables, were retained, and 1 were removed. All p-values ($Pr > ChiSq$) are less than 0.05 as specified by the entry and exit criteria.

Note: No (additional) effects met the 0.05 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Effect		DF	Number In	Score Chi-Square	Wald Chi-Square	Pr > ChiSq	Variable Label
	Entered	Removed						
1	vcompl		1	1	93.5165		<.0001	vcompl
2	lfar_stilman		1	2	10.4426		0.0012	lfar-stilman
3	lsafety		1	3	9.5172		0.0020	lsafety
4	satmmode_bus		2	4	11.7160		0.0029	satmmode-bus
5	satmmode_car		2	5	10.1537		0.0062	satmmode-car
6		lfar_stilman	1	4		2.7101	0.0997	lfar-stilman

Table 5.4.5 Summary of stepwise selection

5.4.1 Motivational factors

Only four factors appeared to have a significant influence (at the 5% level of significance) on carpool behaviour. The non – significant factors were removed from the final model. Only two variables (lsafety and vcompl) were found to impact positively carpooling. For example, the safety (lsafety) during carpooling increases the odds to carpool by 72% with confidant interval of 95%. This situation can be justified be the fear people have to share rides with strangers. Then the guarantee of safety during commuting times increases the likelihood to carpooling.

5.4.2 Discouraging factors

Only two variables (satmmode car and satmmode bus) have a negative impact on carpooling. For example, the commuters being satisfied with the car as main transport mode, this situation decreases the odds to carpool by 90%. Obviously, when someone is satisfied with the use of the car as commuting mode, it is difficult to convince him to shift to another transport mode.

5.5 CHAPTER SUMMARY

Chapter 5 has presented the findings generated from the Matlab programming process, geocoding, mapping with ArcGIS and a LRA with SAS. The following three research objectives were addressed in this research: (1) carpool groups' formation; (2) calculation of the shortest path; (3) mapping the carpool system; and (4) analysing factors that appear to be associate with carpool formation and use.

The results from the Matlab process suggested that many potential carpoolers are located in the centre of Liege. The LRA brought focus to several factors associated with carpool formation and use, these included the following significant factors: safety, satisfied with car and bus as transport mode, and CS is very complicated

The implication and recommendations of the results for TDM, and directions for future research are discussed in the next chapter.

CHAPTER 6. CONCLUSION

The present alarming climate change issue has become a concern of every researcher. The climate change is due to global warming which is resulted from the higher quantity of some gases in the atmosphere such as CO₂. The indicators of the climate change are many and have been amplified by the some factors like the increasing level of urbanisation, some energy source production such as industries, deforestation, pollutant vehicles, airplanes, household activities, etc.

The higher difference of temperatures, and devastating floods in some regions are the main consequences of the climate change. Many initiatives and researches are under study to stop this situation. The TDM proposes some alternative transport modes such as carpooling, cycling and walking as answers to the climate change issue. The aim of proposing the carpool is to improve the daily commute on one hand, and reduce the CO₂ emission on the other hand. Carpooling reduces the number of vehicles on the roads, therefore the emission of CO₂ reduces as well. The advantages of carpooling are many. Among them, the most important are: reduces CO₂ emission by cars, solves roads congestion, reduces commuting time, saves travel costs, and improves comfort and friendship of riders while commuting.

Carpooling is not a new concept in TDM policy. The literature on history of carpooling shows that carpooling had started during the World War II and had extended during the fuel crisis (section 1.2.4). The current environment, economic, and transportation issues mentioned in Chapter 1, provides a need of not only develop and improve carpool formation and use during the duration of the issues, but also permanently diminish the gap between the SOV use and alternative modes of transportation.

This research has examined the variables that influence carpool formation and use. The research included setting up some constraints in Matlab leading to carpool groups' formation and calculation of the shortest path using algorithms. The above output (carpool groups and the shortest path), both with the destinations (faculties) were mapped in ArcGIS for the visualisation of the results. The final step was the logistic regression analysis with SAS, constructed to identify the more significant variables related to carpool formation and use. Furthermore, the research explored the use of ICT and its impact on carpooling.

