POLITECNICO DI MILANO

School of Architecture Urban Planning Construction Engineering

Master of Science in Urban Planning and Policy Design

THESIS TOPIC

STUDY OF COMMUTERS MODAL SHARE AND DEVELOPMENT OF STRATEGIES TO SHIFT THE CAR DEPENDENCE INTO A MORE SUSTAINABLE MOBILITY: THE STUDY CASE OF POLITECNICO DI MILANO

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Dedicado a nuestros padres y familias.

Nuestros compañeros de vida.

Y los amigos de aventuras y viajes

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Abstract

The content of this work is devoted to find out issues on the transportation habits among Politecnico di Milano population that adversely affect the sustainable mobility. We proceed afterwards with the design of strategies and policies to tackle and improve these issues. The methodology used to identify the problems is, first one: the interpretation from a territorial point of view of a survey made by the Città Studi Sustainable Campus project in year 2015. This survey gathered information about the transportation modal choices, among Politecnico di Milano university population (n=9,763 students, n=2,185 staff members). The main tool used for this stage was Geographical Information System Software (GIS) that allow us to visualize and evaluate the travel behaviors. In particular, it was studied its relation with the accessibility to public transportation infrastructure and networks likewise the frequency of their journeys. We analyzed, in particular, the diffusion of originated trips directed to the most important campuses of Politecnico: Leonardo Citta Studi located in the east-central part of Milan and Bovisa located in the north-west border of Milan. Subsequently we proposed a variety of Transport Demand Policies (TDM) aiming the promotion of the public transportation instead of non-motorized mobility, shifting specifically the choice from the car (there are more than 80,000 journeys made by car in the academic year) promoting alternatives like train and regulate the use of cars with parking restrictions and carpooling programs. Finally we also perform calculations to figure out the estimated cost of (TDM) strategies implementation, considering different scenarios according to assumptions based in the state of art provided by the Città Studi Sustainable Campus project.

Riassunto

Il contenuto di questo lavoro è dedicato a scoprire le questioni sulle abitudini di trasporto della popolazione del Politecnico di Milano, che influiscono negativamente sulla mobilità sostenibile. Si procede poi con la progettazione delle strategie e politiche per affrontare e migliorare questi problemi. La metodologia utilizzata per identificare i problemi è, in primo luogo: l'interpretazione dal punto di vista territoriale di un'indagine fatta dal Campus Sostenibile Progetto in 2015. Questa indagine ha raccolto informazioni sulle scelte modali di trasporto della popolazione universitaria del Politecnico di Milano (n = 9,763 studenti, n = 2,185 membri del personale). Il principale istrumento utilizzato per questa fase è stato il "Geographical Information System Software" (GIS) che ci permettono di visualizzare e valutare il comportamento di viaggio. In particolare, è stata studiata la sua relazione con l'accessibilità alle infrastrutture di trasporto pubblico e delle reti, la frequenza dei loro viaggi, i mezzi di trasporto pubblici più utilizzati e la loro ripartizione tra la dimensione territoriale della Regione Lombardia. Abbiamo analizzato, in particolare, la diffusione di viaggi originati diretto alle più importanti sedi del Politecnico: Leonardo Città Studi si trova nella parte centro-orientale di Milano e Bovisa situato al confine nord-ovest di Milano. Successivamente abbiamo proposto una serie di politiche di trasporto demand (TDM) il cui obbietivo è la promozione del trasporto pubblico, invece di mobilità non motorizzata spostando in particolare la scelta dalla macchina (ci sono più di 80,000 viaggi effettuati con l'auto durante l'anno accademico), promuovendo come alternative come (formare) i terni e regolare l'uso delle automobili con divieti di parcheggio e programmi di carpooling. Infine abbiamo anche fatto calcoli per conoscere il costo stimato di implementazione (TDM) strategie, considerando diversi scenari in base alle ipotesi basate nello stato dell'arte fornite dal Campus Sostenibile Progetto.

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1. Introduction

Nowadays the achievement of sustainable mobility is a highly important concern; this concept was introduced by European Union in 1992. The transport was considered then as a human activity with negative effects on the natural environment (E.U, 1992).

According to some scholars there are two basic operations to accomplish the sustainability in the transportation field. On the one hand it is necessary to decrease the transport energy consumption per capita. On the other hand it is imperative to enhance the supply of transportation services and improve accessibility to public transport (Hall, Gossling, 2015). Therefore the formulation of the hypothesis for this work is strongly related with those challenges that European Union is actually facing.

The initial hypothesis for this work is that there are a considerable amount of commuters going to Politecnico di Milano by private car, despite the large network of public transportation in the inner Milano city and the vast systems of trains serving the Lombardy region. The campuses chosen for this work are Leonardo and Bovisa, since those attract the higher percentage of trips: 91% of the trips among all the campuses in Politecnico di Milano.

The main figures of the survey made by Città Studi Sustainable Campus project show us that 24% of the staff commute with car, while in the students situation it correspond to 8%. These figures provide a clear picture about the total number of journeys made by cars going to Leonardo and Bovisa during the academic year, compound by 145 days, which are 80,192 according to the Città Studi Sustainable Campus project survey. If we extrapolate this number to the universal population assuming that transportation habits are similar in proportion to the ones surveyed by this sample, trips made by car turn out to be 399,466. Hence there we have enough room to improve the sustainable mobility.

The first part of this work will be devoted to make a territorial interpretation of mobility habits among the university population of Politecnico di Milano. The early intention of this exercise is verify if the hypothesis is by itself correct, this

interpretation will allow us to establish if there is existing car dependence among university students and staff.

The second objective of this interpretation is to figure out if there are special conditions along the territory which force people to use the car because definitely they ran out of options. Basically we want to define three aspects:

1. Accessibility to public transportation.
2. Resistance among car users to shift their mean of transportation.
3. Lack of environmental awareness and knowledge about other more sustainable options.

Universities are considered as important urban equipment that attracts a considerable amount of people coming from a wide variety of places, therefore the campus are also generators of traffic. Politecnico di Milano is one of the most representative universities located in the city of Milan with presence in Leonardo Citta Studi located at the east-central part of Milan and Bovisa located in the north-west border of Milan. A project called Città Studi Sustainable Campus project was created between Politecnico di Milano and University of Milan on 2011 to transform and promote the sustainability of environment around the "Citta Studi" neighbourhood area. Product of this efforts made to improve the environment quality, a survey was created by Politecnico di Milano`s Manager of Mobility. It was a sample to answer online voluntarily by the university population, both students and staff.

The main structure of the Città Studi Sustainable Campus project survey was composed by questions about the origin and campus of destination regarding the main trip which is the one going to attend lessons. According with those answers the university population were asked to provide detailed information of transport mean chosen including private one like car and motorcycle, public means like train, subway, bus, tram and finally non-motorized modes like walking, bicycle and even skateboard.

The same question was inquired for a secondary journey which is the one made by people when they are doing different activities than lessons. Others aspects were asked on the survey like the frequency of attention to lesson during the

academic years and the exams period likewise the availability of a season ticket for both the regional and urban transportation systems.

The information abstracted of this survey was used by the project Città Studi Sustainable Campus project to obtain the distances made by university population and forwardly calculate the figures of emissions and pollution like carbon dioxide generated by different means of transportation, however the territorial dimension was not considered. The first goal of this work is to provide an interpretation of that very important data on the territorial and geographical dimensions. Thus, the principal tool used in the present study to accomplish this goal was the use of Geographic Information Systems (GIS).

There are crucial facts that can be described thanks to the representation retrieved with this procedure. 1.) Evidence the behavior of individuals in relation with the place they live within the region. 2.) Check the relation between the availability of transportation and choices made by people. 3.) Figure out the relation among distance from the destination-origin and car dependence. 4.) Provide a state of the art about the private means of transportation. This final consideration turns out to be an issue to tackle.

According with some scholars there are three different types of approaches to achieve a sustainable mobility that correspond to the following courses of action: Improve, Shift and Avoid. By Improve it means to get a better efficiency on transportation means. Shift refers to the alteration of current schemes due to their bad performance. Avoid finally aims to reduce those unsustainable habits among commuters (Holden & Linnerud, 2015). There is a diverse number of sustainable mobility policies designed to accomplish a successful result. It is necessary to apply those policies as a set of programs working together, thus the result must be more effective since the three axes are tackled (See figure 1).

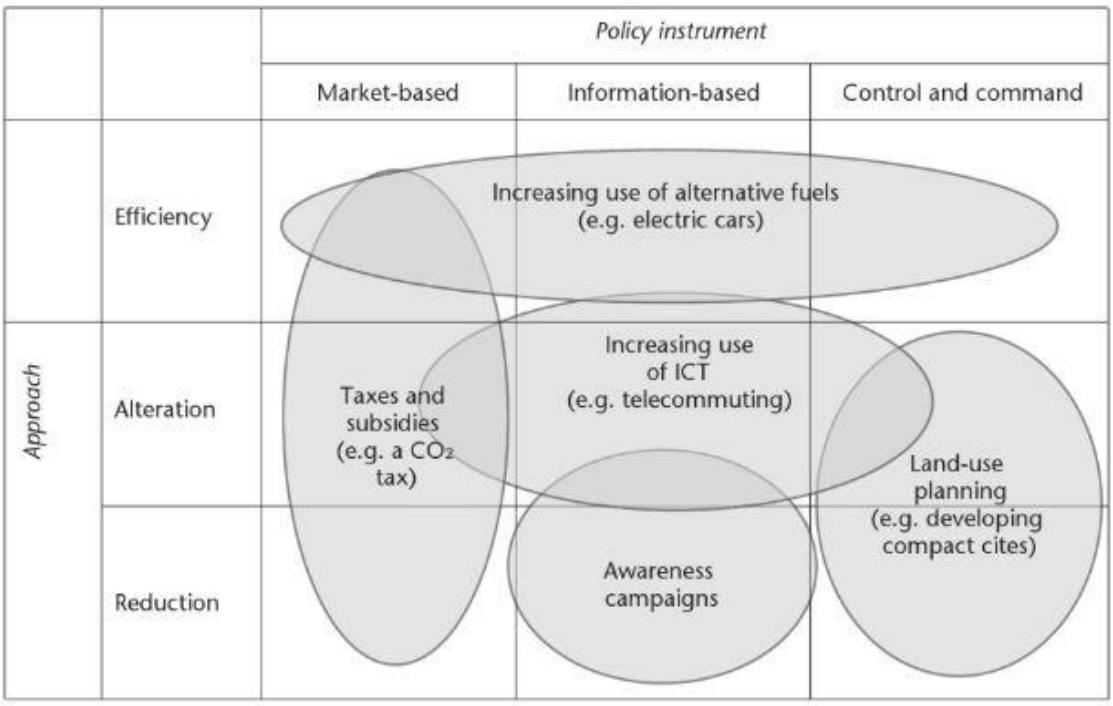


Figure 1 Mobility Policies. Holden & Linnerud, 2015.

