Analysis of mobility behaviour and transport demand management. Case study: Tiburtino Industrial Site.

Faculty of Civil and Industrial Engineering
Department of Civil, Construction and Environmental Engineering
Master Degree in Transport Systems Engineering

Course of Transport Modelling and Planning

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A papà, mamma e Alberto

The present thesis was written within an internship in the company MOVESION S.r.l.

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1. Introduction

The increase in population, accompanied by an increase in the availability of travel opportunities have awaked the interest in understanding how people use the space around them and their opportunities. Hand in hand, during the last century, a constant growing of the productive sector has been experienced as well. As a consequence, the need of mobility of people raised day by day. That's why understanding the travel behaviour of individuals and groups is crucial nowadays.

This work mainly focuses on the so called systematic mobility, *i.e.* all that kind of movements that occur in the most common moments of the day. The outward trip in the morning towards the workplace and inward one in the evening towards the household, are the biggest causes of traffic and congestion especially in the urban centre.

Collecting this information is not a simple task because of two main factors: defining the characteristics and the indicators that properly describe travel behaviours, which deals with different research areas, and obtaining travel data from large groups of respondents, which is fundamental for this kind of analysis.

The thesis is composed by three main parts. The first is related to the theoretical definition and description of what is mobility management and all its components. The second is the case study: the application of all those principles to an actual case. The third one deals with the proposal of some kind of interventions in order to shift the car users toward more sustainable modalities.

The theoretical principles explained in the first part has been applied to an existing case study, one of the most important and extended industrial site in the whole centre of Italy: the Tiburtino Industrial Site. It is located in the eastern side of the city of Rome covering around 800 hectares and involving more than 20 000 individuals per day, both employees and visitors. Despite the relevance of this area, a longstanding problem of accessibility affects this zone reducing its competitiveness in the national and international industrial sector. In light of this, an in depth analysis of the mobility habits of individuals constituting the Industrial Site is necessary in order to propose the most effective interventions.

Moreover, re-think the concept of mobility providing sustainable solutions will give the possibility to gain a noticeable reduction of emission factors like carbon monoxide and dioxide, particulate matter, methane, volatile organic compounds, nitrogen oxides.

2. Mobility Management

2.1. Transport as a key factor in the evolution of human beings and socio-economic development

In the past the concept of transport was assigned to very simple mode like walking or pulling from beasts, but a relevant renewal to that was given by the coming of innovation in the field of locomotion with the allowance to carry people and freight with high performances. First the use of steam and then of petrol and electricity, especially regarding the rail sector, changed the mind of mobility from "by hand" to "mechanized".

In the 20th century, the widespread diffusion of the private car led a relevant revolution in terms of mobility, changing the previous settings of urban concept and its functionality. The passage has been as extent as it has been fast. In around fifty years the large majority of the population could easily purchase a private vehicle especially thanks to determined political strategies which promoted the development of the automotive sector.

Mobility is a complex system involving several mode of transport, like road-based, rail-based, via sea and air, interacting with infrastructures through transport services. The individual is in the middle of these two entities both from the *user* side and from the *target* one of all the possible benefits or externalities.

Indeed, transport sector is responsible of: the 33% of the overall energy consumption in the EU-28 and of 39.1% in Italy; the 31.8% of the CO_2 emission for the EU-28 and 33.2% for Italy with 1 067 and 113.7 million of tonnes of CO_2 emitted respectively. Unlike what happened in other sectors, like real estate or agricultural, the environmental impact due to mobility hadn't any reduction seeing a general increase of emissions around the 20% in the last thirty years. In general, this is caused by several aspects related to the existing facilities and to their disposition which by construction are petrol dependent. This makes difficult and rarer drastic renewals of the fleets which anyway still maintain the previous problems.

Thus, despite transport sector has been one of the most relevant industrial innovations of recent history, there is not any evident solution capable of cancelling the impacts of an always increasing demand of mobility. Managing the demand through a sustainable vision is the only solution that allows to obtain considerable results. This is possible by means of two main practices: shifting the mode of transport from private towards the collective one and using the best and newest technologies available on the market.

2.2. The role of mobility management in sustainability field

Mobility Management is a concept which deals with two main components: promotion of sustainable mobility and management of transport demand by analysing the daily habits of users and trying to shift them towards *eco-friendlier* solutions. The measures at the basis are soft like: information, communication and coordination of stakeholders' activities. Generally, the soft measures are assigned to enhance as much as possible the positive effects of hard ones. In other words, the sustainable mobility policies shall bring out the best from the existing facilities and let the new ones be compatible with the ecological standards. Moreover, the economical investments required are not so huge, but can ensure at the same time a very high Cost to Benefit ratio.

This concept is strictly related to the management of demand and not of supply, consequently no interventions like construction of new tram lines or bicycle paths are foreseen. The goal is to provide the capability to satisfy the need of moving wherever without any restrictions for both relationships and business purposes, without renouncing to beware human and ecological aspects.

A more sustainable mobility doesn't face only the polluting emissions and all the negative externalities but it also reduces the negative effects due to sedentary life-style, air and noise pollution and accidents density.

The possible measures foreseen by Mobility Management are listed below:

- Information

  Giving the final user the possibility to access several information by means of various media is a powerful instrument. The accessible data regard positioning as well as timing of a given mode of transport (e.g. local public transport) making easier the use of it. The user can be allowed to know before and during the trip the current position of the vehicle running and the missing time.
- Promotion

  The idea at the basis is the encouragement to spontaneously change mind by diffusing and touching people's sensitiveness with respect to environment and ecology. No innovative mode of transport shall be proposed rather the consciousness of existing alternatives shall be sensitised. This can be obtained by focusing on the positive effects resulting from changing the own habits in favour of more sustainable ones, like health's improvement if reducing the movements by car and increasing the ones by bike.
- Organization and coordination

  The optimization of car usage is one of the key point in MM. it's very often to see vehicles on the road with only the driver inside. That's why providing services which make easier practices like *car-pooling* and *car-sharing* could allow to obtain relevant results in terms of traffic congestion and pollutant emissions. Car-pooling is that practice in which a driver, moving from origin to destination, gives the ride to other people travelling the same trip. Car-sharing instead foresees the rent of vehicles avoiding to own one. These vehicles are located in strategic point-of-interest and can access to all urban traffic zones.

- Education

  The present category consists of matching MM policies with the educational system both for younger and for employees. People should be aware of sustainability and its application field especially in the mission of reducing the use of private car.
- Telecommunications and smart-working

  One possible solution could be the management of the actual need of reaching a workplace or a public office as well as optimizing the working time. For some specific jobs the physical presence of employees is not required everyday and nowadays technological means allow to be productive remotely. On the same basis some public offices could change the working time in different moments of the day so to not concentrate the activities in the most congested hours.
- Incentives and supplementary actions:

  These kind of measures are not direct but can anyway have a strong impact. Introducing them makes easier the acceptance of MM policies directing users' behaviour. For instance, parking management, in terms of number, fares and restrictions, accompanied with other measures, may lead people to change their habits. Else, when designing new building areas together with their own authorisation some specific transport performances must be provided by the body in charge so to make satisfied the demand but applying MM ideas.

Therefore, MM aims at improving citizens' quality of life and at reducing as much as possible the externalities that the community must suffer because of transport choices; thus, the application of specific measures is assigned to make more efficient and smarter use of available transport mode.

The main externalities to be faced are the ones caused by systematic mobility of workers and students crowding the road arteries in the peak-hours, these are:

accidents, congestion, air and noise pollution. They are mainly due to the too much large use of private car and in general of individual transport systems.

The capability to manage transport choices becomes fundamental not only in terms of quality of life but also in terms of attractiveness of the urban context. Urban centre's organisational and physical characteristics make possible to better apply generalized mobility plan. This requires a renovated interpretation of urban planning in which accessibility, connectivity, sustainability and multi-modality are the founding principles aimed at reducing car dependency. Indeed, despite the modern *car-centric* society brought benefits to individuals, especially drivers and passengers, there are a number of negative direct and indirect effects whose monetisation is difficult although their individuation isn't.

In this regard, a new meaning of private car must be carried out, proposing valid alternatives and increasing people awareness and importance of collective transport. This will imply as indirect consequence several benefits at social inclusion level by limiting exclusion phenomena.

2.3. European legislation

The pioneering state of Mobility Management in Europe was the Netherlands, where the first ECOMM (European Conference on Mobility Management) was convened in 1997. On that occasion the experiences of many European states and the United States of America were shared.

In light of the success of that event, the European Platform on Mobility Management (EPOMM) was introduced, which would be the network of the governments of the countries involved in this issue, represented by their respective ministries responsible for mobility and transport. It is a non-profit international organization based in Belgium, Louvain.

More generally, European legislation focuses mainly on improving fuel quality, on the differentiation of energy sources used in transport and, lastly, the improvement of emission standards as well as the promotion of good practice.

One of the Directives regulates the admissible sulphur content of liquid fuels (EU Directive 2016/802) by setting the threshold at 1.00% by mass; Directive 98/70/EC, adapted subsequently by Directive 2003/17/EC, lays down the quality and environmental specifications of petrol and diesel fuels used for road transport. About energy differentiation, Directive 2014/94/EU promotes the construction of infrastructures for alternative fuels such as electricity, hydrogen, biofuels and natural gas.

2.4. Italian legislation

In Italy, a comprehensive settlement of Mobility Management has been given mainly with two Urban Sustainable Mobility decrees issued by the Italian Ministry of Environment, Land and Sea (MATTM): the first on 27th March 1998 and 20th December 2000 the second, both bear the name by the minister Edoardo Ronchi who issued them. Later on, the 28th December 2015 law #221 has been declared on green economy policies and reduction of natural sources' use.

The most noticeable parts of the Decrees and Law are reported below.

- 27th March 1998 Ministerial Decree "Urban sustainable mobility"

Art. 1

Regions must adopt within 30th June 1999 the regional plan for air quality, referred to 20th May 1991 Decree of Environment Minister.

Art. 2

Mayors of all municipalities included in high-risk areas for air pollution adopt adequate measures, in accordance with health legislation, for the prevention and reduction of polluting emissions, according to air quality limits and objectives laid down in Ministerial Decrees of 25th November 1994 and 16th May 1996.

Art. 3

Enterprises and public bodies with individual local units with more than 300 employees and enterprises with altogether more than 800 employees located in the municipalities mentioned in art. 2, must draw up the employees "Home-to-Work Trip Plan" (HtWTP); for this purpose, a mobility responsible is nominated as "Company Mobility Manager". The plan is aimed at reducing the use of private mode of transport and at better organizing schedules to limit traffic congestion.

The plan shall be delivered to the municipality within 31st December of each year and shall be updated yearly describing the measures adopted and the results achieved.

The municipalities mentioned in art. 2 set up a support structure for coordinating mobility manager and transport companies. Companies and bodies with individual local units with less than 300 employees can anyway identify mobility managers and take advantage of the support structure.

Art. 4

The municipalities mentioned in art. 2 encourage associations and enterprises in organizing services so to let people to collectively use private vehicles and to prevent them from being used by one single individual. These will be subject to a proportional contribution according to time spent distance travelled.

The incentives above described are intended as long as the provided services take place with electric, hybrids, natural gas or LPG vehicles equipped with devices for the abatement of pollutant emissions, or registered in accordance of Directive 94/12/EEC.

- 20th December 2000 Ministerial Decree "Incentives to the programmes proposed by corporate mobility managers"

Art. 1

The realization of interventions about the organization and management of people and goods' mobility demand wants to be promoted in this decree. The goal is the reduction of environmental impacts coming from traffic in urban areas, through the implementation of sustainable mobility policies. According to this, as integration for the 27th March 1998 Ministerial Decree, it is established that such a structure of support and co-ordination of those Company Mobility Manager, heads to the figure of the "Area Mobility Manager". His duties are:

- To promote dissemination, training and guidance actions the companies and bodies concerned under the Decree;
- To assist companies in drawing up the HtWTP;
- To foster the integration between HtWTP and Municipal Administration policies in a logic of network and modal interconnection;
- To verify solutions, with the support of companies that manage local transport services, by road and rail, for improving and integrating services, with complementary and innovative transport systems, to ensure intermodality and interchange, to increase the use of bicycles and/or rental services for electric and/or low impact vehicles;
- To ease collective taxi services, car-pooling and car-sharing;
- To provide technical support for the definition of criteria and arrangements for direct contributions and incentives to sustainable mobility projects;
- To promote the deployment of low-impacts transport systems and vehicles;
- To supervise the environmental benefits and vehicular traffic decongestion due to the implemented.

This decree also presents a series of limitations and guidelines about financial resources (art. 2), limits of co-financing (art. 3), beneficiaries (art. 4), submission of applications (art. 5), conditions for the admissibility (art. 6), proposed projects' evaluation (art. 7), financing and withdrawal methodology (art. 8).

- 28th December 2015 Law #221 "Environmental provisions to promote green economy measures and limit the use of natural resources"

Art. 5, paragraph 6

In order to ensure the reduction of air and noise pollution and of energy consumption, the increase in safety levels of transport and road traffic, the minimisation of the use of private car with the containment of traffic, in compliance with current regulations and without prejudice to the educational autonomy and freedom of choice of teachers, the Ministry of Education, within 60 days the implementation of this Law, shall adopt specific guidelines to encourage the establishment in all schools of all levels, within the framework of their administrative and organizational autonomy, the "School Mobility Manager". He or she will be chosen on a voluntary basis and without reducing the educational load, in accordance with the plan of the educational offer, with the school system and taking into account the existing educational organization.

The school mobility manager has the task of organizing and coordinating the Home-to-School Movements; maintaining links with municipal structures and transport companies; to coordinate with other schools in the same municipality; to verify solutions, with the support of companies that manage the road-based or rail-based local transport services, for the improvement of the services and the integration of the same ones; to guarantee the intermodality and the interchange; to favor the use of bicycle and the rental services of electric vehicles or with low environmental impact; to inform the regional school office about any problems regarding disabled people mobility. No new or increased burden on public finances shall result from the implementation of this subparagraph.

2.5. Home-to-Work Trip Plan

As prescribed in the decrees, the HtWTP (Piano Spostamenti Casa-Lavoro according to the Italian nomenclature) must be drawn up yearly for some specific companies or bodies having defined characteristics. This document allows the Company Mobility Manager to gather all the possible information about the systematic mobility of workers and to set the most proper planning. Indeed, the most critical and congested hours of the day, are the ones when employees go to the workplace in the morning, and go back home in the evening. The predictability in time and space of these daily movements is the key factor as a weakness of congestion problem, since the room for manoeuvre is very high. The reduction of the use of private car, is the most relevant goal of this transport analysis in a sustainable vision.

The drafting of this project consists of three main phases:

1. Objective demand analysis phase

   An in depth analysis of the current situation is foreseen in the first step of the Plan. This study is carried out through the submission of two specific questionnaires: the first intended to the Company Mobility Manager and the second to the employees. These are fundamental in order to properly understand all the information describing the current state of mobility in the company as well as workers' profile and daily habits respectively. It is noticeable the role played by the employee since his opinion can be expressed in a formal way assuming the relevance of the decision maker.

   The information provided by the Mobility Manager regard internal and external context analysis, achievable objectives' definition and undertaken initiatives.

   The ones gathered by the workers' side are of three main categories:

- Technical information:

  Origin and destination of the trip, chosen mode of transport, distance and travel time, time of leaving and arrival home and workplace respectively, average cost.
- Social elements:

  Attitude and judgement on local public transport, suggestion for possible improvements, problems suffered daily.
- Propensity to change:

  Willingness to diverge the current modal choice in favour of a more sustainable one.

2. Design phase

   After having collected all the data useful to build up the framework, the Mobility Manager is asked to propose some specific interventions with the scope of reducing externalities. As already explained, these interventions are defined policies introducing new services suitable for being aware of alternative solutions. Among them, the EPOMM foresees policies like: promotion actions, car parking management, car-pooling, car-sharing, eco-driving, flexible working hours, improvements for public transport accessibility, park and ride, personalized travel assistance, telework, van pooling.

3. Monitoring phase

   Monitoring follows the implementation phase. This step is crucial since its outcomes represents the goodness of the design strategy and thanks to the yearly update it is possible to understand and define, and eventually correct, the mobility interventions.

Operating all these steps by hand would be very heavy from a computational point of view. That's why in this work thesis a sector-specific software has been used in order to perform all the steps, starting from the compilation of questionnaires till the carrying out of the indicators. A detailed description of this software will be given in the following chapter. Nevertheless, the coordination and communication activities are fundamental for the Area Mobility Manager, in order to highlight employees' need for mobility purposes as a central urban problem.

Other than the environmental benefits for both citizens and urban context, a number of advantages may be defined thanks to this plan. From an enterprise point of view, managing the demand through a sustainable vision may lead to:

- Regularity in the morning arrival;
- Possible creation of socialization among employees, with improvements of working activity synergies;
- Possible offer of a useful service enhancing working activity;
- Reduction of parking lots and their reallocation for other purposes;
- Revenues from parking fares;
- Increase of company accessibility;
- Strengthening the corporate image.

From the employee's side the advantages consist of:

- Lowered cost of transport;
- Lowered travel time;
- Possible economic prizes if choosing sustainable transport mode;
- Reduction of road accidents;
- Enhanced public transport regularity;
- Reduced psychophysical stress due to urban traffic congestion;
- Facilities and services improvements for who already used alternative modes;
- Strengthening of the social relations within colleagues if sharing these ideas.

3. Software and simulation model

3.1. MobilityManager

3.1.1. The company MOVESION S.r.l.

The company MOVESION S.r.l. was founded in 2014. Now is an accomplished transport engineering company working in the field of the sustainable mobility and company welfare, developing mainly software useful for the mobility manager’s activity. The society is now active at international level with 3 offices: Rome, Swiss and Luxemburg.

The core business is the developing and marketing of software tools aimed to plan and manage the employee’s systematic mobility with ideas and principles of sustainability in urban areas.

Among the others, MOVESION as software house has developed the suite “Mobility” involving a number of software that are: MobilityManager, MobilityTicket, MobilitySchool, MobilityCompany and MobilityCity. In particular, in thesis work MobilityManager has been used that is particularly useful for the company mobility manager for the drafting of the Home-to-Work trip plan.

3.1.2. Introduction to the software

The software is capable to gather all the needed data to be analysed from both Company Mobility Manager and employees; thus according to the simulation model that will be deeply described in the immediately following chapters, the mobility indicators as well as the results coming from the intervention phase can be carried out. The survey destined to the Mobility Manager deals with general information, parking, company vehicles, accessibility, public transport, company transport service, carpooling; on the employee’s side instead the questionnaire is about personal data, working position, working activity, trip habits, characteristics of movements, private vehicles, trip preferences and other alternatives.

The main features of the software are shown. It is web-based and consequently accessible simply thanks to an internet connection both through personal computer and through smartphone.

1. The Mobility Manager can open the investigation through the specific control panel. Using this tool, he can name the survey and set the dates of beginning and end.

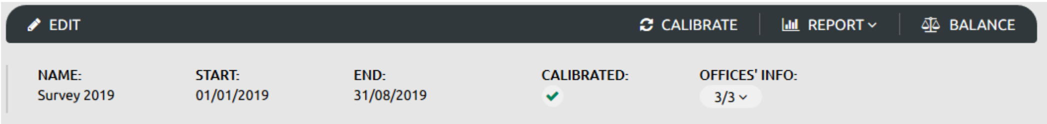


Figure 1 – Control Panel

2. The Mobility Manager has the task to fill in and complete his own questionnaire. By completing the questionnaire, a detailed description of the characteristics of the company in terms of mobility (number of parking lots, company cars, software to manage carpooling, company bicycles, etc.) is given.

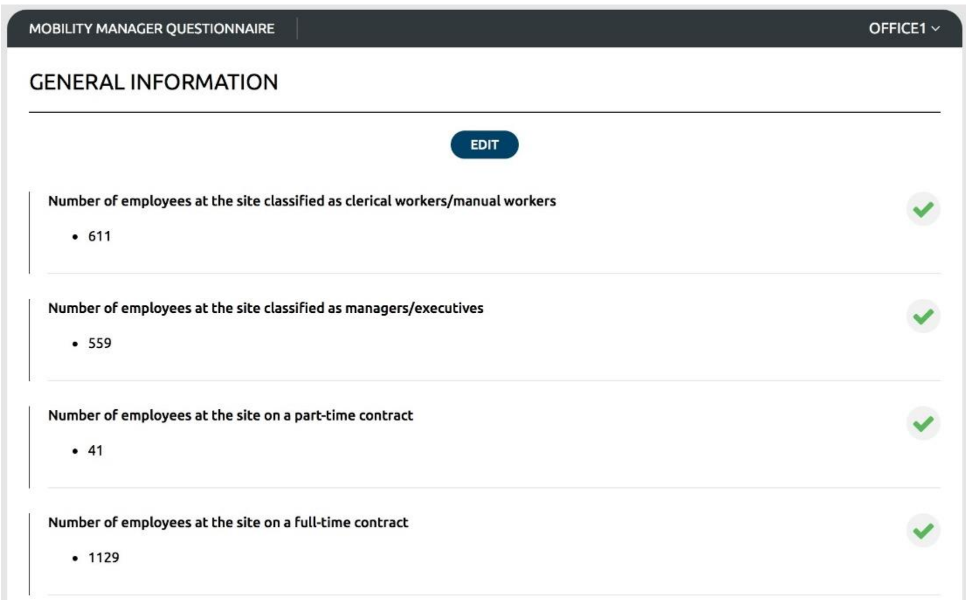
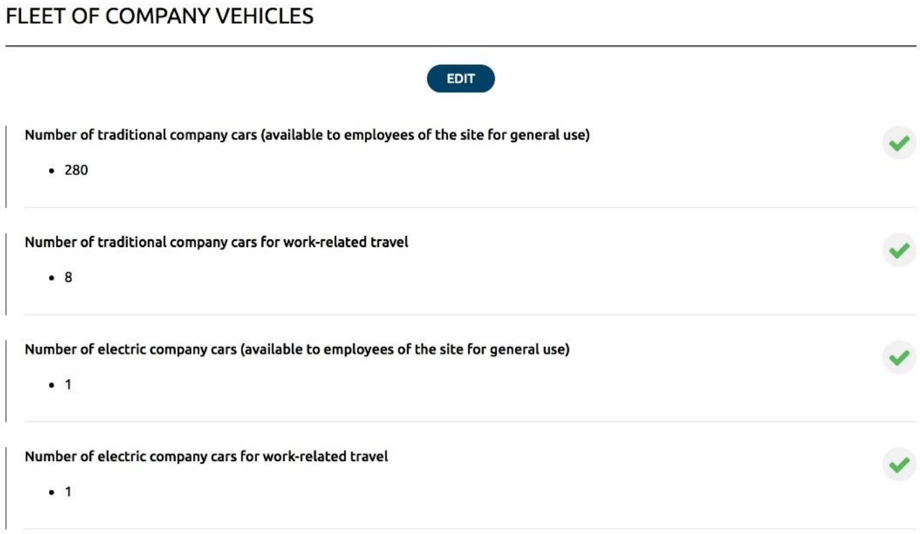


Figure 2 – Questionnaire #1



FLEET OF COMPANY VEHICLES

EDIT

Number of traditional company cars (available to employees of the site for general use)

- 280

Number of traditional company cars for work-related travel

- 8

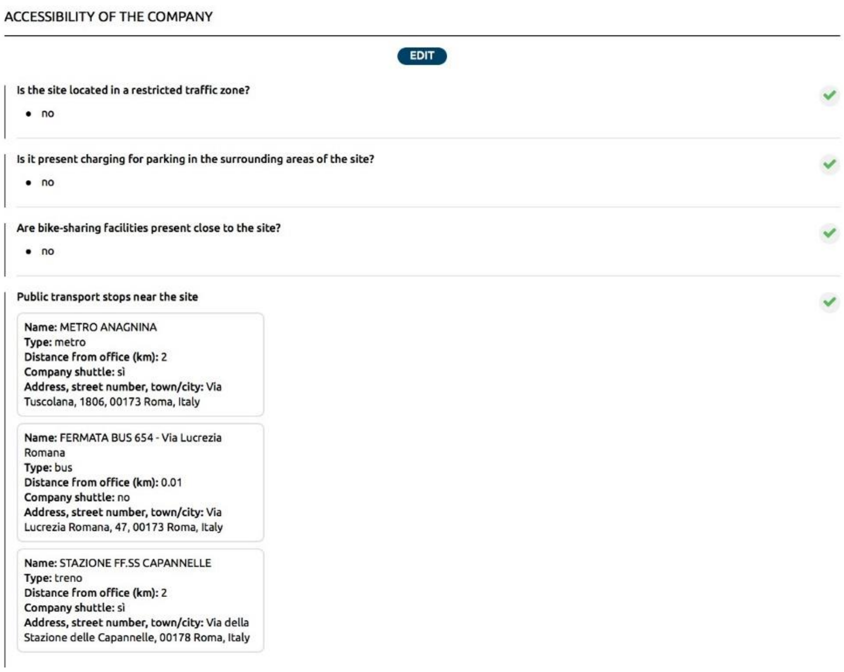
Number of electric company cars (available to employees of the site for general use)

- 1

Number of electric company cars for work-related travel

- 1

Figure 3 – Questionnaire #2



ACCESSIBILITY OF THE COMPANY

EDIT

Is the site located in a restricted traffic zone?

- no

Is it present charging for parking in the surrounding areas of the site?

- no

Are bike-sharing facilities present close to the site?

- no

Public transport stops near the site

Name: METRO ANAGNINA
Type: metro
Distance from office (km): 2
Company shuttle: sì
Address, street number, town/city: Via Tuscolana, 1806, 00173 Roma, Italy

Name: FERMATA BUS 654 - Via Lucrezia Romana
Type: bus
Distance from office (km): 0.01
Company shuttle: no
Address, street number, town/city: Via Lucrezia Romana, 47, 00173 Roma, Italy

Name: STAZIONE FF.SS CAPANNELLE
Type: treno
Distance from office (km): 2
Company shuttle: sì
Address, street number, town/city: Via della Stazione delle Capannelle, 00178 Roma, Italy

Figure 4 – Questionnaire #3

3. Once the Mobility Manager completed his own questionnaire, which gives us a satisfactory overall vision of the company condition in the field of systematic mobility, he has to send to all the employees their questionnaire. Through their answers the Mobility Manager can observe the current condition and understand (also through the software simulation) if implementations to the services are needed to be introduced. The questionnaire is particularly useful to put in evidence the different problems

that employees have to face systematically in the home-work place trip. A specific section is based on the willingness (or propensity) to change the mobility habits of employees: if and under which conditions employees are willing to change their modal choice (from private car to more sustainable alternatives). Obviously, a full cooperation and honest answers (not underestimating the completion of the survey) is fundamental to observe a scenario that represents the reality and decide (if necessary) technical interventions.

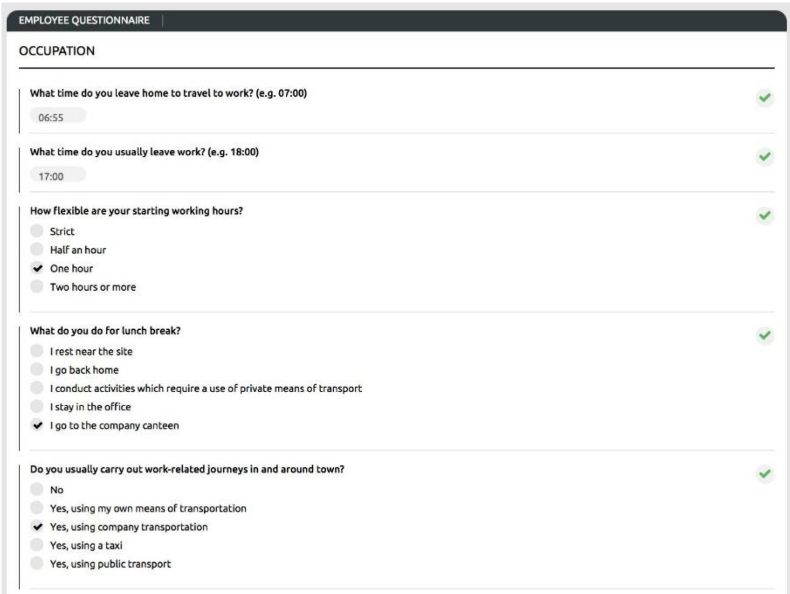


Figure 5 – Employee's questionnaire

4. Through the main control panel, the Mobility Manager can control in real time the progress and the overall condition of the survey. Thanks to a specific tool, is possible to view those that have compiled in an exhaustive manner the questionnaire, those who have not completed and those that have not opened the questionnaire at all.

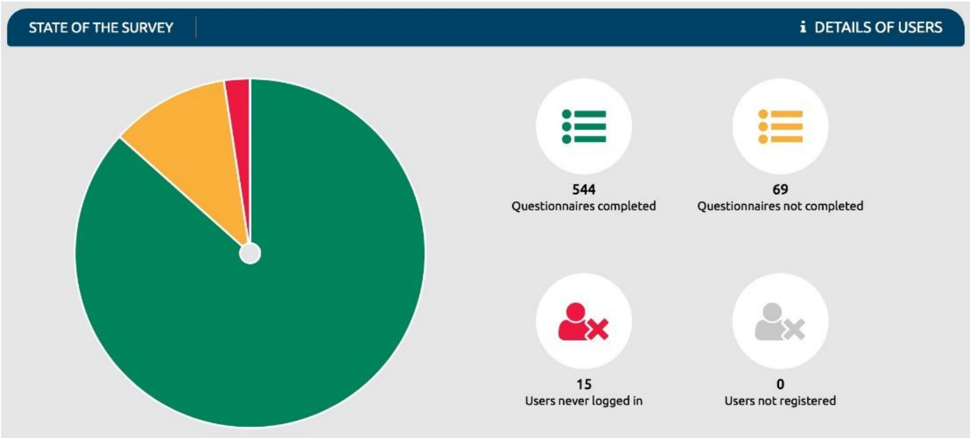


Figure 6 – State of the survey

Then, to increase the rate of compliance, the mobility manager can send a customized message to the various employees, in order to obtain acceptable levels.

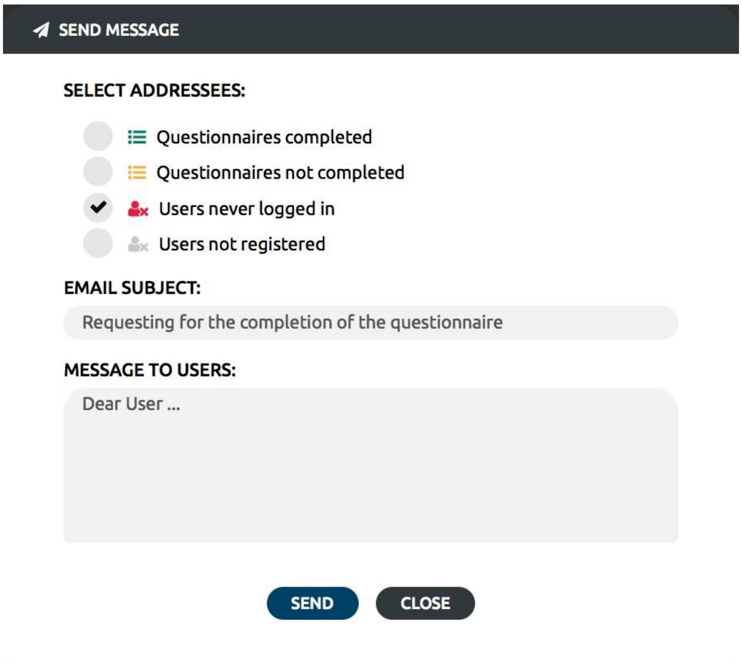


Figure 7 – Contact form

5. Once the survey achieves a sufficient answering rate, the Mobility Manager can obtain through the software a number of data in terms of employees' habits, indicators of mobility, graphs and a general excel file (survey's report) that can be downloaded. The most important indicators provided by the software are:

- Mobility (or Transport) Indicators: modal split, total kilometres covered, average length of trips.
- Environmental Indicators: annual emissions of CO_2, PM_{10}, CO, NO_X and so on. To calculate the environmental indicators, the method "COPERT IV" (COmputer Programme to calculate Emissions from Road Traffic) is implemented in the software and then the emission factors expressed in g/km are obtained matching the COPERT data with also ACI data about Northern, Centre and Southern Italy.
- Indicators of willingness to change (propensity to change mobility habits to reach workplace).
- Indicators of judgement (how an employee perceives the mobility and the trip from home to workplace).

The Mobility Manager can display all the processed data in PDF format or in Excel and it's also possible to obtain aggregated or disaggregated data.

Movesion - Mobility Manager Report

Report survey

Date:	29/04/2019
Company:	company1
Survey:	Survey 2019 (from 01/01/2019 to 31/08/2019)

Offices:	office1	office2	office3
Number of employees:	1170	130	389
Questionnaires completed:	497	49	0
Completed (in percentages):	42.48	37.69	0

Indicators:

Modal split (%)

IMSPLIT_NM	office1	office2	office3	Total average
traditional bicycle	0.40%	0.00%	0.00%	0.36%
company bus	0.00%	0.00%	0.00%	0.00%
traditional car low hour	8.06%	6.12%	0.00%	7.89%
car-pooling driver	0.60%	2.04%	0.00%	0.73%
car-pooling passenger	0.60%	0.00%	0.00%	0.55%
traditional car peak hour	55.44%	71.43%	0.00%	56.88%
traditional motorcycle	6.25%	2.04%	0.00%	5.87%
multi-modal	6.85%	2.04%	0.00%	6.42%
on foot	0.81%	0.00%	0.00%	0.74%
public transport	20.97%	16.33%	0.00%	20.55%
Total	100.00%	100.00%	0.00%	100.00%

Figure 8 – MobilityManager's Excel report

Type of disaggregation	office1	office2	office3
car-pooling driver	0.6	2.04	0
car-pooling passenger	0.6	0	0
company bus	0	0	0
multi-modal	6.85	2.04	0
on foot	0.81	0	0
public transport	20.97	16.33	0
traditional bicycle	0.4	0	0
traditional car low hour	8.06	6.12	0
traditional car peak hour	55.44	71.43	0
traditional motorcycle	6.25	2.04	0

Figure 9 – Modal split indicator

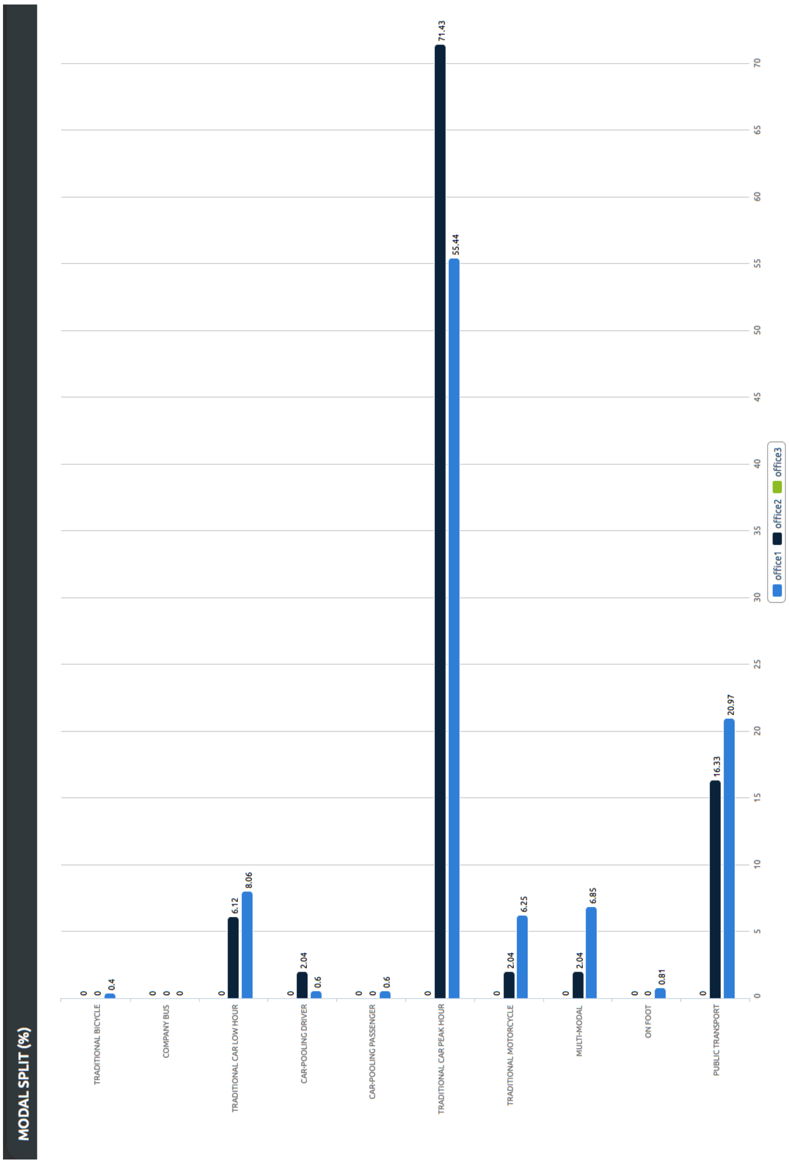


Figure 10 – Modal split graph

6. The Map Tool is a useful function. Every user is represented (anonymously) on the map and every data is geo- referenced. The convenience of a tool of this type is that it can be easily understood the main dynamics of mobility that characterize the company and help the knowledge of problems that affect employees' mobility. On the map is possible to select different filters and play a match between the cartographic data and the indicators or answers of employees.