This concluding chapter summarizes the main findings of this research. Next, it provides recommendations on how to improve the CS especially for students' commutes. This is followed by a brief description of the contributions this research has made in transportation

field. Finally, the chapter concludes with a description of how this research may be expanded in the future.

6.1 SUMMARY OF KEY FINDINGS

This section presents the main findings of the research as detailed in the following steps to answer the research which was concerned of finding algorithms to develop the CS:

Filtration

The filtration process consist of excluding respondents who have omitted some important information for carpool groups' formation (postal address and faculties), and for LRA (demographic, and commuting mode). For the groups' formation, the filtration process was the same for the data1 and data2. The LRA was applied on the data1 only.

After filtration, 505 respondents remain for data1 and 7152 respondents for data2. The lack of useful information about the majority of respondents was a big challenge during the research. The original data for data1 contained 1433 respondents, and after filtration the number of respondents was 505 respondents. Fortunately, to get the sample of 505 respondents, some arrangements were done, where for example the missed respondent's age was added by taking the average value of ages of all respondents. The same arrangement was done on the missing value about the monthly transport budget of the respondent. Otherwise, the remaining sample should have been very small and non-representative of the original sample.

Geocoding process

This process is done both for respondents' data1 and data2, and for the faculties. The raw data needed for geocoding are: address, postal code, city and country. The results are represented in ArcMap as a shapefile, where addresses are represented as round blue colour points for students' addresses for data1, round electron gold colour for students' addresses for data2 and square pink colour for the faculties (the destinations (faculties) are the same for data1 and data2).

Mapping the carpool system

The mapping of the CS is done in five steps: (1) import and represent the formed groups, (2) calculate groups' centroids, (3) calculate groups' lines, (4) calculate groups' polygons (bounding boxes), (5) calculation of Euclidian distance and lastly (6) calculate and represent the shortest paths from every group's centroid to their faculties. For the data1, 69 groups were formed with a maximum of 5 persons and a minimum of 1 person. 27 quarters were identified as the origins and 10 faculties as the destination. Next, groups' centroids, groups' lines, and groups' polygons were calculated and mapped (figure 5.3.4.1). For the data2, since the information about car ownership was not given, the percentage of students who have a car were calculated from data1, and was found to be 20%. This percentage (20%) was then assigned to the data2 for doing simulations. The first simulation considered that 20% of students has a car, 40% for the second simulation, 60% for the third simulation, and finally 80% for the fourth simulation.

Logistic regression analysis

The final step of this research was the LRA. 20 carpooling predictor variables were analysed, where only 4 (satmmode car, satmmode bus, Isafety, vcompl) were found to be significant. The outcome variable carpl-dr-pas=1 (carpooling as driver or passenger) was modelled. The 2 variables (Isafety, vcompl) have a positive effect to the carpool formation and use. The Isafety and vcompl variables increase the likelihood to carpooling, whereas the remaining 2 other variables (satmmode car, satmmode bus) decrease the likelihood to carpooling. The carpool designed model was successful since the coefficient c was greater than 0.5 ($c > 0.5$) for all the 6 step of the LRA.

6.2 CONTRIBUTIONS OF THE THESIS

The contributions of this research are significant in TDM and behavioural science contexts. The research analysed conveniently the questionnaire and the shapefiles from the faculty of science and applied sciences of the ULg, where the need for a sustainable carpool system for students commuting to ST was identified. This thesis represented a unique contribution, as the first study on carpool formation and use, to the mobility amelioration of ULg students

commuting to ST for their studies. Furthermore, analysing factors with the aim to understand their impact on carpooling was also a substantial contribution to the carpooling literature.