In the specific case of Politecnico di Milano we want to propose Transport Demand Policies (TDM) to increase public transport accessibility and promote the shift from private means to public modes. Obviously it is necessary to think about giving subsidies to university population, these costs are measured in economic figures assuming there is going to be an exact number of people taking advantage of them.

Other policies more coercive like the prohibition to use internal parking spots for free in the case of staff or the introduction of a parking toll for the street parking spots situated close to the university campuses supported by the installation of parking meters. In fact, the territorial interpretation had shown that some employees and students prefer to use their cars, even if they are living at a walking or biking distance from the campus, supposedly by the parking free benefit.

Carpooling strategy will be also considered on this work, a similar project was already developed by the Politecnico di Milano on September 2011, called PoliUniPool it was designed to create a platform were students and employees would have the possibility to share their private cars (Colorni et al, 2011).

However this project was not successful and did not acquire the critical user's mass, which derives in the closure of the project. During the development of this project we contacted Professor Alberto Colorni, who was in charge of the project development, in order to get his feedback about the drawbacks and possible causes of the failure. This will be explained in deep during the chapter dedicated to the policies explanation.

Ultimately this work will also make an evaluation of the existing bus routes supply in those municipalities with high car dependence, to have an idea about the actual supply and verify if the lack of public transport supply is a determinant cause of car dependence. The final stage of this work is to perform an assessment of the cost derived from the implementation of these policies.

Regarding the policies on the shifting approach we will draw different possibilities to consider theoretical incomings derived from the use of parking spots. With respect to the reduction strategies there will be proposed some courses of action addressed to increase the awareness about transportation impacts among university population, since this seems to be a crucial factor in the successful accomplishment of sustainable mobility.

2. Literature review

One of the objectives of this work is propose and design policies devoted to shift the extensive use of private modes of transportation into public mean, based on the interpretation of quantitative data from the territorial point of view. Therefore the literature review is oriented to revise these topics and have a look to other successful experiences developed in the world.

We would like to mention first the use of automobile which is widespread in the urban centers and is the main cause of environmental pollution, infrastructure damage, fuel consumption and traffic congestion. Thus the main effort of Transport Demand Policies (TDM) is to shorten the use of cars or change the commuter's choice for public transportation systems. Nonetheless, the car is perceived by users as the most comfortable mode of transportation and it offers to its users the availability and readiness that public transport lacks, then this policies frequently provoke resistance (Tertoolen & Van Kreveld, 1998).

Usually those policies devoted to reduce car dependence use strategies like provide information to car users about the environmental consequences and financials costs derived from their choice. Nevertheless if these actions are able to increase the awareness of people about environmental issues it appears to be that they are not capable of perform a change in the behavior of car users, because commuters are not aware of their own participation on pollution and even they tend to claim that other users are responsible for the drawbacks caused to environments (Tertoolen & Van Kreveld, 1998).

This early review of literature is suggesting a key aspect for the development of this work: those strategies asking car users to have the willingness of reduce their car dependence is not a successful method. Then it is necessary to enlarge the spectrum of possibilities and options to accomplish this goal.

Parking spots are a matter of big importance for car users: this is a condition that affects directly the accessibility of the private transportation modes which is considered the most important advantage of car in terms of attractiveness (Marsden, 2006). This fact can be easily explained if we consider a scenario

where destination places does not have enough parking spots and as a consequence drivers have to park their private automobiles at a far distance from their work or in our case study the university.

Besides this condition if parking spots located at a very closer walking distance are strongly charged with a tool, this condition will cause an effect in the behavior and choices made by commuters. With this regard it is plausible to note that European cities have autonomy as local entities to design and implement policies for the management of parking spaces in the city: regulations, market, requirements, restrictions and so forth (Mingardo & Van Wee, 2015).

Introduction of pricing parking and raising prices on those areas which currently have a parking pricing method appears to be the most successful financial discouragement for car users. Increase the price has a very bigger impact on travel behavior than other components of total trip cost like the gasoline or the maintenance costs associated (Toor & Havlick, 2009). However this situation has a superior likelihood of occurring if there is a good enough supply of public transportation means capable of satisfy the increase on demand.

Thus the parking pricing practice will be considered on the development and proposition of Transport Demand Policies, furthermore there is a fact that our case study is an scenario where the biggest percentage of commuters are students, these kind of population is unlikely to choose their university based on parking availability contrary with other uses like commercial activities and working activities.

The issue related with transportation fares is the subsequent topic of interest in the development this project. Governments around the so-called developed world: Europe and United States, have come to agreed that the construction of new roads or the enhancement of streets profiles is not the solution to solve the problems of congestion and pollution (Cullinane, 2002). There is another possible choice that consists in the improvement of public transportation provision and the reduction of fares to attract people.

Transport Demand Policies include a strategy known as Transit Pass that has a basic idea of give subsidies to the university population both students and staff to grant them the full access to transportation service at least in lesson and exams period during the academic year. These subsidies can vary in the percentage of coverage according with the availability of resources at the university budget and the distance that persons are located with respect to the campus.

All in all, the implementation of this strategy represents a huge economic effort, nevertheless we want to present a study performed at University of Trieste in Italy where has been demonstrated that it is the most efficient action to accomplish the reduction of car use (Rotaris & Danielis, 2015). It does not seems to be economic and financially sustainable due to the high number of students and the conduction of university resources destined mostly in academic purposes (Rotaris & Danielis, 2015).

We want also to consider another experience in the US; it is worth to mention that is context quite different than Europe but in the specific realization of the Transit Pass had obtained successful results. The first one of this kind of programs was made in 1969 at the University of California-San Diego (Toor & Havlick, 2009). Since then many other programs has been developed to enhance the use of public transportation among universities population.

The experience in most of the US universities is to make a contract with the transportation provider company in the town and arrange discounts to grant the universal access for its population. In many cases the first experience is only realized with students since this sort of arrangements is a bit more complicated if is imposed on the staff population. However, after the first year implementation and having accomplished an increase in the public transportation ridership as well as the benefits obtained by students, employees usually begin to ask to be covered by the Transit Pass program (Brown, Baldwin & Shoup, 2001). The bigger subsidies are granted to students but the situation with employees is usually giving them lower subsidies.

Up to this point there is a question about fund raising, with this regard according with experience on US universities the principal fund raising activity made is the create pricing parking within the university facilities.

Transport Demand Management strategies, like the Transport Pass, work as an efficient action if they are combined with other kind of policies, like: parking pricing, increase bus routes frequency, creation of new bus lines to provide better accessibility to those people who live in places located in long distances from the transportation network, creation of carpooling programs and endorsement of existing programs. With this spectrum of possibilities it is more likely to produce efficient results among the population (Litman & Lovegrove, 1999). Then if it is considered the implementation of this Transport Demand Management strategies, the next step must be the calculation of the impact among the university population, the society in general, the neighborhoods where universities are located and finally the impact in the environment.

The aim of this work is not to enter in the detail of the industrial measurement of economic dimension of a program like this one, but it is reasonable to mention a variety of aspects that must be taken into consideration within the process of decision-making.

We would like to mention the benefits for the transportation company if a Transit Pass program will be realized. Usually universities pay in advance to the transportation company for the provision of this service; obviously this will represent a financial advantage specifically for the cash flow.

The management of cash is a crucial point in the operation of transport providers since everyday thousands of operations are made therefore it needs the public attention and the money handling is also a factor that the transport company does not have to provide for university population.

Access to the system requires cards or tickets printed, but in the case of university user they can deal with this activity directly using their universities identification cards. A benefit for the transport company in the future is the fidelity of user that at the current moment are students receiving a subsidy but

in the moment they finish their studies they are more likely to become users who will pay complete fares.

This passage has the intention to create awareness about the possibility to accomplish arrangements between the university and the transport company in order to obtain preferential fares for its population reducing the cost of the program. Nevertheless this work will not enter into details with this regard since it is not a matter of a Transport Demand Management strategy but it is an industrial approach.

3. Methodology

One of the projects and activities that concern to Citta Studi-Campus Sostenible hold by Politecnico di Milano and Università Degli Studi di Milano is the study of mobility credits to encourage sustainable mobility among students and employees. In 2015, between July and October, the General Management of Politecnico di Milano, in collaboration with Città Studi Sustainable Campus project, developed a survey on student and workers traveling to Politecnico campuses. This involved a questionnaire devised as part of the Carbon Management Plan of Politecnico to promote further sustainable forms of mobility and lower greenhouse gas emissions. The questionnaire was not mandatory and was made with a compulsory part and a voluntary one.

The compulsory part of the questionnaire had also three main parts: The first one was focused on the socio-economic aspects of the interviewee regarding the origin of the journey and the Politecnico destination campus.

The second part considered the frequency of the journey along the academic year (lessons time) and during the exams period. It also considered the modal share selected by the interviewee to make the trip that could be a combination of eight modes: car, motorbike, train, subway, tram, bus, bicycle and skateboard. There was also the option to select the walking mode; however, this option could not be considered in combination with another mode.

The third part was focused on the characteristics of a secondary journey which is a less frequent alternative to reach Politecnico campuses. This secondary journey could consider different origin and different Politecnico campus to the one considered in the first part.

The voluntary part of the questionnaire wanted to know the advantages and disadvantages of the selected modal share by the interviewee, an opinion regarding incentives to use bicycle to reach different Politecnico campuses, an opinion related with the main issues of Politecnico regarding mobility and an

opinion of the best way to communicate information about initiatives related with sustainable mobility.

The present study is mainly focused on the compulsory part of the questionnaire because its objective is to improve the modal share in terms of reduce the use of private transport means. The analysis is focused on motorized means of transportation as train, public transport and automobile due to the low share that represent the trips made by foot, bicycle and skateboarding.

The methodology of present study is composed by 1) Collection of the results from the described mobility survey and 2) Preparation of the survey results in order to manage them in a graphic way with GIS software (Creation of SHAPE files).

3.1 Data collection

Politecnico di Milano campuses are spread across northern Italy, specifically spread across Lombardy region. There are seven campuses, main ones located in Milan whose are Leonardo and Bovisa, one located in Lecco, one in Como, one in Mantova, one in Cremona and one in Piacenza.

The Citta Studi-Campus Sostenibile survey has collected almost 12,000 answered mobility questionnaires. From this universe 84% represent questionnaires answered by students and 16% by workers. Guereschi (2015) in his dissertation work named *In Bici al Politecnico. Beneficio Socio-Ambientali e Riduzione delle Emissioi di* Co_2 *Passando Alle Due Ruote* has deleted the results that could distort the universe of the data set. Guereschi (2015) has cleaned the data set of the survey results using a statistical procedure that consider outliers whose represent observation points that are distant from other observations. The quantity of questionnaires considered after the cleaning and considered in the development of the present study is categorized and summarized in the Table 1.

Table 1 Quantity of questionnaires. Own elaboration.