   To better understand the power of that tool, for instance a Mobility Manager that is able to provide a carpooling software to employees and can observe these two situations: high propensity to carpooling but no employees living in same areas (difficult to realise); geographical concentration of employees' residence but low propensity to change mobility habits.

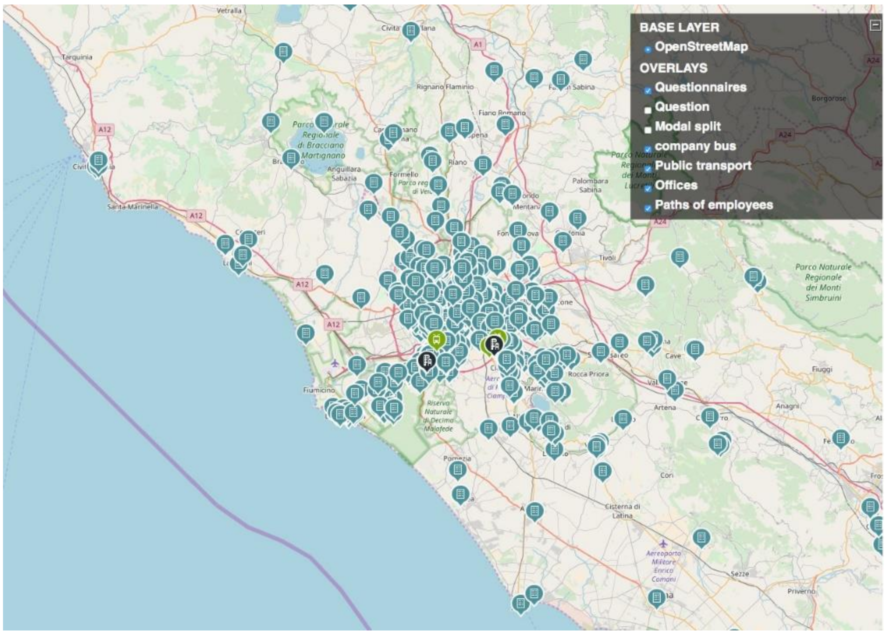


Figure 11 – Map tool #1

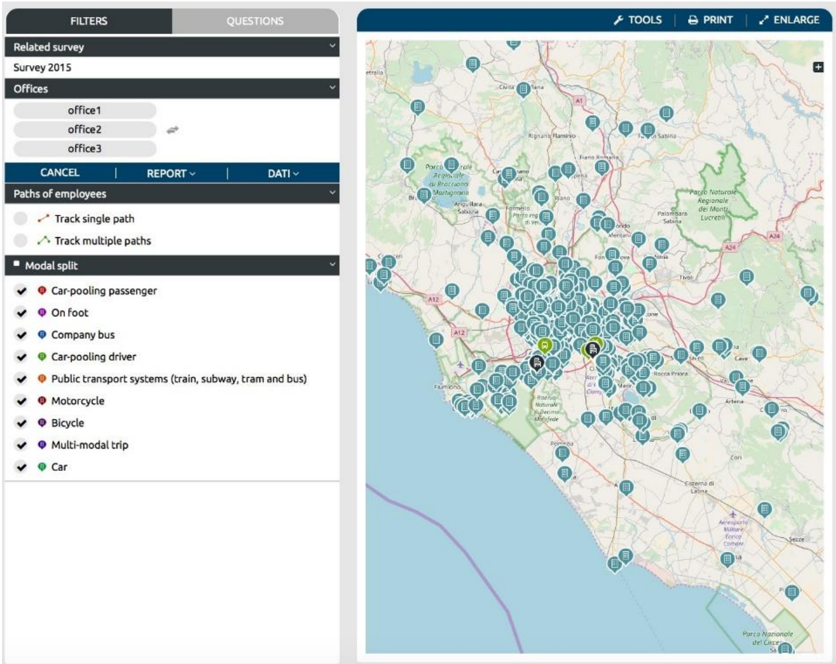


Figure 12 – Map tool #2

7. Finally, the "Balance Tool" and the "Interventions Tool" can be analysed:
   - The Balance Tool is fundamental to estimate (in monetary terms) the impacts of the mobility on the Company's Stakeholders: Employees, Community and Company.
   - After having analysed all the mobility indicators and the impacts generated by the systematic mobility of the employers, the Mobility Manager has the task to decide if interventions are needed. The software provides the extremely functional tool of simulating every kind of intervention.

Entities	Survey 2019
COMPANY	
Missed Production	-406 302.68 €
Incentives	0 €
Fares	0 €
Realization costs	-10 000 €
Total	**-416 302.68 €**
EMPLOYEES	
Fuel	-299 917.58 €
Vehicle purhcase	-431 925.52 €
Vehicle maintenance	-19 887.08 €
Highway toll	-36 005.9 €
Fines	-34 719.39 €
Vehicle insurance	-180 081.94 €
Accidents	-107 167.77 €
LPT Subscription	-75 448.24 €
Total	**-1 185 153.41 €**
EXTERNALITIES	
Polluting Emissions Costs	-10 308.21 €
Road Accidents	-19 818.83 €
Incomes from fares	493 637.57 €
Total	**463 510.53 €**

Figure 13 – Balance Tool #1

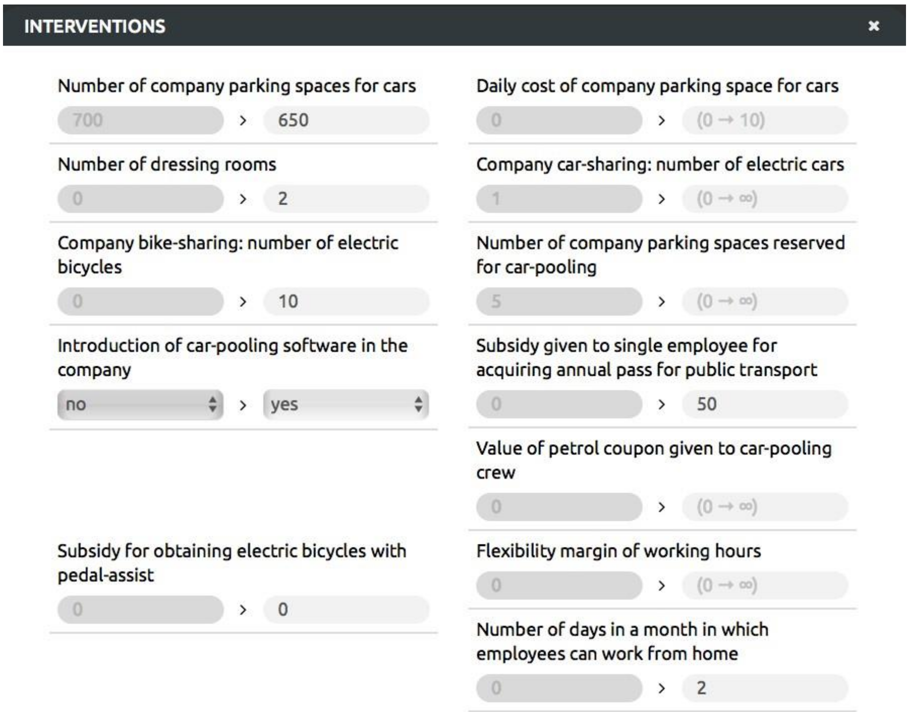


Figure 14 – Interventions' panel in MobilityManager

3.2. Random Utility Theory

3.2.1. Discrete choice model

Random utility models are a general class of models which work in many fields of application. They are particularly suitable to model people behaviour and especially consumers' one. The most noticeable models are the Multinomial Logit and the Probit.

Random Utility Theory is expressed according the following hypotheses and assumptions:

- The actor is a rational user that in the decision making process will try to maximise his profit or benefit, namely his utility (*i.e.* minimising his disutility);
- The set of alternatives K the user is facing with, namely choice set, is finite or discrete;

$$k = 1, 2, 3, \dots, n \qquad k \in K$$

- A utility or disutility, in terms of travel cost or travel time, is assigned by the user to each possible alternative;
- Since utilities are unknown they are defined as random variables having a probability density function (PDF).

The analytical expression of the utility of k-th alternative is described in the following:

$$u_k = v_k + \varepsilon_k$$

where v_k is the systematic utility and ε_k the random residuals.

Since the analyst is an external observer, can only evaluate the systematic utility defined as the expected value, or mean, of the random variable:

$$v_k = E(u_k)$$

To make the systematic utility meaningful, it shall be added of an error term, namely random residuals ε_k, representing the deviation from the mean. They are jointly distributed according to $\varphi(\underline{\varepsilon})$ distribution. Indeed, two or more utilities may have not-null correlation in case of sharing of some characteristics.

Given the difficulty in quantifying the value of utility, what is of interest is the probability of an alternative k to be chosen, namely the probability that its utility u_k is higher or equal than u_h's one.

$$p_k = \Pr\ (u_k \geq u_h, \forall\ h, k \in K)$$

$$p_k = \Pr\ (v_k + \varepsilon_k \geq v_h + \varepsilon_h, \forall\ h, k \in K)$$

The expected value w of the maximum perceived utility is called satisfaction or inclusive utility and it's defined as follows:

$$w = E\ (Max(u_k, \forall\ k \in K))$$

Named $E_k(\underline{v})$ the portion of space where u_k is the maximum utility

$$E_k(\underline{v}) = \{\underline{\varepsilon} \in \mathbb{R}_n \mid \varepsilon_h \leq v_k - v_h + \varepsilon_k, \forall\ h \in K\}$$

the general formulations of probability and satisfaction in the continuous case take the form below:

$$p_k = \int_{E_k(\underline{v})} \varphi(\underline{\varepsilon})\, d\underline{\varepsilon} = \int_{\varepsilon_k = -\infty}^{+\infty} \int_{\varepsilon_h = -\infty}^{v_k - v_h + \varepsilon_k} \varphi(\underline{\varepsilon})\, d\underline{\varepsilon}$$

whilst the satisfaction:

$$w = \int Max(\underline{v} + \underline{\varepsilon}) \cdot \varphi(\underline{\varepsilon})\, d\underline{\varepsilon} = \sum_{k \in K} \int_{E_k(\underline{v})} (v_k + \varepsilon_k) \cdot \varphi(\underline{\varepsilon})\, d\underline{\varepsilon}$$

It is not feasible to integrate numerically the probability expression from a computational point of view; hence a discretization process is performed. The probability φ_i of each case is:

$$\varphi_i = \int \varphi(\underline{\varepsilon_i})\, d\underline{\varepsilon}$$

This has to be assigned to the set of validity of the k-th choice, according to the case:

$$I_k = \{i \in I \mid u_k = v_k + \varepsilon_{ki} \geq v_h + \varepsilon_{hi} = u_h, \forall\, h \in K\}$$

Thus, the probability of each alternative is:

$$p_k = \sum_{i \in I_k} \varphi_i$$

and the satisfaction:

$$w = \sum_{k \in K} \sum_{i \in I_k} (v_k + \varepsilon_{ki}) \cdot \varphi_i$$

3.2.2. Mathematical properties of the model

The choice map, function that assigns to each alternative the probability depending upon the systematic utility v, is a vector function of a vector.

$$\underline{p} = p(\underline{v})$$

i) It is differentiable and strictly positive as the φ is a C^0 class function.

ii) The choice map function is monotone and not decreasing:

$$[\,p(\underline{v}_1) - p(\underline{v}_2)]^T \cdot (\underline{v}_1 - \underline{v}_2) \geq 0, \forall\, \underline{v}_1, \underline{v}_2 \in \mathbb{R}_n$$

iii) It is *invariant*, if the random residual distribution is independent of the systematic utility. As a consequence, the probability doesn't change if a constant is summed to all systematic utilities:

$$\underline{p} = p(\underline{v} + c \cdot \mathbb{1}) = p(\underline{v})$$

Regarding the satisfaction, it is a scalar function of a vector and it is:

iv) greater than the systematic utility, which is greater than the mean:

$$p(\underline{v})^T \cdot \underline{v} \leq Max(\underline{v}) \leq w(\underline{v})$$

v) a convex function;

vi) differentiable. For invariant models, its gradient is the probability itself:

$$\underline{\nabla} \cdot w(\,\underline{v}\,) = \frac{\partial\, w}{\partial\, v_h} = \sum_{k \in K} \int_{E_k(\,\underline{v}\,)} \frac{\partial(v_k + \varepsilon_k)}{\partial\, v_h} \cdot \varphi(\,\underline{\varepsilon}\,)\, d\underline{\varepsilon} = \int_{E_h(\,\underline{v}\,)} \varphi(\,\underline{\varepsilon}\,)\, d\underline{\varepsilon} = p_h$$

3.2.3. The systematic utility

The most relevant part of the model is the systematic utility, depending upon:

- the alternative k-th,
- the decision maker and his/her preferences,
- the choice context like time, purpose of trip.

In the decision making process, each user looks at these choice attributes in a different way by its subjective nature. It is assumed the systematic utility as a linear function of the attributes and of the parameters β to be calibrated and determined. The possible formulations are presented below:

$$v_k(\underline{a}) = \sum_{x \in X} \beta_{P_{xk}} \cdot a_x$$

$$v_k(\underline{a}) = \sum_{p \in P} \beta_P \cdot a_{X_{pk}}$$

Being:

k	alternative
a_x	value of the generic attribute $x \in X$
$\beta_{P_{xk}}$	parameter associated with attribute x
$a_{X_{pk}}$	attribute associated with parameter p
β_P	value of the generic parameter $p \in P$
X	set of model attributes
P	set of model parameters
K	set of alternatives

The first one is more suitable for transport applications since the attributes are fixed while the parameters are calibrated, however the result, from an analytical point of view, is the same as shown in the simple example below.

Given the following sets, in case of three alternatives:

$$K = \{car, bus, walk\}$$

$$P = \{0, Value\ of\ time\ VOT, own_{car}, ASC_{bus}, ASC_{walk}\}$$

$$X = \{time_{car}, time_{bus}, time_{walk}, own_{car}, 1, 0\}$$

Fixing the attributes (generic element of the table) means having parameters β to be calibrated.

fixed attributes		alternatives k		
		car	bus	walk
parameters β	VOT	$time_{car}$	$time_{bus}$	$time_{walk}$
	own_{car}	own_{car}	0	0
	ASC_{walk}	0	0	1
	ASC_{bus}	0	1	0

Table 1 – Systematic utility fixing attributes

While when β parameters are fixed, the attributes in the first column have to be calibrated.

fixed parameters		alternatives k		
		car	bus	walk
attributes x	$time_{car}$	VOT	0	0
	$time_{bus}$	0	VOT	0
	$time_{walk}$	0	0	VOT
	own_{car}	own_{car}	0	0
	1	0	ASC_{bus}	ASC_{walk}

Table 2 – Systematic utility fixing parameters

By applying the above mentioned definition of systematic utility, for each alternative it results:

$$v_{car} = \beta_{VOT} \cdot a_{time_{car}} + \beta_{own_{car}}$$
$$v_{bus} = \beta_{VOT} \cdot a_{time_{bus}} + \beta_{ASC_{bus}}$$
$$v_{walk} = \beta_{VOT} \cdot a_{time_{walk}} + \beta_{ASC_{walk}}$$

It must be highlighted the introduction of two entities that are the Alternative Specific Constant (ASC) and the Alternative Specific Attribute (ASA). To each alternative of the model, except one, a *service* parameter is assigned called ASC or β_{ASC}. It is associated to a dummy attribute, called ASA, which is equal to 0 or 1 if it activates the related alternative or not. In the previous example ASC_{car} is missing since it's defined as a function of the other two coefficients ASC_{bus} and ASC_{walk}, this allows to univocally determine them in calibration phase.

The need of introducing the ASCs is to describe the preferences of the user and to represent the relative utility of one alternative whit respect to another. On the other hand, all the imperfections of knowledge about what the user perceives are taken into account, like the ones deriving from: omission of attributes, proxy attributes, errors in the evaluation of the attributes from the decision maker's side and dispersion of people's groups when modelled as aggregate.

3.3. MobilityManager software's structure

In the following table, the model's structure of the software is shown:

	alternatives								
parameters β	CPT	MCT	BCT	PED	TRA	PAR	CPD	CPP	CLT
bSAMREV	USAMCPT	USAMMCT	USAMBCT	USAMPED	USAMTRA	USAMPAR	USAMCPD	USAMCPP	USAMCLT
bFEACHO	UFETCPT	UFETMCT	UFETBCT	UFETPED	UFETTRA	UFETPAR	UFETCPD	UFETCPP	UFETCLT
bMCTASA		ONEASA							
bBCTASA			ONEASA						
bPEDASA				ONEASA					
bTRAASA					ONEASA				
bPARASA						ONEASA			
bCPDASA							ONEASA		
bCPPASA								ONEASA	
bCLTASA									ONEASA
bBIKEW		UEWOMN	UEWOMN						
bCARW	UEWOMN								UEWOMN
bBIKEY		UEYONG	UEYONG						
bCARY	UEYONG								UEYONG
bWRKTP	UMNGR								UMNGR
bFMLY	UFMLY								UFMLY
bMINOR	UFMLMNA								UFMLMNA
bFLXCR									UFLXBL
bFLXMC		UFLXBL							
bNONAVL	UCARAVIL	UMCAVIL	UBKAVIL	UWLKAVIL	UTRAAVIL	UPARAVIL	UCARAVIL		UCARAVIL
bEAVL			UEBKAVIL						
bMCTDIS		CARDIS							
bBCTDIS			UBKDIST						
bPEDDIS				UWLKDIST					
bHOMSTD					UHSDIST				
bHOSTDC						UHSDISTC			
bCARPTM	CARDIS								
bCARTIM									CARDIS
bCPTIM							CARDIS		
bCPPTIM								CARDIS	
bTRATIM					UPUTRTIME				
bPARTIM						UPUTRTIME			
bTRANS					UTRNCH				
bCST	UCSTCAR				UCSTPT	UCSTPT	UCSTPCAPO	UCSTPCAPO	UCSTCAR
bNRNPLW								UNRNPLW	
bSCRPRK		UCOPRKMC	UCOPRKBK						
bPARSAT						UTPSATS			
bTPTSAT					UTPSATS				
bPARLOT						PARLOT			
bSFTBKL			SFTBKL						
bCAPRK	UCCRPAR						UCCPPAR		UCCRPAR
bWTRVEH			UWTRVEHC	UWTRVEHC	UWTRVEHC	UWTRVEHC		UWTRVEHC	
bWTREVEH			UWTREVEH	UWTREVEH	UWTREVEH	UWTREVEH		UWTREVEH	
bWTREBK			UWTREBK	UWTREBK	UWTREBK	UWTREBK		UWTREBK	
bDRERMS			DRERMS						
bSHWERS			SHWERS						
bGRABAK			UGRABACK	UGRABACK	UGRABACK	UGRABACK		UGRABACK	
bCPOINF							UCPOINF	UCPOINF	
bLUNBRK	ULNBREK	ULNBREK					ULNBREK		ULNBREK
bACCSTP	UACSTOP								UACSTOP
bGENSTP	UGNSTOP	UGNSTOP							UGNSTOP
bSCNTU					SCNTU	SCNTU			
bBKCO			UBKCO						
bEQUP			UEQUP						
bSTLN			USTLN						

Table 3 – MobilityManager software's structure

The first column of the table contains all the parameters β of the model, while the first row all the available alternatives to employees in terms of transport mode. All the other elements are the attributes. Their position in the table identifies the parameter and the alternative they are related to.

The estimation of the attributes of the model, is made possible through the information coming by the answers to the questionnaire. The higher is the answer rate and the better is the calibration accuracy of parameters.

The different mobility alternatives in the availability of the employees and that the model can simulate are:

- Car during peak hour (CPT)
- Car during low hour (CLT)
- Motorcycle/scooter (MCT)
- Bicycle (BCT)
- Walking (PED)
- Public transport (TRA)
- Park and ride (PAR)
- Car-pooling as a driver (CPD)
- Car-pooling as a passenger (CPP)

The different attributes can be divided into 6 different categories, for each one a brief description is given:

3.3.1. Level of service attributes (LoS)

The attributes of Level of Service are the ones regarding the quality of supply and affect the phase of choice of individual alternatives.

- CARDIS is equal to the home-to-work travel distance and is calculated knowing the residence address and the company's one where he works. This attribute is included in the utility functions of the following alternatives: car during peak hour, car during low hour, carpooling as a driver and carpooling as a passenger. For each of these alternatives, CARDIS is multiplied by a different coefficient, bCARPTM for car during peak hour, bCARTIM for car during low hour, bCPTIM for carpooling as a driver and bCPPTIM for carpooling as a passenger, in order to take into account all the different influence that the home-to-work travel distance can have in choosing these three options.

- UBKDIST is very similar to CARDIS, with the only difference that it is equal to 0 when bicycle is not an available alternative (see "Non-availability attributes"). The reason why it has been decided to create this different attribute and not to use CARDIS also for the "bike" alternative is because, with this logic, during the calibration the negativity of this alternative when the distance is too much to be covered by bicycle is taken by the non-availability attribute and not by the distance attribute. As mentioned, this attribute is included in the utility function of the bike alternative and it is multiplied by the coefficient named bBCTDIS.
- UWLKDIST has the same logic of UBKDIST, with the only difference that, since it refers to the walking alternative, the limit distance for which going by foot is feasible is lower. The coefficient by which this attribute is multiplied is named bPEDDIS.
- UHSDIST is equal to the distance from home to the nearest bus stop if the person reaches it by walking; it is equal to 0 otherwise. This attribute is included in the public transport utility function and it is multiplied with the coefficient named bHOMSTD.
- UHSDISTC is equal to the distance from home to the nearest bus stop if the person reaches it using a private mean of transport; it is equal to 0 otherwise. This attribute is included in the park and ride utility function and it is multiplied by the coefficient named bHOSTDC.
- UPUTRTIME is equal to the home-to-work travel time using public transport. This attribute is included in the utility functions of the public transport and park & ride alternatives, but for both it is multiplied by a

different coefficient: bTRATIM for public transport and bPARTIM for park and ride. The reason is that it is assumed that travel time has a different influence when choosing public transport and when choosing park and ride.

- UTRNCH is equal to the number of necessary transfers to reach the site by public transport. This attribute is included in the utility function of public transport alternative, multiplied by bTRANS.
- UCSTCAR is equal to the cost that the employee pays or would pay to park his car near the site. The reason why this attribute does not include the total amount of money that the employee pays or would pay to arrive at work by car is because the latter cost is divided into two parts: the parking fee, taken into account by UCSTCAR, and a cost that is proportional to the distance and, as a consequence, indirectly taken into account by the attribute CARDIS. This attribute is included in the utility functions of the two car alternatives, and it is multiplied by bCST in both cases.
- UCSTPT is equal to the cost that the employee pays or would pay to go to work by public transport; it is included in the utility functions of public transport and park and ride alternatives, always multiplied by the mentioned bCST coefficient.
- UCSTPCAPO is equal to the fee that car-pooling crews should pay to park the car in the company parking, if the latter is accessible by the employee; the attribute is equal to the cost for parking the car outside the company otherwise. This attribute is included in the utility functions of the two car-pooling alternatives and, in both cases, it is multiplied by the mentioned bCST coefficient.
- UNRNPLW is an attribute that takes into account if the person lives near the workplace (in this case its value is 1), and it is included in the utility function of car-pooling as a passenger, multiplied by bNRNPLW; the

reason why this attribute has been introduced is because people who live near the workplace have a higher probability to find someone who cross the area where they live and so share his car with them.

- UTPSATS corresponds to the person's level of satisfaction with public transport: the higher is the value and the higher is the satisfaction. This attribute is included in the utility function of public transport and park and ride alternatives, but it is multiplied by two different coefficients in two cases: bPARSAT for park and ride, and bTPTSAT for public transport.
- PARLOT is equal to 1 if there are car parks at the main public transport stops which can be used to arrive at the site without transfers; it is included in the utility function of the park and ride alternative and it is multiplied by the coefficient named bPARLOT.
- SFTBKL is equal to 1 if there are safety bike lanes that arrive at the site where the person works. This attribute is included in the utility function of the bike alternative, where it is multiplied by bSFTBKL coefficient.

3.3.2. Socio-economic attributes (SE)

The socio-economic attributes regard the social and economic aspects that influence the employees in the decision-making process.

- UMNGR is the third socio-economic attribute of the model and it takes into account the role of that person in the company; in particular, if the interviewed is a manager, the value of the attribute is 1. This attribute is included in the utility functions of the two car alternatives multiplied by bWRKTP, because it is expected that a manager tends to use a car to go to work.
- UEWOMN is the first and classical socio-economic attribute and it takes into account if the interviewed person is a woman; its value is 1 if the person belongs to the female gender and 0 if belongs to the male one.

This attribute can be found, multiplied by bBIKEW, in the utility function of motorcycle and bicycle alternatives, and, multiplied by bCARW, in the utility function of the two car alternatives. It has been decided to create two different coefficients because it is expected that women tend to choose the car rather than the motorcycle or the bike.

- UEYONG considers if that specific person is young or not; if the person is less than 40 years old, he is considered young and the attribute's value is 1. This attribute can be found, multiplied by bBIKEY, in the utility function of motorcycle and bicycle alternatives, and, multiplied by bCARY, in the utility function of the two car alternatives. The reason why it has been decided to create two different coefficients is because it is expected young people tend to choose a bike or a motorcycle to go to work rather than a car.
- UACSTOPS is equal to 1 if the person needs to stop off during the home-to-work trip for taking children to school or other family business. This attribute is included, multiplied by the bACCSTP coefficient, in the utility function of the two car alternatives: it is expected that employees who need to take children to school or other family's members elsewhere tend to go to work by car.
- UGENSTOP is equal to 1 if the person needs to stop off during the home-to-work trip for reasons different from taking children to school or other family business. This attribute is included, multiplied by the bGENSTP coefficient, in the utility function of the two car alternatives and of motorcycle: it is expected that employees who need to stop off during the home-to-work trip for reasons different from taking family's members where they have to go tend to go to work by car or by motorcycle.
- UMNGR is the third socio-economic attribute of the model, and it takes into account the role of that person in the company; in particular, if the interviewed is a manager, the value of the attribute is 1. This attribute is

included in the utility functions of the two car alternatives multiplied by bWRKTP, because it is expected that a manager tends to use a car to go to work.

- UFMLY takes into account if the person is the only member of the family, situation in which the value of the attribute is 1. This attribute is included in the utility function of the two car alternative and it is multiplied by the bFMLY coefficient.
- UFMLMNA is a socio-economic attribute too, and its value is equal to 1 if there is at least one member of the interviewed person’s family who is not autonomous in his movements. This attribute is included in the utility function of the two car alternatives and it is multiplied by the bMINOR coefficient.
- UFLXBL is an attribute that takes into account the flexibility that the considered person has in his starting working time; in particular, it is equal to 1 if the considered person has a flexibility on the starting working time of two or more hours, 0.5 if the flexibility that he has is of just one hour, 0.25 if the flexibility is of half an hour and, finally, 0 if the working time is strict. This attribute is included in the utility function of car during low hour, multiplied by bFLXCR, and in the utility function of motorcycle, multiplied by bFLXMC.
- ULNBREK is equal to 1 if the person has to return home or to conduct activities which require the use of a private mean of transport during lunch break. This attribute, always multiplied by bLUNBRK, is included in the utility functions of car during peak hour, car during low hour, motorcycle and car-pooling as a driver: the idea is that if a person has to move during the lunch break, the same person would be inclined to choose the alternatives that let him have a private mean of transport available at the site of work.

3.3.3. Choice attributes

These attributes are related with the choices made by the employees interviewed. This category includes all the attributes of the second row of the table: USAMCPT, USAMMCT, USAMBCT, USAMPED, USAMTRA, USAMPAR, USAMCPD, USAMCPP and USAMCLT.

These attributes usually have a value of 0, and are connected with the theory of stated preferences, that will be treated in one of the next paragraphs. The coefficient by which all of these attributes are multiplied is the same for each alternative and is named bSAMREV.

In the third row of the table contains additional attributes of the choice: UFETCPT, UFETMCT, UFETBCT, UFETPED, UFETTRA, UFETPAR, UFETCPD, UFETCPP, UFETCLT. The generic attribute UFET- assumes different scores depending on how much individual priorities match with the reasons identified as those that lead to choose the specific alternative.

In the following table it is shown how they are related to the mode of transport and the reasons that lead a person to choose one in particular.

	CPT	MCT	BCT	PED	TRA	PAR	CPD	CPP	CLT
Security	•				•		•	•	•
Health	•						•	•	•
Comfort	•							•	•
People's driving	•	•							•
Autonomy	•	•	•						•
Lack of efficient alternatives	•	•							•
Inefficient public transport	•	•	•				•	•	•
Non work related activities	•	•	•						•
Lack of cycle paths	•	•		•					•
Least stressful option		•	•	•			•	•	
Travel time		•	•	•					•
Environmental impact			•	•	•	•	•	•	
Difficulty of parking				•	•	•		•	
Cost			•	•	•	•	•		

Table 4 – Correlation among mode of transport and reasons

The last choice attribute is ONEASA. It assumes always value equal to 1. This attribute is included in the utility function of all the alternatives except for the alternative "car during peak hour", and is multiplied by a coefficient different for each of these alternatives.

3.3.4. Non-availability attributes

This category of attributes is extremely important because they take into account if a specific travel alternative is available or not for an employee. Below there's the description of the main attributes of Availability in the template:

- UCARAVIL takes into account if the person has a car that is available for his home-to-work trip; in that case the value of this attribute is 0, otherwise is 1.

- UMCAVIL takes into account if the person has a motorcycle that is available for his home-to-work trip; in this case, the attribute is equal to 0.
- UBKAVIL takes into account if the person lives near enough to the site to reach it by bike; in this case, the value of this attribute is 0, otherwise is 1.
- UWLKAVIL takes into account if the person lives near enough to the site to reach it by walking; in this case, this attribute is equal to 0, otherwise to 1.
- UTRAAVIL is equal to 0 (public transport is available) if the interviewed person arrives or would arrive at the nearest public transport stop by walking; if it is not the case, the value of this attribute would be 1.
- UPARAVIL is equal to 1 (park and ride is not available) if the interviewed person arrives or would arrive at the nearest public transport stop by walking; if the person uses or would use a private mean of transport (car, motorcycle or bike), park and ride would be available.

All of the attributes listed above are multiplied with the same factor called bNONAVL.

In the model there is an additional attribute of availability: UEBKAVIL. This attribute differs from the previous ones because it is equal to the cost of an electric bicycle, which is refunded by the company of the employee if the distance travelled in the journey to and from work is such as to allow the employee to use an electric bicycle.

If not, the value of this attribute is equal to 0. The attribute UEBKAVIL is multiplied by the coefficient bEAVL and is included in the utility function of the alternative modal "bicycle".

3.3.5. Parking attributes

The attributes of this category take into account the supply in relation to the availability or otherwise of parking spaces.

- UCCRPAR takes into account if the person can access the company parking with the car and it is included in the utility functions of the two car alternatives.
- UCCPPAR takes into account if the person can access the company parking as part of a car-pooling crew and it is included in the utility function of the car-pooling as a driver alternative.
- UCOPRKMC takes into account if the person can access the company parking with a motorcycle, and it is included in the utility function of the motorcycle alternative.
- UCOPRKBK takes into account if the person can access the company parking with a bike, and it is included in the utility function of the bicycle alternative.

UCCRPAR e UCCPPAR are multiplied by the same coefficient, bCAPRK, because it is assumed that the positive influence that the possibility of leaving the car in the company parking is the same in choosing car-pooling as a driver, car during peak hour and car during low hour. Similarly, UCOPRKMC and UCOPRKBK are multiplied by the same coefficient, bSCRPRK, because it is assumed that the positive influence that the possibility of leaving the motorcycle or the bike in the company parking is the same in choosing bicycle and motorcycle.

3.3.6. Additional service attributes

The additional attributes refer to the provided services in terms of parking. Here the main attributes are presented:

- UWTREBK is equal to the ratio between the number of electric company bikes available for people who work at the site and the number of employee of the site. This attribute is always multiplied by the same coefficient, bWTREBK, and it is included in the utility functions of five alternatives: bicycle, walking, public transport, park and ride and carpooling as a passenger.
- DRERMS is equal to 1 if employees are provided with locker rooms, and it is included, multiplied by bDRERMS, in the utility function of the bike alternative.
- SHWERS is equal to 1 if there are showers at the site that can be used by employees, and it is included, multiplied by bSHWERS, in the utility function of the bike alternative.
- UGRABACK is equal to 1 if there is a plan in place to ensure employees at the site can get home quickly in case of emergency. This attribute is always multiplied by the same coefficient, bGRABAK, and it is included in the utility functions of five alternatives: bicycle, walking, public transport, park and ride and car-pooling as a passenger.
- UWTRVEHC is equal to the ratio between the number of traditional company cars available for people who work at the site and the number of employees of the site. This attribute is always multiplied by the same coefficient, bWTRVEH, and it is included in the utility functions of five alternatives: bicycle, walking, public transport, park and ride and car-pooling as a passenger.
- UWTREVEH is equal to the ratio between the number of electric company cars available for people who work at the site and the number of employees of the site. This attribute is always multiplied by the same coefficient, bWTREVEH, and it is included in the utility functions of five alternatives: bicycle, walking, public transport, park and ride and car-pooling as a passenger.

- UCPOINF is equal to 1 if there is an IT system that puts in contact people who take the same route at the same time. This attribute is always multiplied by the same coefficient, bCPOINF, and it is included in the utility functions of the two car-pooling alternatives.
- SCNTU is equal to 1 if the company provides the employee with a discount to acquire the annual pass to public transport. This attribute is always multiplied by the same coefficient, bSCNTU, and it is included in the utility functions of public transport and park and ride alternatives.
- UBKCO is equal to 1 if the company provides the employee with a traditional bicycle, and it is included, multiplied by bBKCO, in the utility function of the bike alternative.
- UEQUP is equal to 1 if the company provides the employee with a discount to acquire the outfitting useful to arrive at work by bicycle, and it is included, multiplied by bEQUP, in the utility function of the bike alternative.
- STLN is equal to 1 if the company provides the employee with a discount for acquiring an insurance policy for the bike, and it is included, multiplied by bSTLN, in the utility function of the bike alternative.