Every year, the number of admitted students at ULg increases. Some initiatives were taken to reduce this rapid growth especially in faculties of medicine and veterinary medicine (Torres et al., 2011). Facing this situation, it is expected a corresponding rise in transport demand. This research proposes the carpool system as an answer to the current and expected mobility issues that students are facing or may fronting in the coming days. More broadly, the findings may be used by the ULg, Government, or any TDM oriented organization to enhance their understanding of carpool formation process and major factors that impact its formation and use.

The challenges encountered while filtering the data from the questionnaire and the shapefiles, will provide the faculty of science and applied Sciences of the ULg with information on how to improve their survey. Moreover, this research gives an opportunity to the ULg to better promote carpooling among the students' community.

6.3 RECOMMENDATIONS

The findings of this research provide insight into the process of carpool formation and use. The recommendations of this research are addressed to the four main actors of the carpool organisation at ST. The ULg has to take its responsibilities in application and promotion of alternative modes such as carpooling, cycling and working. Because carpool always need other modes of TDM policy, cycling and working related infrastructures have to be enhanced at the ST site. As shown in the literature, students are attracted by initiatives started by the fellow colleagues or by their institution. The ULg has to develop a carpool platform that involves students to stimulate a huge number to carpooling. Some strategies like free parking for carpoolers, transport loan for students who carpooling, carpool promotion campaigns and spots have to be developed to ensure effectiveness of the CS.

The Government has an important role to play in promoting the carpool formation and use. Because carpooling does not require additional infrastructures, it is the cheapest policy of the TDM. Therefore the Government does not need many investments to develop this system. The majority of students do not know the TDM policies promoted by the Government with their related advantages. This lack of information makes students not to participate massively

to carpooling. The Government has to promote carpool for students commuting to ST by providing more information on carpooling to change commuting behaviour of students. Thus, this will be the only way of reducing roads congestion and CO₂ emission from cars.

The TDM oriented organizations have to take the opportunity presented by the lack of a carpool system at ST. This should expand their business and increase the organization income since ST has a larger students' community.

Finally, students must take conscience of the current climate change by changing their commuting behaviour. They must be interested by majors undertaken by the Government to protect the environment, since they are the most informed community about vulnerabilities of our environment. The sense of responsibility of students to protect our Planet, must make them shifting form current transport modes to less pollutant modes such as carpooling.

6.4 PERSPECTIVE

This research has also given rise to some potentially interesting and policy relevant directions for future research. Examining carpool formation using the software such as Matlab which is based on algorithms for programming and modelling, mapping with ArcGIS and analysing predictor variables could better explain the decision making process for carpool formation and use. The Matlab programming could be helpful in the carpool formation process context. Furthermore, the logistic regression used in this research contributes highly to understand the variables that have to be taken into account when predicting the likelihood to carpooling. While this study has examined demographic, commute modes, costs and motivations, questions remain about how subjective norms, like social status and peoples' attitudes, potentially influence the carpool decision. Moreover, little is known about the barriers that commuters could face when attempting to generate carpools. With respect to the modelling work, it could be useful to improve the study of predictor variables within the logistic regression model. For example, the socio-demographic and spatial factors would be of more value with the inclusion of data on household composition (partner, children), educational attainment, employment, parking, etc. This task will require collaborative development of future versions of the surveys issued by students commuting to ST. Additional steps should also be taken to extend the analysis to include both the students' home location (origins) and trip-ends (faculties) of the commute. The disclosure of data on complete trips will facilitate

deeper analysis of the relationship between economic and transport geography, workplace TDM policies, and carpool formation. The distance calculated from in ArcGIS, is a Euclidian distance: distance from the groups' centroids to the faculties. Then we calculated the shortest paths from the groups' centroids using the network analyst tool. In the future research, the least cost path or shortest path can be calculated using the OD matrix (Origin-Destination matrix) for example by using some heuristics algorithms or travel salesman problem for distance optimization.

Lastly, and while one of the main contributions of this work has centred on understanding the role of specific algorithms in carpool formation, gaining more insight into the time it takes for a user to create a carpool and learning more about the influence of demographic, costs and motivations factors on the carpool formation process could prove to be useful in identifying the sustainable carpool situation. This type of research may directly influence initiatives taken to generate more carpools.