Category	Leonardo	Bovisa	Lecco	Como	Mantova	Piacenza	Cremona	Total
Students	**4,948**	**3,925**	**310**	**160**	**116**	**197**	**107**	**9,763**
assegnista di ricerca	88	76	1	5	0	0	3	173
assegnista di ricerca; cococo	9	8	3	0	0	0	0	20
cococo	22	11	1	1	1	0	0	36
Dottorato	218	104	2	4	0	0	0	328
Support staff	**337**	**199**	**7**	**10**	**1**	**0**	**3**	**557**
Docente a contratto	145	136	12	10	12	16	4	335
Part time professors	**145**	**136**	**12**	**10**	**12**	**16**	**4**	**335**
Personale Tecnico-Aministrativo	533	129	8	9	10	10	3	702
Technical and administrative staff	**533**	**129**	**8**	**9**	**10**	**10**	**3**	**702**
Professore associato	178	72	3	3	0	0	1	257
Professore ordinario	91	39	2	0	1	0	0	133
Ricercatore legge 240	35	13	2	1	0	0	1	52
Ricercatore universitario	92	50	3	0	1	2	1	149
Research staff	**396**	**174**	**10**	**4**	**2**	**2**	**3**	**591**
Total Workers surveyed	**1,411**	**638**	**37**	**33**	**25**	**28**	**13**	**2,185**
Total Sample surveyed	**6,359**	**4,563**	**347**	**193**	**141**	**225**	**120**	**11,948**
Share surveyed (%)	**53.20%**	**38.20%**	**2.90%**	**1.60%**	**1.20%**	**1.90%**	**1.00%**	**100.00%**

From the total sample considered, 9,763 journeys for students and 2,185 for employees can be seen that Leonardo and Bovisa are the only campuses that attract significant number of journeys, more than 91% of the journeys

represented in the mobility survey. Regarding the total universe of students and workers whose attend Politecnico di Milano campuses the share of questionnaires considered in this study are significant for both cases, however more representative for staff:

Table 2 Considered questionnaires and total universe. Guereschi, 2015.

	Students	**Workers**	**Total**
Considered	9,763	2,185	11,948
Total universe	42,878	5,755	48,633
Percentage	23%	38%	25%

Based on the distribution of students and workers among Politecnico population presented in the mobility survey and the total universe shown above there has been estimated the cost of the policies mentioned in the transport demand strategies presented in the last part of the present study as well as the estimated quantity of people that could have benefit from the different strategies.

3.2 Data preparation

In order to have the relevant information regarding modal share and use it within GIS software, the data set has been organized considering the number of commuters generated by the municipalities and the nine administrative zones inside Milan. Hence, each campus will have two SHAPE files, one considering the trips generated from different municipalities without considering Milan and one considering the commuters generated from the different nine administrative zones inside Milan. The attribute to identify the different municipalities in the SHAPE files is the code of statistics (PRO_COM) and the attribute to identify the zone inside Milan is it administrative code (ZONADEC). The information is organized in order to have data sets for students and workers.

There have been identified seventeen possible relevant transportation combinations, as follows. The remaining cases are grouped under "other".

1. Only car.
2. A combination of Private Transport (PiT), that can be either car or motorbike, and train.
3. A combination between PiT and Public Transport (PuT) that can be subway, tram or bus.
4. A combination of PiT and bicycle.
5. A combination between train, PiT and PuT.
6. A combination between train and PuT.
7. A combination between train and bicycle.
8. Only train.
9. Only PuT.
10. A combination between PuT and bicycle.
11. Only bicycle.
12. By foot.
13. A combination between trains, PuT and bicycle.
14. A combination between PiT, bicycle and PuT.
15. A combination between PiT, bicycle and train.
16. A combination between PiT, bicycle, train and PuT.
17. Only motorbike
18. Other

Therefore preparing the SHAPE files to work with GIS software there have been developed attributes according to each one of the considered combinations for the primary and secondary journey, for example the attribute J1C1 means quantity of commuters that make their primary journey with combination one (Only car) and J2C1 means secondary journey made with combination one. In order to summarized the combinations there are also total number of commuters for primary journeys and secondary journeys, J1Total and J2Total, respectively.

There have been prepared, for the primary and secondary journey, four main combinations where prevails either the use of train, public transport (PuT), private transport (PiT) or no motorized modes:

1. Prevail of train within the modal share: Sums up the quantity of commuters that use the combinations 2, 5, 6, 7, 8, 13, 15 and 16. In the SHAPE files it is represented by J1pTRAIN for primary journeys and J2pTRAIN for secondary journeys.
2. Prevail of public transport (PuT) within the modal share: Sums up the quantity of users of combinations 3, 9, 10 and 14. In the SHAPE files it is represented by J1pPUT for primary journeys and J2pPUT for secondary journeys.
3. Prevail of private transport (PiT) within the modal share: Sums up the quantity of users of combinations 1, 4 and 17. In the SHAPE files it is represented by J1pPIT for primary journeys and J2pPIT for secondary journeys.
4. Prevail of non-motorized means within the modal share: Sums up the quantity of users of the combinations 11 and 12. In the SHAPE files it is represented by J1pNM for primary journeys and J2pNM for secondary journeys.

Besides the transport modal share to reach Politecnico di Milano campuses, the data preparation considers the frequency of the primary and secondary journeys to reach the university during the academic year in lectures time or exams sessions, always discriminating by municipality or zone inside Milan. In order to understand the attributes related with frequency of trips in the resulting SHAPE files must be clear the next statements:

1. J1fLec1: Related with the primary journeys made between the 0% and 10% of lectures time (J2Lec1 in the case of secondary journey).
2. J1fLec2: Related with the primary journeys made between the 10% and 20% of lectures time (J2Lec2 in the case of secondary journey).
3. J1fLec3: Related with the primary journeys made between the 20% and 30% of lectures time (J2Lec3 in the case of secondary journey).
4. J1fLec4: Related with the primary journeys made between the 30% and 40% of lectures time (J2Lec4 in the case of secondary journey).
5. J1fLec5: Related with the primary journeys made between the 40% and 50% of lectures time (J2Lec5 in the case of secondary journey).

The sequence follows until J1fLec10 for primary journey and J2Lec10 for secondary journey. In the case of exams period there is the prefix *Exa* with the same intervals, for instance J1fExa2 represents the primary journeys made between the 10% and 20% of exam session (J2Exa2 in the case of secondary journey).

There is also considered the number of commuters with different types of transport season ticket. Considering urban transport, extra urban, train, car sharing, carpooling and bike sharing.

In the case of the SHAPE files prepared to Leonardo and Bovisa there has been considered the reason of choosing the mean of transport to reach the campuses. The reason of choose the way of transportation could be related with speed, price, comfort, safety, availability of additional services, autonomy, non-availability of other way of transportation, family reasons and finally the availability of share the trip with other commuters.

Finally, in the data set of workers there is a subdivision regarding the kind of job:

1. Support Staff: *Assegnista di ricerca, cococo, Dottorato*.
2. Part time professor: *Docente a contratto*.
3. Technical administrative staff: *Personale tecnico-amministrativo*.
4. Research Staff: *Professore associato, Professore ordinario, Ricercatore Legge 240, Ricercatore universitario*.

4. Results and analyses of the data set

The results and analyses of the data set consider two main aspects:

- Current travel arrangements.
- Spatial distribution of journeys attracted by Politecnico campuses.

The analyses of the data set will give understanding of the spatial distribution of the generated trips among the different municipalities in Italy, mostly in northern Lombardy, and the qualities of the territory that motivate the commuters in the decision of transport.

4.1 Current travel arrangements

Before the development of maps about the distribution of journeys to Politecnico di Milano campuses it is important to understand which are the modes most used by commuters from the outside and from the inside of Milan (See Figure 2). The most used modal shares are those where the train prevails for students and workers. Combinations where public transport prevailS occupy the second order in the rank for students.

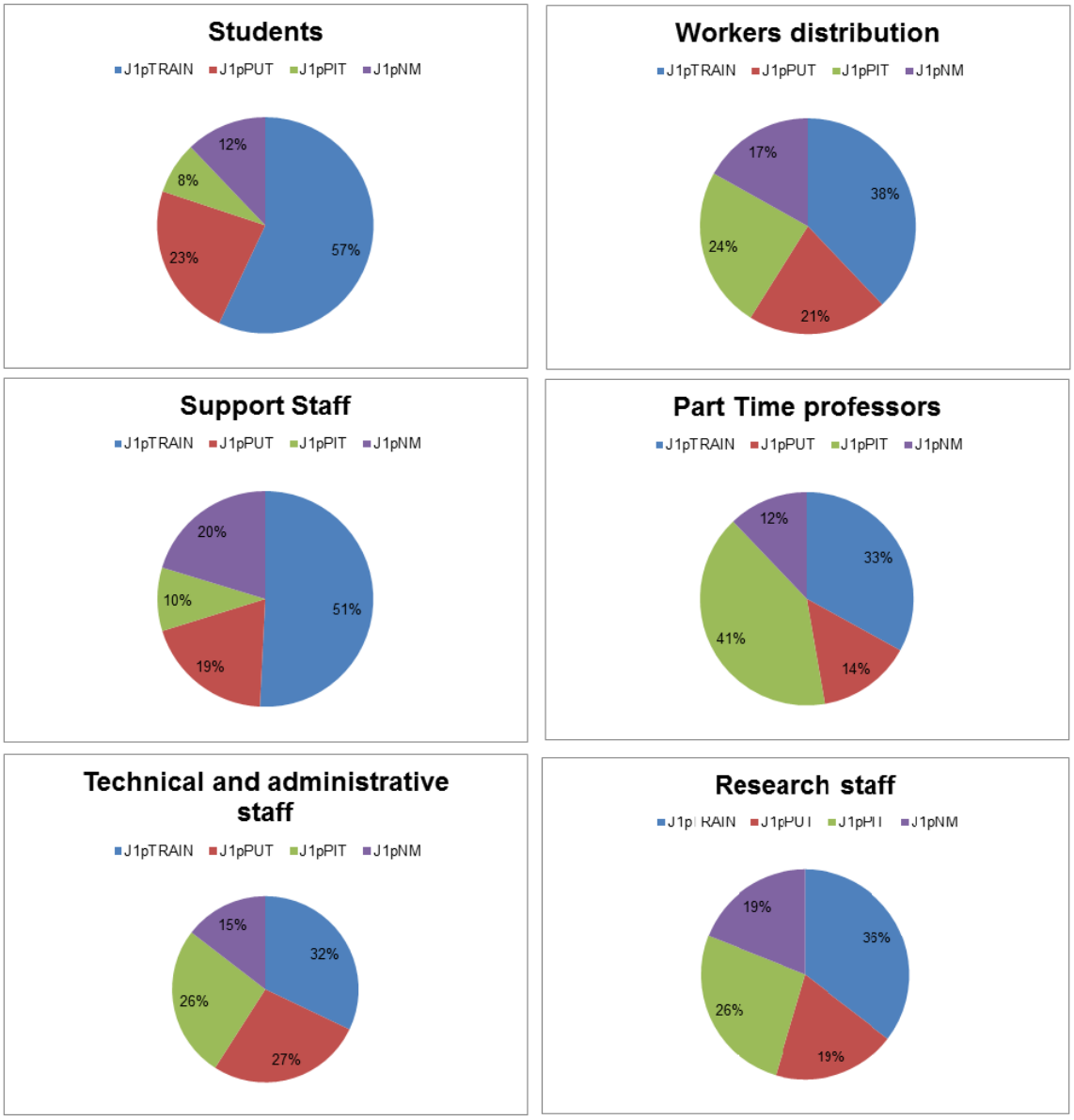
Despite the percentage of journeys where public transport prevails is similar for both workers and students, workers prefer to use private mean to reach the university. There is a non-significant difference between the percentage of workers and students that use no motorized means.