3.4. Multinomial Logit Model

The Multinomial Logit is the main random utility model and the most widespread. Its assumptions are about the previously mentioned random residuals ε_k, as one of the two components of the utility u_k. The hypotheses are listed below:

i) Independence

This means having null covariance and as a consequence null correlation coefficient:

$$Cov\left(\varepsilon_i, \varepsilon_j\right) = \sigma_{\varepsilon_i \varepsilon_j} = 0 \qquad \rho_{\varepsilon_i \varepsilon_j} = \frac{\sigma_{\varepsilon_i \varepsilon_j}}{\sigma_{\varepsilon_i}\sigma_{\varepsilon_j}} = 0$$

ii) Identically distributed

iii) Distributed according to the Gumbel random variable. Its expression is the following:

$$\Pr(\varepsilon \leq x) = Exp\left(-Exp\left(-\frac{x}{\theta} - \gamma\right)\right)$$

Being:

	$\theta = 0.78 \cdot \sigma$	scale parameter
	$\sigma = \sqrt{\sigma^2}$	standard deviation
	$\sigma^2 = \frac{\pi^2 \cdot \theta^2}{6}$	variance
	$\gamma = -0.577$	Euler-Mascheroni constant

The properties of a Gumbel variable are:

- Null expected value

$$E(\varepsilon_i) = 0 \quad \forall j$$

- Stability with respect to the maximization if having the same parameter:

$$Max\ (u_k : k \in K) = gumbel\ variable$$

- Instability with respect to the summation, which means that the sum of two random Gumbel variables doesn't give back a Gumbel variable.

The probability of the alternative k is given by the following formulation:

$$p_k = \frac{\exp\left(\frac{v_k}{\theta}\right)}{\sum_h \exp\left(\frac{v_h}{\theta}\right)}$$

It is possible to express the probability since the Logit model has got an integral in closed form. For the same reason, the satisfaction too has a closed form:

$$w = \theta \cdot Log\left(\sum_k \exp\left(\frac{v_k}{\theta}\right)\right)$$

3.4.1. Dependence on the difference among systematic utilities

Let's consider two possible alternatives:

$$K = \{A, B\}$$

In this case the model is called Binomial Logit and the probability of one alternative is:

$$p_A = \frac{\exp\left(\frac{v_A}{\theta}\right)}{\exp\left(\frac{v_A}{\theta}\right) + \exp\left(\frac{v_B}{\theta}\right)} = \frac{1}{1 + \exp\left(\frac{v_B - v_A}{\theta}\right)} = \frac{1}{1 + \exp\left(\frac{\beta}{\theta} \cdot (a_B - a_A)\right)}$$

As the systematic utility is a linear form of attributes and parameters, the ratio $\frac{\beta}{\theta}$ is always present, and that is going to be calibrated as explained in 3.6.

Furthermore, the probability of one alternative depends upon the difference among the two systematic utilities. The possible results of p_A are tabled below according to a number of systematic utilities values.

$(v_B - v_A)$	p_A
$= 0$	$= 0.5$
$tends\ to - \infty$	$tends\ to\ 1$
$tends\ to + \infty$	$tends\ to\ 0$

Table 5 – Difference among systematic utilities

In the first case it means that the alternatives have the same utility, hence the model assigns the same value of probability to each. In the other cases, the probability tends to 1 when alternative A has an infinitely greater systematic utility and tends to 0 when B has.

Also the parameter θ plays a role since when it tends to 0 the model becomes deterministic, assigning probability 1 to the reference alternative; on the contrary when it tends to ∞, the error is so huge that completely clouds the systematic utility making all the alternatives equiprobable. The graph is an S-shaped semi symmetric graph as shown below:

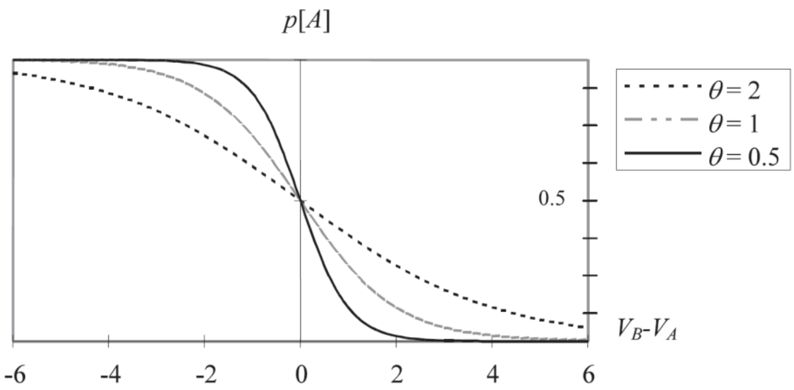


Figure 15 – Relation among systematic utility and scale parameter

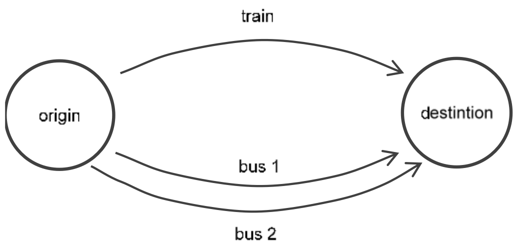
3.4.2. Disadvantages of model

The disadvantages of the Logit model are inside the basic assumptions. The model is not capable to identify alternatives that a user in real life could distinguish and to which he would assign different probabilities. This is named Independence of Irrelevant Alternatives (IIA). Let's give an example.

In case of two cities linked by train service and two lines of bus service, having the same travel time and cost, the Logit model will calculate a probability equal for all the three alternatives, whilst in actual fact the user will perceive only two real alternatives.

$$p_{bus1} = p_{bus2} = p_{train} = \frac{1}{3}$$

Indeed, the two buses will be aggregated as a single alternative.



$$p_{train} = \frac{1}{2}$$
$$p_{bus} = \frac{1}{2}$$

Figure 16 – IIA example

3.4.3. The role of the model in demand estimation

Transportation demand is structured in the following way:

$$d_{o,d,m,r}^{g,s,h} = f\left(\underline{a^{SE}}, \underline{a^{LOS}}, \underline{\beta} \right)$$

Where:

- o origin
- d destination
- m mode of transport
- r route
- g user class
- s purpose
- h reference period

Therefore, the demand is a function that depends upon the socio-economic and the level of service attributes as well as the parameters β.

With the aim of determining the average value of demand flow, a specific procedure is carried on. Indeed, the total demand is the fraction of the demand generated from a given origin multiplied by the probabilities associated to the decision making steps. It is identified with the name of "4-steps Model" and it is summarised with following expression:

$$d_{o,d,m,r}^{g,s,h} = d_{o}^{g,s,h} \cdot p_{d|o}^{g,s,h} \cdot p_{m|do}^{g,s,h} \cdot p_{r|mdo}^{g,s,h}$$

The logical process is presented in the flow chart below.

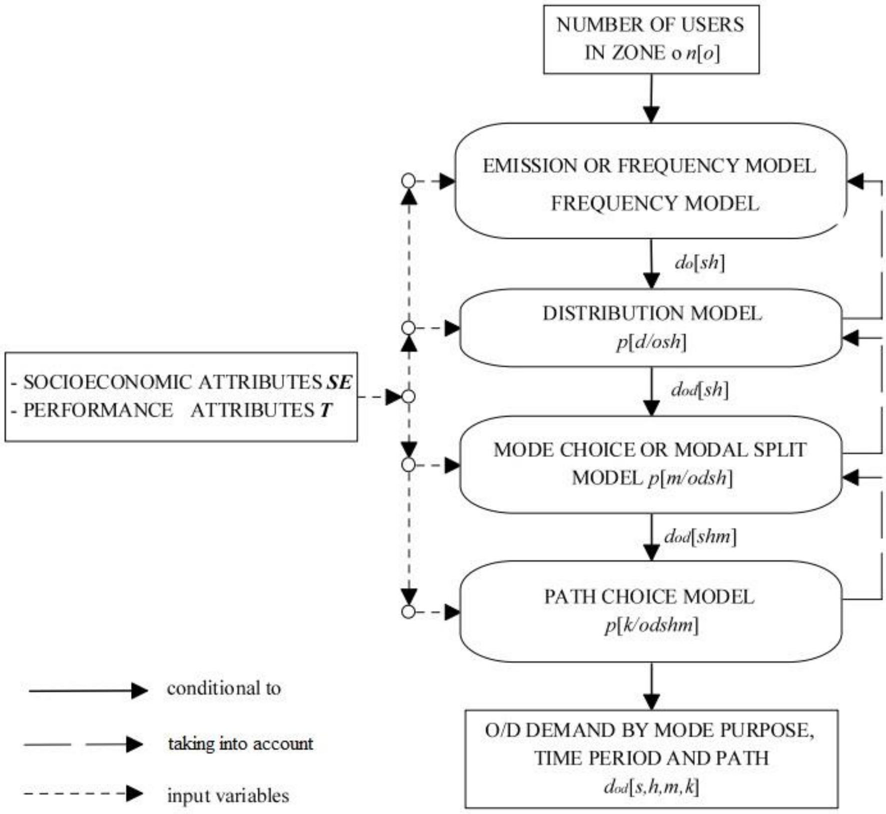


Figure 17 – Demand estimation flowchart

Where: $d_o^{g,s,h}$ trip production which gives the number of users in class g who, from origin zone o, undertake a trip for purpose s in a time period h;

$p_{d|o}^{g,s,h}$ distribution model which gives the fraction of users in class g in terms of probability, undertaking a trip from origin zone o, for purpose s in a time period h towards destination zone d;

$p_{m|do}^{g,s,h}$ mode choice model which gives the fraction of users in class g in terms of probability, undertaking a trip from origin zone o to zone d, for purpose s in a time period h, that uses mode m;

$p_{r|mdo}^{g,s,h}$ route choice model which gives the fraction of users in class g in terms of probability, travelling from zone o to zone d for purpose s in a time period h using mode m, that uses path r.

The third step is the one of our interest, the modal choice is indeed modelled by a Logit model. It properly describes the choice that people daily face with among the possible alternatives. As already mentioned to each possible mode of transport a utility is assigned assuming that the user will choose the one with the highest value. The closed form of the probability can be written as:

$$p_{m|do}^{g,s,h} = \frac{\exp\left(\frac{v_{mk}}{\theta}\right)}{\sum_h \exp\left(\frac{v_{mh}}{\theta}\right)}$$

where the set of alternatives is populated by all transport modes.

The assumptions about the lack of correlations between alternatives previously made are still valid leading to a variance-covariance matrix Σ of the kind:

$$\Sigma = \frac{\pi^2 \cdot \theta^2}{6} \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix}$$

The above mentioned matrix has as many rows (and columns) as the alternatives are, with only one value of variance due to the homoscedasticity nature of the model.

3.5. Stated preferences methodology

The stated preferences methodology is fundamental to calibrate models that consider non-concrete situations. It could happen that one or more attributes may be equal to zero for all the interviewed people because the service or facility is missing at all. For instance, if showers are not provided to employees, the relative attribute SHWERS would be equal to zero making impossible to simulate the intervention of installation of that kind of facilities.

In order to overcome this limitation, non-real situations are presented to the interviewed who is asked of what alternative would be chosen in the stated situation. This technique allows to have both records coming from real situations and from hypothetic ones, called revealed and stated preferences respectively.

When using this methodology, people tend to confirm the current choice when a stated situation is presented. To avoid this problem, a "confirmation" attribute has to be introduced in the model for each alternative. It is always equal to 0 if the record comes from a revealed preference, while, if it comes from a stated preference in which the person has chosen the same alternative used at the current situation, the confirmation attribute associated to the mode of transport currently used is equal to 1. In the model that has been specified in the previous paragraph, the confirmation attributes, one for each alternative, are USAMCPT, USAMMCT, USAMBCT, USAMPED, USAMTRA, USAMPAR, USAMCPD, USAMCPP E USAMCLT.

Another problem of the stated preferences methodology is that the value of the parameter θ is different if referring to real-world scenarios or fictitious ones. To overcome this kind of problem, when the calibration of the model is realised taking into account both types of scenario, it is necessary to introduce a scale parameter, with the purpose of considering this difference. The scale parameter is multiplied by all the coefficients when the data comes from the stated preferences.

3.6. Mention of calibration and validation technique

3.6.1. Calibration of a model

Through the collection of data, it is possible to calibrate model's coefficient. These data comprehend both inputs and outputs of the model itself and the aim is calibrating the coefficients by matching among them.

The ordinary least square is one of the most efficient and common calibration method however, it doesn't suit in case of random utility models and probabilistic problems in general. That is why another method has been implemented namely the maximum likelihood estimation.

The variables at stake are the systematic utility and the probability expressed as follows; β are going to be calibrated.

$$v_k\left(\underline{a_u}, \underline{\beta}\right) = \sum_{p \in P} \beta_P \cdot a_{X_{pk}u} \qquad\qquad p_k = p_k\left(\underline{v_k}; \underline{\beta}\right)$$

The attributes associated from each user u to the systematic utility and the choice made represent the sample S. The calibration process consists of minimising the so called *estimator*, which is the likelihood function of the parameters β.

$$L\left(\underline{\beta}\right) = \prod_{u \in S} p_{k_u}(v_k(\underline{a_u}, \underline{\beta}), \underline{\beta})$$

The product among the probabilities is made possible since the random sampling is simple, hence the events are statistically independent. For operational reasons, the calibration is performed maximising the logarithm of $L\left(\underline{\beta}\right)$ (or minimising the $-L\left(\underline{\beta}\right)$). Due to the logarithms properties it results:

$$Log\left(L(\underline{\beta})\right) = \sum_{u \in S} Log(p_{k_u}(v_k(\underline{a_u}, \underline{\beta}), \underline{\beta}))$$

It stands for the probability of goodness of representation of the universe and the highest value possible is sought. By maximising the above expression, the vector $\underline{\beta}$ of parameters is obtained.

$$\underline{\beta} = \arg\max\left[Log\left(L(\underline{\beta})\right)\right] = \arg\max\left[\sum_{u \in S} Log(p_{k_u}(v_k(\underline{a_u}, \underline{\beta}), \underline{\beta}))\right]$$

3.6.2. Validation of a model

After having calibrated the model, the vector $\underline{\beta}$ has been found out. The validation phase aims to judge if the model is adherent to the real facts or not. A number of methodology can be applied.

1. Informal tests

   These test regard the checking of $\underline{\beta}$ values, signs and ratios one by one. They must be reasonable and have the right power of explananation.

2. Formal tests

   The formal tests on null hypothesis are conducted by controlling the probability of having the mean of the sample within the universal distribution assumed normal-standard. They are based on the Student *t* statistic.

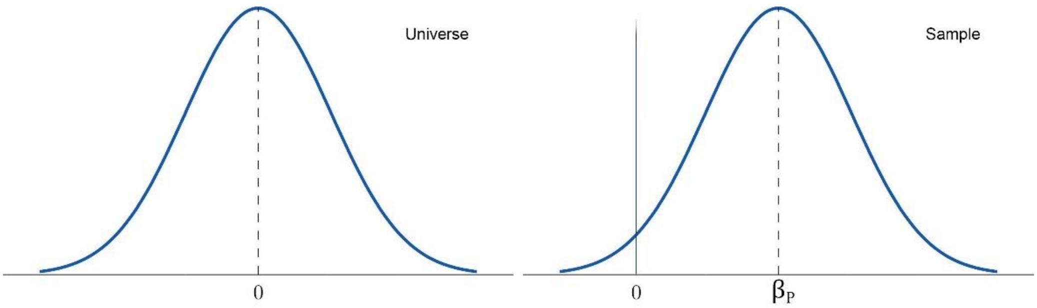


Figure 18 – Universe and sample distribution

By definition, the normal standard distribution has got null mean and variance equal to 1, consequently the standard deviation too is equal to 1. It is assumed for the sample to have the same standard deviation of the universe because what is relevant in this test is the relation among expected values.

	Universe	Sample
mean μ	0	β_P
variance σ^2	1	1
standard deviation σ	1	1

Table 6 – Universe and sample characteristics

The following indicator is carried out, in order to evaluate the displacement between the mean of the sample with respect to the universe's one.

$$t = \frac{\beta_P - \mu}{\sigma}$$

The higher is the value of t, higher is the confidence with which the hypothesis can be rejected. This means that a very low value of t is requested in order to have a good representativeness of the universe. For instance, if t = 3 the sample can be rejected with around the 99% of probability.

Another indicator is carried out by the rho-square statistic. It is defined as:

$$\rho^2 = 1 - \frac{Log\ (L(\beta_P))}{Log\ (L(0))}$$

The test can judge the model as:

- Perfect, when $\rho^2 = 1$. This means that $Log\ (L(\beta_P)) = 0$, therefore the argument of the logarithm, i.e. the probability of goodness of the sample, is equal to 1.
- Useless, when $\rho^2 = 0$. This means that $Log\ (L(\beta_P)) = Log\ (L(0))$ therefore $\beta = 0$ and the events are equiprobable.

In real cases it is impossible to have $\rho^2 = 1$ and an acceptable value stands at 0.66.

3. Alpha validation

Finally, this test compares the results of the model with the ones of a survey. Let:

- k_u^{max}: be the alternative with the maximum probability to be chosen, gave back by the model;
- k_u: be the alternative actually chosen by the user;

- α: be a certain threshold of probability, fixed by the modeller.

Three possible situations may arise, as shown in the following figure.

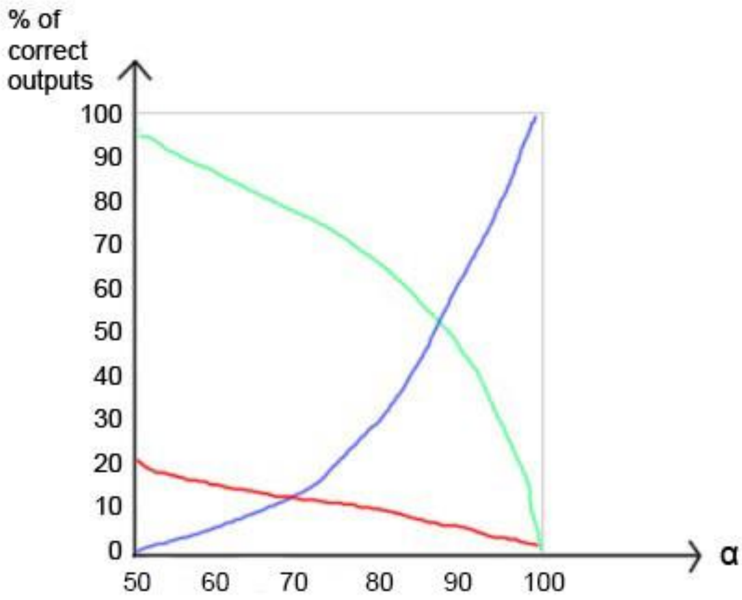


Figure 19 – Alpha validation outcomes

- Clearly right: is the green curve if $p_{k_u^{max}} \geq \alpha$ and $k_u^{max} = k_u$. For low values of α a high percentage of outputs well represent reality, decreasing as α increases. This is reasonable because as the "goodness" or "fit" requested increase, the percentage of correct outputs decreases.
- Clearly wrong: is the red curve if $p_{k_u^{max}} \geq \alpha$ and $k_u^{max} \neq k_u$. Even for low values of α the percentage of goodness is very low.
- Unclear: is the blue curve if $p_{k_u^{max}} < \alpha$. It doesn't make sense that as the requested goodness increases the percentage of good outputs arises too, to the point that for $\alpha < 0.5$ or even less the percentage of outputs would less or equal zero.

PART TWO

4. Case study: Tiburtino Industrial Site

4.1. Characterization of the Site

The Tiburtino Industrial Site is the largest industrial area of Rome and it is located in the north-east of the suburbs. It doesn't spread only in a wide area but it collects a large number of companies making it an attractive spot: every morning it is the destination of approximately twenty thousand among employees, visitors and operators to the movement of goods.

Figure 20 – Tiburtino Industrial Site location

The area covers about 8 km^2, equivalent to 800 hectares, and is delimited between two main arteries, the Tiburtina street and the A24 highway Rome-Teramo, and two urban streets: Tor cervara street and Tecnopolo street.

As far as the productive sectors in which the companies are inserted, informatics, electronics and ICT are the most fervent fields arriving in the years to a very high level of specialization and reference in national field.

Over time, both sides of production have established not only from the software point of view, but also from the real manufacture. Many companies are directly involved in the construction and design of satellite components, orbiting platforms and space transport systems that show the particular vocation of enterprises to the aerospace sector, including the management of a global satellite navigation system. The mechanical, metalworking and plant engineering sector is also important in the field of materials, thermotechnology and telecommunications. Regarding the distribution of enterprises, the smaller ones tend to concentrate more in the central areas while the larger medium-sized ones in the outer zones.

The study of mobility, due to the high number of actors involved, is a very important aspect both from the companies' side and from the one of urbanization.

The Tiburtino Industrial Site involves 24 companies with more than 20000 employees with a daily traffic between 10 and 50 heavy vehicles and approximately 3000 tons of goods enlivened per year for each company. This is symptomatic of the high level of attraction that the Site exerts on the Roman and national industry.

4.2. Territorial framework

The Tiburtino Industrial Site raised along the Tiburtina-Valeria street, one of the seven main consular roads of Rome. It takes its name from the cities it connected and still links nowadays: Rome and Tibur, now known as Tivoli. Whilst "Valeria" bears the name from the Roman consul Marco Valerio Massimo who established its building in 286 B.C.. This name is in accordance with the Royal Decree of May 18, 1933, n. 1770 that changes its name from the simple "Tiburtina". The road, ending in Pescara, was the main connection between the city of Rome and the Adriatic Sea.

Figure 21 – Aerial sight of the Site

The territory has been inhabited since the dawn of time and the activities left several archaeological rests especially in among Ponte Mammolo and Settecamini. There's nothing left of the numerous sepulchres that flanked the ancient Tiburtina between the V and the IV mile; the great circular mausoleum near the actual street of Casal de' Pazzi has been completely demolished in the forties. During the process of territory urbanization, the only structures that survived are: a resting place near Stanislao Cannizzaro street, the sepulchre near Padre Lino da Parma street where the cippo is preserved in travertino with the indication of the VI mile and a line of the ancient street with funeral structures and rests of an ancient warehouse located at km 10,300. In any case, Roman villas, medieval towers, ancient quarries and bridges accompany the route traced by this important street although they are not valued as they would deserve.

An entity that has always strongly characterized the area is the Aniene river that was used for the movement of building material such as tuff and travertine and that, thanks to its tributaries, it was also a great source of water for the vast agricultural funds.

It is from the Twenties of the past century (about 1922-23) that some industrial settlements begin to born in the Tiburtina area; soon after, from 1924 to 1937, the so-called official villages raised, they are social housing settlements built in the areas of the Agro Romano, imagines to transfer the residents of the older town, destined for gutting and renovations. This confirms the transformation of the area from agricultural to industrial, from countryside to urban suburbs, which will characterize the new identity of the quadrant in favour of the abandonment of the "rural soul", for a newer worker one. The residential settlements of San Basilio, Pietralata and Colli Aniene begin to shape up, symbolizing how the demographic and urban context was that of the metropolitan suburbs.

Since 1976 the whole area surrounding Tiburtina, near the junction with the GRA, is included in two detailed plans for productive settlements: 18L– tiburtino with an extension of 320 hectares and 9L – Tor cervara 44 hectares. Both plans are public initiative regarding the works of primary urbanization that, through specific interventions, rediscover and value a new functional profile equipped with the necessary supporting infrastructure, environmental quality and settlement, but especially able to give adequate answer to the current demand for localization of the Roman production system. This has not, however, contrasted over time the construction of manufactured products built abusively, in fact in the following years several recovery interventions were carried out, consisting in radical restructuring, or in the demolition of used buildings, to build new edifices, socialization and urbanization area and squares.

Today the axis of Tiburtina connects the Roman periphery directly with two of the most populous municipalities of Lazio (Guidonia and Tivoli) and is one of the most densely inhabited quadrants of the metropolitan area of Rome.

4.3. Sample creation

This project has been activated and carried on by Unindustria that is the is the Association of Manufacturers and enterprises of Rome, Frosinone, Latina, Rieti, Viterbo. They act as a pivot of economic development in the provinces of Rome, Frosinone, Latina, Rieti, Viterbo and as a benchmark in our territory's cultural and social life.

The Tiburtino site is emblematic in the city of Rome in terms of entrepreneurship and industry spanning more than 150 companies. Computing, electronics and ICT are the most fervent fields within the pole bringing the specialization in these topics to a very high level and reference in the national field.

Over the time, both sides of production have established not only from the software point of view, but also from the real manufacture. Many companies are directly involved in the construction and design of satellite components, orbiting platforms and space transport systems that show the particular vocation of enterprises to the aerospace sector, including the management of a global satellite navigation system. Together with this, defence and electronics make Lazio the only Italian region to have all the aerospace sectors present.

The mechanical, engineering and plant engineering sectors are also important in the materials, thermotechnology and telecommunications sectors. Recently, however, to respond to new needs such as diagnosis, treatment, rehabilitation but above all to prevent and slow down disease and aging, the number of present realities, whose activity is focused on biomedical and related equipment, new methods of microbiological analysis has increased, on the preservation of stem cells and products and solutions for health care.

There are also other areas covering business services, financial services, supervisory training and advice and security technology systems, management and organizational advice for the development of systems for business and technicalcommercial management, legal protection of medical personnel, development of human resources and insurance brokerage up to the tourism industry.

As far as the distribution of enterprises is concerned, the smallest tend to concentrate more in the central areas.

The sample has been made up of the following companies which participated to the survey reaching around 1000 completed questionnaire.

Figure 22 – Companies' logos

They are located as shown in the following figure:

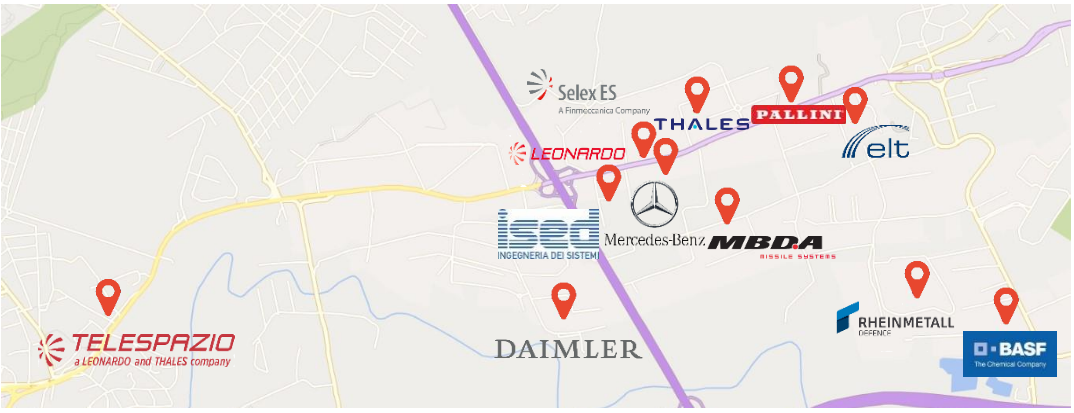


Figure 23 – Sample's companies location

This is actually a very good answer rate making possible a very reliable mobility plan as reported in the following chapters of part two.

5. The Home-to-Work trip plan of the Site

5.1. Data collection

In this section it will be deeply analysed compiled by the employees of the companies involved in the survey through the software MobilityManager. These questionnaires contain both the main information on the mobility choices made by the company's workforce and the characterisation of the individuals concerned, in terms of age, gender, qualification, residence, place of work and personal aptitudes. This knowledge is at the basis of the formation of a framework of the current situation, and is also essential for the identification of effective measures for a more sustainable mobility.

Indeed, the analysis of the questionnaires allows to understand the nature of the choices of mobility carried out and to identify any constraints and criticalities present in the current scenario of mobility, with specific reference to individual workers or the local transport system. The results of the interviews, reported and elaborated in the following study, refer only to the employees who completed the questionnaire. All data, sorted and classified, are shown in chart form to ease the comprehension and have been aggregated among companies. The graphs shall be accompanied by the relevant analyses containing the information that can be deduced from the reported data.

5.1.1. Answering rate

The following pie chart shows the number of completed and not questionnaires.

Out of a total of 5526, in green there are 1065 completed questionnaires and 4461 employees who have never logged in to complete the survey.

Below are the percentages of completion of the questionnaires on the total number of employees:

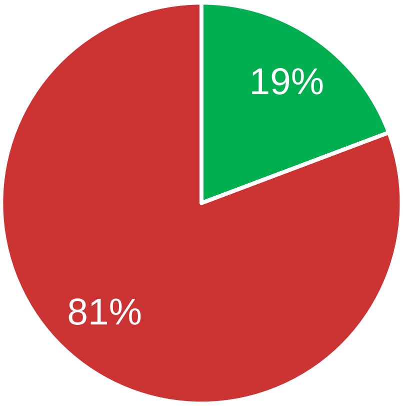


Figure 24 – Answering rate

Despite the green percentage may seem to be low, actually more than one thousand of individuals constitute a very strong representative sample, capable to describe very well the so called "universe".

5.1.2. Employees' profile

This section summarises the main personal and occupational characteristics of employees. Please note that the information relates to the employees who replied to the questionnaire.

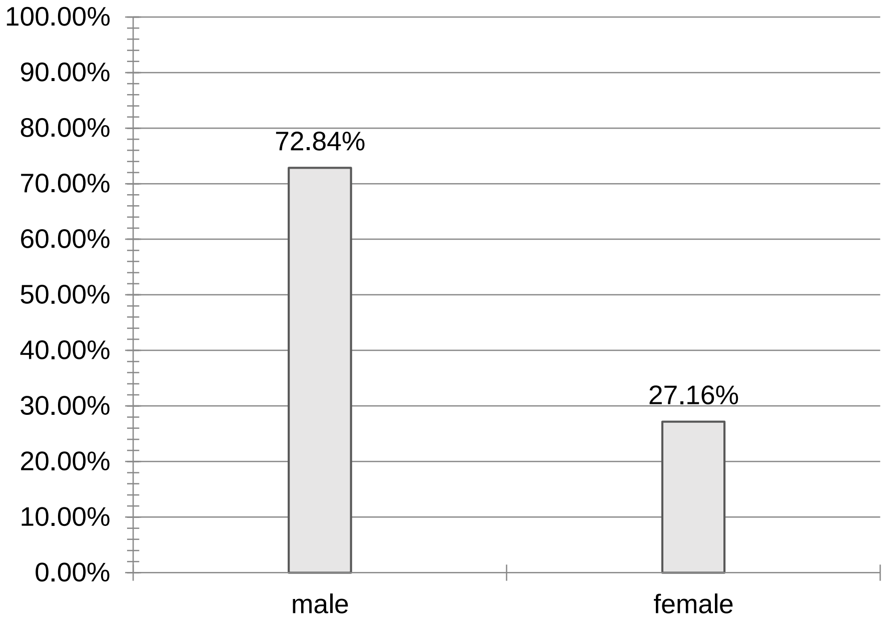


Figure 25 – Gender

The majority of the employees are male, around the ¾ out of the total with respect to female.

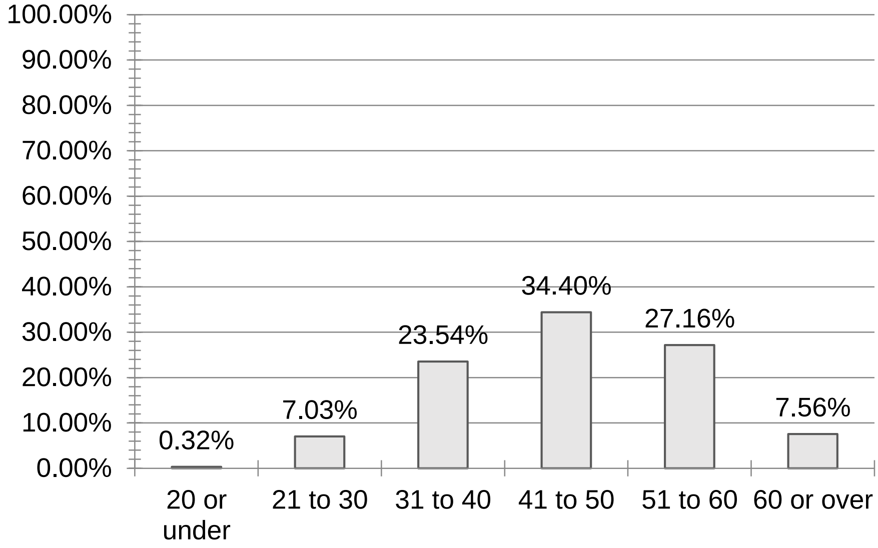


Figure 26 – Age split

Twenty y/o employees are almost null in the sample, whose majority stands among 41 to 50 y/o; a good percentage is recorded for both 31 to 40 and 51 to 60 ranges.

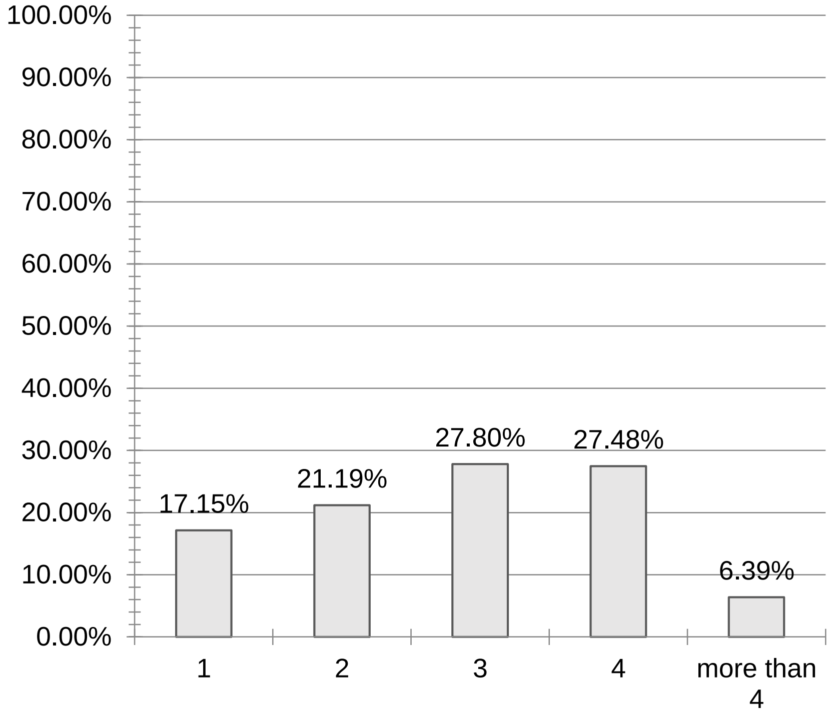


Figure 27 – Members in your family

On average, for all companies, there is a low proportion of employees with a household of more than four. For all holdings, there is an average percentage of households of 2, 3 or 4 persons over 90 %.

The diagram shows the percentage of employees in the household who are unable to move independently and who therefore need to be accompanied for their travel. This figure is part of the transport analysis for home-to-work journeys as it is necessary to consider the strong need for autonomy and flexibility of this category of employees, who may need to change their path in order to accompany those family members. In the first instance it could be expected some resistance from these to the use of modes of transport such as carpooling or public transport.

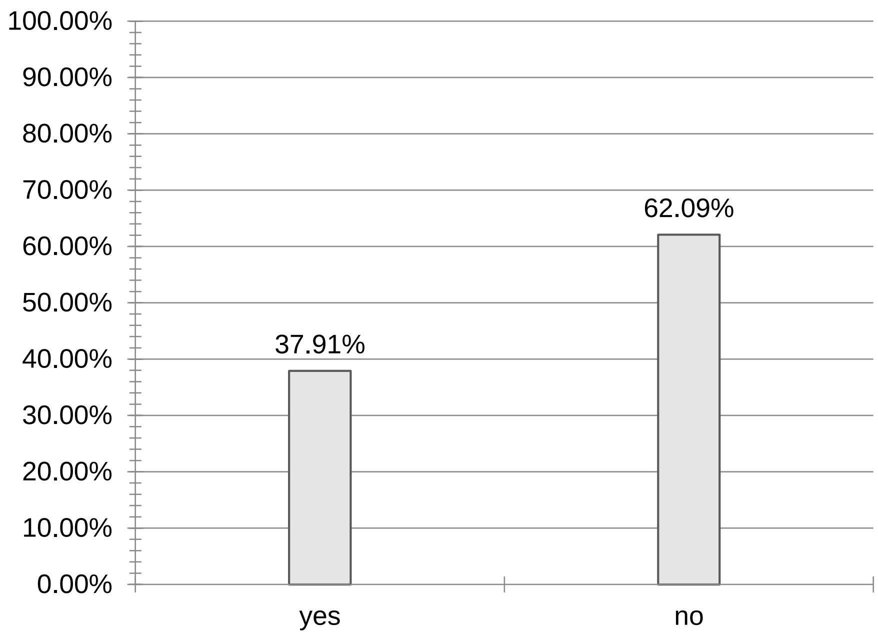


Figure 28 – Presence of disabled in your family

More than 60 % of all employees declared that they did not have family members unable to move independently.