In conclusion, this thesis has provided some further insight into the carpool process. It is evident that there is an urgency to act in developing sustainable alternatives to current SOV commuting reality at ST such as carpooling.

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APPENDICES

DATA 1 MATLAB PROGRAMMING

```
clc
clear all
format long G
```

```
% Read DATA, we removed the first line (title)
```

```
[ndata, text, alldata] = xlsread('Enquete.xlsx','Treatments','A2:AG508');
[ndatav, textv, alldatav] = xlsread('Enquete.xlsx','NeighbourQs','A1:AA10');
[Coordinates, textc, alldatav] = xlsread('Enquete.xlsx','Treatments','G2:H508');
```

```
% ndata are quantitative data, text are qualitative data, alldata are ndata
% and text combined, ndatav, textv, alldatav are referring to the neighbor
% quarters of every quarter.
```

```
% Quarter Treatment
```

```
% Searching the unique quarters in column 4
[quartiersUniques, IA, IC] = unique(alldata(:,4));
```

```
% Calculating occurrence numbers of every quarter (number of persons leaving
% each quarter)
occurrencesQuartiers = hist(IC,length(quartiersUniques));
```

```
%Sum of results (verification)
checkSumQuartiers=sum(occurrencesQuartiers);
```

```
% Faculties treatment
```

```
[facultesUniques, IA2, IC2] = unique(alldata(:,13));
% in unique, the first number is the element of a matrix with non repeated
% elements, the second conected with the given matrix gives the ordered elements without
% repetition, whereas the last conected with the first gives the given matrix
```

```
occurrencesFacultes= hist(IC2,length(facultesUniques));
sum(occurrencesFacultes);
```

```
% Car treatment
```

```
[voituresUniques, IA3, IC3] = unique(ndata(:,25));

occurrencesVoitures = hist(IC3,length(voituresUniques));
```

```
sum(occurrencesVoitures);
```

```
%Group creation in the quarters at least 5 persons going to the same faculty
```

```
%Loop on all passengers
```

```
%initializing variables
```

```
N1 = length(ndata); %size of quantitative data  
N2 = length(quartiersUniques); %size of quarters  
N3 = length(facultesUniques); %size of faculties  
N4 = length(voituresUniques); %size of available vehicles  
M1 = zeros(N1,N2);  
M2 = zeros(N1,N3);  
M3 = zeros(N1,N4);
```

```
% Grouping IDs of people in the same quarters
```

```
for k=1:N1  
    for j=1:length(quartiersUniques)  
        tj = strcmp(quartiersUniques(j,1),alldata(k,4));  
        if tj==1  
            M1(k,j) = ndata(k,1);  
            Ma = sparse(M1); %output groups, show individuals according to their quarters  
            break  
        end  
    end  
end
```

```
% Grouping IDs of people in the same faculty
```

```
for k=1:N1  
    for j=1:length(facultesUniques)  
        tj = strcmp(facultesUniques(j,1),alldata(k,13));  
        if tj==1  
            M2(k,j) = ndata(k,1);  
            Mb = sparse(M2); %output groups  
            break  
        end  
    end  
end
```

```
% Grouping IDs of people having the vehicle
```

```
for k=1:N1  
    for j=1:length(voituresUniques)  
        tj = (voituresUniques(j,1)==ndata(k,25));  
        if tj==1  
            M3(k,j) = ndata(k,1);
```



```

for k=5:5:N
    m_Ind2 = [];
    WW = []; %sub individual group;
    for index=1:5
        if index==1
            m1=1;
            for m=1:N

                if ID(m,1)~=a&&ID(m,4)==2&&m1==1
                    IDD = [IDD;ID(m,:)];
                    WW = [WW;ID(m,:)];
                    index_m = m;
                    ID(index_m,1) = a;
                    m_Ind2 = [m_Ind2 m];
                    m1 = m1+1;
                end
            end

        else
            m2=1;
            m_Ind1 = []; Dist_p = [];

            for m=1:N
                if
                    IDD(1,1)~=0&&ID(m,1)~=a&&ID(m,3)==ID(index_m,3)&&ID(m,2)==ID(index_m,2)&&
                    m2==1
                        Dist_p = [Dist_p
                    Distance([Coordinates(index_m,2);Coordinates(index_m,1)],[Coordinates(m,2);Coordinates(
                    m,1)])];
                        m_Ind1 = [m_Ind1 m];
                    end
                end
            end
            if isempty(Dist_p)~=1&&m2==1

                [m_Dist,m_Ind2] = min(Dist_p); % Tag minimum distance for next choice group
member
                m = m_Ind1(m_Ind2);

                if Dist_p(m_Ind2)~=0
                    IDD = [IDD;ID(m,:)];
                    WW = [WW;ID(m,:)];
                    ID(m,1) = a;
                    m2=m2+1;
                    m_Ind2 = [m_Ind2 m];
                end
            end

            for q=2:10
                m_Ind1 = [];Dist_p = [];
                if ndatav(q,ID(index_m,3))~=0&&m2==1