Regarding the patterns of workers, it can be seen that the use of combinations where the train prevail has the highest percentage of journeys for support staff, technical and administrative staff and research staff. The support staff is the category of workers that uses the less a private transport mean to reach Politecnico di Milano campuses and part time professors are the ones that use it the most.

However, part time professors represent the smallest portion of the workers that answered the questionnaire, 335 people (15% of workers sample); due to their

kind of work they come less frequently to the university. Regarding the use of no motorized means and the use of public transportation it can be said that the behavior is quite similar for both modes along the categories of workers.

Figure 2 Current travel arrangements. Own elaboration.



4.2 Spatial distribution of commuters

The present section summarizes the spatial distribution of people attracted by the different campuses of Politecnico di Milano considering the modal share of the primary journeys as well as the secondary ones and the relation between the frequency and availability of public transport ticket to reach the university.

4.2.1 Primary journeys attracted by Politecnico di Milano Campuses

To understand the spatial distribution and the quantity of commuters attracted by each one of the campuses there have been prepared general maps discriminating the quantity of commuters generated from municipalities outside Milan and the quantity of commuters generated from the nine different administrative zones inside Milan.

In the case of main journeys attracted by Leonardo campus and generated by students it can be said that the concentration of trips is not only located in Milan, it is spread among Lombardy and northern Italy as well. The highest concentration of students can be appreciated in northern Lombardy as an envelope bounded by main municipalities as Lodi at south, Brescia at east, Lecco, Como and Varese at north and Novara at west. Based on the data set, municipalities like Novara, Monza and Bergamo generated more than forty students that commute; therefore it can be said that students are concentrated in municipalities where there is a good supply of train infrastructure.

In a longitudinal way, it seems that students inside Lombardy have a pattern of location along the rail line that connects two important cities in Italy, Turin and Venice. Perpendicular to this line there is a concentration of students among the rail line that connects the Swiss Alps with southern Italian cities, like Florence.

Inside the metropolitan area of Milan, Vigentino, Chiaravalle and Gratosoglio (Zone 5) and Baggio, De Angeli and San Siro (Zone 7) generate the lowest amount of trips by students to Leonardo; they have less than one hundred commuters; however the other administrative zones generate almost one thousand commuters, each. Hence it can be said that subway line M3, yellow line, as well as the bus lines and tram lines supplied in this area would have higher demand by students because along the neighborhoods that they pass by there is the highest concentration of students.

The geographical distribution of students going to Leonardo campus is summarized and shown in the next figure.

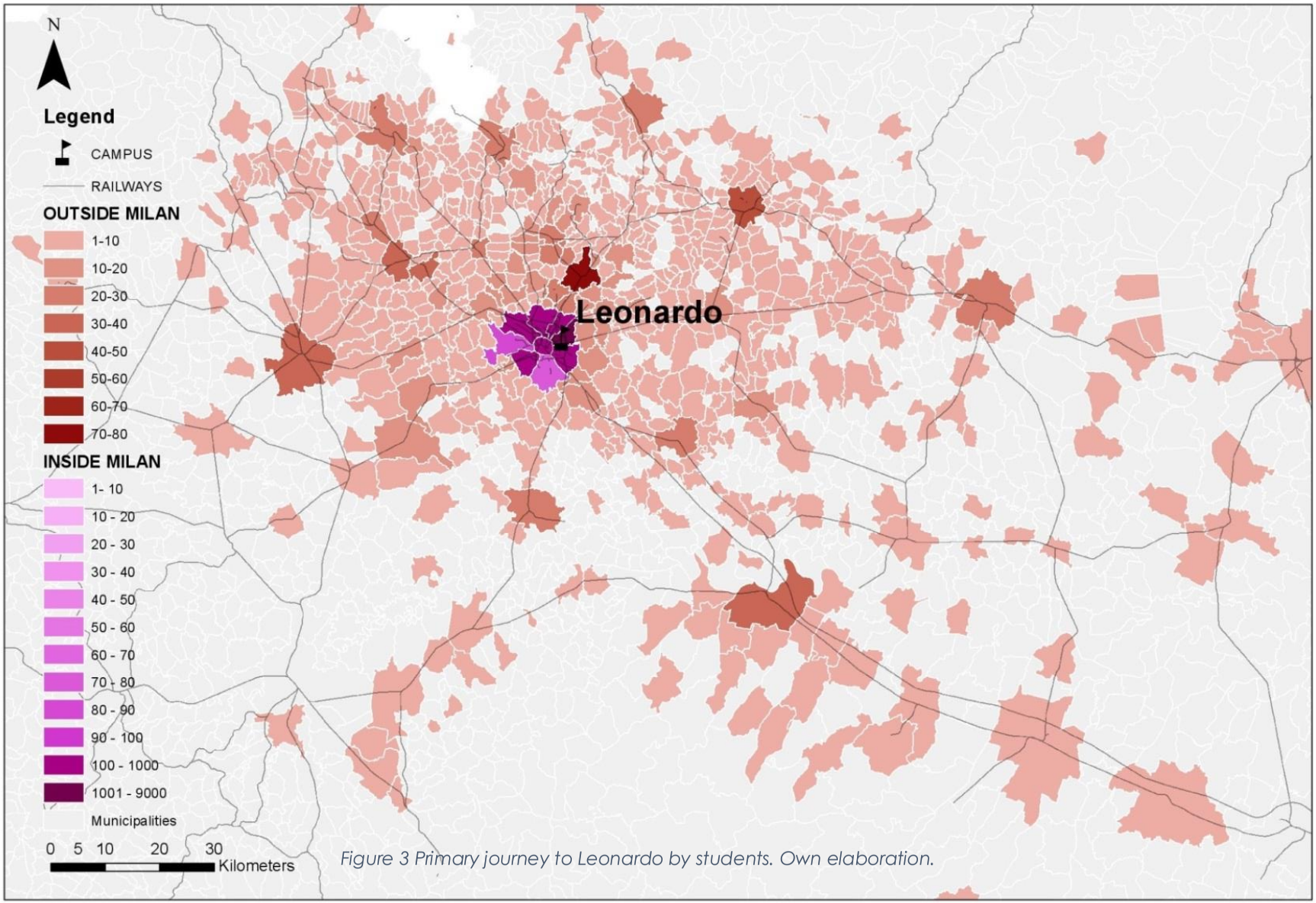


Figure 3 Primary journey to Leonardo by students. Own elaboration.

The pattern related with the geographical distribution of workers that commute to Leonardo has a similar geographical distribution as student's pattern; nevertheless the quantities are much lower.

Outside Milan there is a notorious presence of workers in northern Lombardy however the quantities manifested by each municipality in all cases are lower than thirty commuters.

The presence of workers going to Leonardo seem to be more representative inside Milan, specifically in Città Studi, Lambrate and Porta Venezia neighborhoods (Zone 3). Hence the demand of public transport inside this area could have the highest value in terms of workers as well as quantity of non-motorized commuters.

The geographical distribution of workers going to Leonardo campus is shown in the next map.

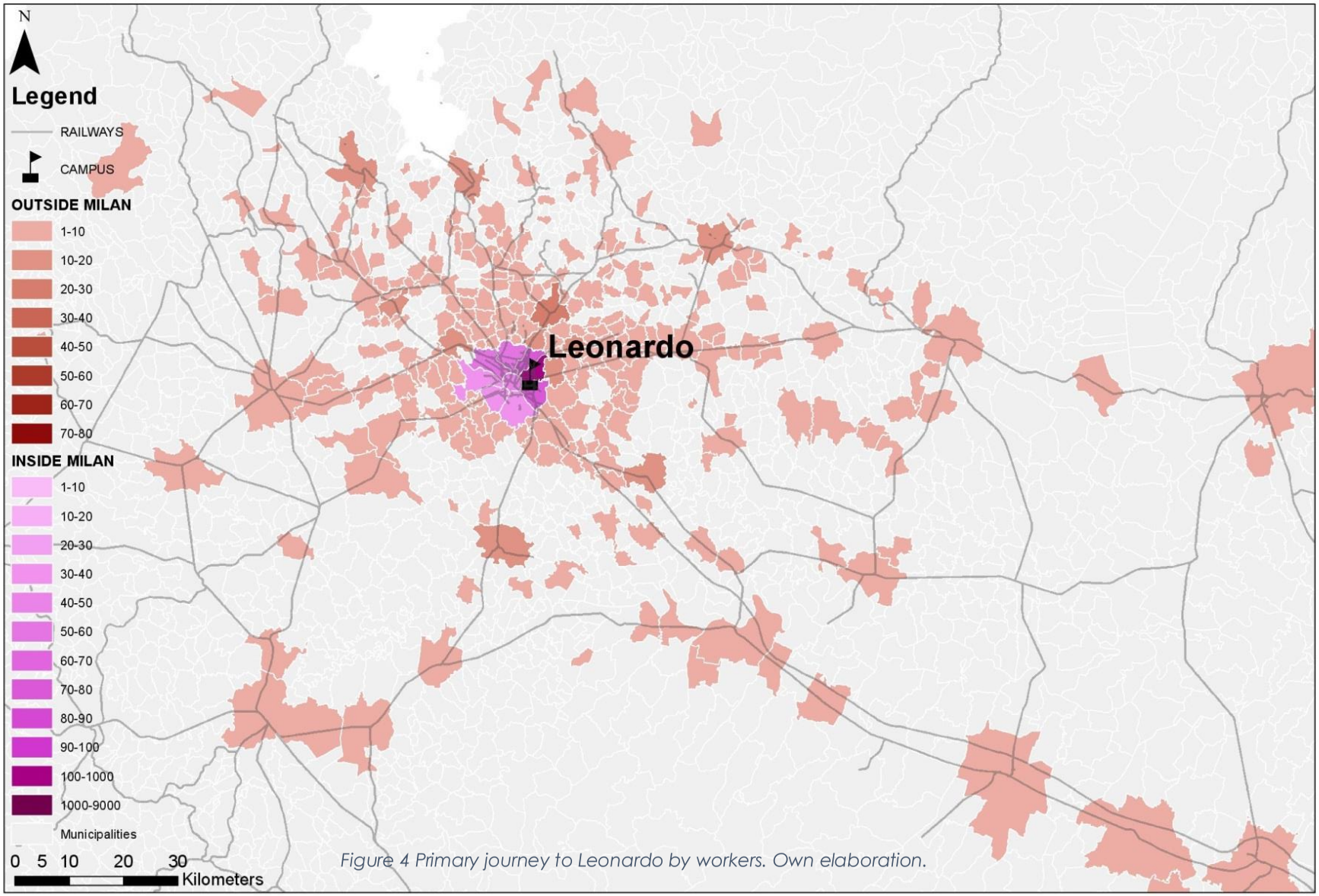


Figure 4 Primary journey to Leonardo by workers. Own elaboration.