The percentage breakdown of employees according to the nature of the contract governing their employment relationship is given. Almost all employees have an open ended contract indicating a stable workforce, which has the necessary serenity to be able to plan their home-to-work mobility in the long term. This is the optimal context in which to design targeted interventions, which can lead to stable changes in employee modal choice behaviour.

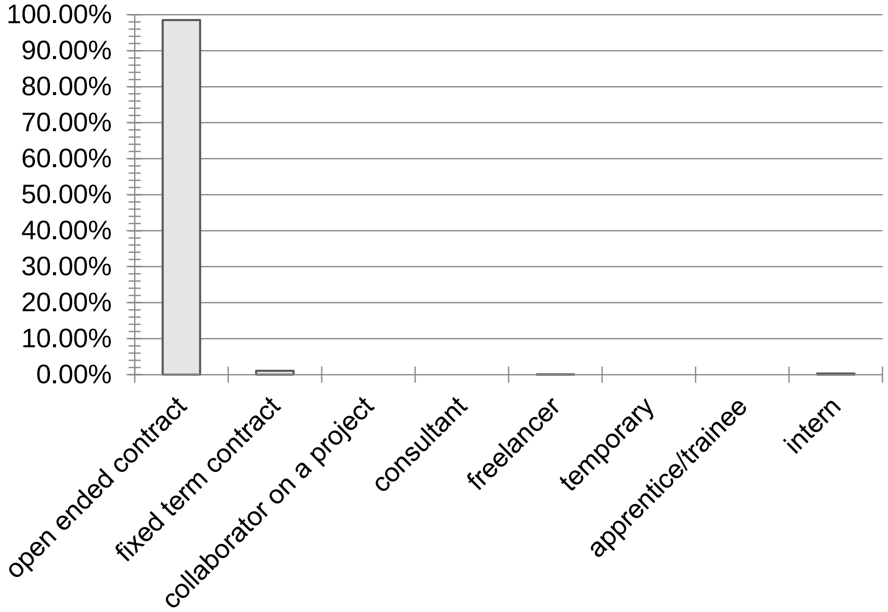


Figure 29 – Relationship with the company

5.1.3. Travel habits

In the following chart the number of working days declared from employees is shown:

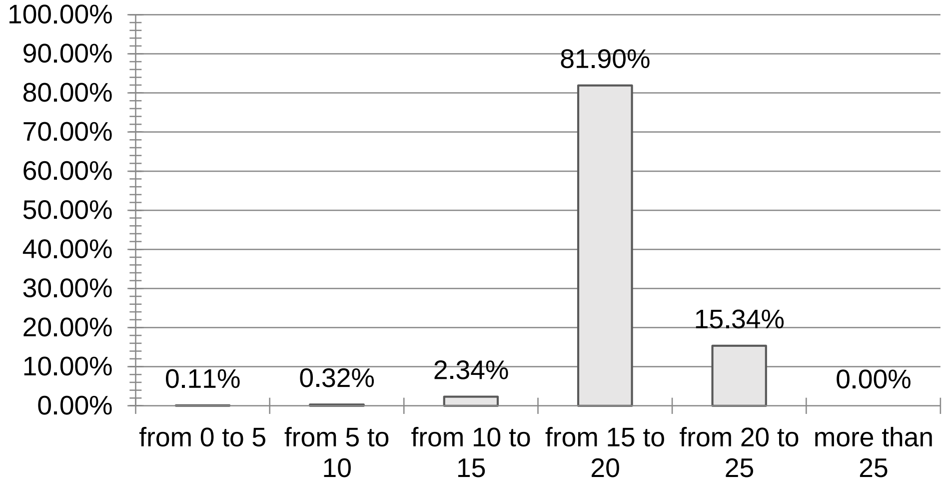


Figure 30 – Number of working days

The large majority of employees declared to work between 20 and 25 days per month.

In the following bar chart the entrance and exit hours are presented. The most congested hour in the morning is the one within 7:00 and 8:00 with more than 50% of individuals going to work; in the evening, roads are congested by more than 70% of people going back home.

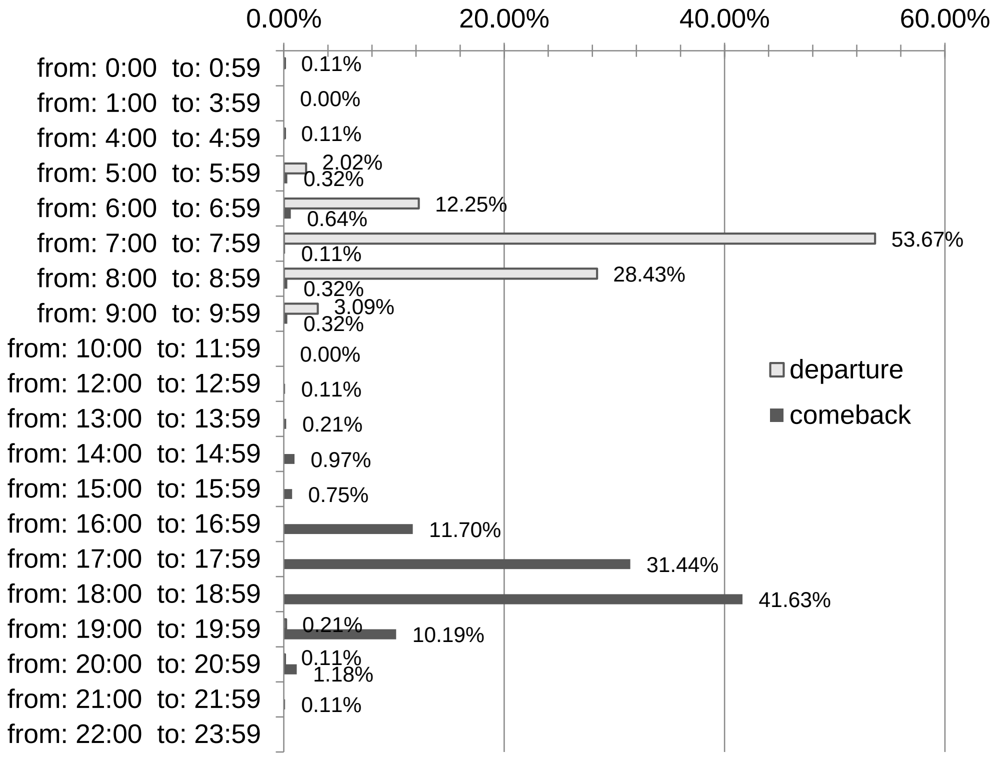


Figure 31 – Departure and comeback hours

That is what actually defines the concept of "peak-hour".

The chart on the right shows the degree of flexibility in the entrance at work in the morning. It is noticeable that if a high rate of flexibility existed, there could be a good propensity in using alternative mode like public transport and carpooling, whose flaw may be an extension in travel time.

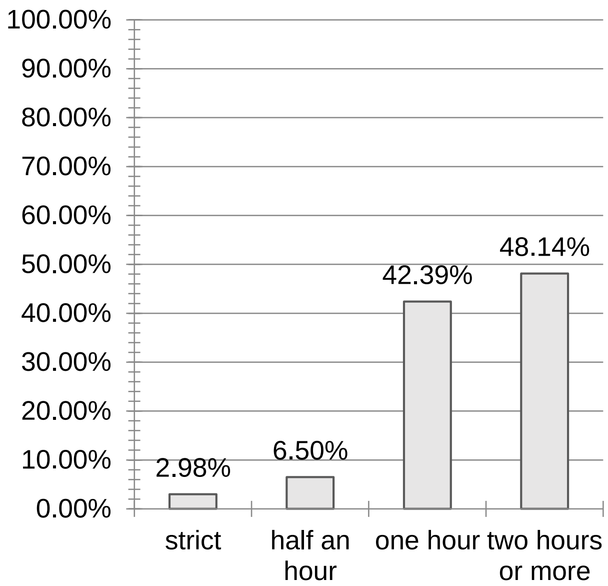


Figure 32 – Flexibility

Then, employees were asked about the activities during lunch time.

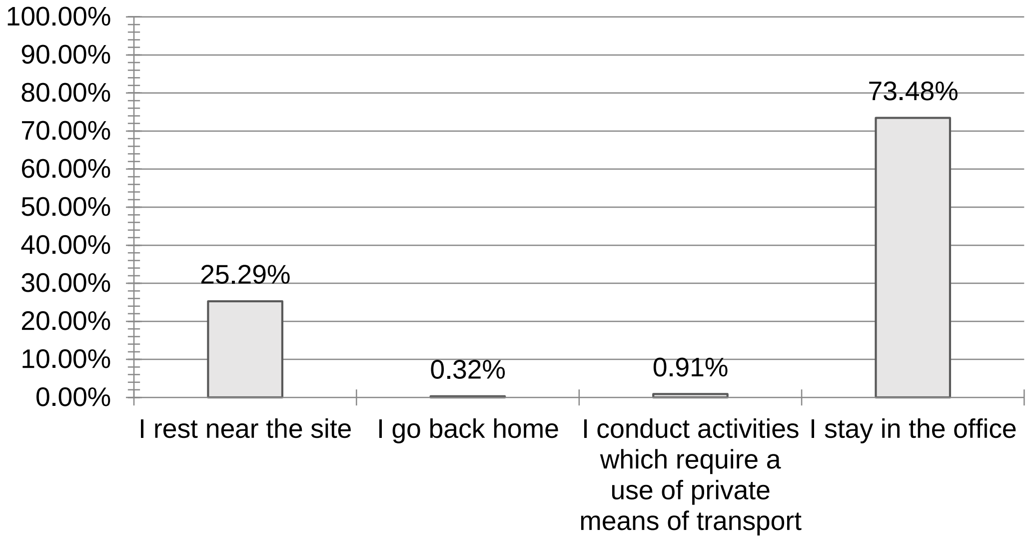


Figure 33 – Activities during lunch time

Almost all of them doesn't move away from the workplace, thus the lack of need of a private vehicle during that time may suggest again to use an alternative one.

The same is confirmed about the frequency of stops during the home-to-work trip: the 75% go directly to work from home without any other needs.

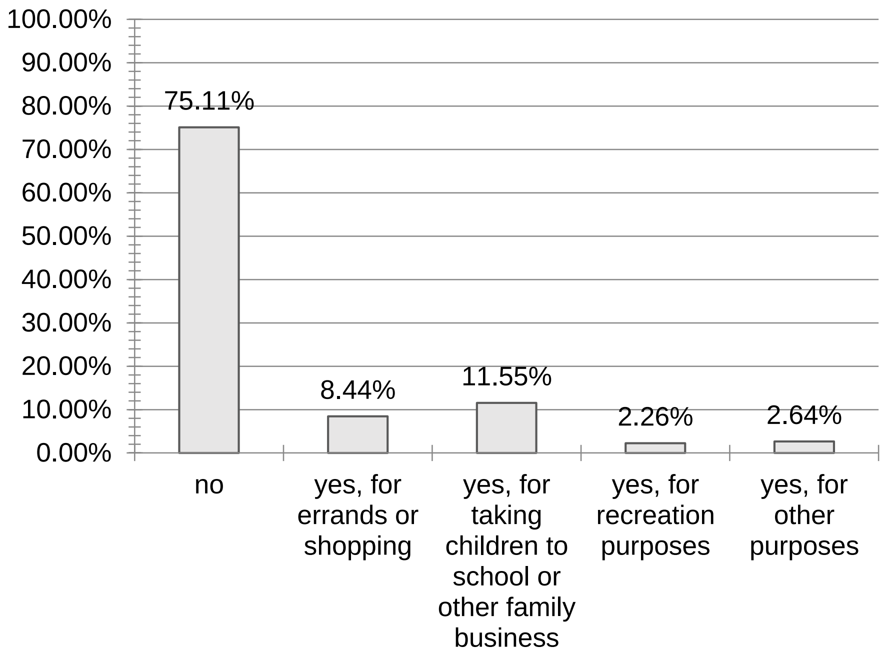


Figure 34 – Stops during home-to-work trip

5.1.4. Ownership of private vehicles

The following chart shows the availability of a vehicle to reach the workplace. Almost all of the employees own a private vehicle, the other 20% owns motorcycle and bicycle.

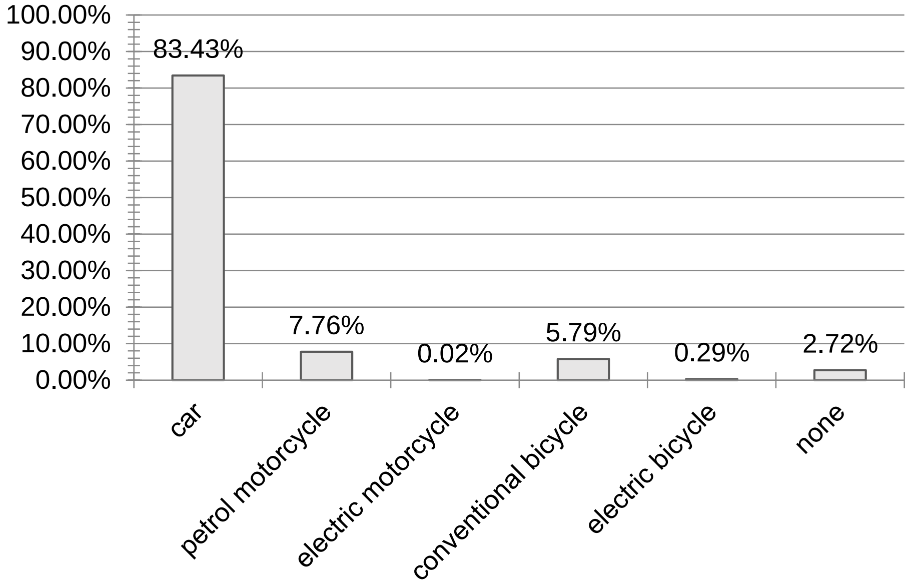


Figure 35 – Vehicles' availability

The diagrams below give a description of the typology of the owned car. This question has been asked only to cars' owner. The former about the supply whilst the latter about the emission class, according to EURO classification.

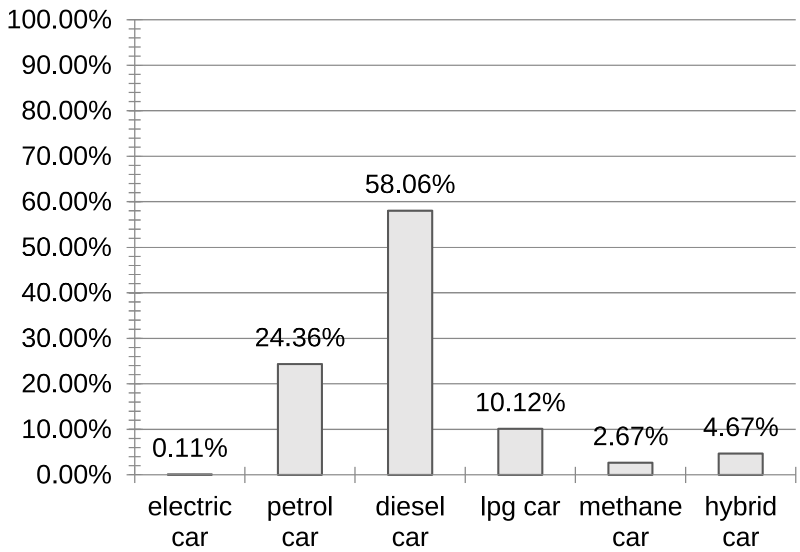


Figure 36 – Fuel supply

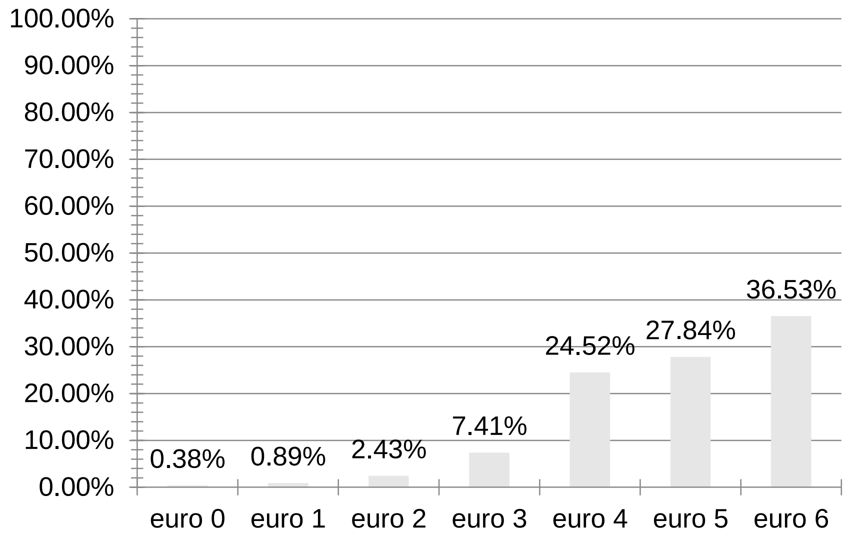


Figure 37 – Classification emissions for cars

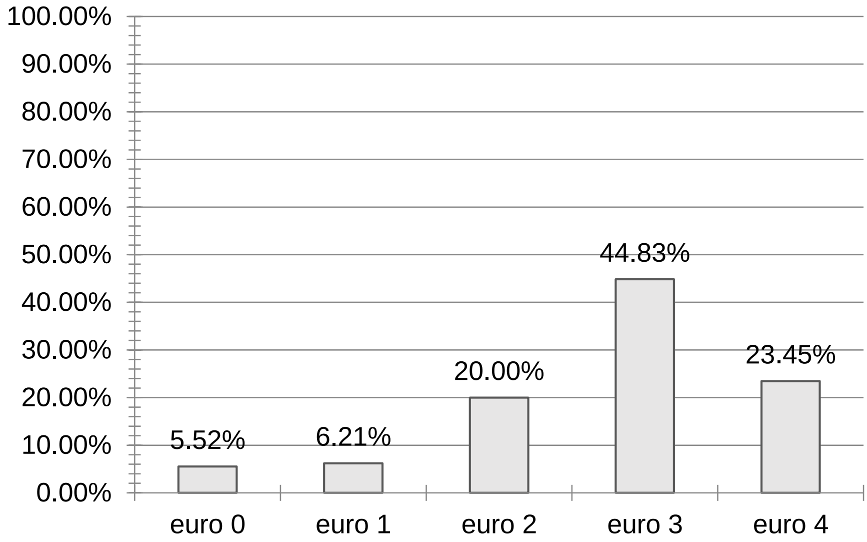


Figure 38 – Classification emissions for motorcycles

For what concerns cars, the fleet is higher than EURO 5 for more than 60%. Motorcycles too are quiet new but the majority stands at a EURO 3 standard. These results are rather satisfactory but could be improved.

5.1.5. Parkings

In this paragraph it will be discussed the parking of cars and how employees behave about it.

The following diagram describes the possibility to access to the company car park.

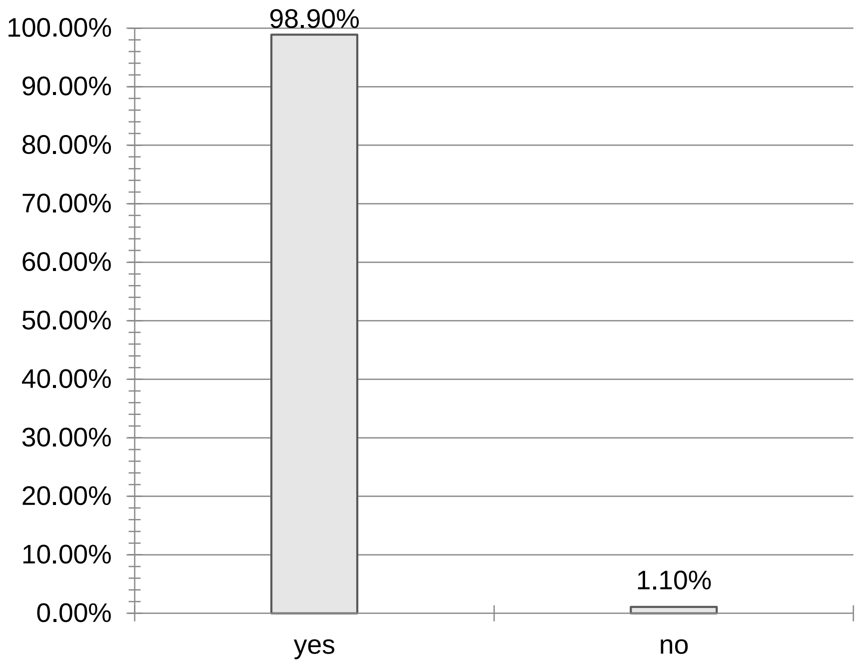


Figure 39 – Possibility to access the company's parkings

Thanks to the suburban nature of the Site, each company has wide parking areas outside the buildings. These slots are actually available to all employees.

Alternatively, the car would be parked on street for most people, as described in the following figure:

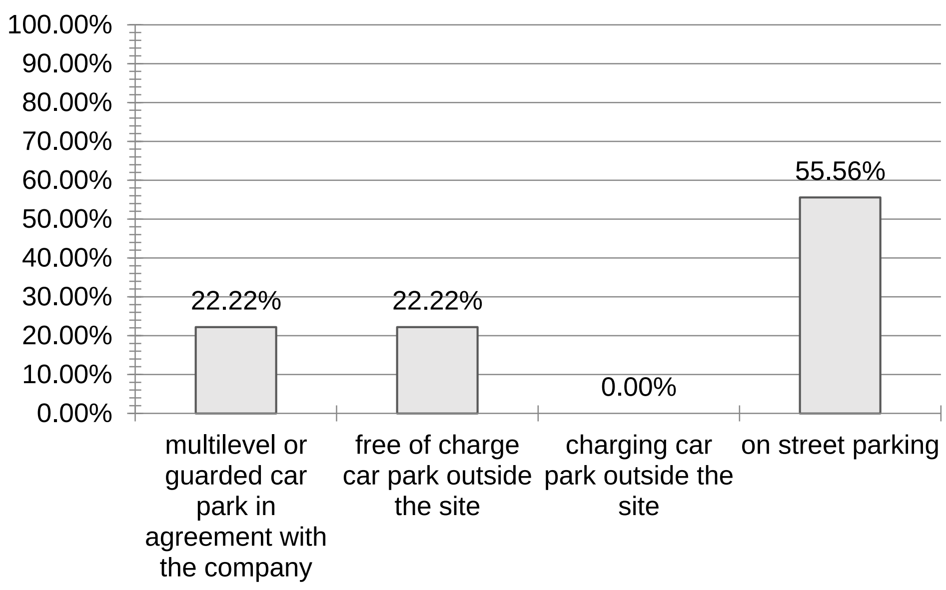


Figure 40 – Parking of cars

Then, workers were asked about the perception on the existence of problems for parking the car in the proximity of the workplace. For the reasons previously explained, the 75% declared to not to have problems in parking the vehicle.

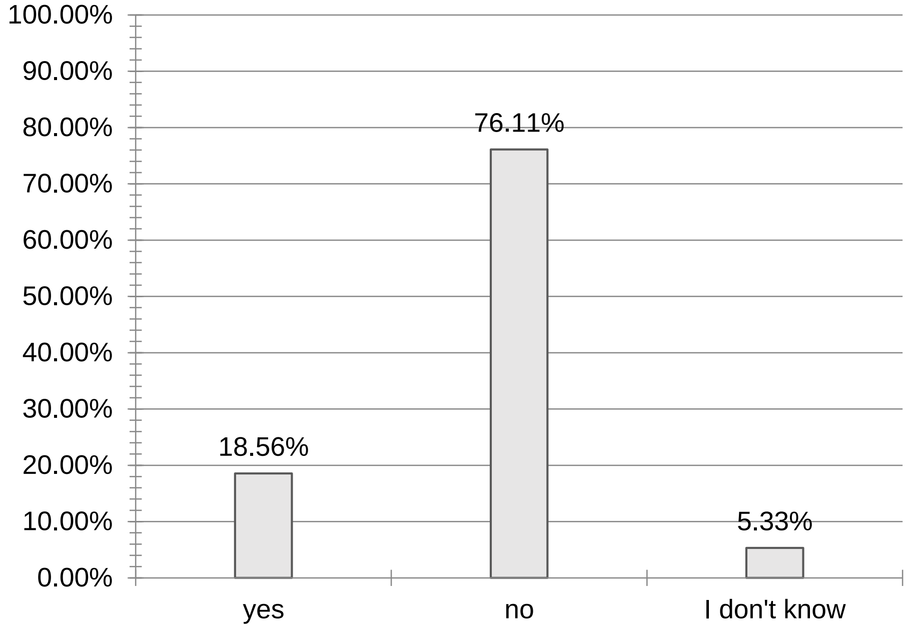


Figure 41 – Problems of parkings near workplace

The same cannot be said for what concerns bicycles, indeed more than the 50% of respondents state that adequate facilities for parking bikes are missing.

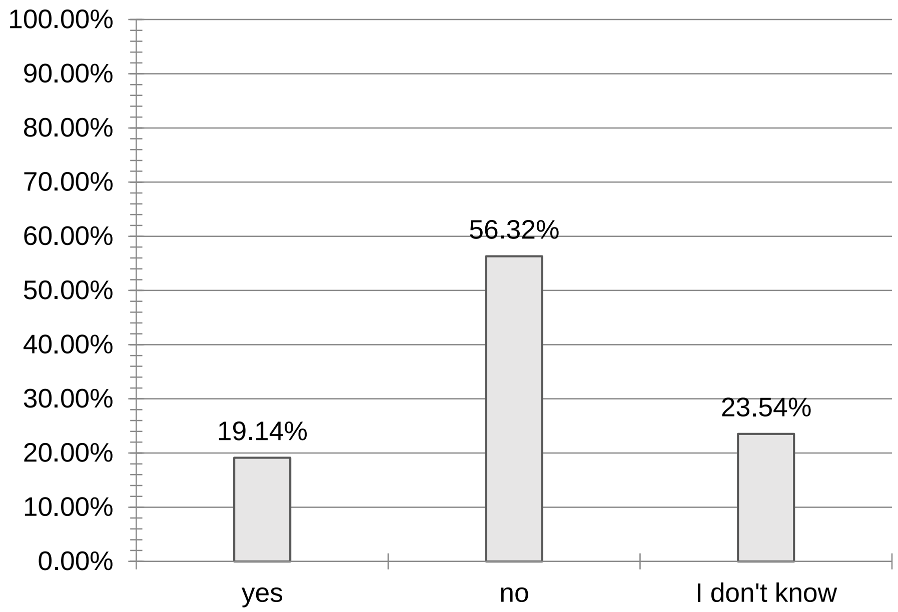


Figure 42 – Adequate parkings for bikes

5.1.6. Domiciles

This section describes the geographical distribution of employees' domiciles. This figure is particularly relevant for the analysis of home and work journeys, since domicile is the point of origin of travel. The overall indicators given in the section about the estimation of externalities derived from the processing of the workplace location. A map showing the location of the domiciles of employees is given. Specifically, the images refer to the geographical area closest to the city.

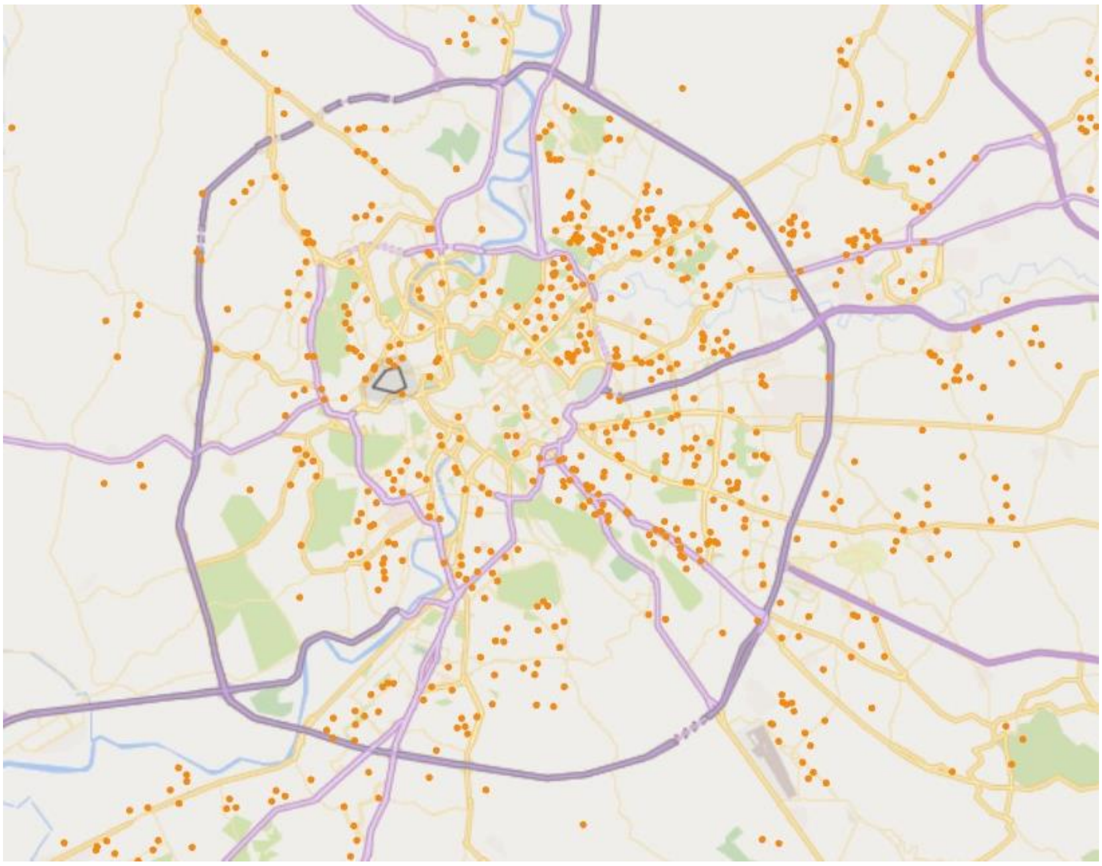


Figure 43 – Geolocalization of employees' domiciles

The following heat map shows the urban density of workers that concentrate mainly in the north-east sector of the city that is the nearest area to the Tiburtino Site. This datum suggests the real possibility to design a collective transport system based on that area.

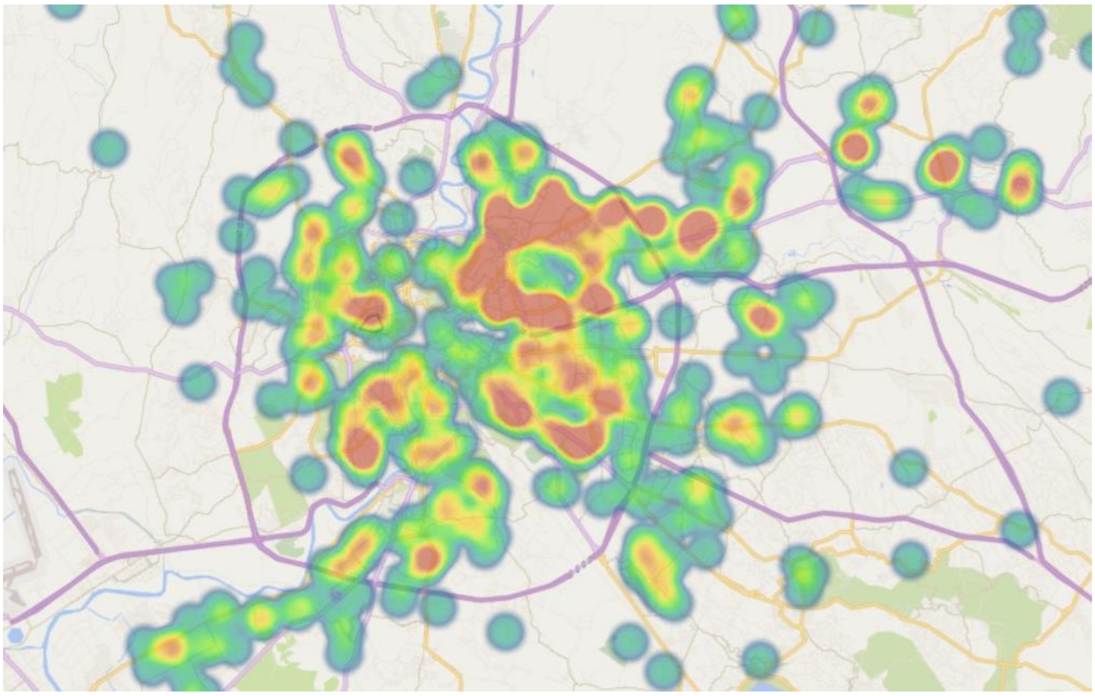


Figure 44 – Heat map of domiciles

This is confirmed by the correlation among domiciles and companies' location as shown in the following.

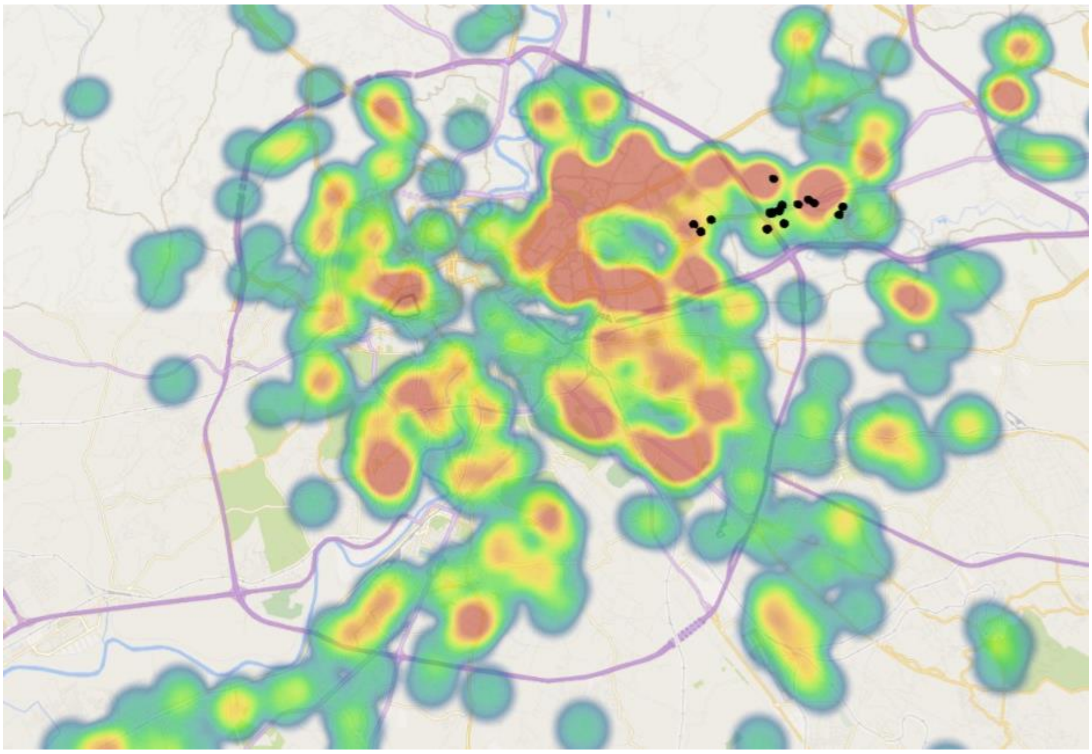


Figure 45 – Heat map of domiciles and companies

5.1.7. Modal split

This section the data on the declared modal split by employees for home and work journeys is analysed.

The following information is of fundamental importance for the assessment of employee's behaviour according to their mobility needs.