```

```

        for m=1:N
            if
                IDD(1,1)~=0&&ID(m,1)~=a&&ID(m,2)==ID(index_m,2)&&ID(m,3)==ndatav(q,ID(index_
                    m,3))
                    Dist_p = [Dist_p
                        Distance([Coordinates(index_m,2);Coordinates(index_m,1)],[Coordinates(p,2);Coordinates(p
                            ,1)])];
                    m_Ind1 = [m_Ind1 m];
                end
            end
        end
        if isempty(Dist_p)~=1&&m2==1
            [m_Dist,m_Ind2] = min(Dist_p); % Tag minimum distance for next choice
group member
            m = m_Ind1(m_Ind2);
            if Dist_p(m_Ind2)~=0
                IDD = [IDD;ID(m,:)];
                WW = [WW;ID(m,:)];
                ID(m,1) = a;
                m_Ind2 = [m_Ind2 m];
                m2 = m2+1;
            end
        end
    end
end
end
end
end
if isempty(WW)~=1
    for kp=1:length(WW(:,1))
        Group.G(kp,1:4,kk) = WW(kp,:);
    end
end

if isempty(m_Ind2)~=1

    for kj=1:length(m_Ind2(1,:))
        Coordinates_C(kj,1) = Coordinates(m_Ind2(kj),2);
        Coordinates_C(kj,2) = Coordinates(m_Ind2(kj),1);
    end

    [x] = Search_Centroid(Coordinates_C);
    ID_CENT = [ID_CENT;x];
    clear Search_Centroid Coordinates_C
end
kk = kk+1;

end

mm = 0;
A = [];

```



```

for j=1:length(Group.G)
    jc = [j; j; j; j];
    A = [A; Group.G(:,j) jc];
end
tt = char({'ID' 'Faculty' 'Quarter' 'Car' 'Group'});
fid = fopen('Group.G.txt','wt');
for ii = 1:size(A,1)
    if ii==1
        fprintf(fid,'%8s %16s %10s %10s %10s\n','ID','Faculty','Quarter','Car','Group');
    end
    fprintf(fid,'%10d\t',A(ii,:));
    fprintf(fid,'\n');
end
fclose(fid);

% edit Group.G.txt

tt = char({'Long' 'Lat'});
fid = fopen('ID_CENT.txt','wt');
A = [ID_CENT];
for ii = 1:size(A,1)
    if ii==1
        fprintf(fid,'%10s %10s\n','Long','Lat');
    end
    fprintf(fid,'%10f\t',A(ii,:));
    fprintf(fid,'\n');
end
fclose(fid);