The distribution of main journeys attracted by Bovisa campus by students has a similar behavior as Leonardo campus case. The concentration of commuters is mainly located in municipalities at the north of Milan where train infrastructure supply is very strong. Monza is a municipality that generates more than fifty commuters followed by Varese with more than forty commuters. Municipalities as Novara, Busto Arsizio and Bergamo reach more than thirty commuters. All in all, the highest amount of students that commute to Bovisa is bounded by the municipalities surrounded by Novara, Varese, Lecco and Bergamo. Due to the geometry of the rail lines could me mentioned that the lines in the direction Turin-Venice has the higher demand of students to reach Bovisa campus.

Inside Milan the neighborhoods that compound the administrative zone number 8: Fiera, Gallaratese and Quarto Oggiaro have has the highest concentration of students that commute to Bovisa campus. Due to the availability of a train station near the campus it can be said that the subway lines M3 and M2 has a highest demand of Bovisa commuters because they connect with the suburban railway that allows to reach Bovisa.

The geographical distribution of students that commute to reach Bovisa is shown below in the Figure 5.

Regarding workers can be said that are well distributed all over Lombardy region. There are no municipalities with a representative concentration of commuters. The municipalities that have commuters have a quantity between ten and twenty commuters. As in the case of students, Politecnico di Milano staff located outside Milan is located in municipalities served by good train infrastructure. Municipalities like Novara, Varese, Lecco, Monza, and Brescia are examples of it.

Inside Milan, the neighborhoods with a higher presence of Politecnico staff are Città Studi, Lambrate, Porta Venezia, Porta Garibaldi and Niguarda.

The spatial distribution of workers going to Bovisa campus is presented in the Figure 6.

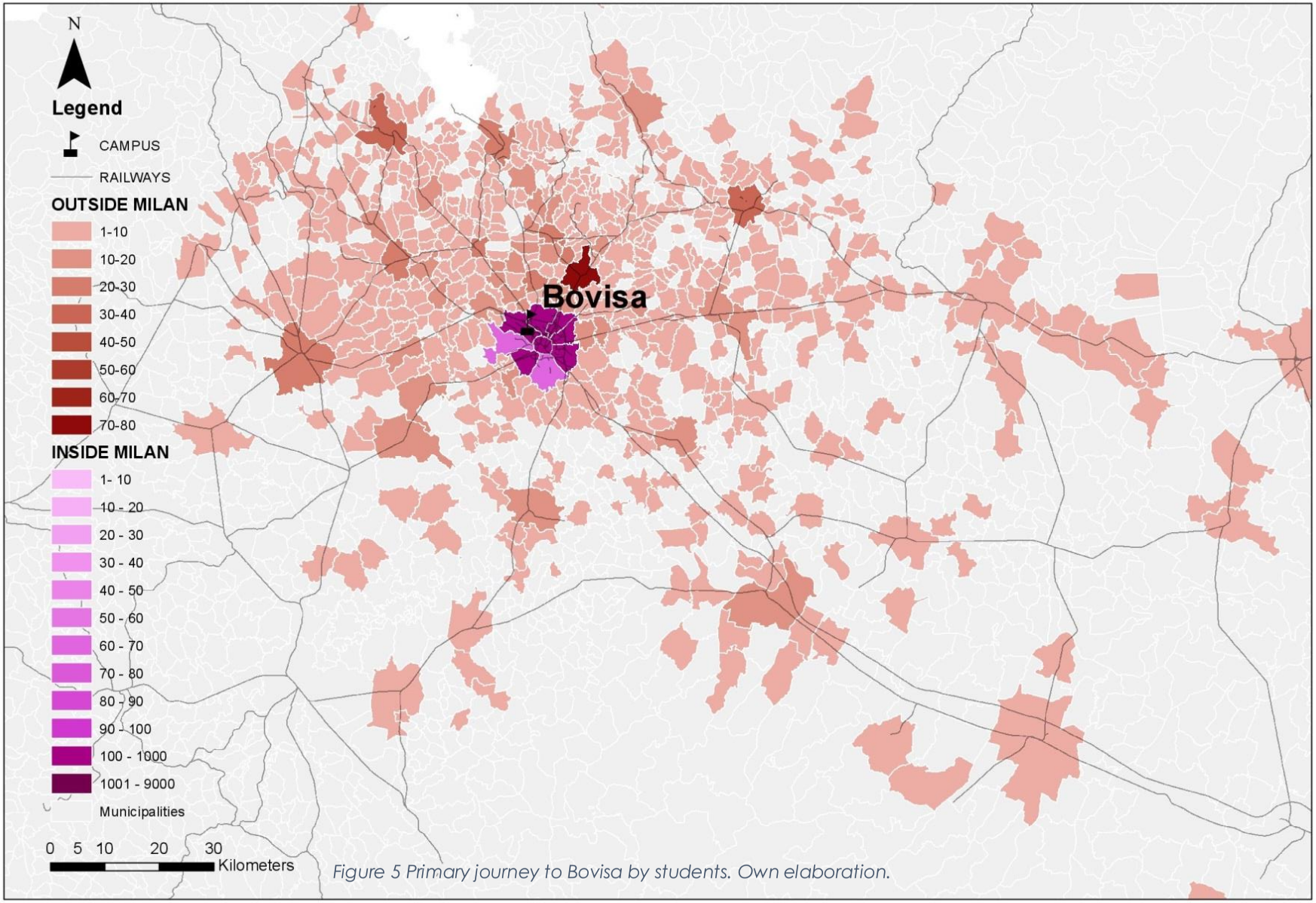


Figure 5 Primary journey to Bovisa by students. Own elaboration.

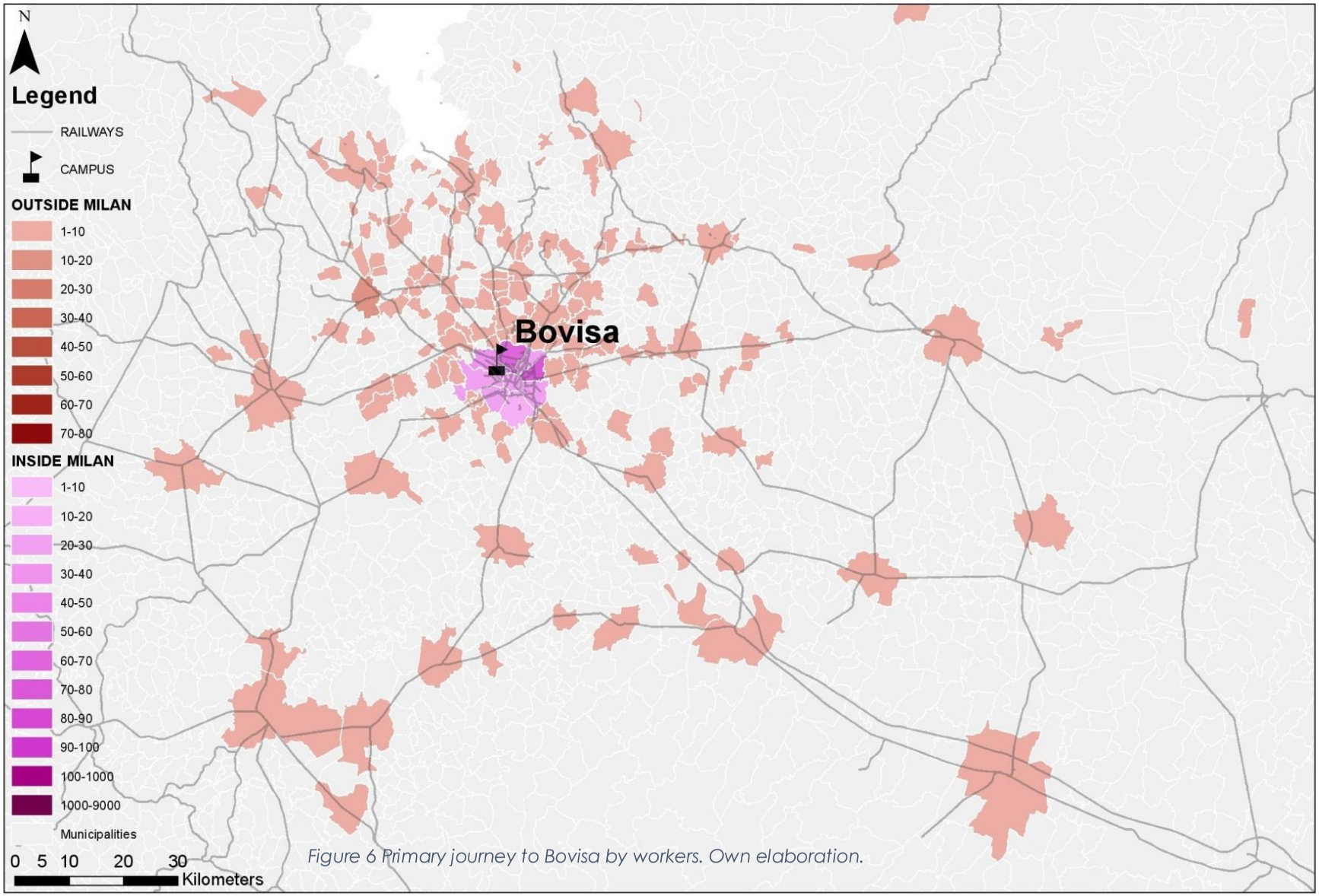


Figure 6 Primary journey to Bovisa by workers. Own elaboration.

Considering Lecco, Como, Mantova, Piacenza and Cremona campuses, the concentration of students is generally located at municipalities close to each one of the campuses and primary in the same municipality where the campus is located. In the case of distribution of Politecnico di Milano staff attending these campuses the highest amount of generated journeys is located in the same municipality where the campus is as in students' case.

In the Table 1 has been shown that the data set associated to these campuses represents less than 10%. The trips attracted by these campuses are among municipalities that mostly have railway supply and due to the low amount of trips made by students and workers it can be made sketches related with the envelopes of the municipalities that generate the most representative trips for each one of the campuses outside Milan. The results of these envelopes are shown next in the Figure 7.