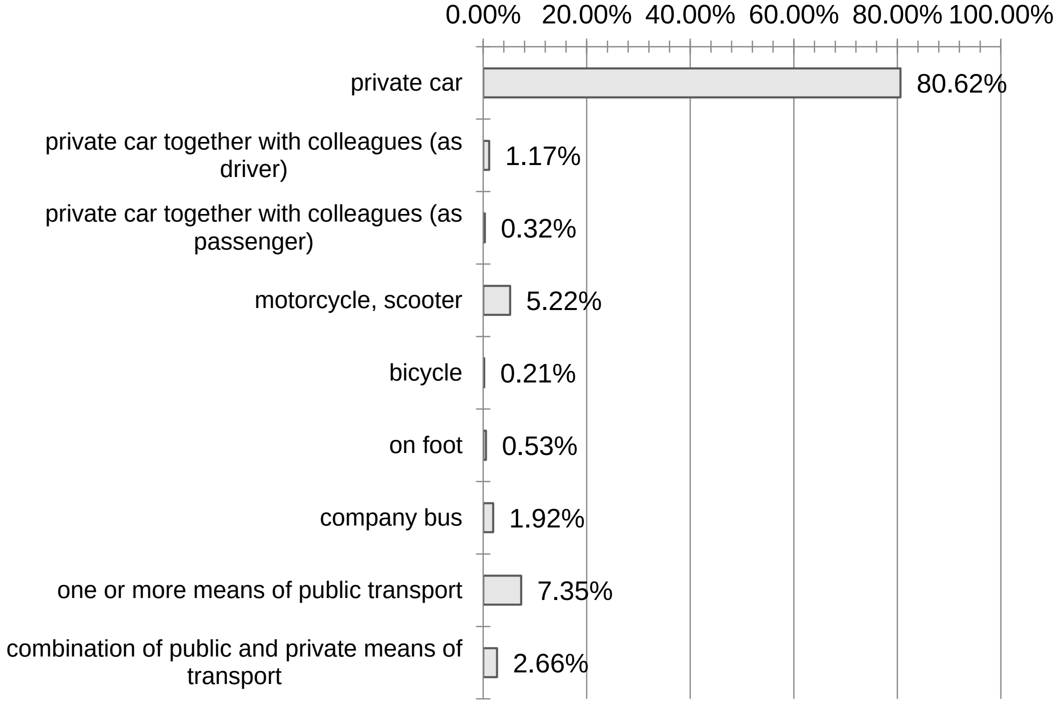


Figure 46 – Modal split

The same information is reported on map where in red there are private vehicles and in yellow collective transport. It is noticeable the large majority of cars.

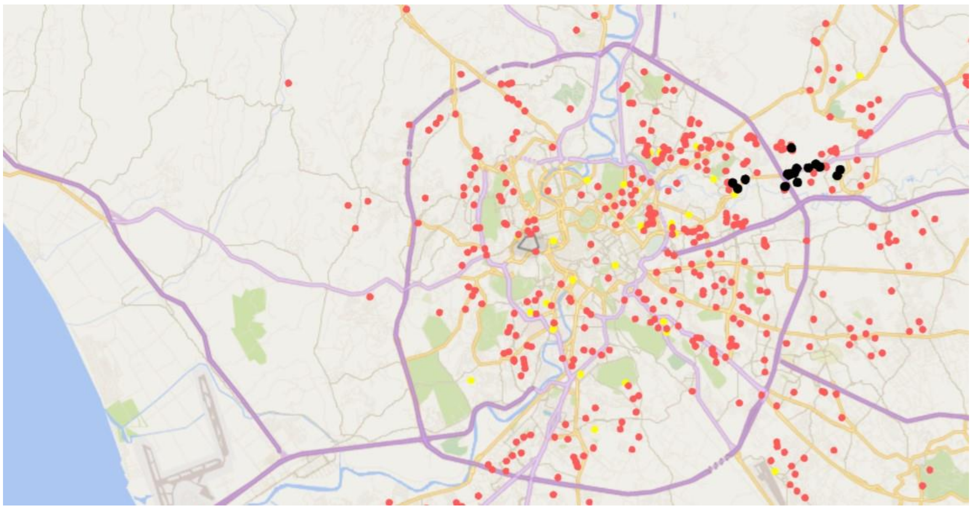


Figure 47 – Geographical modal split

The following diagram shows the percentage of employees who use at least one mode of transport other than the usual one, and how often this occurs. A variability in travel habits on the one hand it shows a certain predisposition to change and the possibility to vary own behavioural models, on the other hand, it highlights the need to plan a fairly flexible mobility plan, able to adapt to individual needs that may vary from day to day.

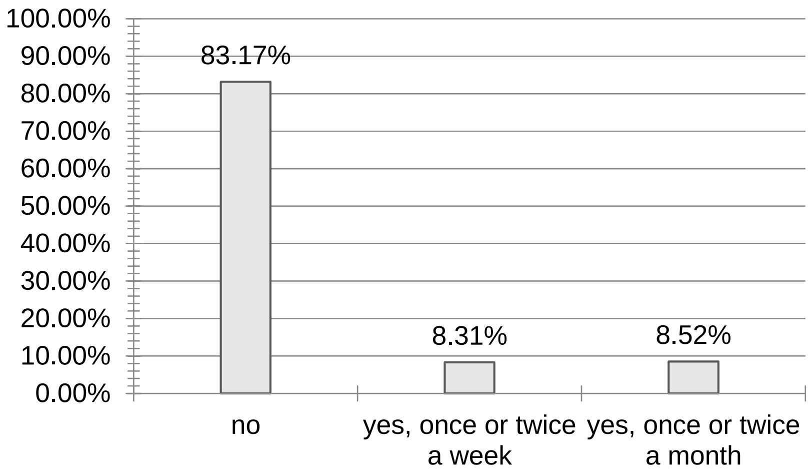


Figure 48 – Usage of an alternative mode of transport

There is, for all companies, a low predisposition to the use of different ways to go to the workplace.

In the figure that follows the percentages of the employee who use the same mode to go to work in the opposite season; also in this case a low propensity to the modal change is recorded.

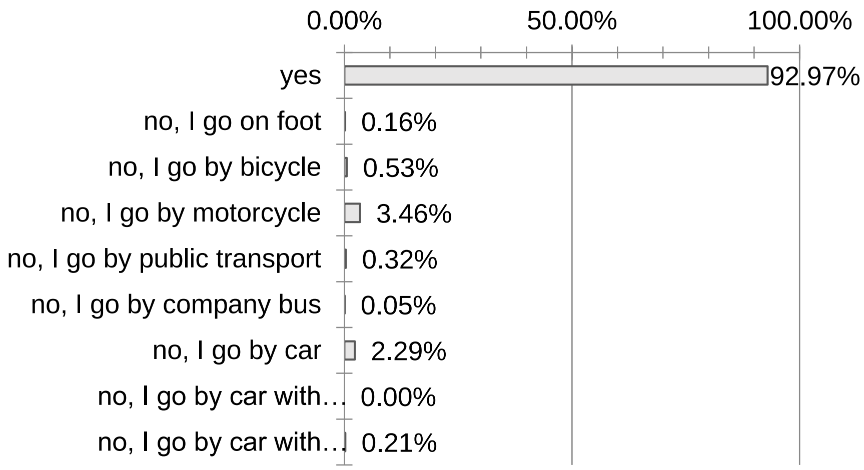


Figure 49 – Usage of same mode in the opposite season

This suggests that the climate conditions do not intervene on the modal choice of employees.

In the diagrams below it can be observed the total number of journeys made per year with the several modes of transport. Only the private car stands at more than 2,600,00 of movements in a year. The other one is about the average length of each movement.

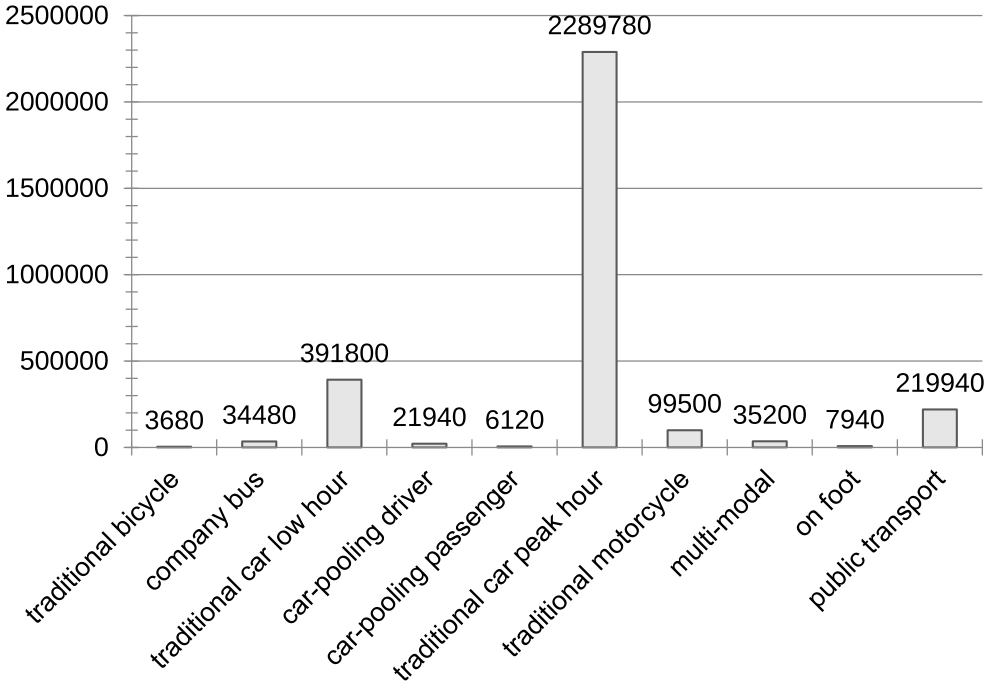


Figure 50 – Number of trips in a year (#/year)

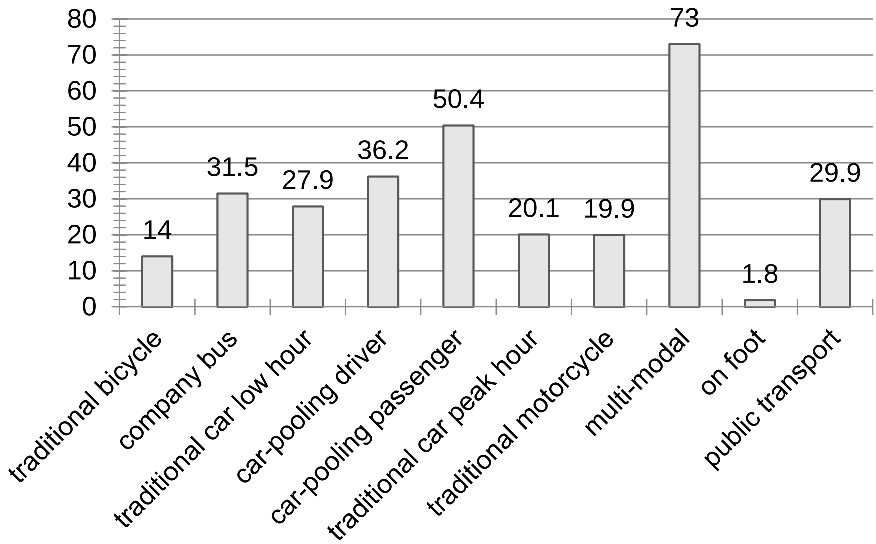


Figure 51 – Average length of one single trip (km)

The results are as expected since the multi-modal has the highest values, however the number of movements of the latter are a minority.

Then the total distance covered in km with each mode of transport is presented.

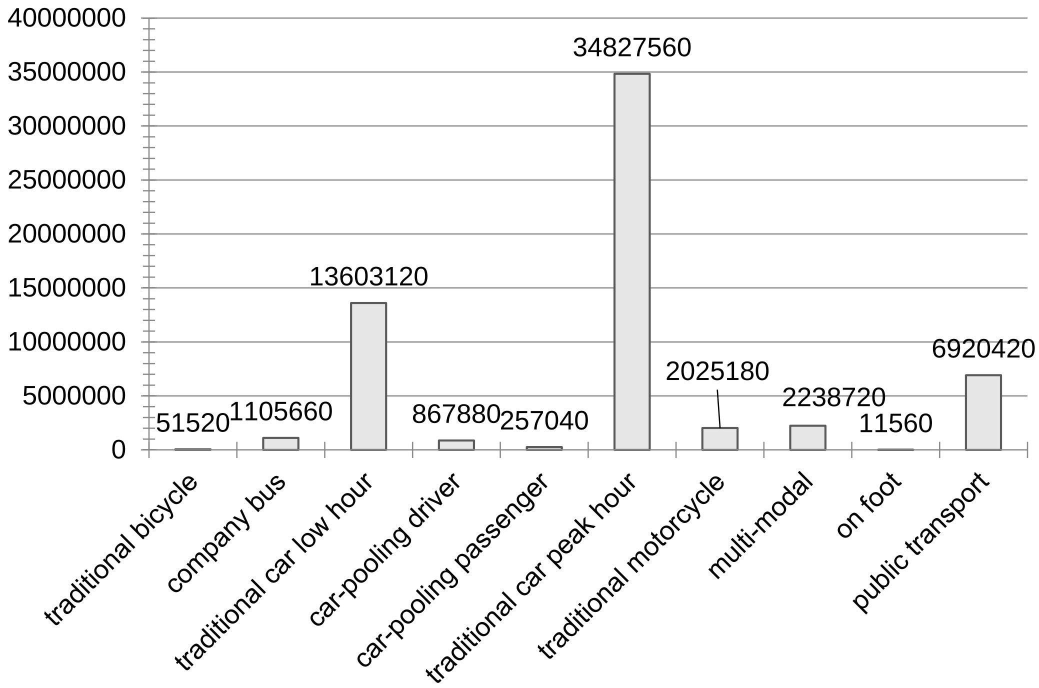


Figure 52 – Total distance covered (km/year)

Finally, the perceived duration of the journey is shown in minutes.

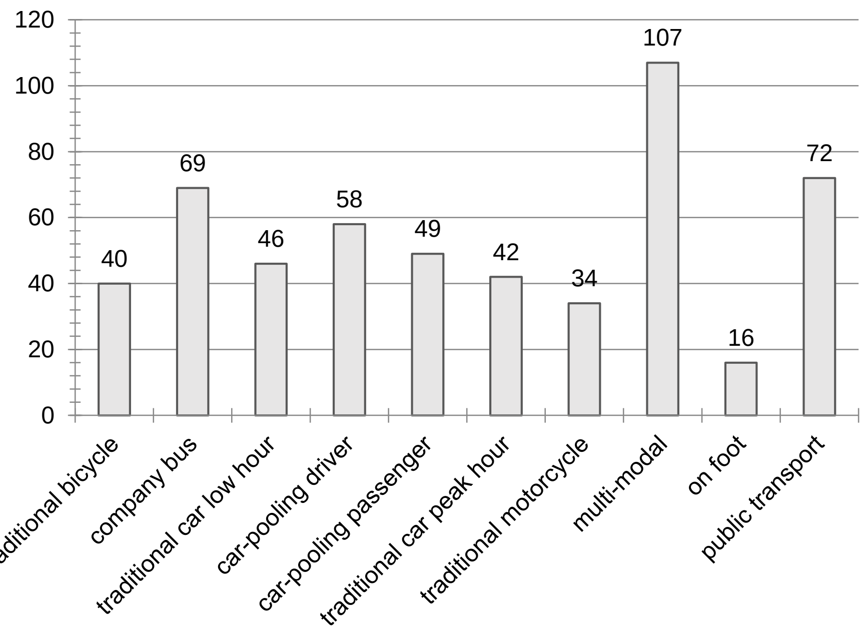


Figure 53 – Percieved trip duration (min)

Note that this is not the actual needed time to reach the destination but it is a perceived one, based on the value assigned to the time spent when travelling. However, the datum remains extremely significant as an indicator of the psychological effects associated with movements (such as stress, profitable use of time, etc.) that can alter the perception of time spent in travel.

It is noticeable the times needed for multi-modal and public transport with almost two hours and one hour respectively. This is in accordance with the mobility choices.

5.1.8. Reasons of modal choice

In this section, the information on the reason about the modal choice of employees are analysed. This information is useful to understand which are the reasons that lead the worker to the current mobility choices in order to be able to plan interventions that tend to diverge the modal split in favour of more sustainable transport modes. The following diagrams show the reasons of the choices for the different modalities to perform the trip. It is specified that the motivation "savings" refers to the savings perceived by employees in terms of both time and cost. The layout is "*mode of transport/reason*" and to each the percentage is assigned.

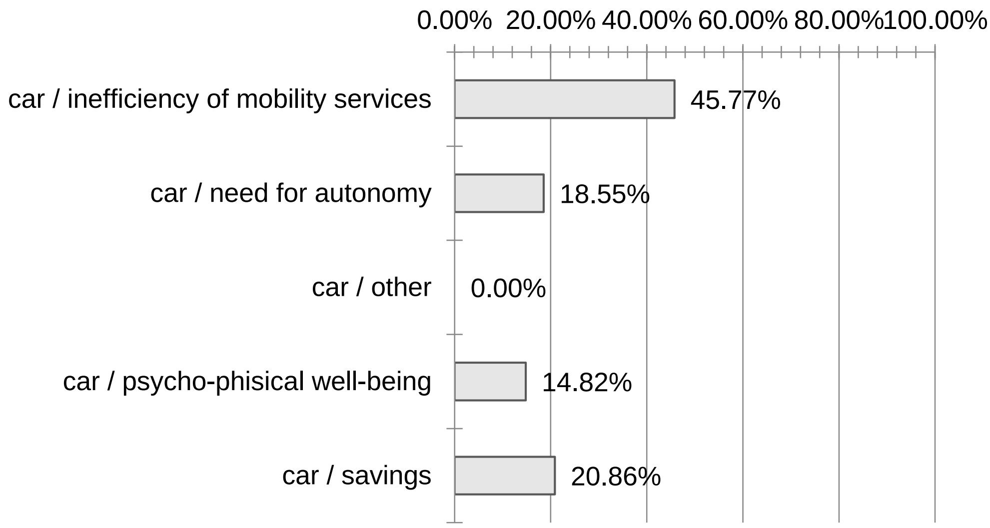


Figure 54 – Reasons of car's user

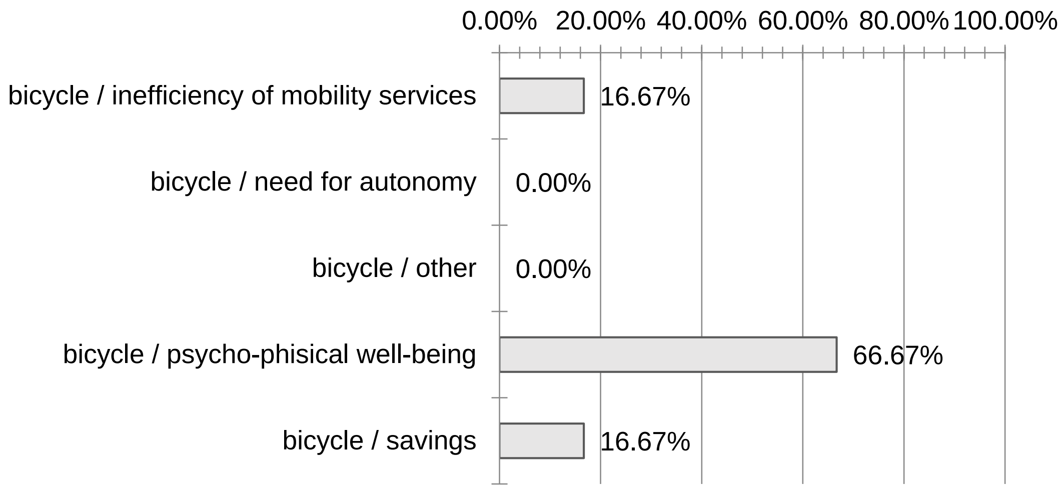


Figure 55 – Reasons of bicycle's user

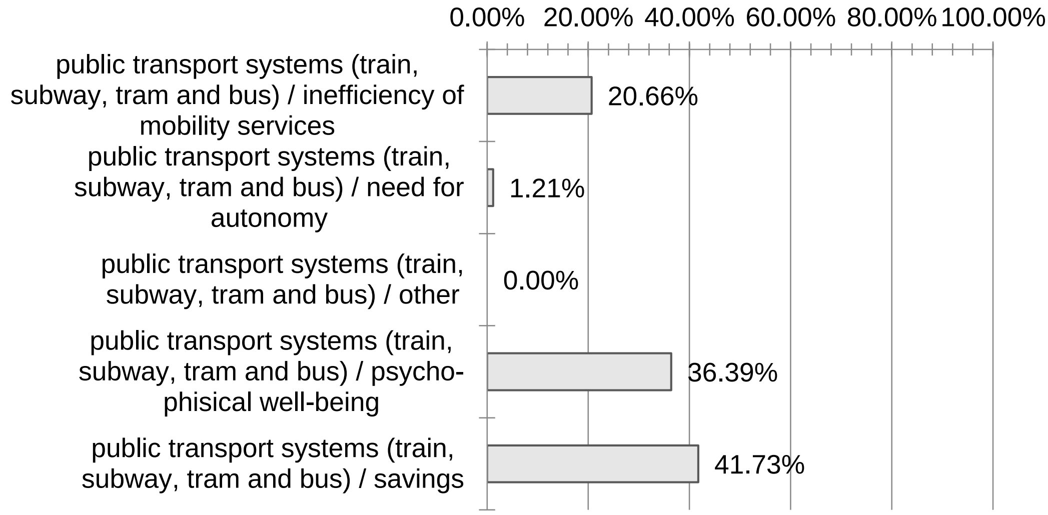


Figure 56 – Reasons of PT's user

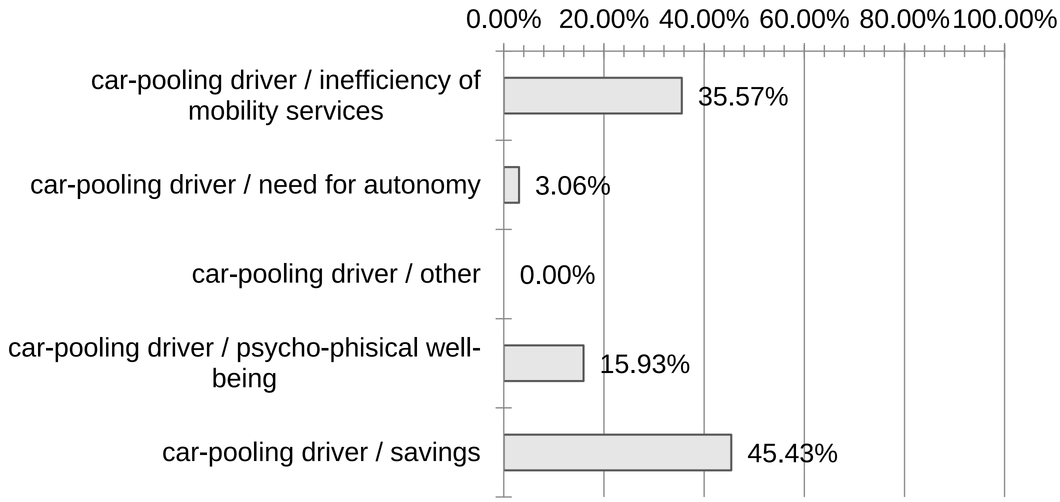


Figure 57 – Reasons of carpoolers' user

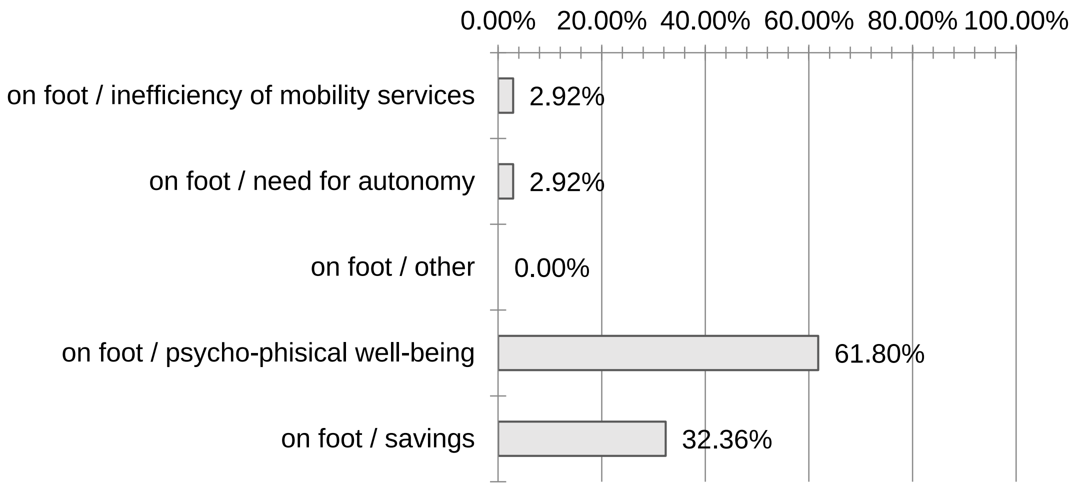


Figure 58 – Reasons of pedestrians

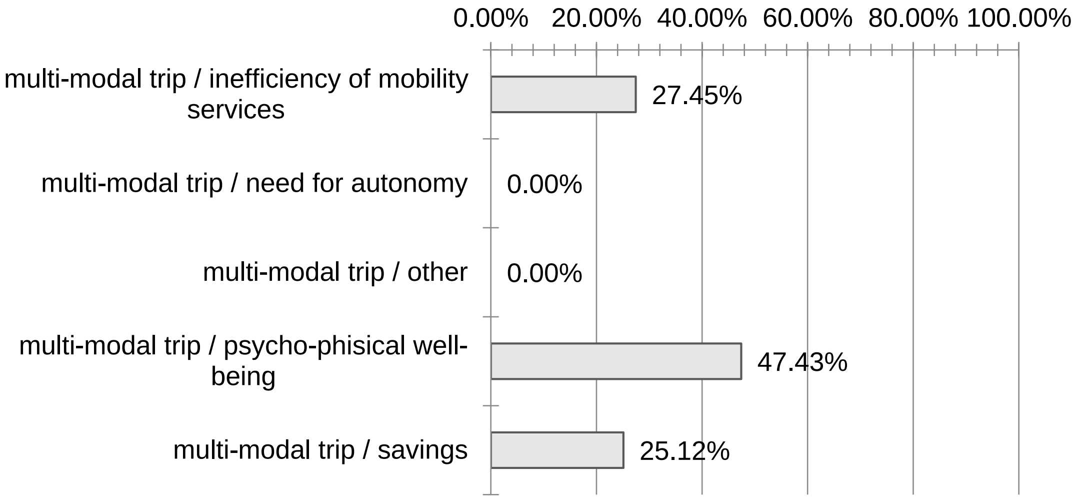


Figure 59 – Reasons of multi-modal's user

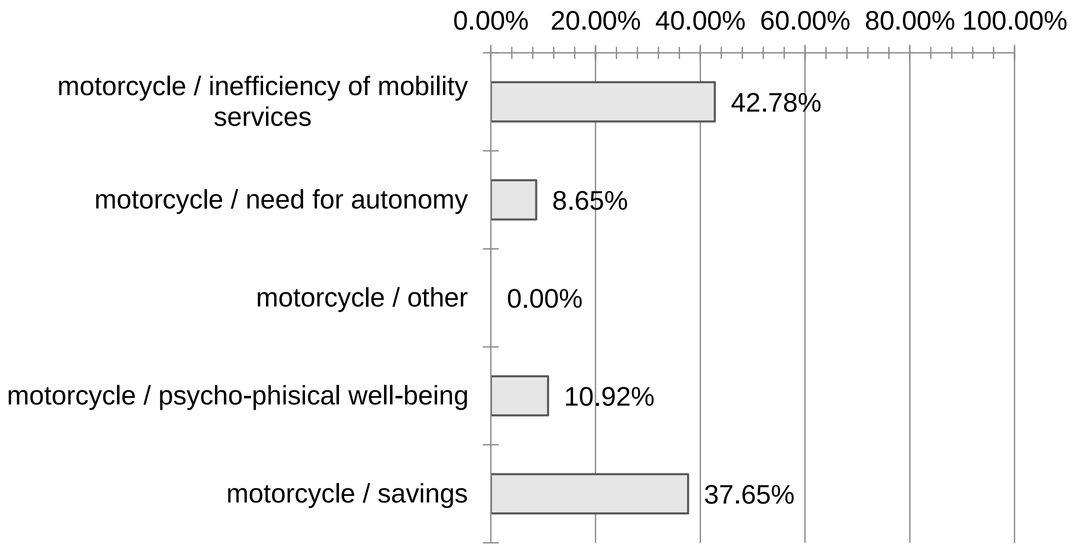


Figure 60 – Reasons of motorcycle's user

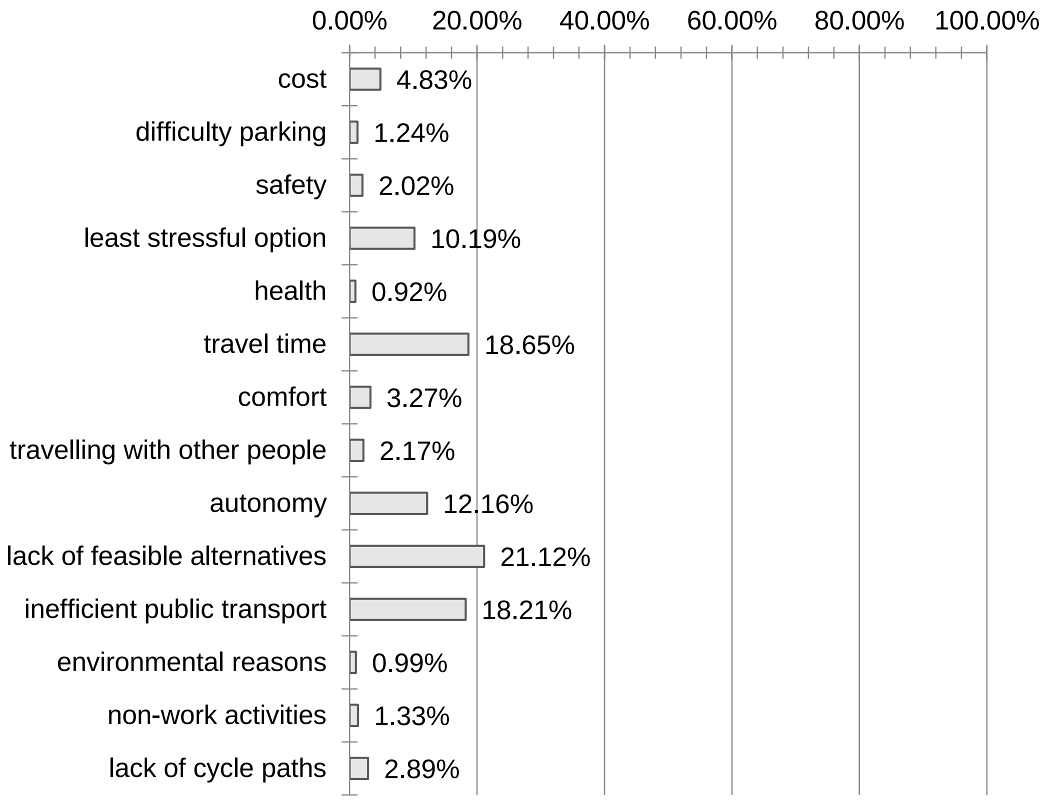


Figure 61 – Overall motivations

The overall graph shows that the lack of feasible alternatives is the higher one followed by the inefficiency of public transport.

5.1.9. Focus on Local Public Transport

The paragraph aims to highlight the problems encountered with regard to the LPT (Local Public Transport) mode. The analysis of the quality of the public transport service is useful to understand the main problems that bind its use.

This specific question was submitted only to those who indicated public transport or multimodal as chosen modalities.

In the following the split among public modes is shown.

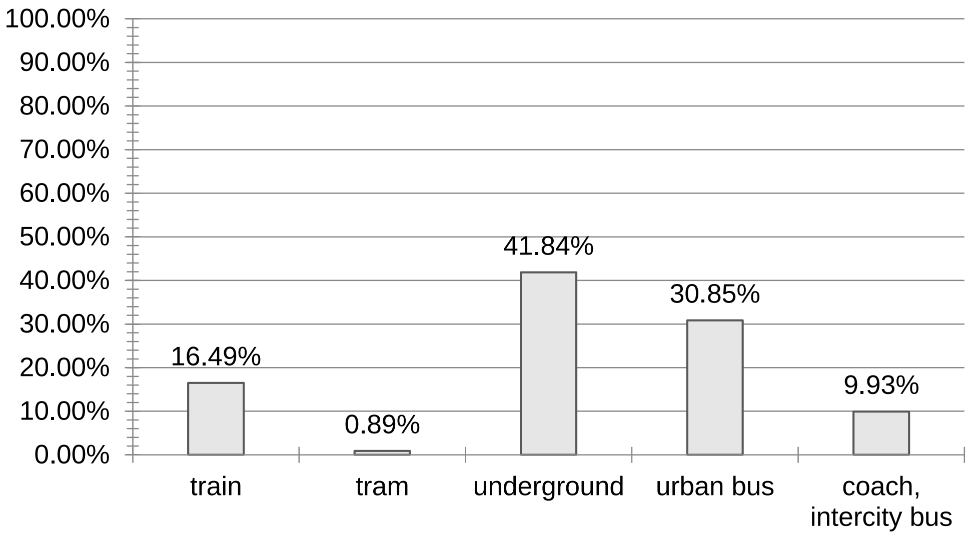


Figure 62 – PT split

The chart below reports the annual cost for public transport that workers support or would support.

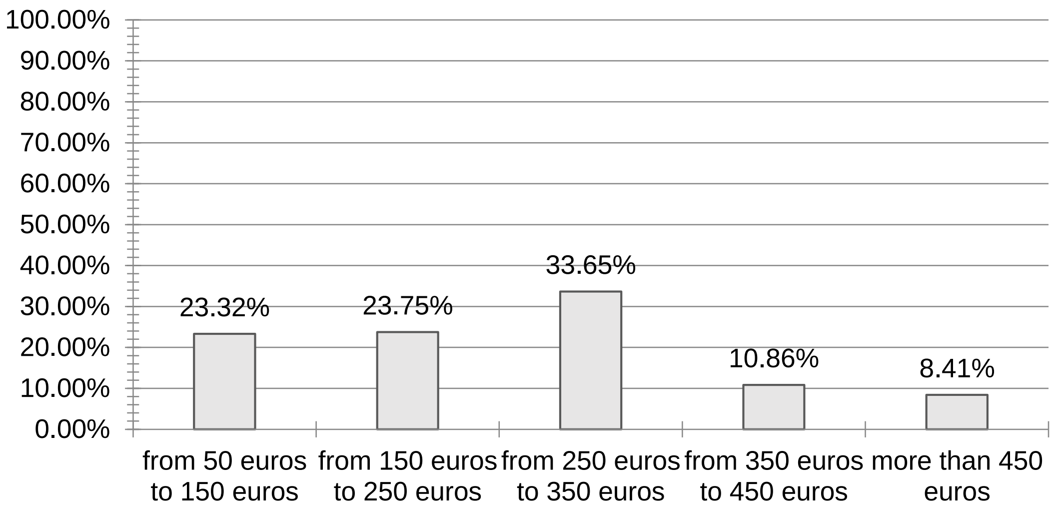


Figure 63 – Annual subscription to PT

Employees who do not currently use public transport have been asked to indicate the travel time they would spend using public transport. The chart below shows that a very large portion of employees would travel for less than 100 minutes. It should be noted that this figure refers to the time perceived by employees, which is therefore liable to change in relation to the time actually spent. For instance, a trip in less comfortable conditions or with transhipment is perceived with a longer duration than one characterized by good levels of comfort.