```

DATA 2 MATLAB PROGRAMMING

```
clc
clear all
format long G

tic
% Read DATA, we removed the first line (title)

[ndata, text, alldata] = xlsread('Data2Treats.xlsx','A2:F7153');
[ndatav, textv, alldatav] = xlsread('Enquete.xlsx','NeighbourQs','A1:AA10');
[Coordinates, textc, alldatac] = xlsread('Data2Treats.xlsx','C2:D7153');

% ndata are quantitative data, text are qualitative data, alldata are ndata
% and text combined, ndatav,textv,alldatav are referring to the neighbor
% quarters of every quarter.

% Quarter Treatment

% Searching the unique quarters in column 4

clear unique

[quartiersUniques, IA, IC] = unique(alldata(:,5));

% Calculating occurrence numbers of every quarter (number of persons leaving
% each quarter)

clear hist

occurencesQuartiers = hist(IC,length(quartiersUniques));

%Sum of results (verification)
clear sum

checkSumQuartiers=sum(occurencesQuartiers);

% Faculties treatment

clear unique

[facultesUniques, IA2, IC2 ] = unique(alldata(:,2));

% in unique, the first number is the element of a matrix with non repeated
% elements, the second conected with the given matrix gives the ordered elements without
% repetition, whereas the last conected with the first gives the given matrix
clear hist

occurencesFacultes= hist(IC2,length(facultesUniques));
```

```

sum(occurrencesFacultes);

clear sum

% Car treatment
Np = 4; % car percentage
XP = zeros(1,Np);
XG = [];
XP0 = 20.6; % initial percentage

for kp=1:Np

    XP(kp) = XP0*kp;
    N1 = length(ndata);%size of quantitative data

    N2V = floor(XP(kp)*N1/100);
    N2E = N1-N2V;
    % Generating cars
    VTI = [ones(N2V,1);zeros(N2E,1)];
    VT = VTI(randperm(N1)); % generating cars randomly
    NC = sum(VT); %total number of cars

    clear unique
    [voituresUniques, IA3, IC3 ] = unique(VT);

    %Group creation in the quarters at least 5 persons going to the same faculty

    %Loop on all passengers

    %initializing variables

    N2 = length(quartiersUniques); %size of quarters
    N3 = length(facultesUniques); %size of faculties
    N4 = length(voituresUniques); %size of available vehicles
    M1 = zeros(N1,N2);
    M2 = zeros(N1,N3);
    M3 = zeros(N1,N4);

    % Grouping IDs of people in the same quarters

    for k=1:N1
        for j=1:length(quartiersUniques)
            tj = strcmp(quartiersUniques(j,1),alldata(k,5));
            if tj==1
                M1(k,j) = ndata(k,1);
                Ma = sparse(M1); %output groups, shows individuals according to their quarters
                break
            end
        end
    end

```

```

end
end

```

% Grouping IDs of people in the same faculty

```

for k=1:N1
    for j=1:length(facultesUniques)
        tj = strcmp(facultesUniques(j,1),alldata(k,2));
        if tj==1
            M2(k,j) = ndata(k,1);
            Mb = sparse(M2); %output groups
            break
        end
    end
end
end

```

% Grouping IDs of people having the vehicle

```

for k=1:N1
    for j=1:length(voituresUniques)
        tj = (voituresUniques(j,1)==VT(k));
        if tj==1
            M3(k,j) = ndata(k,1);
            Mc = sparse(M3); %output groups of individuals who have a vehicle
            break
        end
    end
end
end

```

% Possible groups

%=====

MD(:,1)=nonzeros(Mb); % Ordering groups depending on faculties

```

for j=1:N1
    for k=1:N1
        for l=1:11
            if MD(j,1)==M2(k,l)
                MD(j,2) = l;
                for m=1:N1
                    for n=1:27
                        if MD(j,1)==M1(m,n)
                            MD(j,3) = n;
                            for p=1:N1
                                for q=1:2
                                    if MD(j,1)==M3(p,q)
                                        MD(j,4) = q;
                                        break
                                    end
                                end
                            end
                        end
                    end
                end
            end
        end
    end
end