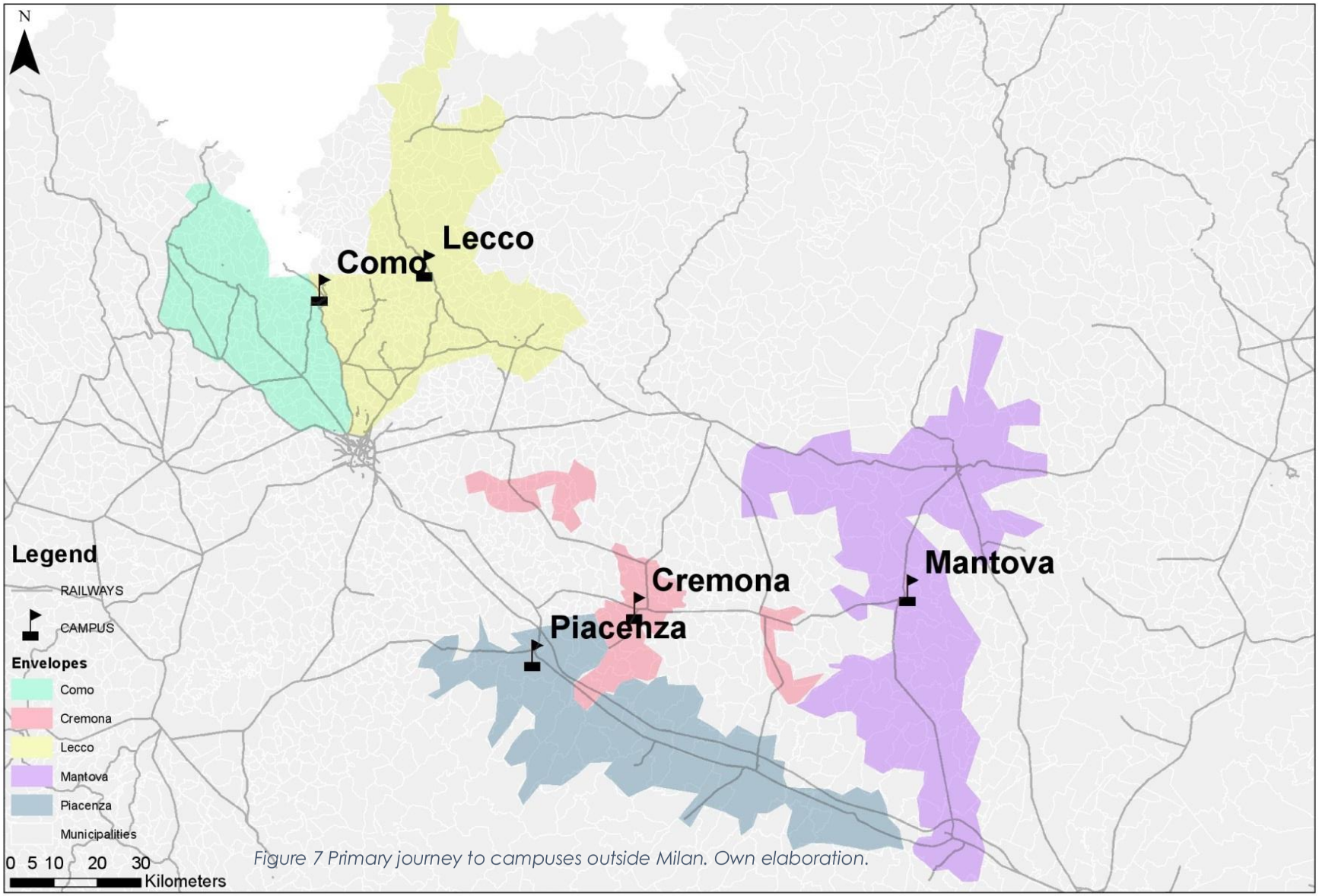


Figure 7 Primary journey to campuses outside Milan. Own elaboration.

4.2.2 Primary journeys attracted by Politecnico di Milano Campuses by train, public transport and private transport

If we consider the combinations of transportation where the use of train, use of private transport and use of public transport prevails it can be said that the train prevails over the other modes. The train service has a higher amount of students and workers that use it to reach the campuses located inside Milan, Leonardo or Bovisa.

Students are more used to commute with public transport than workers either to reach Leonardo or Bovisa. The share of students that use private car is quite similar to workers one to reach Leonardo campus, however there is a representative difference in the case of Bovisa. Thirty one percent of workers that attend Bovisa use private means of transportation instead of seven percent for students.

The quantity of commuters by mean are differentiated for both Milan campuses below in the Table 3.

Table 3 Commuters by mean. Own elaboration.

Campus	Location	Students			Workers		
		Train	PuT	PiT	Train	PuT	PiT
Leonardo	Outside Milan	1,592	40	959	423	125	146
	Inside Milan	44	1,235	97	8	291	130
	Total	**1,636**	**1,275**	**1,056**	**431**	**416**	**276**
	Share (%)	**41%**	**32%**	**27%**	**38%**	**37%**	**25%**
Bovisa	Outside Milan	1,946	27	121	226	2	84
	Inside Milan	976	366	127	136	39	93
	Total	**2,922**	**393**	**248**	**362**	**41**	**177**
	Share (%)	**82%**	**11%**	**7%**	**62%**	**7%**	**31%**
Grand total		**4,558**	**1,668**	**1,304**	**793**	**457**	**453**
Share (%)		**61%**	**22%**	**17%**	**47%**	**27%**	**27%**

There is a high presence of students that attend Leonardo campus with the use of train outside Milan. In fact, the share of students that commutes with this mean over the total quantity of students in each municipality almost reaches a percentage higher than fifty percent. The highest concentration is located in municipalities far from Milan in an estimated radius of 15 km. Municipalities along the rail line that allows the transportation between Parma at south and Como at north as well as the rail line that allows the mobility between Novara at west and Brescia at east have cities with a representative quantity of students that use train to reach Leonardo. The municipalities with the highest concentration are located at the north of the rail line that connects Mortara with Brescia.

Although the train station of Lambrate is 600 m away from Leonardo, the share of students that reach the university by train is much lower than the share of students coming from outside Milan. All the administrative zones have a share lower than twenty percent. This pattern might happen due to the high supply of alternative means of transportation inside the city.

In the case of employees that use transportation combinations where the use of train prevails, it can be seen a similar behavior as students' one. In this case the concentration of commuters gets lower closer to Milan, mostly at east and west of the city. Contrary to students, the concentrations are lower in a radius of 15 km from Milan. Outside this boundary almost all the municipalities that have commuters present a share above seventy percent.

The spatial distribution of students and workers going to Leonardo by train is presented in the following maps.

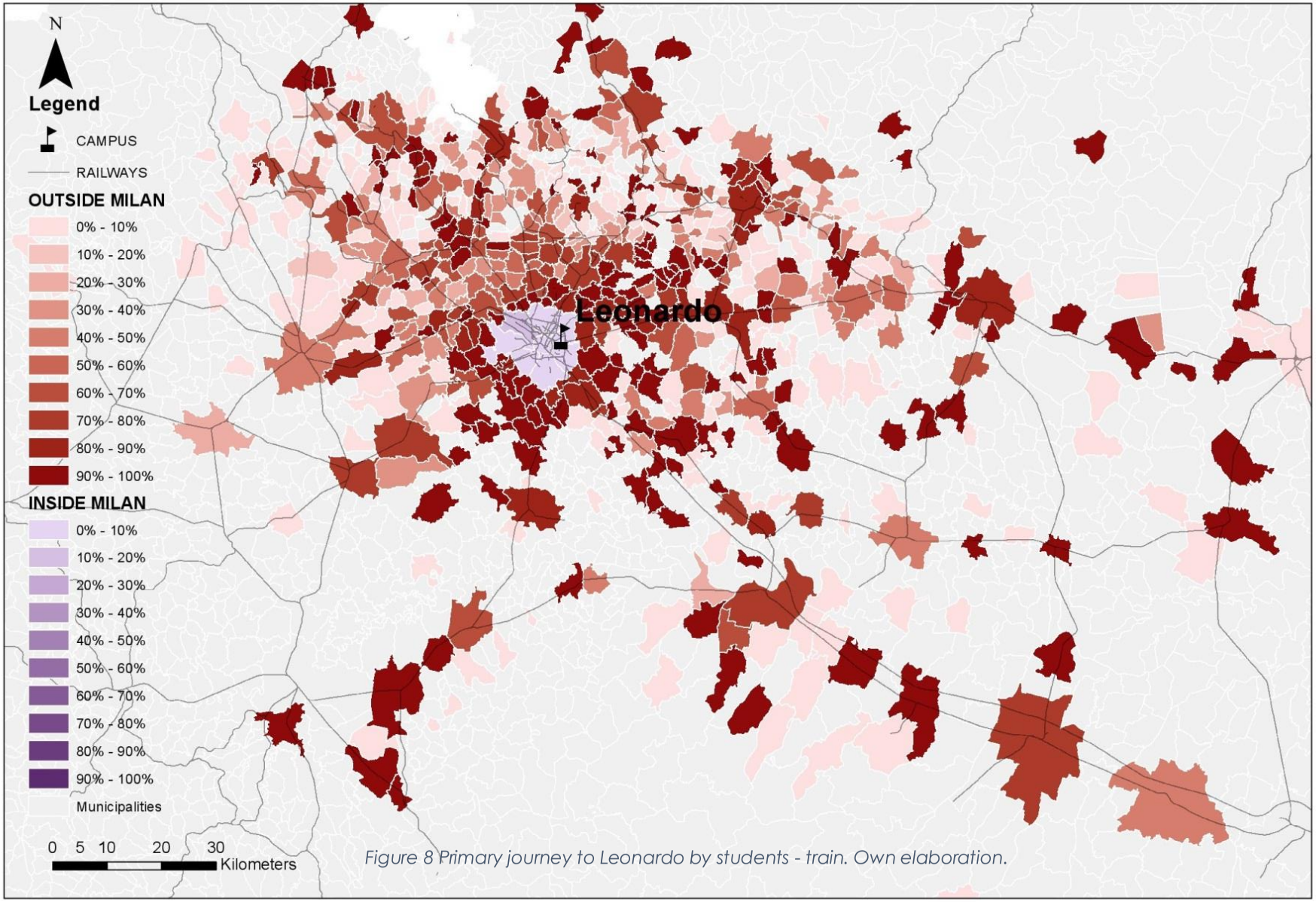


Figure 8 Primary journey to Leonardo by students - train. Own elaboration.