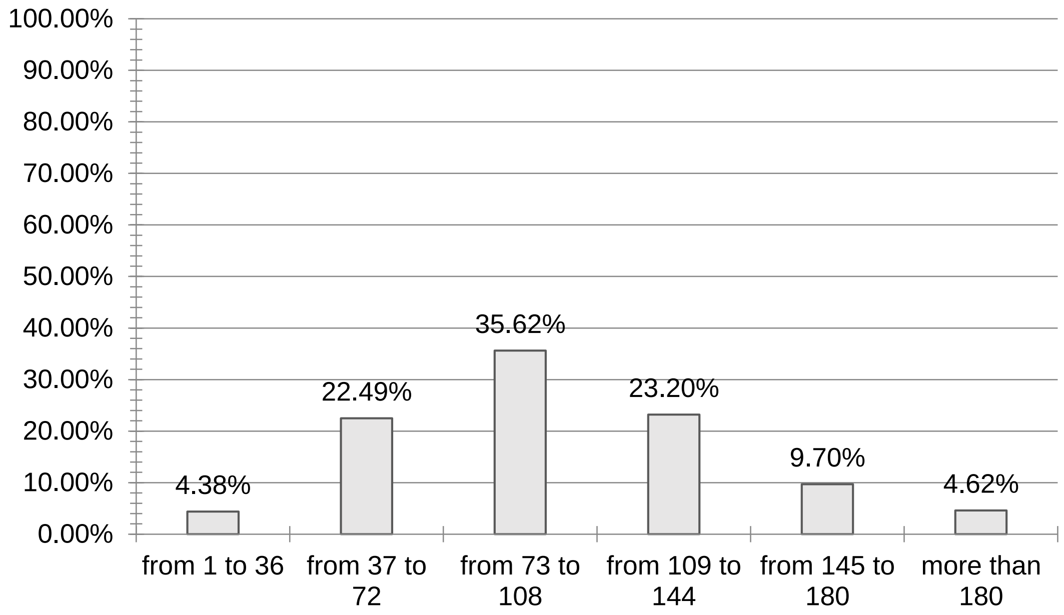


Figure 64 – Trip duration with PT

Then the distance from the household to the nearest public transport stop was asked. The data are quiet homogeneous. However almost all the people would reach it on foot and it could be a problem for distances higher than 500 m (47%).

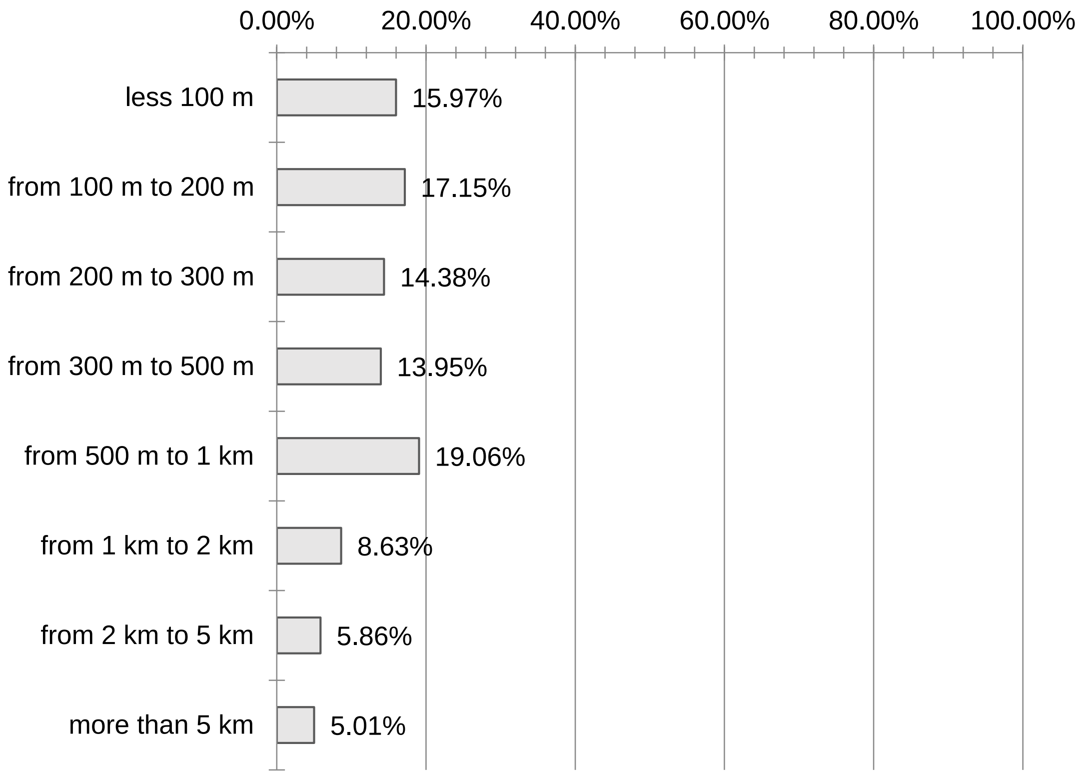


Figure 65 – Distance from stop

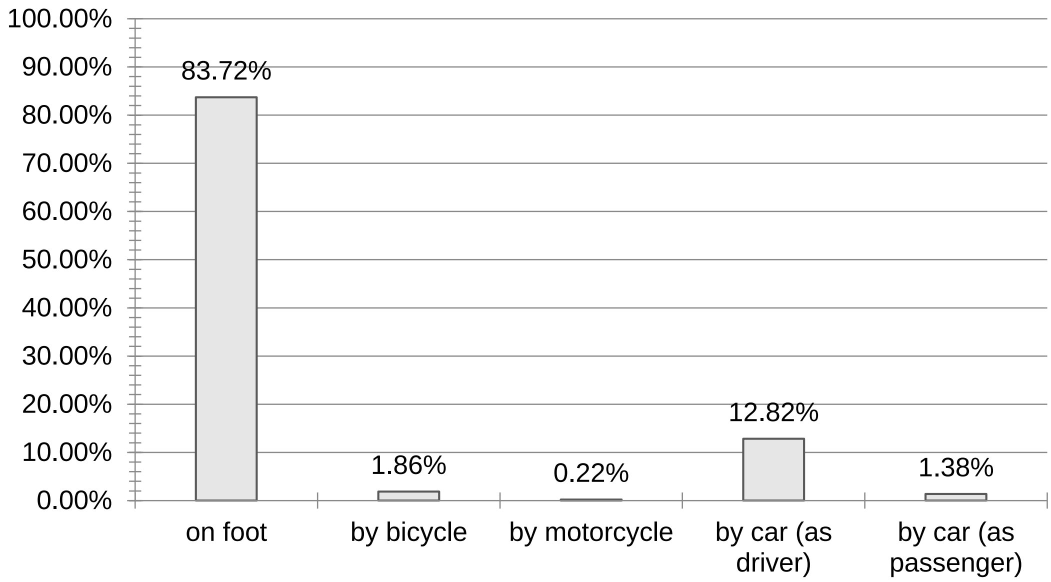


Figure 66 – Reaching of stops

It is noticeable from the graph below that a large portion of employees carry out or would carry out quite a large number of transhipments. This strongly reduces the convenience of travel with public transport and consequently the attractiveness of this modal alternative

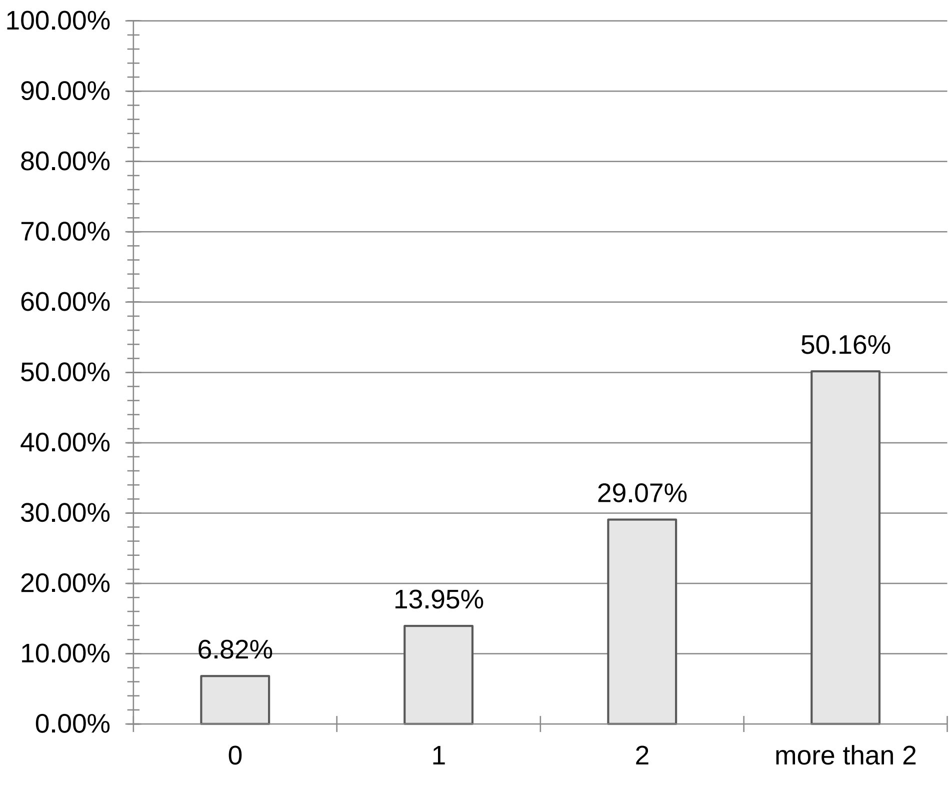


Figure 67 – Number of required transhipments

5.1.10. Judgement of employees

This section is dedicated to show quantitatively the opinions of the employees of the Industrial Site. This type of data is fundamental as well as of absolute importance because it allows to organize a common outline thanks to the judgments of those who daily access to certain infrastructures and perceive their problems.

Judgements have been expressed according to a scale in which 1 is equal to awful and 4 is excellent. The most relevant judgements are about the public services.

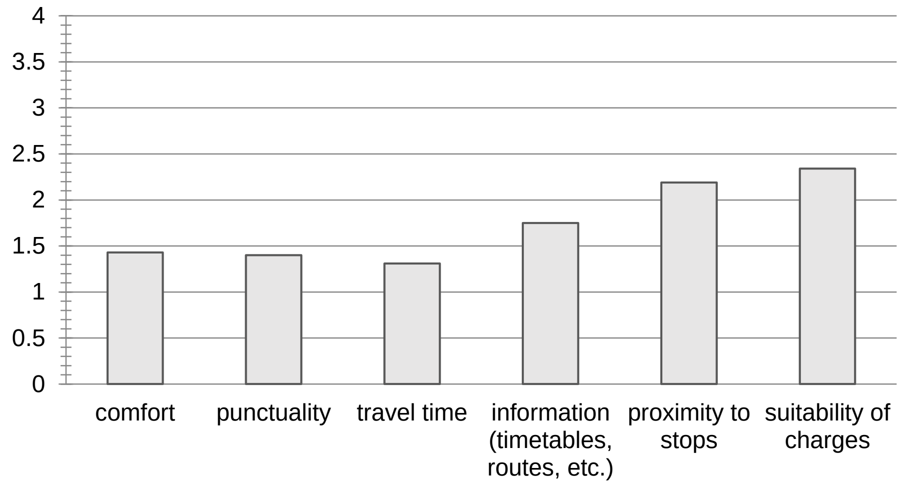


Figure 68 – Opinion on actual PT service

The marks are quiet low, higher than 2 only for charges. Then the most important components are evaluated of public transport.

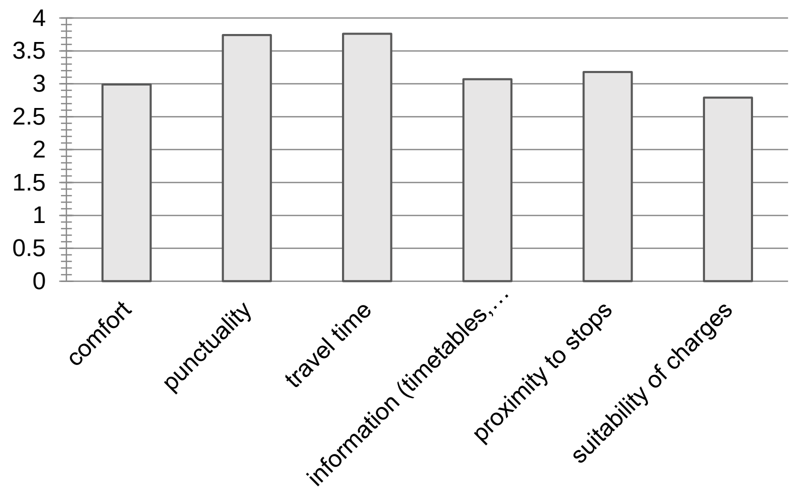


Figure 69 – Relevance of a PT components

Travel time and punctuality are the most important aspects for employees, indeed the LPT shall be very reliable to be considered a valid alternative.

Subsequently, the opinion on the TPL of those who use other modes was investigated: this is extremely significant to understand how the service is perceived by those who do not use it, preferring instead the car, and therefore which are the elements to modify in order to orient them towards a new modal choice. To be noticed is the fact that the judgment of this type of users is lower with respect to the average judgment.

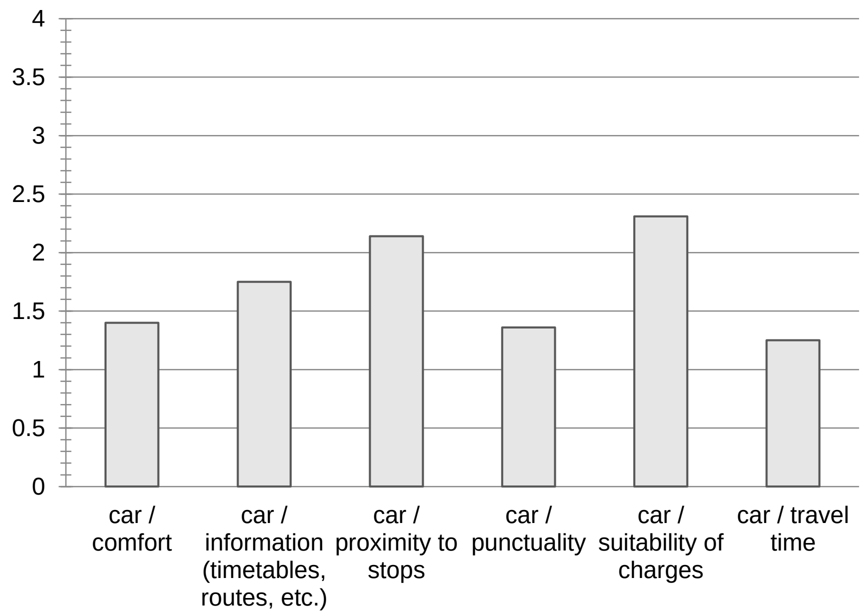


Figure 70 – Opinion on PT from car's user

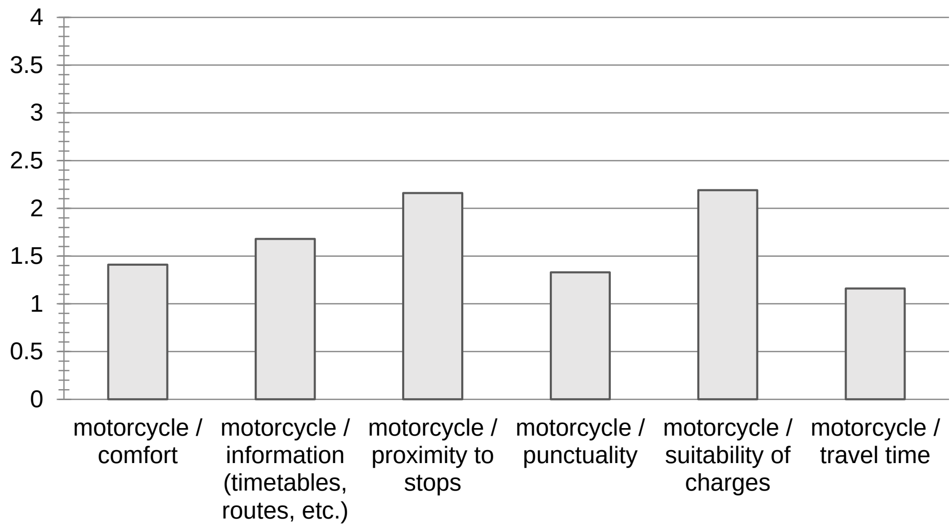


Figure 71 – Opinion on PT from moped's user

It is interesting the opinion about Public Transport from who actually use it everyday.

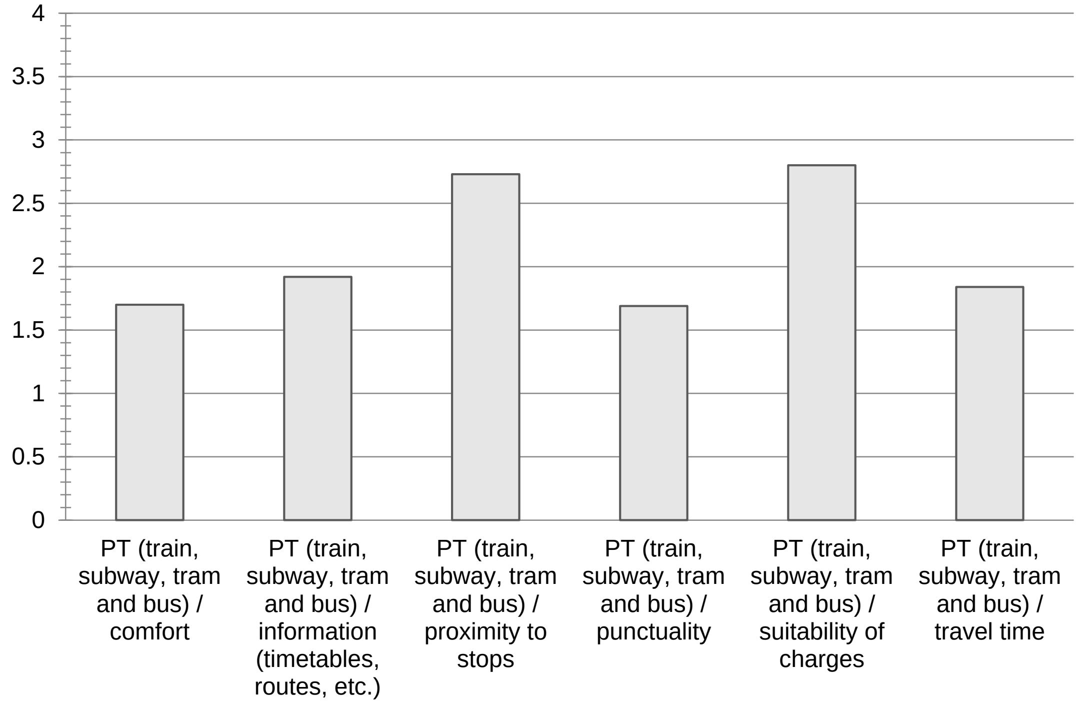


Figure 72 – Opinion on PT from PT user

Again punctuality and comfort are the most critical points, having acceptable results only for fares and capillarity of network.

Employees declared the main problems of the site:

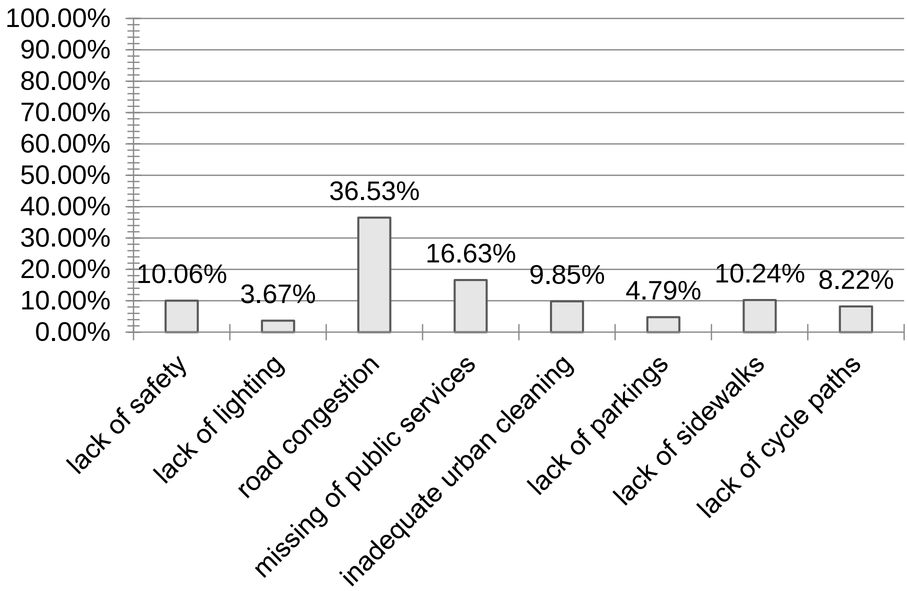


Figure 73 – Problems of Tiburtino Site

The highest one is the road congestion, as expected, also because people tend to use too much the car leading to traffic in the arteries.

5.2. Willingness to change

The present paragraph provides information on employee propensity to change. Assessing employees' willingness to use more sustainable mode of transport serves to calibrate targeted and effective interventions.

The following diagrams provide statistics summarising the willingness to change in modal expressed by the employees of the companies involved.

One of the main objectives in the international context is, in fact, the diversion from private to the public transport system. Specifically, the possibility of shifting the modal split in favour of Public Transport (PT), carpooling, cycling and possibly a company bus service was analysed. The motivations that would lead the employee to choose these modes of transport have been investigated.

First of all, the general willingness to change the modal split with respect to the currently used one namely the private car.

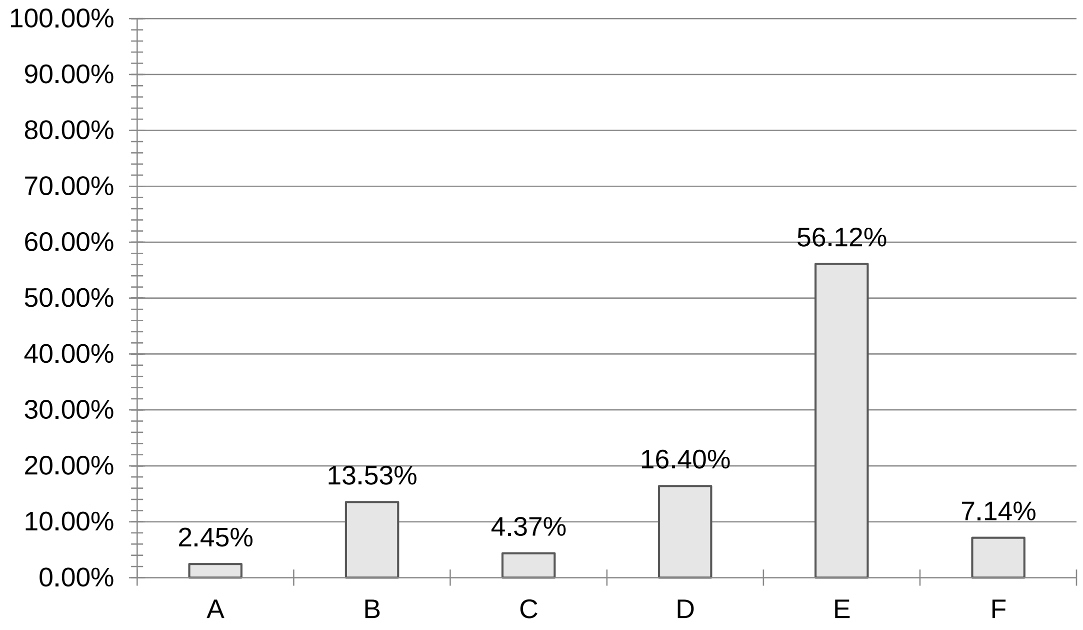


Figure 74 – Attitude toward private car

A. I do not own a car;

B. as I am aware of the many problems associated with car use, I have already tried to use it as little as possible. In the coming months, I will maintain or even reduce my already low level of car usage;

C. at the moment, I use the car for most of my journeys, but I aim to reduce my current level of usage. I already know that for some journeys I will use a different method of transport and I know what that replacement method will be, but I have not yet regularly put these journeys into practice with an alternative means of transport;

D. at the moment, I use the car for most of my journeys. I am currently thinking of not using the car for some or all of these journeys and using a different means of transport, but at the moment I am not sure how I can replace these car journeys or when I should do so;

E. at the moment, I use the car for most of my journeys. I would like to reduce my current level of usage, but I feel that it would be impossible to do so at the moment;

F. at the moment, I use the car for most of my journeys. I am happy with my current level of usage and I do not see any reason why I should reduce it.

The majority declared answer E, so they are aware of the problem concerning road congestion but are unable to change habits.

5.2.1. Carpooling

It has been declared a generalised propensity to adopt a carpooling system as long as the trip time doesn't increase up to more than 5 or 10 minutes and if a system capable to put in contact colleagues is adopted. The 75% indeed gave a positive answer.

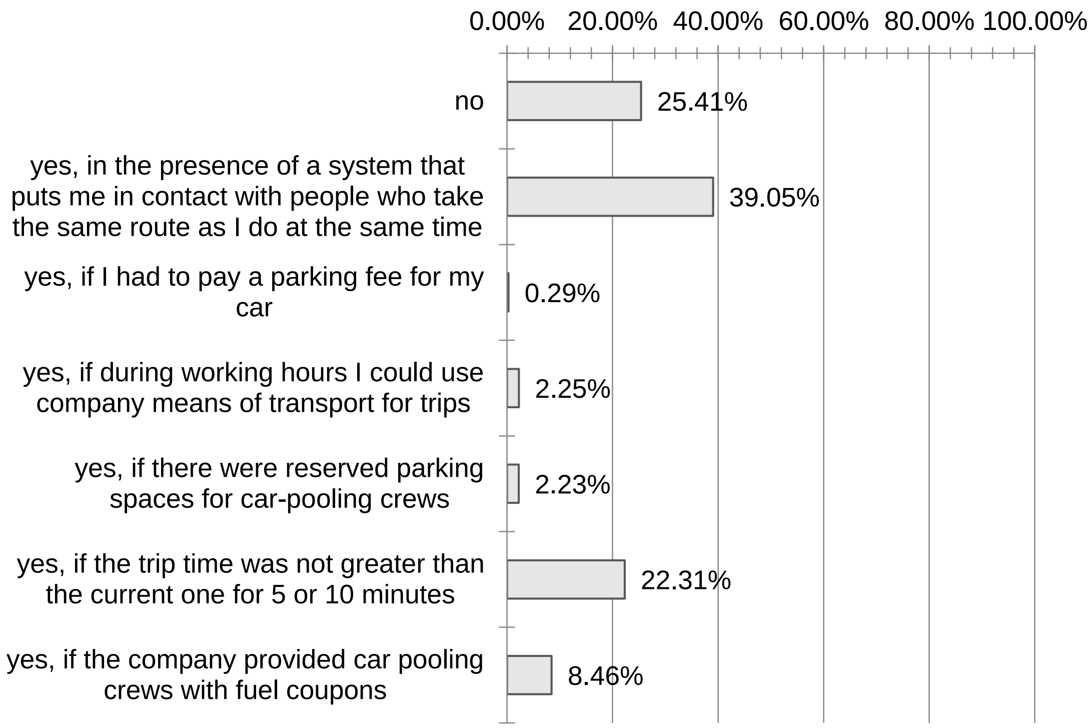


Figure 75 – Propensity towards carpooling

5.2.2. Local Public Transport

The following graph shows the predisposition of employees to the use of public transport to go to work. From the analysis of the results it is evident that the main obstacle to be overcome is the lack of reliability of the service. There is a general low repulsion to the use of public transport, around 20%, and it is seen in reliability the key to make it more competitive and attractive.

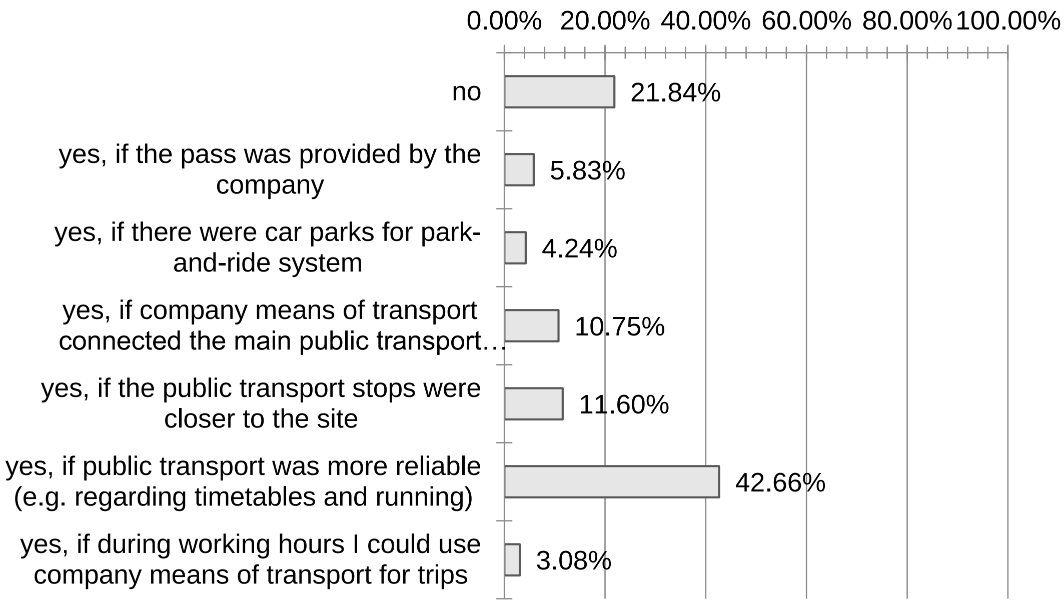


Figure 76 – Propensity towards LPT

Then, the opinion of employees to the possible introduction of a subscription to public transport at a highly discounted price only valid for the journey home-work in the hours of entry and exit was investigated. However, despite the positive nature of the initiative, the lack of confidence in public transport in terms of hourly frequency, stops and difficulties with regard to intermodality, around the 50 % of respondents would not be tempted to use it.

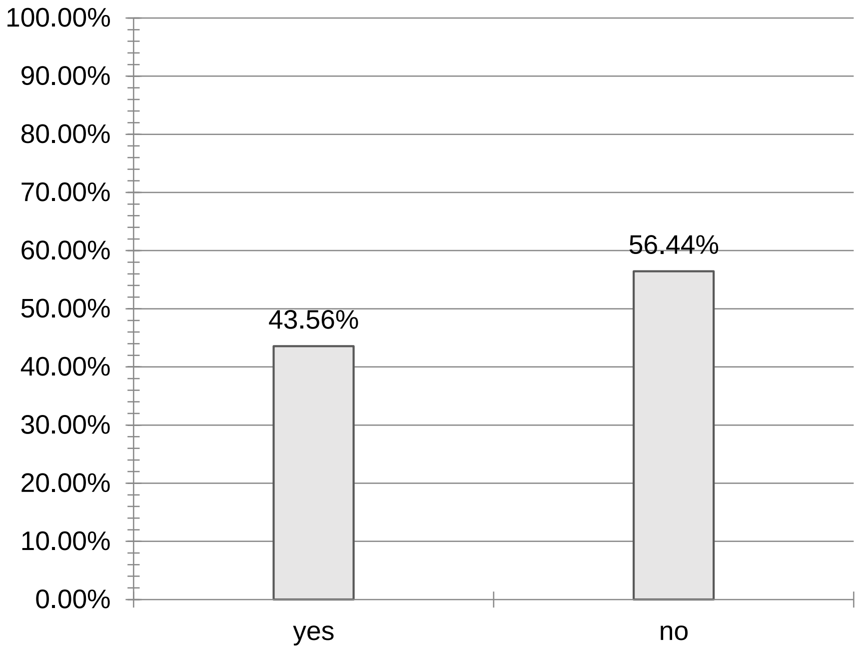


Figure 77 – Propensity towards discount for a LPT agreement

5.2.3. Soft mobility

There is a strong enough opposition to the use of the bicycle in the home-to-work trip. The most relevant interventions, even if marginal as interest, concern the realization of better and safer cycle paths and the realization of changing rooms and showers in the workplace.

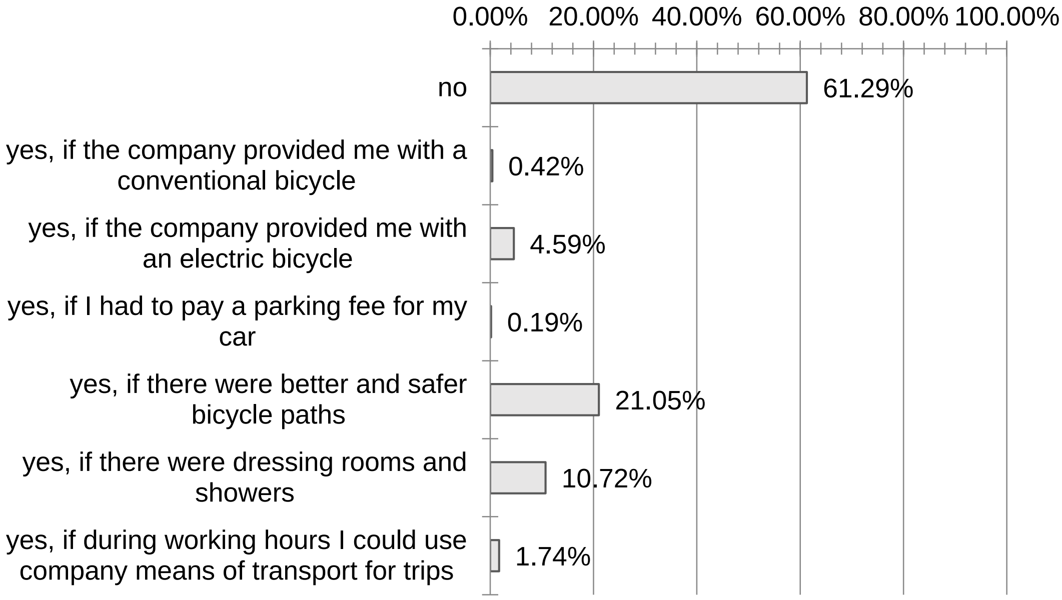


Figure 78 – Propensity towards soft mobility

Even the economic incentive to buy a bicycle wouldn't change the strong conviction to not to use that mode of transport. This is mainly due to the total absence of dedicated facilities.

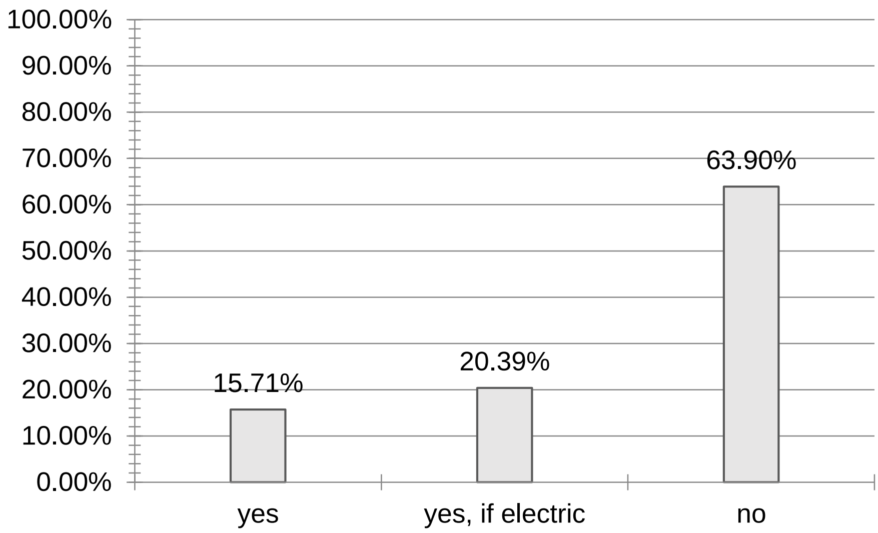


Figure 79 – Propensity towards agreement for purchasing a bike

5.2.4. Company shuttle

The employees' response to the introduction of a company bus service was investigated. As can be seen from the chart below, this service would only be attractive to employees if the different bus stops were close enough to their homes. This gives rise immediately to big limitations for the implementation of the intervention as organizing a service wide enough and branched to satisfy a body dependent of the dimensions of that in analysis moreover, it would be very difficult and strongly expensive.