```



```

clear Distance

Dist_p = [Dist_p
Distance([Coordinates(index_m,2);Coordinates(index_m,1)], [Coordinates(m,2);Coordinates(
m,1)])];
    m_Ind1 = [m_Ind1 m];
end
end
if isempty(Dist_p)~=1 && m2==1

[m_Dist,m_Ind2] = min(Dist_p); % Tag minimum distance for next choice group
member
m = m_Ind1(m_Ind2);

if Dist_p(m_Ind2)~=0
    IDD = [IDD;ID(m,:)];
    WW = [WW;ID(m,:)];
    ID(m,1) = a;
    m2=m2+1;
    m_Ind2 = [m_Ind2 m];
end
else

for q=2:10
    m_Ind1 = [];Dist_p = [];
    if ndatav(q,ID(index_m,3))~=0&&m2==1
        for m=1:N
            if
IDD(1,1)~=0&&ID(m,1)~=a&&ID(m,2)==ID(index_m,2)&&ID(m,3)==ndatav(q,ID(index_
m,3))

                clear Distance
                Dist_p = [Dist_p
Distance([Coordinates(index_m,2);Coordinates(index_m,1)], [Coordinates(p,2);Coordinates(p
,1)])];
                    m_Ind1 = [m_Ind1 m];
                end
            end
        end
        if isempty(Dist_p)~=1 && m2==1
            [m_Dist,m_Ind2] = min(Dist_p); % Tag minimum distance for next choice
group member
            m = m_Ind1(m_Ind2);
            if Dist_p(m_Ind2)~=0
                IDD = [IDD;ID(m,:)];
                WW = [WW;ID(m,:)];
                ID(m,1) = a;
                m_Ind2 = [m_Ind2 m];
                m2 = m2+1;
            end
        end
    end
end

```

```

        end
    end
end
end
end
if isempty(WW)~=1
    for kp=1:length(WW(:,1))
        Group.G(kp,1:4,kk) = WW(kp,:);
    end
end

if isempty(m_Ind2)~=1

    for kj=1:length(m_Ind2(1,:))
        Coordinates_C(kj,1) = Coordinates(m_Ind2(kj),2);
        Coordinates_C(kj,2) = Coordinates(m_Ind2(kj),1);
    end

    clear Search_Centroid

    [x] = Search_Centroid(Coordinates_C);
    ID_CENT = [ID_CENT;x];

end
kk = kk+1;

end

mm = 0;
A = [];

for j=1:length(Group.G)
    jc = [j; j; j; j; j];
    A = [A; Group.G(:,j) jc];
end
tt = char({'ID' 'Faculty' 'Quarter' 'Car' 'Group'});
fid = fopen('Group.G.txt','wt');
for ii = 1:size(A,1)
    if ii==1
        fprintf(fid,'%8s %16s %10s %10s %10s\n','ID','Faculty','Quarter','Car','Group');
    end
    fprintf(fid,'%10d\t',A(ii,:));
    fprintf(fid,'\n');
end
fclose(fid);

% edit Group.G.txt

tt = char({'Long' 'Lat'});
fid = fopen('ID_CENT.txt','wt');
```



```

A = [ID_CENT'];

for ii = 1:size(A,1)
    if ii==1
        fprintf(fid,'%10s %10s\n','Long','Lat');
    end
    fprintf(fid,'%10f\t',A(ii,:));
    fprintf(fid,'\n');
end

fclose(fid);

kp = kp+1;
XG = [XG length(Group.G)];

clear Group.G

end

plot(XP, XG, 'g-*)
legend('number of groups','location','Best')
xlabel('car percentage')
ylabel('number of groups')

toc

```

COORDINATES' DISTANCE TO CHOOSE THE NEXT PERSON IN THE GROUP

```

function [Dist] = Distance(x,y)
    Dist = sqrt((x(1)-y(1))^2+(x(2)-y(2))^2);
end

```

CENTROID CALCULATION

```

function [x] = Search_Centroid(Distt)
N_C = length(Distt(:,1));
x(1,1) = (sum(Distt(1:end,1)))/(N_C);
x(1,2) = (sum(Distt(1:end,2)))/(N_C);
end

```