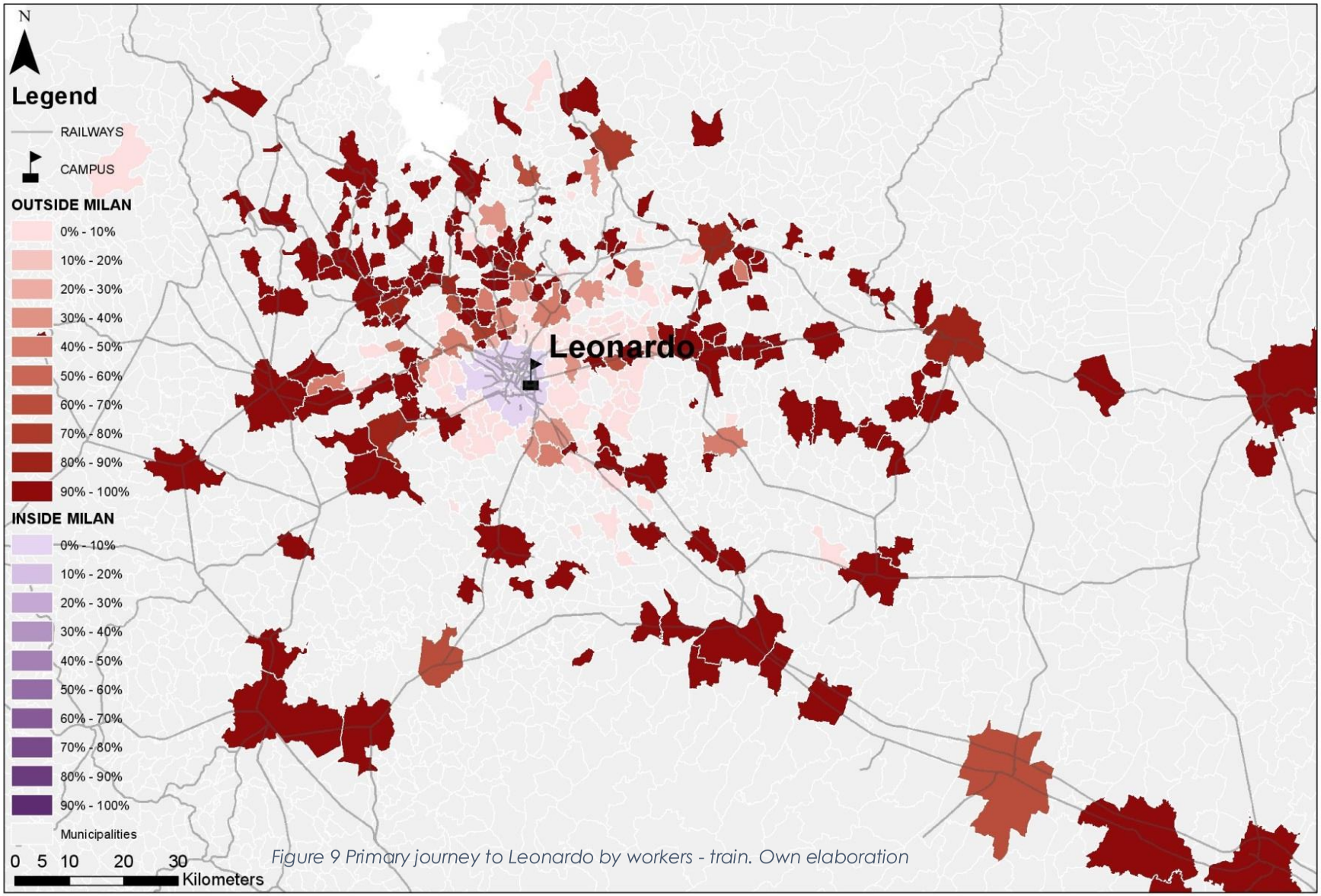


Figure 9 Primary journey to Leonardo by workers - train. Own elaboration

About the use of car or private transport to reach Leonardo campus students don't have municipalities outside Milan or zones inside the city that presents a high concentration of generated trips, however there is a pattern of more car dependency in the municipalities at east of Milan but also in regions with high economic income, like Brianza.

The presence of students that commute with private means to reach Leonardo is mostly spread at the east of the rail line that allows the transportation between cities like Como and Parma. In this area private car users have the supply of important motorways. Indeed there is the supply of four main motorways. There is the supply of the state motorway SS42 that connects Treviglio with Bergamo, the motorway A1 that connects Milan with Naples, the motorway A4 that connects Turin with Sistiana, the motorway A22 which connects Milan with Bologna and finally the motorway A21 that allows the transportation between Turin and Brescia.

At the west of the line that connects Como and Parma there are municipalities with presence of students that commute with car as Morimondo and Abbiategrasso. These commuters use the motorway A4 to reach Leonardo campus.

The spatial distribution of students that use private means of transportation to reach Leonardo is presented in the Figure 9.

In terms of primary journeys generated by workers to reach Leonardo campus with private car, it can be said that there more workers that commute with these means than students that commute with them.

Workers are more car dependent than students outside Milan and there is a clear concentration near the south eastern periphery of Milan. The pattern is clearly different with respect to students': workers tend to use the car when coming from the near periphery, while students use car when coming from far away, but not necessarily from areas without train supply.

The spatial distribution of students that use private means of transportation to reach Leonardo is presented in the Figure 10.

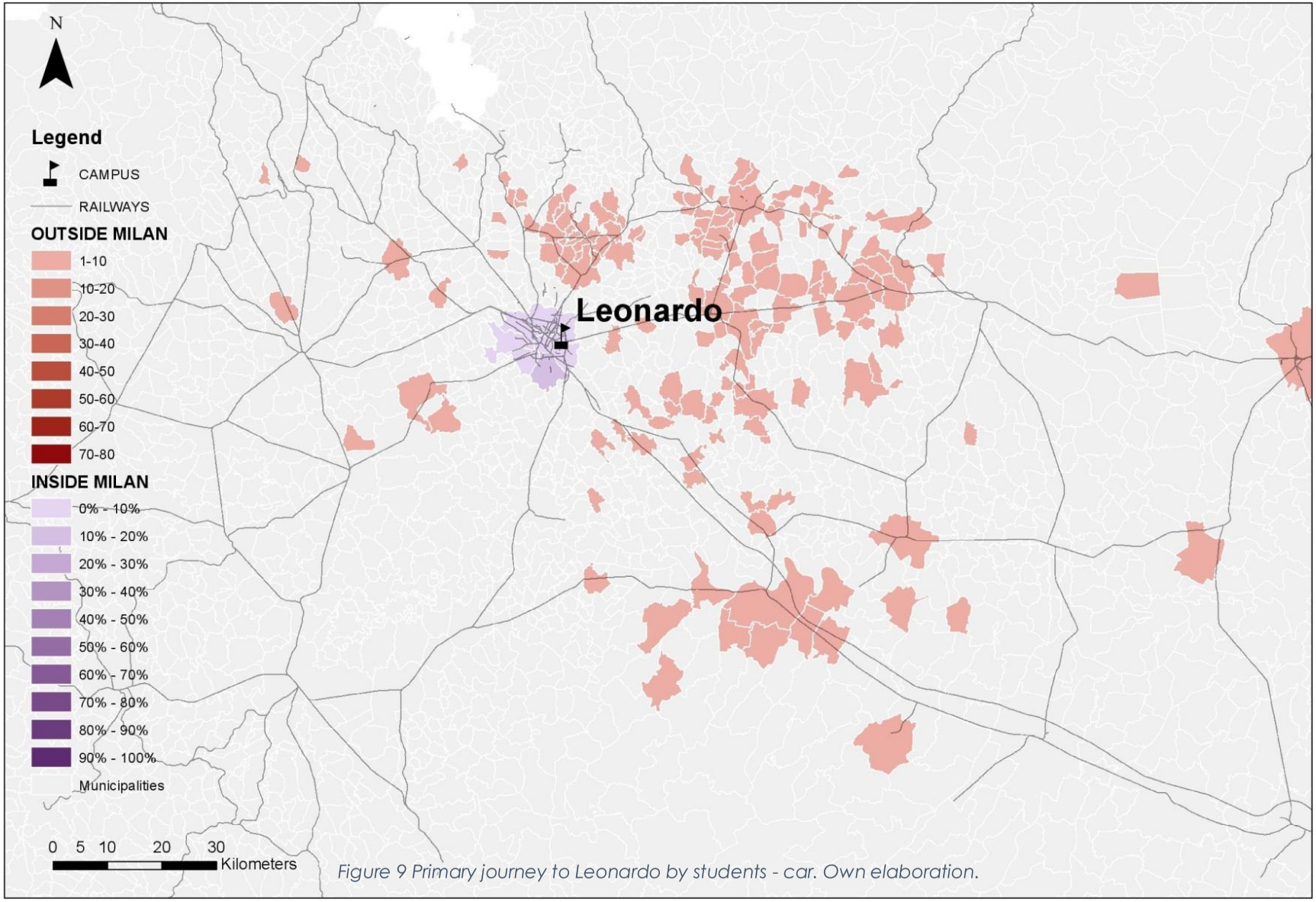


Figure 9 Primary journey to Leonardo by students - car. Own elaboration.

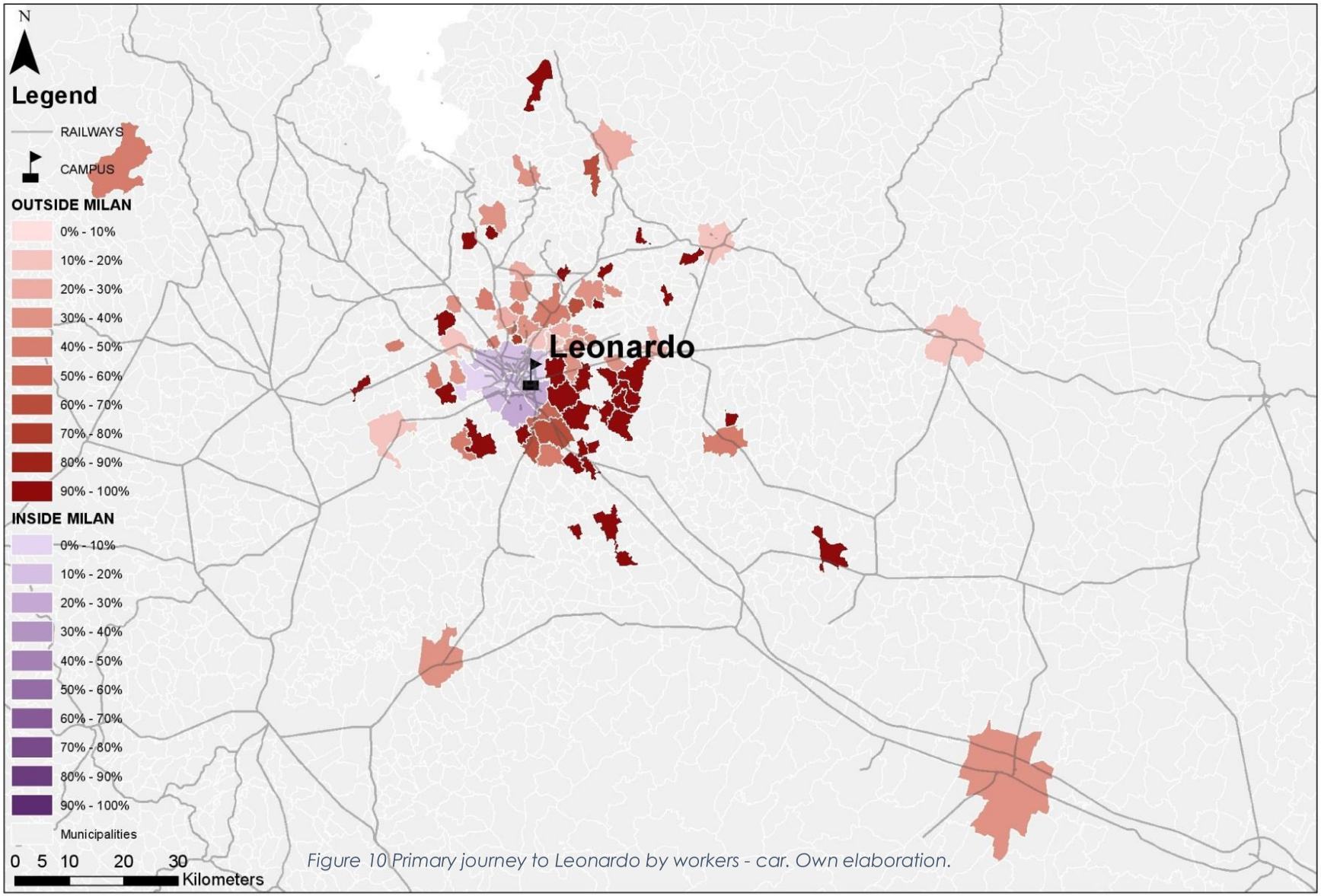


Figure 10 Primary journey to Leonardo by workers - car. Own elaboration.