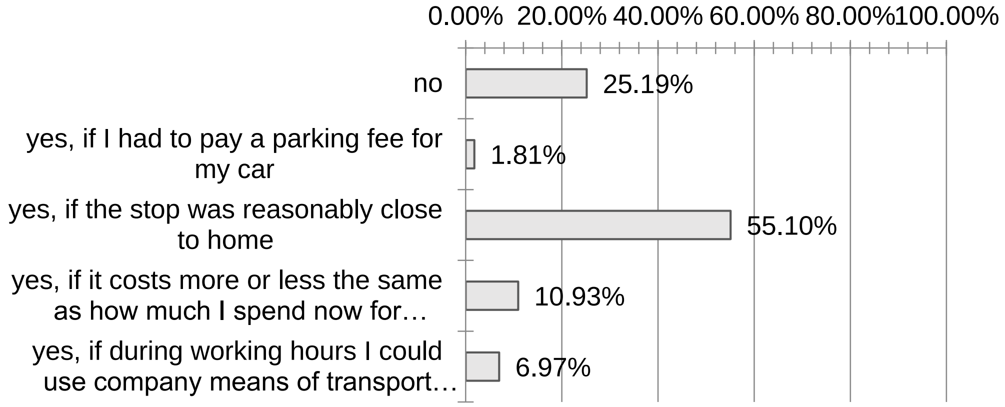


Figure 80 – Propensity towards company shuttle

In this regard the maximum distance that employees would be willing to travel to reach the stop was asked. Almost none of them would accept to walk for more than 1 km, requiring so a very extent and capillary network.

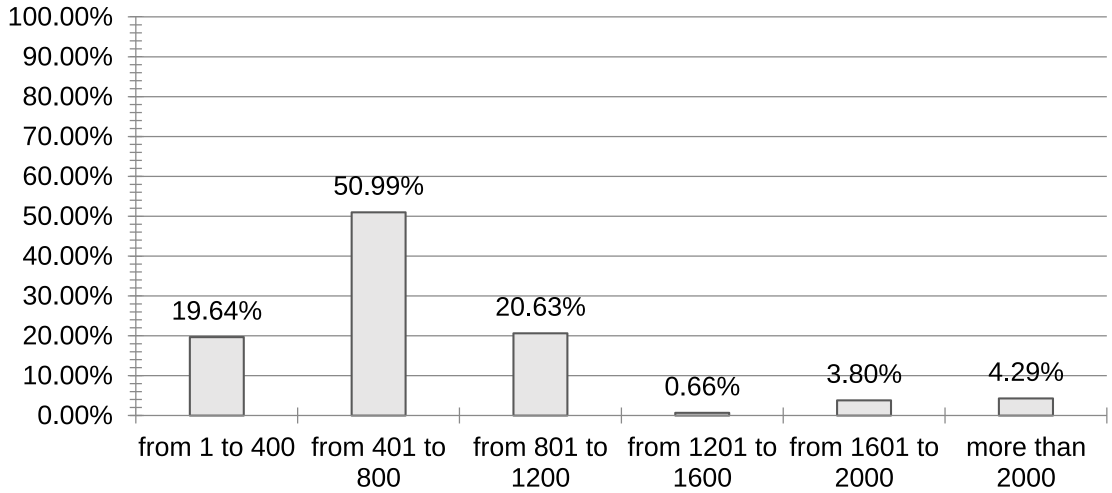


Figure 81 – Maximum distance accepted for shuttle's stops

5.3. Externalities estimation

This chapter gives a quantitative estimate of the environmental externalities produced by the commuting of workers to work and home. The estimation of externalities shall be made for each employee, taking into account both the distance between home and workplace and the mode of transport used. The monitoring of these indicators serves the company to quantify the effects of mobility policies. It is clear that the number of employees in each location affects the quantities produced yearly and that the traditional car remains the most polluting and responsible modality. Therefore, in the mobility policies to be implemented the primary scope remains the reduction of the use of the private car in order to limit the environmental impact of the home-to-work journeys and achieve a higher level of sustainability.

Specifically, the following indicators were calculated on the basis of the COPERT IV model by multiplying the annual kilometres travelled by employees (produced between the road distance to work of employees and the number of times this trip is made in one year) by the coefficient for the indicator analysed, splitted into mode of transport, which indicates the quantity of a particular pollutant produced by that vehicle in 1 km of travel.

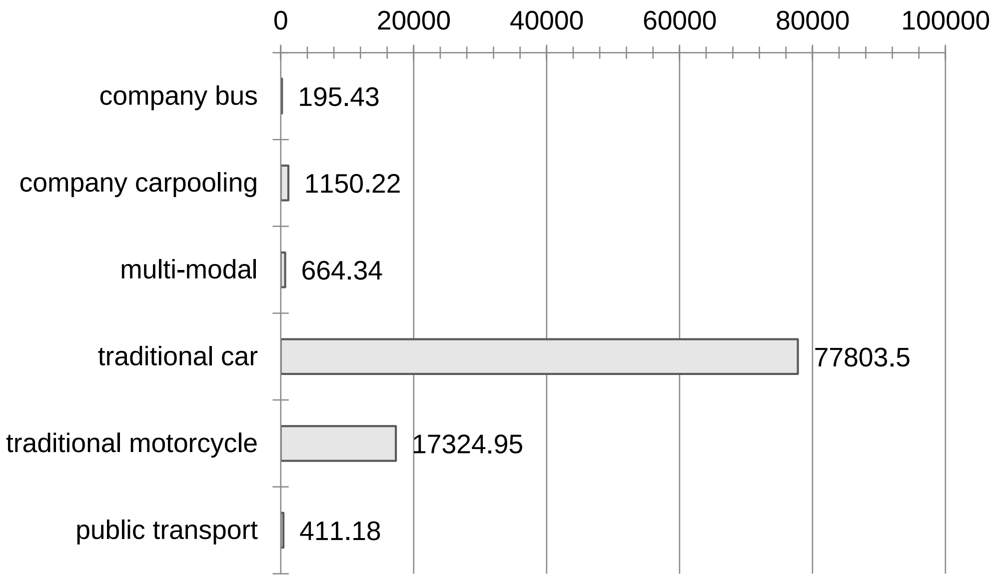


Figure 82 – Carbon monoxide (CO) emitted (kg/year)

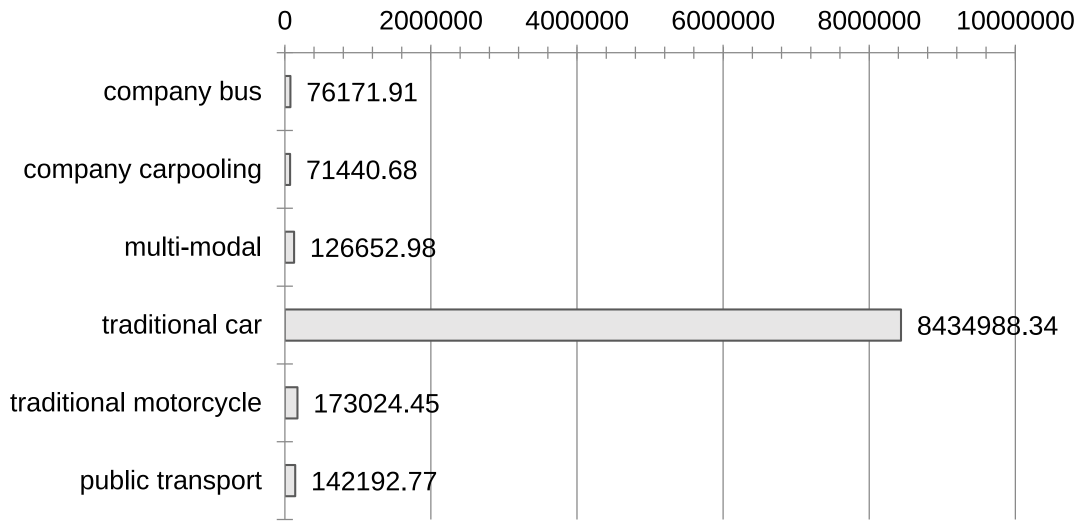


Figure 83 – Carbon dioxide (CO2) emitted (kg/year)

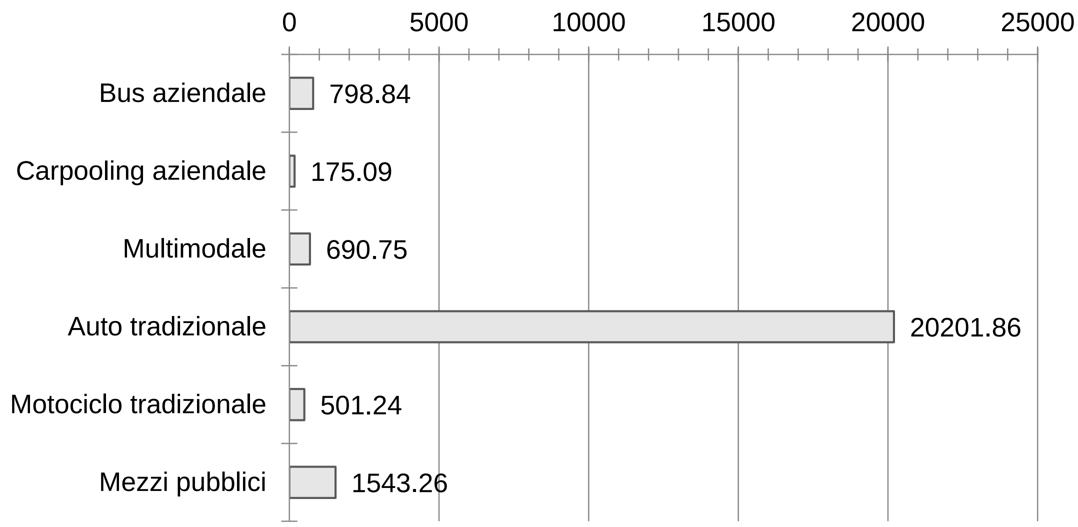


Figure 84 – Nitrogen oxides emitted (NOx) (kg/year)

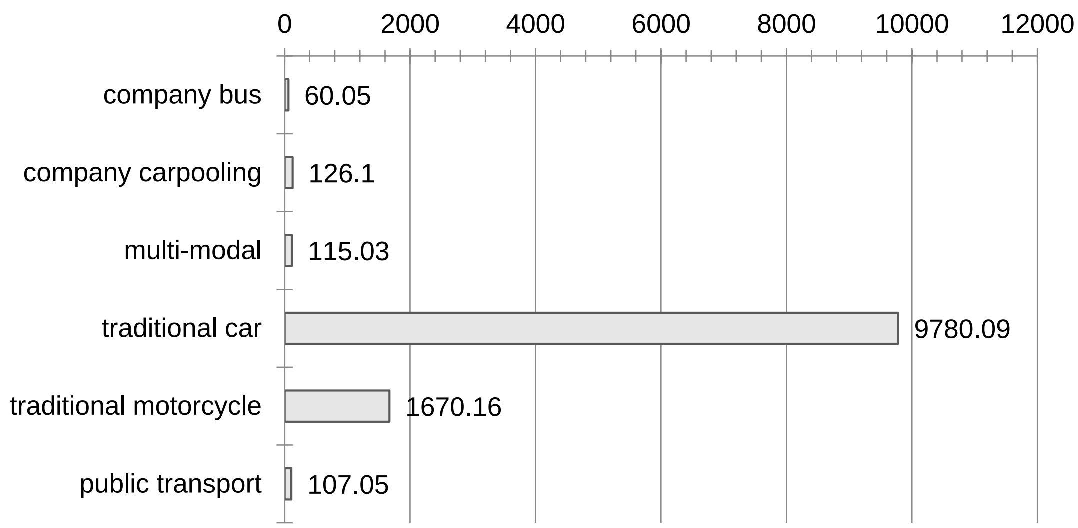


Figure 85 – Volatile organic compounds (VOC) emitted (kg/year)

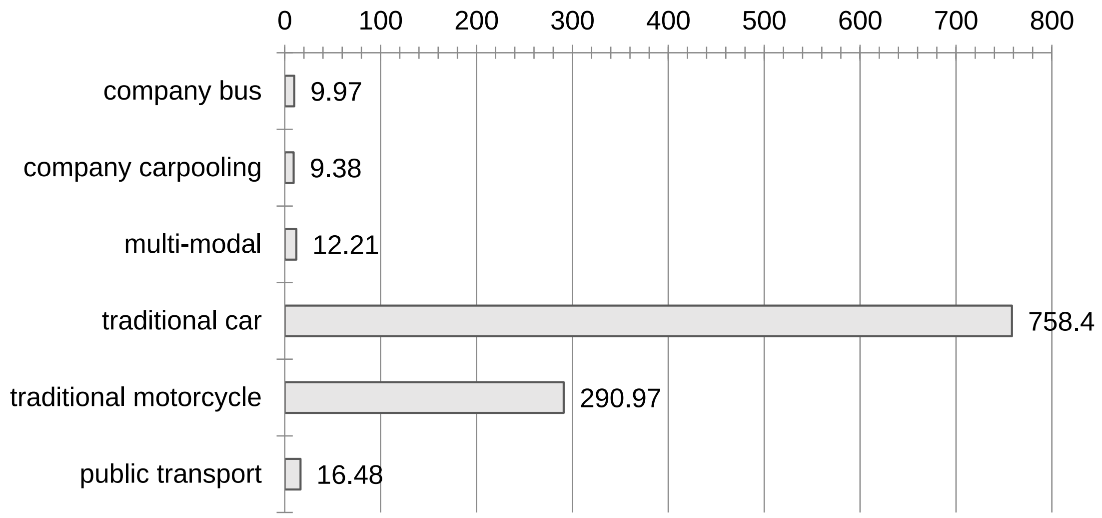


Figure 86 – Methane emitted (CH4) (kg/year)

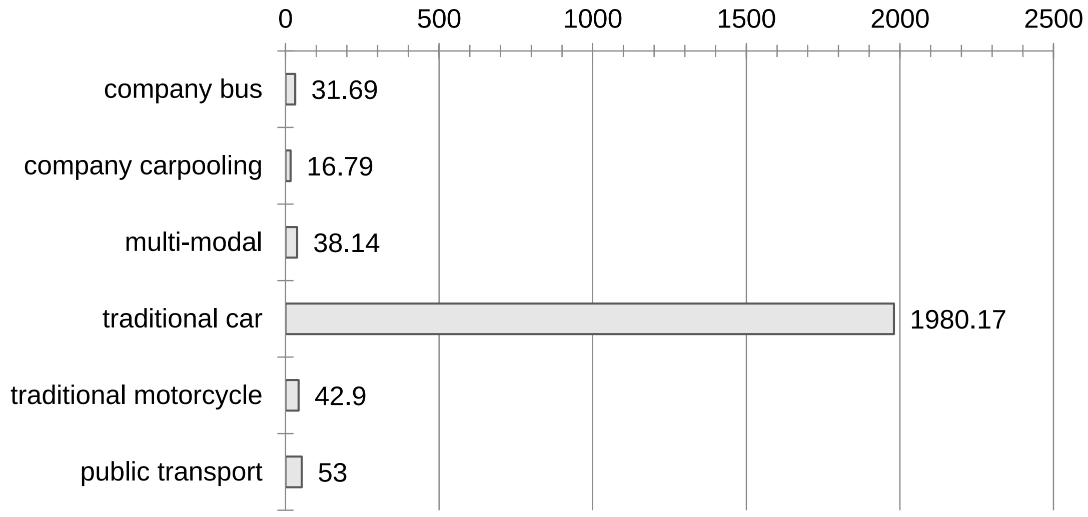


Figure 87 – Particulate matter (PM) emitted (kg/year)

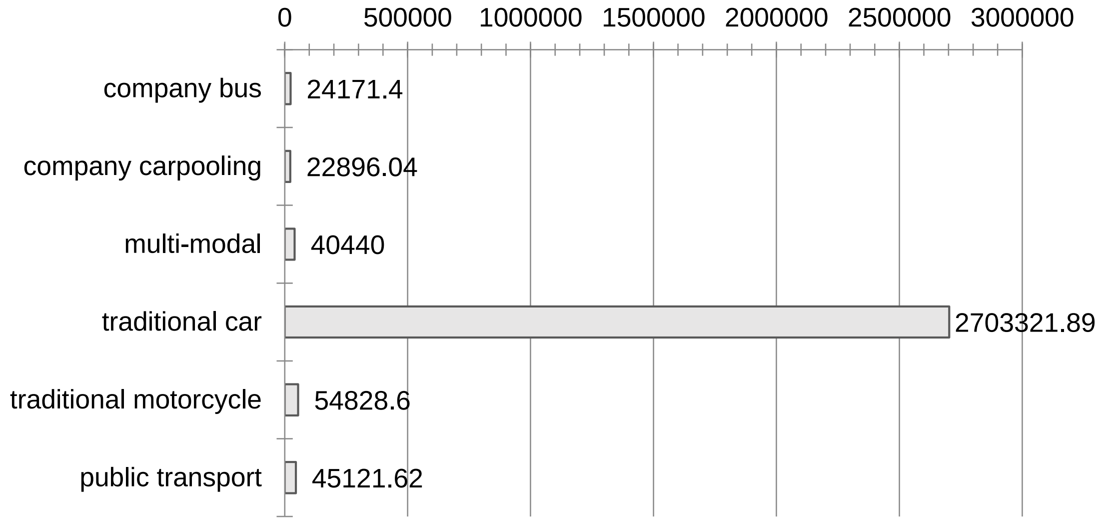


Figure 88 – Fuel consumption (litres/year)

5.4. Balance sheet

The software MobilityManager is also equipped with a tool capable to monetize the effect and the externalities of the mobility choices made. This will be a very useful benchmark in the intervention phase described in chapter 6. All the items of the balance deal with three main stakeholders namely the employee, the company and community, through externalities.

The balance sheet is organized in loss for what concern company and individuals, whilst is an expense in case of externalities, since they are a price supported by the whole community.

Note that the results have been extended to the whole "population" of this case study by means of a proportion.

At the current state the software gave back this result:

Entity	Tiburtino Industrial Site
Company	
Missed Production	-2 119 317.17 €
Incentives	0.00 €
Fares	0.00 €
Realization costs	- 50 000.00 €
Total	-2 169 317.17 €
Employees	
Fuel	-2 573 123.3 €
Vehicle Purchase	-3 709 902.83 €
Vehicle Maintenance	-153 394.83 €
Highway Toll	- 303 298.3 €
Fines	- 304 677.42 €
Vehicle Insurance	-1 500 450.69 €
Accidents	- 766 582.65 €
LPT Subscription	- 151 294.86 €
Carpooling Fuel Voucher	0.00 €
Total	-9 462 724.87 €
Externalities	
Polluting Emission Costs	- 81 073.2 €
Road Accidents	- 126 633.55 €
Incomes from fares	4 251 853.44 €
Total	4 044 146.69 €

Table 7 – Balance sheet

6. Intervention proposal

Thanks to the analysis carried out through the fundamental survey, it has been possible to analyse not only the demographic and territorial data of accessibility, but above all the propensity to change the habit of movement.

This type of information makes possible to guide the actions to be proposed in order to improve the accessibility and in the same way the well-being of the employees of the companies. Moreover, thanks to the acquired information it will be possible to understand from a transportation point of view the reasons of such mobility choices. Indeed, in most cases it is possible to find in the accessibility state the answers to these kind of questions.

The interventions that can be proposed and implemented in this document, follow the policies proposed by the European Platform on Mobility Management (EPOMM) to encourage sustainable mobility in companies or other bodies based on:

- Promoting mobility management as a tool to make mobility environmental friendly, socially equitable and affordable;
- Promoting and further developing mobility management in Europe;
- Support the active exchange of information and learning on mobility management between European countries;
- To act as the main partner for European institutions and national governments in the field of mobility management.

In this present work two main interventions are proposed, also according to the propensity expressed and recorded in the survey completion. The first one deals with the private transport providing a carpooling service whilst the other one with the public transport.

6.1. Carpooling system

6.1.1. Accessibility analysis

Before describing the intervention implementation, a brief accessibility description shall be done. This will help to better understand why the private car has that strength among the possible alternatives.

As already explained the Site is located along the Tiburtina street which together with the G.R.A. provide full accessibility to it. Two are the junctions that serve the area the 13th and the 14th. The former is the one with the Tiburtina road while the latter with the A24 highway.

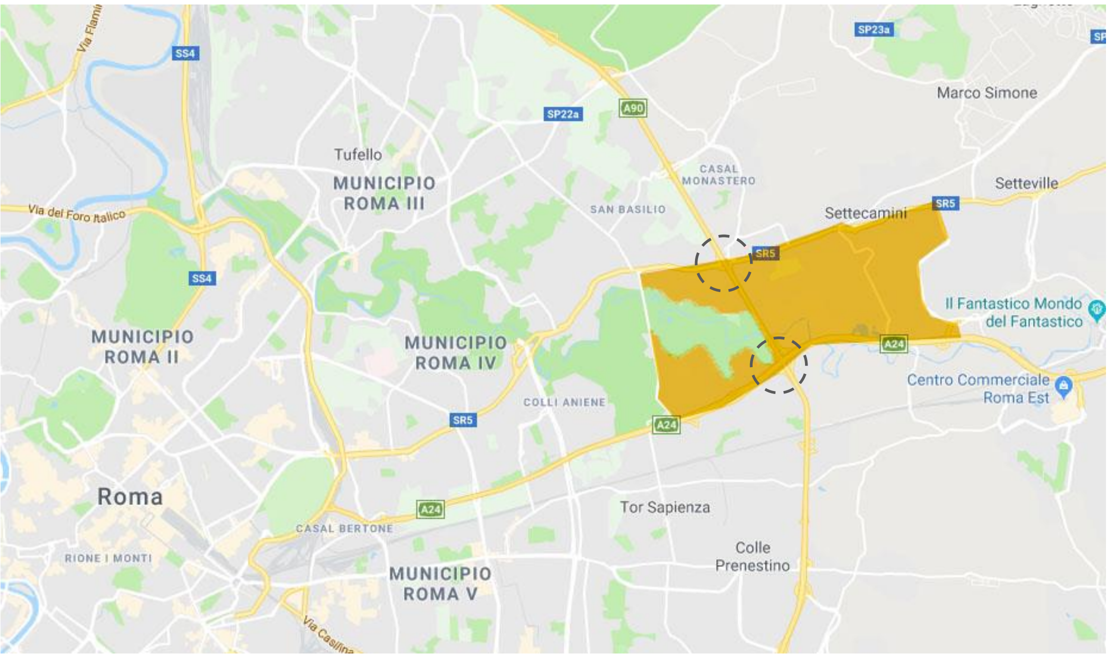


Figure 89 – Junctions 13 and 14 and Site

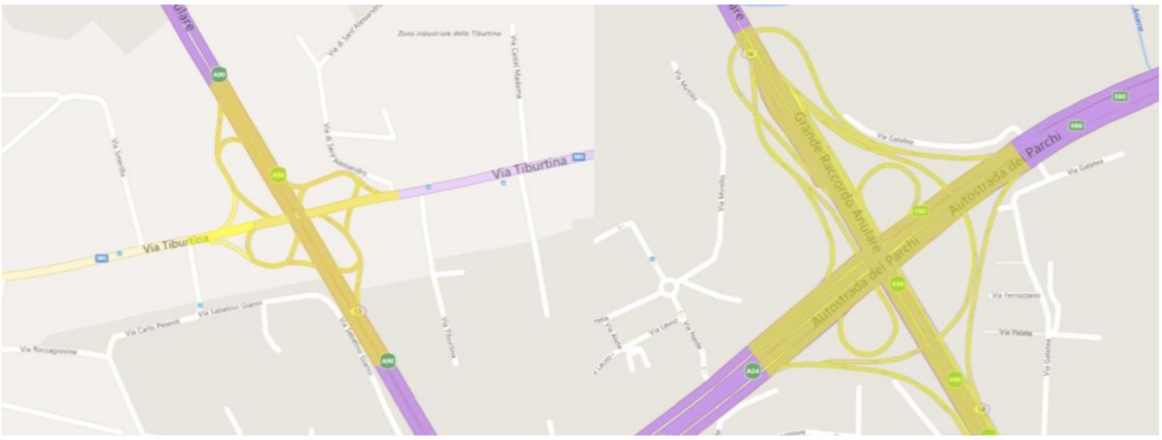


Figure 90 – Junctions 13 and 14 respectively

To witness of the importance of these two intersections, the following images show the level of traffic in the morning peak hour.

Traffic level		
Fast traffic		Slow traffic

Figure 91 – Peak hour junction 13

Figure 92 – Peak hour junction 14

As it can be seen, the level of traffic and congestion stands at "very slow traffic" symptomatic that many people access the area using the private car. Indeed to reach the destination from various zones' of Rome at least 30 minutes are required.

Running times			
less than 30 minutes	btw 30 and 50 minutes	btw 50 and 70 minutes	more than 1 hour and 20 min

Figure 93 – Running times

Despite the closeness of the most inhabited zone by the employees of around 5 km, 30 minutes of travelling are required to reach the destination, that increase up to 1 hour and more if coming from the south-west sector of the city. These are the reasons that let thinking of the carpooling system as a good suitable solution.

6.1.2. Intervention design

The sharing of travel between colleagues is one of the most frequently effective measures of sustainable mobility attracting more and more users.

When talking about car travel it must be noticed that the low average occupancy of the vehicle is the problem that has the greatest impact on both the environment and the fluidity of road traffic. Carpooling is a very powerful tool to increase the average occupancy rate of cars used for home and work journeys. In presence of transport problems, such as the absence of public service in some areas or a supply that does not suit the needs of employees, carpooling becomes the optimal solution to meet the needs of users and at the same time drastically reduce road emissions and congestion.

Obviously the sharing of the trip creates in the users some inconvenience, mainly related to the loss of autonomy in travel and the obligation to change the travel itinerary to reach the homes of other crew members. In light of these renunciations it is always good to introduce incentives to capture the interest of employees. For instance, reserve parking lots in a particularly privileged position inside the company park for vehicles that carry 3 or more passengers. It can be expected a real campaign of approaching the carpooling in which they put in light the advantages under all the points of view, from sharing travel costs to socializing that helps to create a welcoming and pleasant working environment. A computer system on the company intranet could be planned where it can be organized the carpooling service. Below there are the results obtained from the various simulations carried out.

The intervention has been designed as follows:

- 50% of company parking lots reserved for carpooling users;
- business software introduced for car-poolers' management;
- a fuel coupon of 40€ per month for carpooling drivers;
- a flexibility margin of entrance up to 60 minutes.

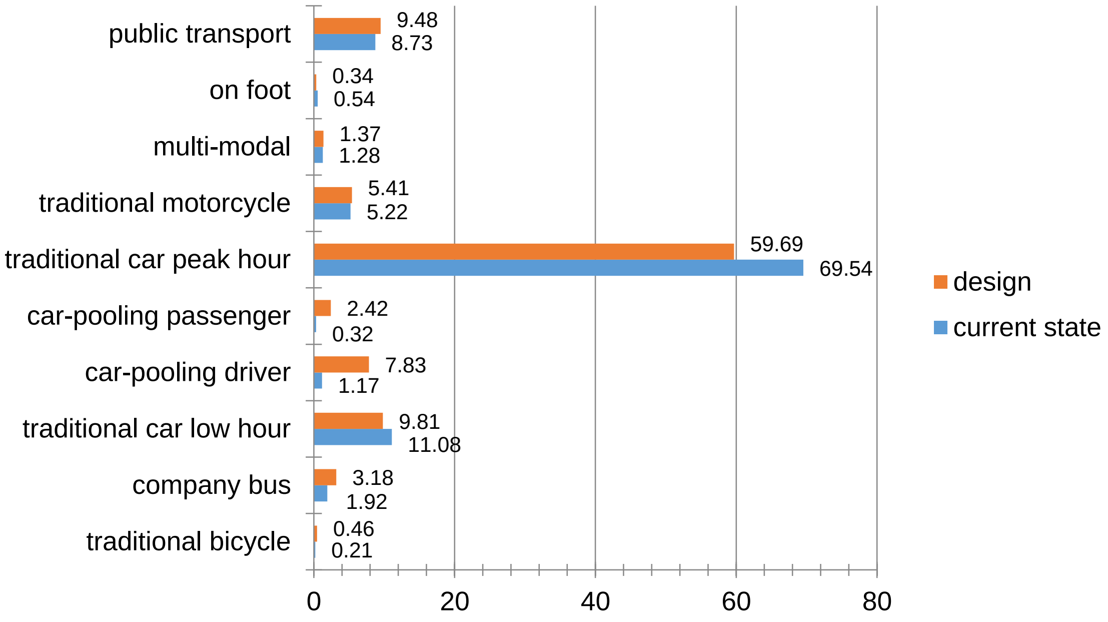


Figure 94 – Modal split (%) carpooling

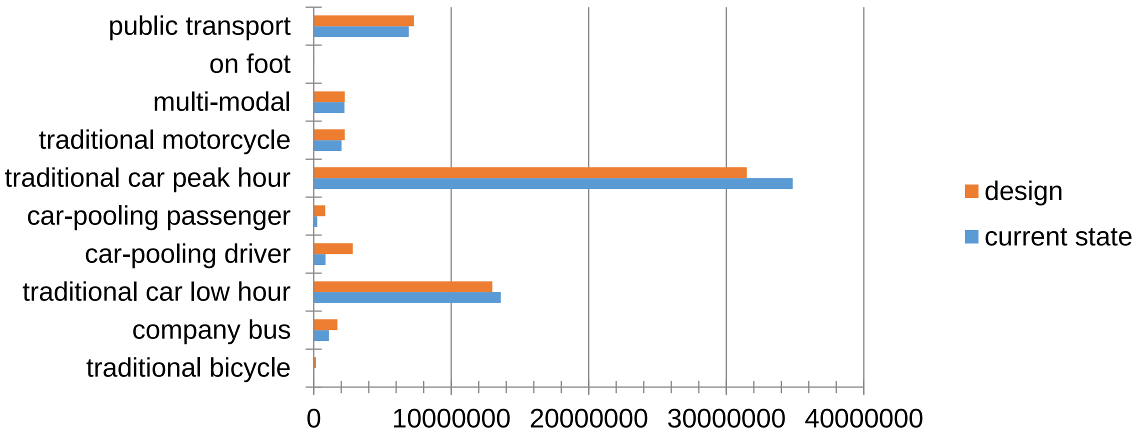


Figure 95 – Total km covered carpooling

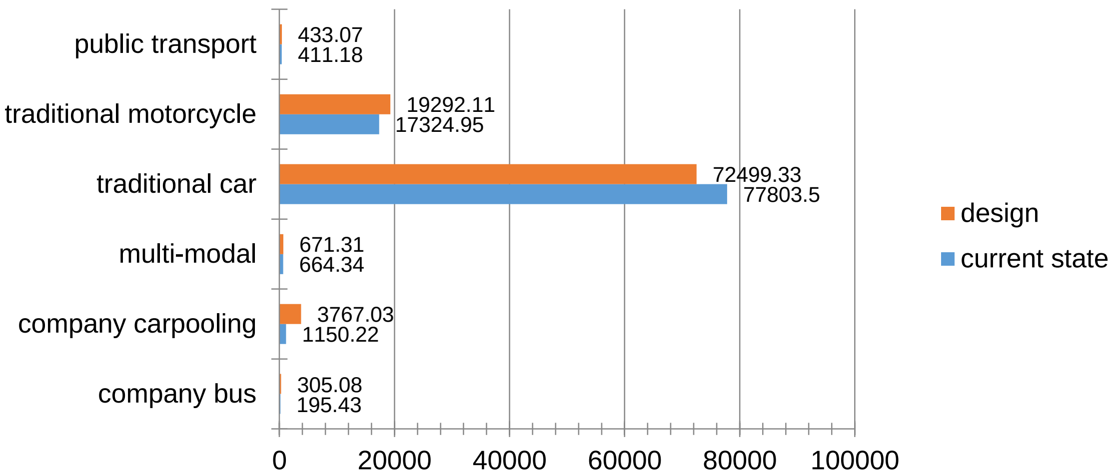


Figure 96 – Carbon monoxide (CO) emitted (kg/year) carpooling

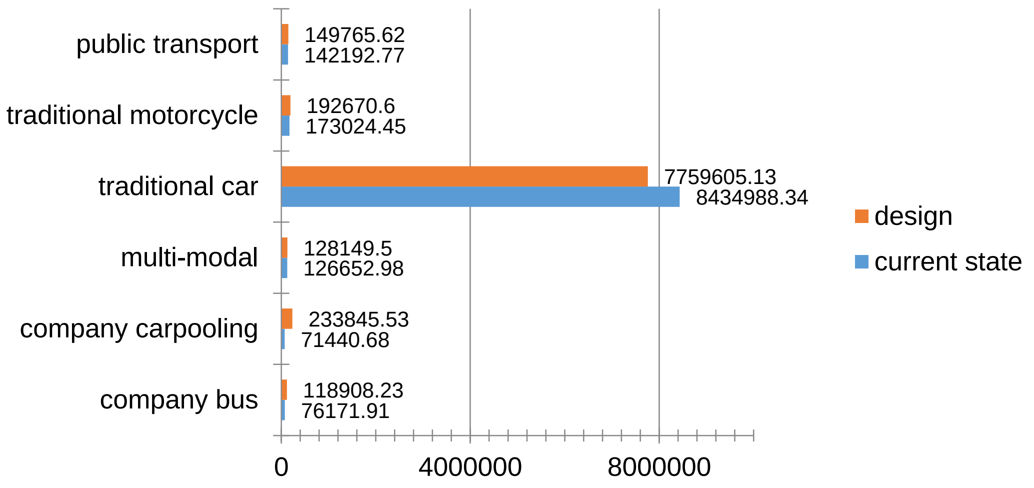


Figure 97 – Carbon dioxide (CO2) emitted (kg/year) carpooling

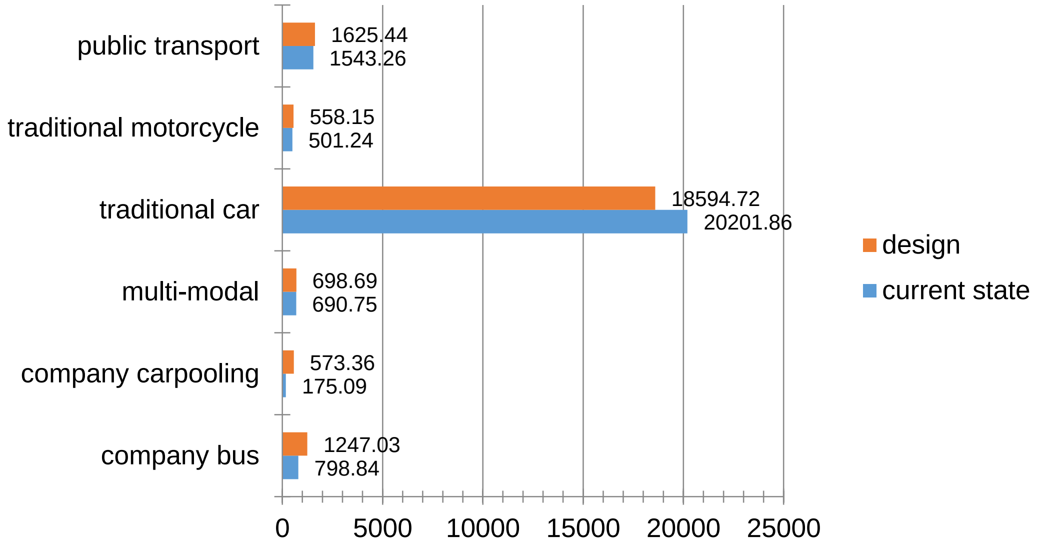


Figure 98 – Nitrogen oxides emitted (NOx) (kg/year) carpooling

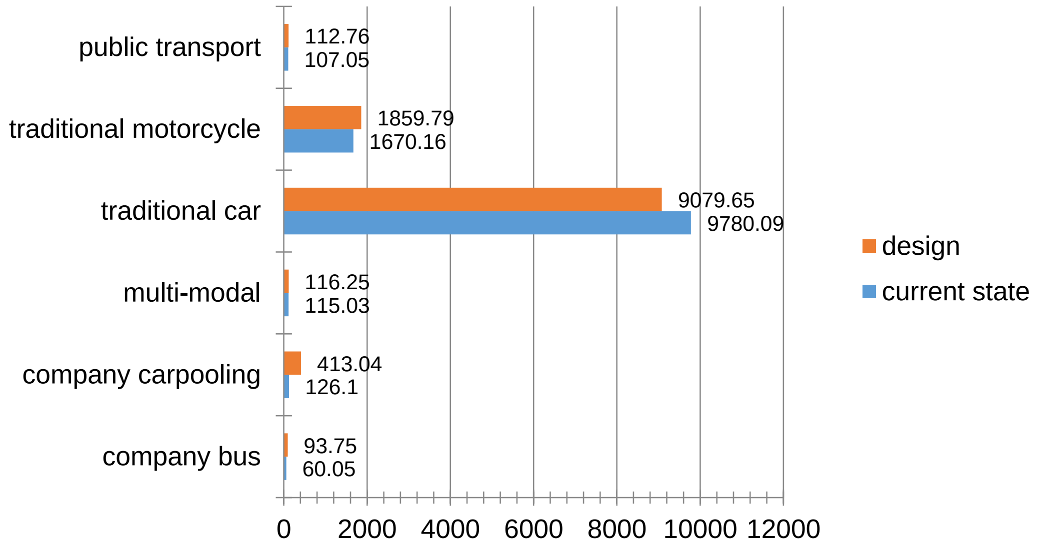


Figure 99 – Volatile organic compounds (VOC) emitted (kg/year) carpooling

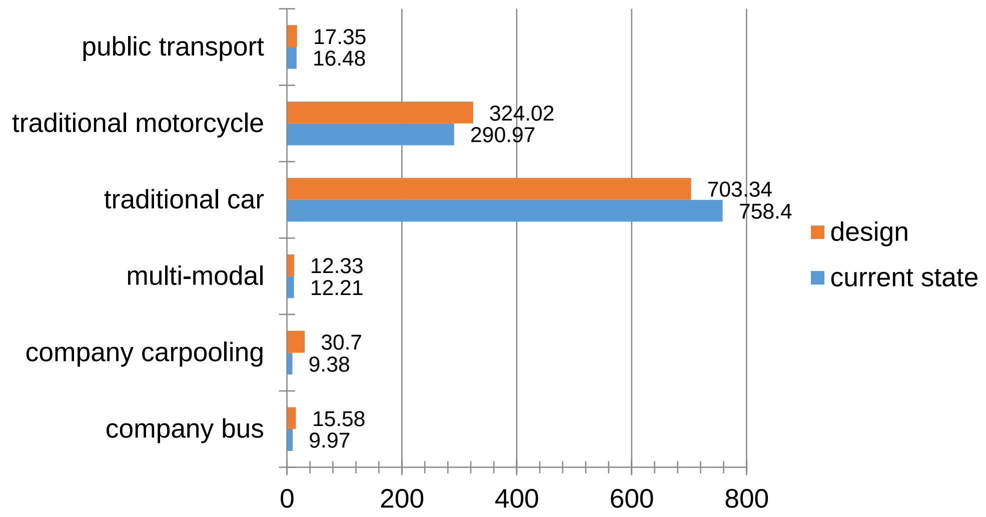


Figure 100 – Methane emitted (CH4) (kg/year) carpooling

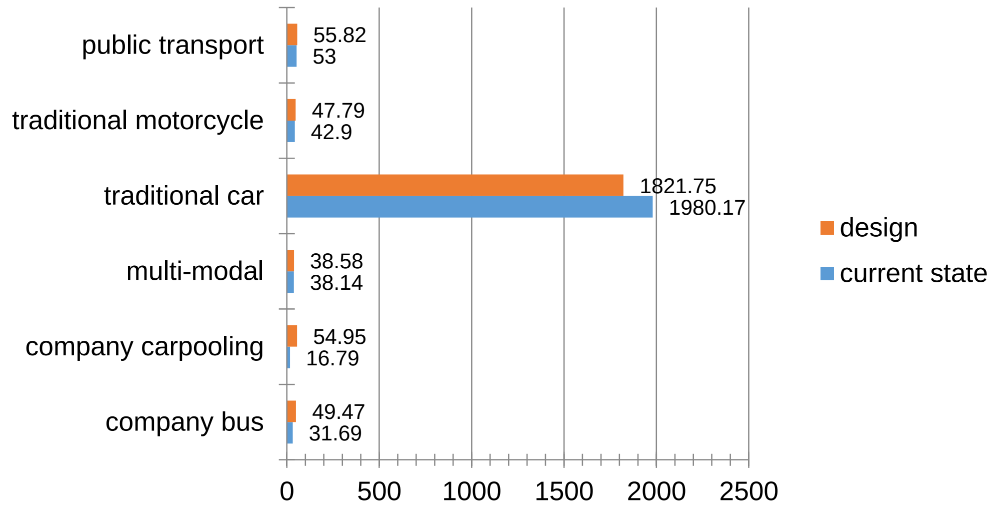


Figure 101 – Particulate matter (PM) emitted (kg/year) carpooling

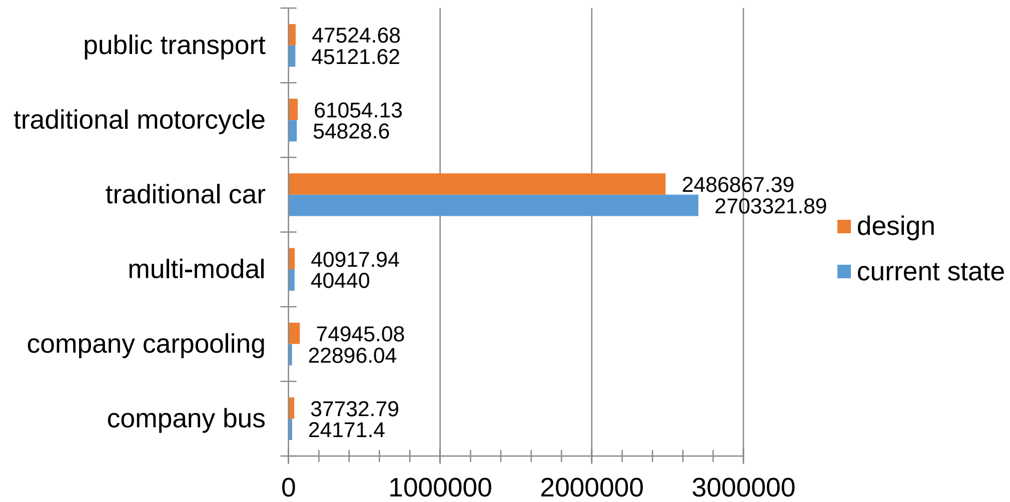


Figure 102 – Fuel consumption (litres/year) carpooling

Entity	Tiburtino Industrial Site	Carpooling
Company		
Missed Production	-2 119 317.17 €	-2 059 262.92 €
Incentives	0.00 €	- 16 800.12 €
Fares	0.00 €	28 196.5 €
Realization costs	- 50 000.00 €	- 50 000.00 €
Total	-2 169 317.17 €	-2 097 866.54 €
Employees		
Fuel	-2 573 123.3 €	-2 476 908.43 €
Vehicle Purchase	-3 709 902.83 €	-3 598 496.16 €
Vehicle Maintenance	-153 394.83 €	-153 406.24 €
Highway Toll	- 303 298.3 €	-298 813.37 €
Fines	- 304 677.42 €	-295 545.18 €
Vehicle Insurance	-1 500 450.69 €	-1 473 207.55 €
Accidents	- 766 582.65 €	-795 767.49 €
LPT Subscription	- 151 294.86 €	-156 522.65 €
Carpooling Fuel Voucher	0.00 €	16 800.12 €
Total	-9 462 724.87 €	-9 231 866.96 €
Externalities		
Polluting Emission Costs	- 81 073.2 €	-77 721.25 €
Road Accidents	- 126 633.55 €	-130 225.64 €
Incomes from fares	4 251 853.44 €	4 124 821.08 €
Total	4 044 146.69 €	3 916 874.19 €

Table 8 – Balance sheet benchmark of cp intervention

The introduction of the carpooling system gave back very good results. The traditional car has been reduced of around the 10% and that has been redistributed almost over the carpoolers driver and passengers. This brought benefits in all the environmental aspects leading to reduction in all the polluting emissions, especially for what concerns carbon dioxide and particulate matter with a reduction of 5% each. What is very noticeable is the overall reduction of fuel consumption. Indeed, again a 5% reduction is recorded passing from 2 890 780 litres to 2 749 042 litres consumed, maintaining the same total number of movements in a year (equal to 3110382). Finally, the balance has been enhanced in its overall values.

This intervention results to be very powerful since, as seen in in chapter 5.1.6 about domiciles' density, the majority if people sharing the same zone of origin could perform the trip together.

6.2. Public transport agreement

6.2.1. Supply analysis

The supply serving the Tiburtino Industrial Site is made up of several modalities: buses, coaches, underground and train.

- Buses

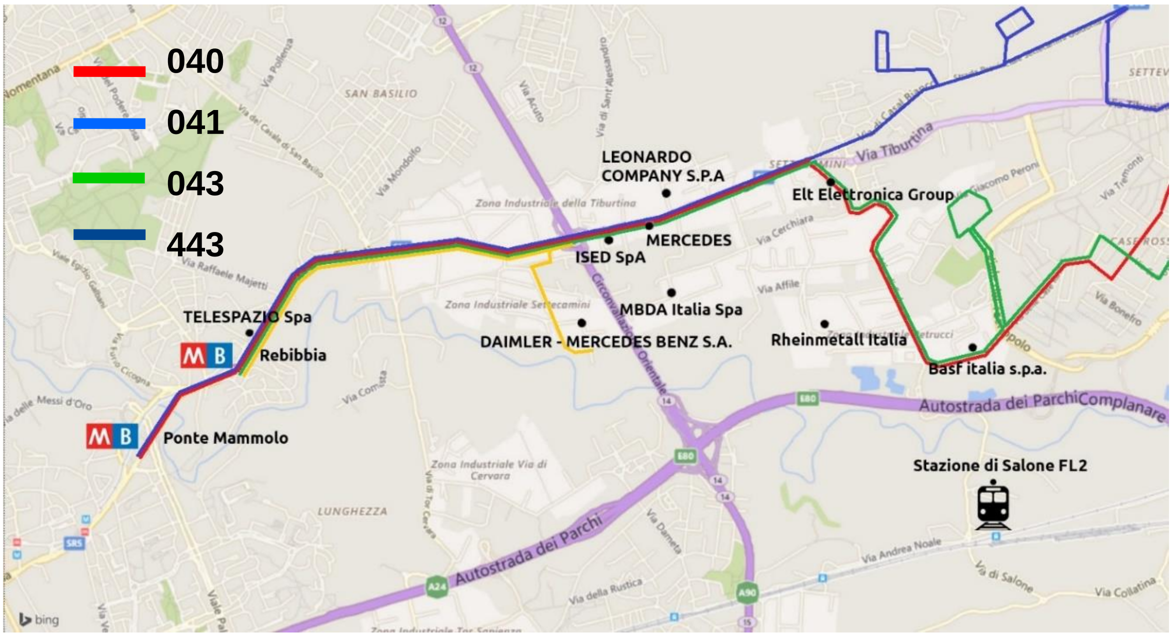


Figure 103 - Buses

The bus lines that serve the area allow a more capillary transport, in fact they transit just along the Tiburtina street in the stretch of interest. The lines in question are:

- 040 Gallesi - Ponte Mammolo (MB)

It starts from the area of Lunghezza passing through Case Rosse street, Salone street (which is also the nearest point for those arriving from the train station) and finally Tiburtina until it connects with the B line, Rebibbia first and Ponte Mammolo then.

- 041 Alba Adriatica/Barisciano - Ponte Mammolo (MB)

This line starts from the residential area of Case Rosse covering another route and along the Tiburtina road reaches the same terminus of line 040.

- 043 Ortucchio - Rebibbia (MB)

This actually runs the same route as the 040 with a slight change in the first stretch in the area of Case Rosse area, ending at the Rebibbia metro.

- 443 Rebibbia (MB)

This line is a circular that starts from the terminus of Metro B by reversing at Bona street

- Regional coach

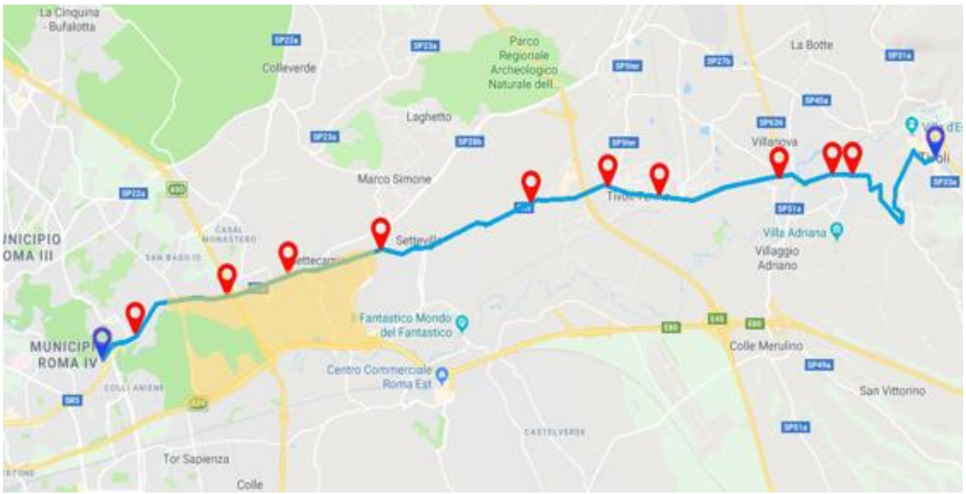


Figure 104 –Regional coach path

It runs from Tivoli to Ponte Mammolo along the Tiburtina street mainly. It is 23 km long with 42 stops. The most important ones are represented in the above picture. The stops along the Site take 11 minutes of run.

- Train service

Figure 105 – FL2 train service

The Salone station, is located along the Roma–Pescara railway and is served by the FL2 trains. Along its urban route it serves the districts of the eastern Roman periphery such as Ponte di Nona, La Rustica, Tor Sapienza and Collatino. It is distant about 5 km from the centroid of the quadrant making it difficult to reach the Site for those who take advantage of this stop. This distance discourages people to use the train because the nearest bus stop is 2 km far on foot, around 30 minutes of walking.

Finally, the table of frequency is presented below.

lines	outward		inward	
	departure time	frequency	departure time	frequency
040	7: 02 21 41 8: 01 20 39 58 17: 05 25 44 18: 03 23 44	$\frac{1}{20\ min}$	7: 10 29 49 8: 09 29 49 17: 05 25 44 18: 03 23 44	$\frac{1}{20\ min}$
041	7: 04 19 34 49 8: 04 19 34 49 17: 10 26 42 58 18: 14 30 46	$\frac{1}{15\ min}$	7: 06 20 35 50 8: 05 20 36 52 17: 10 26 42 58 18: 14 30 46	$\frac{1}{15\ min}$
043	7: 04 36 8: 08 45 17: 06 35 18: 05 35	$\frac{1}{30\ min}$	7: 18 55 8: 32 17: 05 39 18: 12 45	$\frac{1}{30\ min}$
443	7: 06 27 48 8: 09 32 55 17: 12 34 56 18: 18 40	$\frac{1}{20\ min}$	7: 06 27 48 8: 09 32 55 17: 12 34 56 18: 18 40	$\frac{1}{20\ min}$
FL2	$\frac{1}{30\ min}$		$\frac{1}{30\ min}$	
Cotral	7: 00 05 20 40 8: 40 17: 00 15 30 45 18: 00 30 45	$\frac{1}{15\ min}$	7: 26 33 48 8: 03 24 44 17: 24 49 18: 14 44 54	$\frac{1}{20\ min}$

Table 9 - Frenquencies

Note that the frequencies are for the most interesting hours of a typical working day btw the slots of 7:00 – 9:00 am for the morning and 5:00 – 7:00 pm for the evening.

Despite the values may seem good, these frequencies are only theoretical and it's very difficult in actual cases to be applied. This makes the public service not reliable and consequently not a valid choice.

6.2.2. Intervention design

The economic incentive to encourage the use of public transport is certainly one of the most effective means to shift the employees from private to public transport. Easing access to public transport subscriptions, providing discounts compared to normal market prices, is a strategy that many companies have been undertaking for several years and throughout Italy.

From the analysis of national trend, thanks to ISTAT monitoring, it is recorded that in Italy workers using public transport are increasing compared to previous years. Although there are still a lot of people who, in contrast to other European countries, prefer to use the private car to reach the office.

The incentive has been designed as follows:

- 60 minutes of flexibility on the entrance time;
- 150 euros per year to purchase the subscription.

Due to the ease of parking the car inside the company, as for the carpooling intervention, it has been decided to discourage it by means of little daily charge. Moreover, the fare for the annual subscription could be deducted in the monthly payroll so to reduce as much as possible the charge over the household balance. This is made possible thanks to another powerful instrument provided by MOVESION namely MobilityTicket.

The results of this simulation are shown in the following pages.

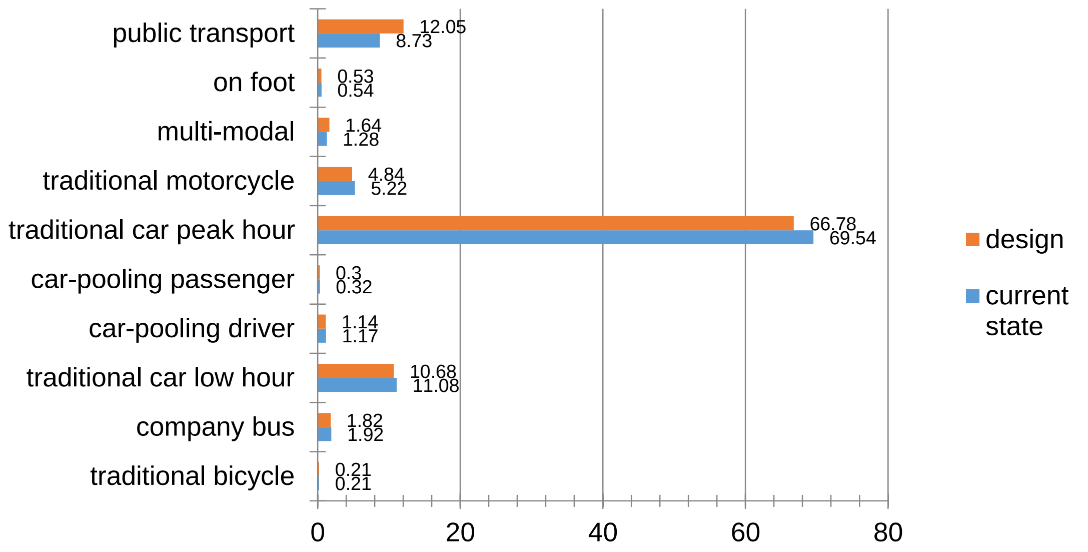


Figure 106 – Modal split (%) lpt

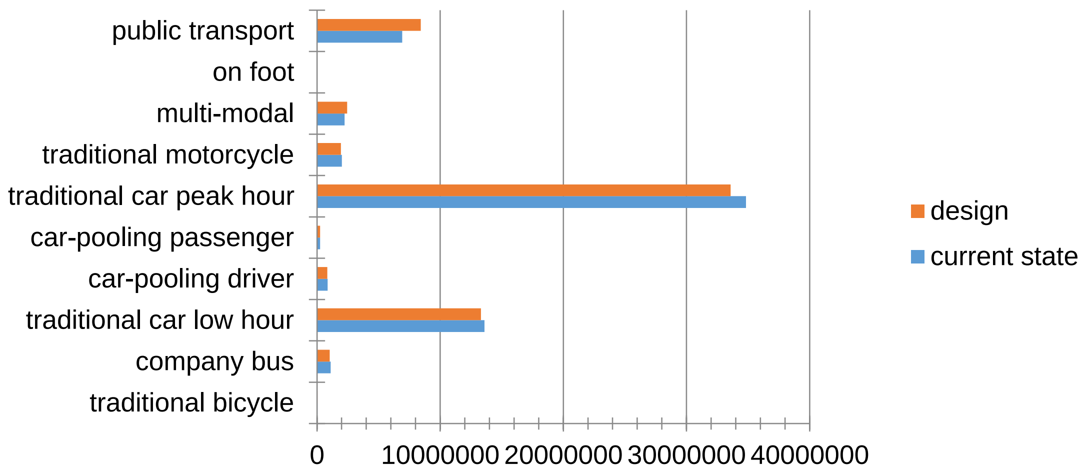


Figure 107 – Total km covered lpt

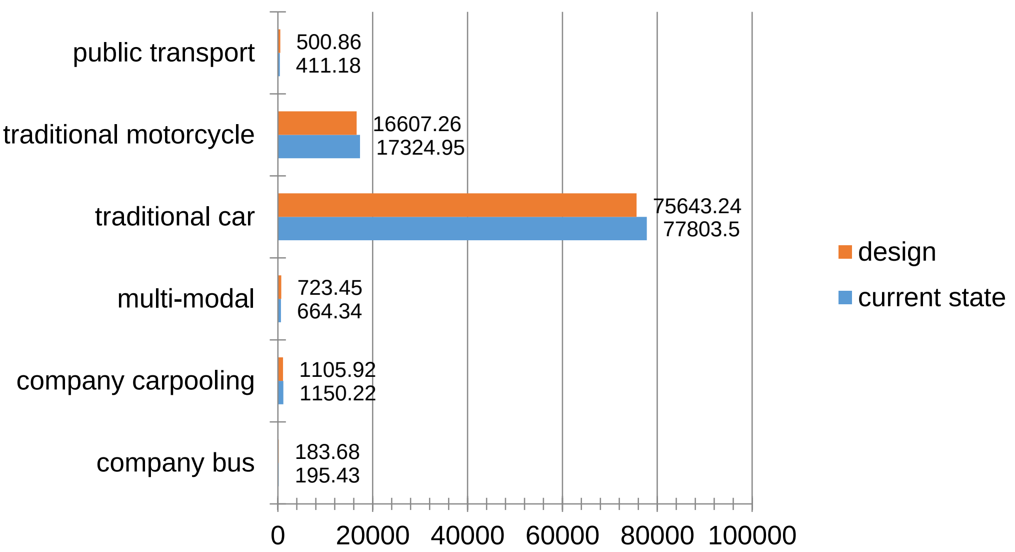


Figure 108 – Carbon monoxide (CO) emitted (kg/year) lpt

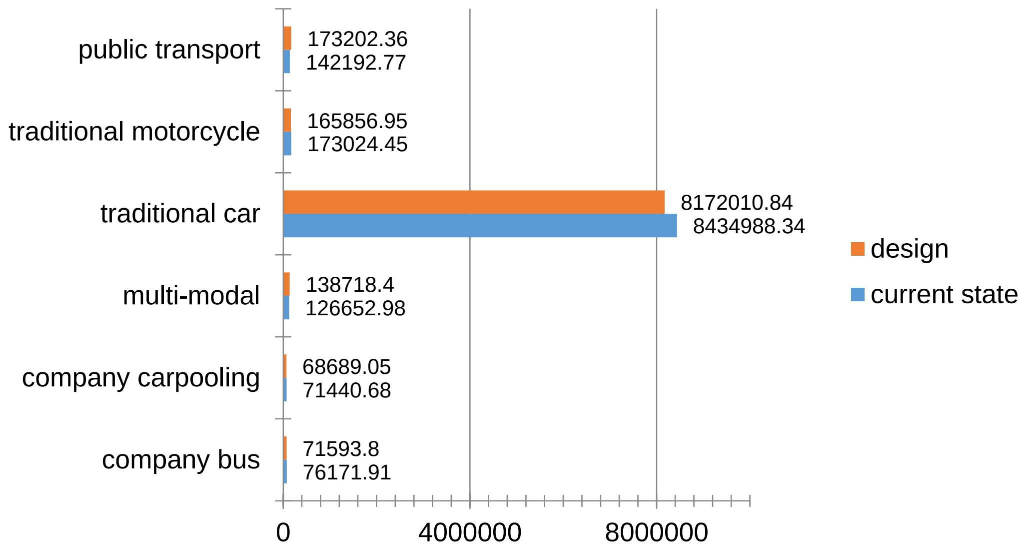


Figure 109 – Carbon dioxide (CO2) emitted (kg/year) lpt

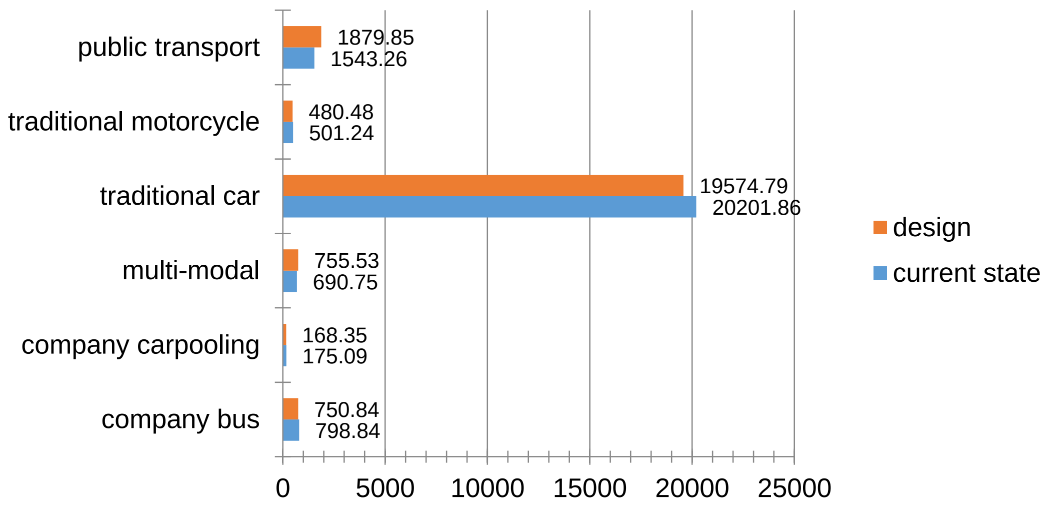


Figure 110 – Nitrogen oxides emitted (NOx) (kg/year) lpt

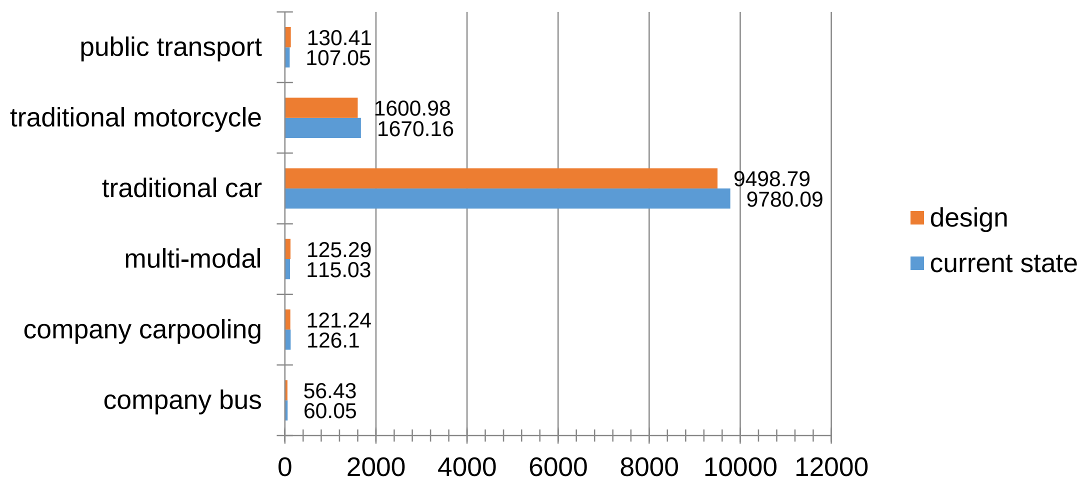


Figure 111 – Volatile organic compounds (VOC) emitted (kg/year) lpt

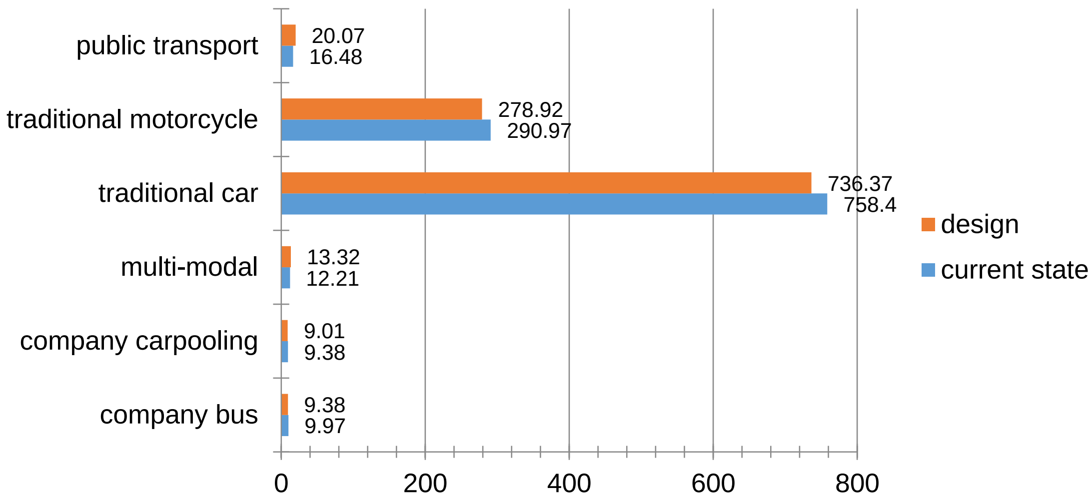


Figure 112 – Methane emitted (CH4) (kg/year) lpt

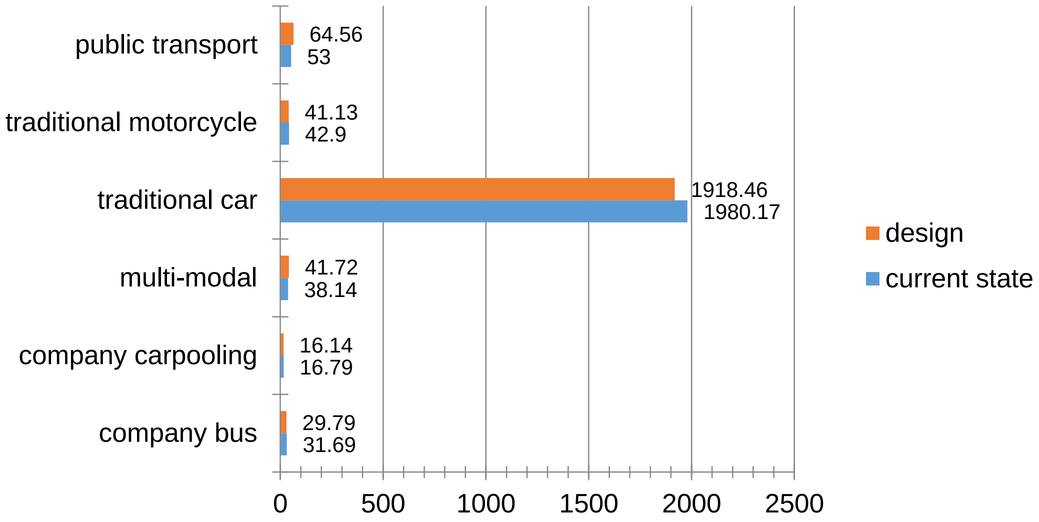


Figure 113 – Particulate matter (PM) emitted (kg/year) lpt

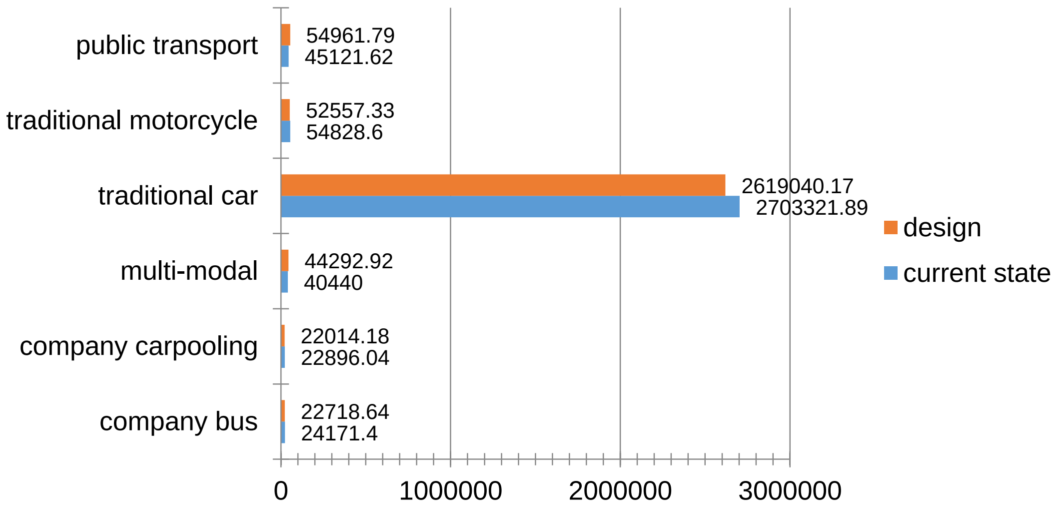


Figure 114 – Fuel consumption (litres/year) lpt

Entity	Tiburtino Industrial Site	Public transport
Company		
Missed Production	-2 119 317.17 €	-2 086 752.66 €
Incentives	0.00 €	- 106 337.83 €
Fares	0.00 €	15 708.77 €
Realization costs	- 50 000.00 €	- 50 000.00 €
Total	-2 169 317.17 €	-2 227 381.71 €
Employees		
Fuel	-2 573 123.3 €	-2 491 547.54 €
Vehicle Purchase	-3 709 902.83 €	-3 612 539.14 €
Vehicle Maintenance	-153 394.83 €	-152 582.22 €
Highway Toll	- 303 298.3 €	-298 684.81 €
Fines	- 304 677.42 €	-296 912.32 €
Vehicle Insurance	-1 500 450.69 €	-1 474 254.8 €
Accidents	- 766 582.65 €	-768 764.64 €
LPT Subscription	- 151 294.86 €	-92 252.06 €
Carpooling Fuel Voucher	0.00 €	0.00 €
Total	-9 462 724.87 €	-9 293 875.36 €
Externalities		
Polluting Emission Costs	- 81 073.2 €	-78 397.06 €
Road Accidents	- 126 633.55 €	-127 294.55 €
Incomes from fares	4 251 853.44 €	4 141 281.51 €
Total	4 044 146.69 €	3 935 589.9 €

Table 10 – Balance sheet benchmark of lpt intervention

In this case the agreement with the local public transport undertaking didn't give back outstanding results. This is mainly due to the fact that people would be willing to use this modality if it were more reliable as a service. Hence, an economic agreement although well accepted, wouldn't fill this limitation.

This kind of soft measure should be accompanied with a strengthening of the existing supply in terms of lines, frequency, dedicated lanes, express shuttle and a general enhanced reliability. However, although weak a reduction of private car is observed leading to benefits in the polluting emissions.

7. Conclusions

This work thesis aims to demonstrate how through the mobility behaviour analysis it is possible to design interventions capable to bring benefits. By means of the software MobilityManager, whose methodology and logic has been deeply discussed, it has been possible to gather fundamental information from the employees of the Tiburtino Industrial Site involving around 20 000 workers; the sample contained around 1000 individuals. These are the basis from which it was possible to carry out transport indicators capable to describe the habits and the reasons of daily mobility choices. Moreover, thanks to the COPERT IV implemented tool the externalities have been calculated, consequently the willingness to change has been investigated. Finally, through the balance sheet all the effects have been monetized.

After having acquired all these data, the design phase could be performed. Starting from the propensity expressed by employees, then in light of the accessibility analysis two possible interventions have been proposed. The simulation model carried out the new indicators showing the changes from the current state to the design one as well as the economic benefits.

In both cases reductions and enhancements have been recorded but the most effective one is the implementation of the carpooling: the modal shift from private car is of 10% and moved to this specific mode. This will for sure help the road congestion in the area of the Site that is known for the high level of traffic. Furthermore, a service like this is very suitable to improve the socialization within colleagues and to better exploit the rate of occupation of each vehicle. This in particular is one of the key aspects of this specific service.

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