Changing to use of public transport, students going to Leonardo with transport combinations where the use of it prevails are concentrated inside Milan. However, the administrative zone where Leonardo campus is located has the lowest concentration, probably due to the highest share of non-motorized trips. This administrative zone is compound by the neighborhoods Città Studi, Lambrate and Porta Venezia.

The total amount of students going to Leonardo campus and inhabit this administrative zone is 1,068 where 57% of them reach the campus by non-motorized means of transportation.

Outside Milan it can be seen a pattern of a more public transportation dependency in the east side of the territory than in the west side. This dependency appears near and inside Casirate d'Adda.

The spatial distribution of students that commute with public transportation to reach Leonardo campus is presented in the Figure 11.

The use of public transportation by workers has a higher concentration in the municipalities along the periphery of Milan, mostly in the northern-east area. Contrary to students, workers seem to use more public transportation outside Milan and less inside the city. As students, inside Milan the administrative zone with the lowest concentration generated with public transport to reach Leonardo Campus is where the university is. Like student's behavior this pattern appears due to the highest share of non-motorized trips.

The total amount of workers going to Leonardo is 293 where 71% of it is made by workers that use non-motorized means of transport. Also inside Milan, the main concentration of public transport users is, not surprisingly, along the M2 connecting Milan with Gessate.

The spatial distribution of students that commute with public transportation to reach Leonardo campus is presented in the Figure 12.

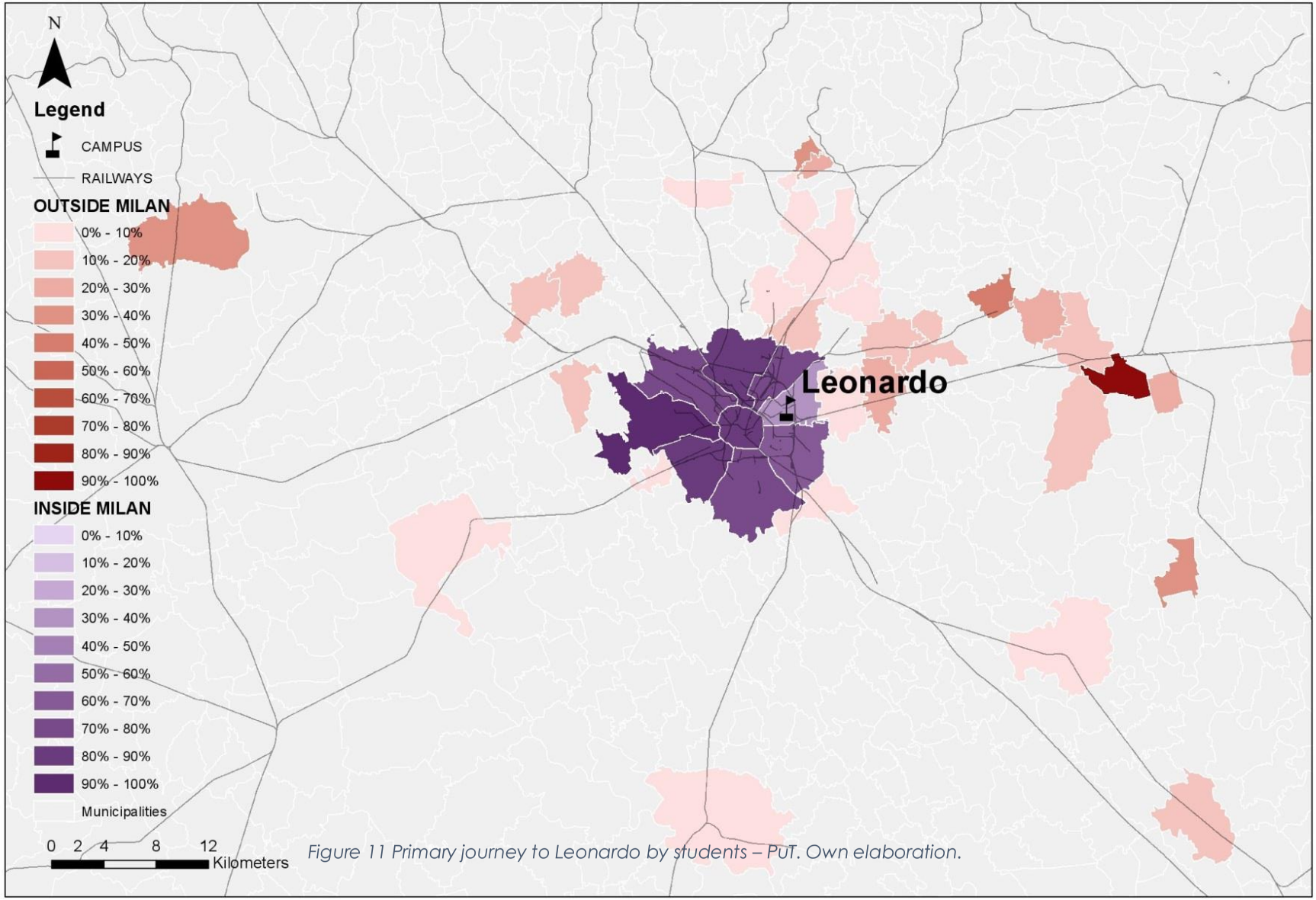


Figure 11 Primary journey to Leonardo by students – PUT. Own elaboration.

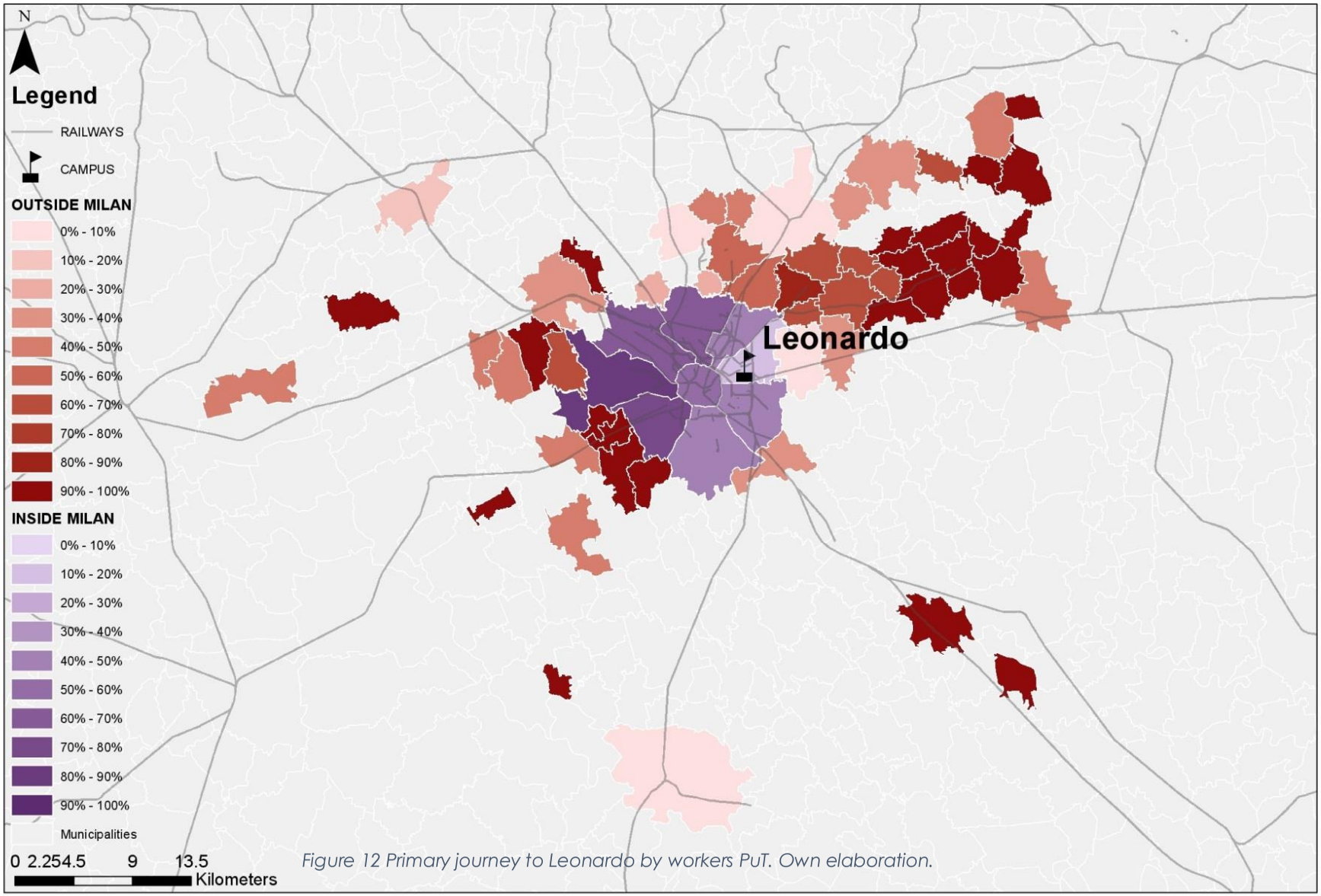


Figure 12 Primary journey to Leonardo by workers PuT. Own elaboration.

The previous interpretation about the spatial distribution of commuters in relation with the different transportation means made for Leonardo campus has been done for Bovisa campus as well:

The use of train by students to get Bovisa is the most preferred mean of transportation due to its conditions of accessibility and supply in the region. There is a train station supplied for the campus itself, Milano Nord Bovisa.

The highest concentration of students that go to the campus with train are in municipalities far away from Milan in a radius of approximately 40 km, however there are municipalities farer from Milan with highest concentrations too. Almost all the municipalities that have students using the train to reach Bovisa present a share above 70% over the total amount of commuters.

Inside Milan there is a high presence of students that use the train to reach Bovisa, they are among the territory with lower concentration in Porta Garibaldi and Niguarda areas.

Workers that commute with train to reach Bovisa area spread among northern Lombardy. Almost all the municipalities that have presence of them exhibit a percentage higher than 60%. To lowest concentration of workers is presented in a radius of 9 km from Milan.

Inside Milan, workers that use train to reach Bovisa are mostly located in the areas of Città Studi, Lambrate, Porta Venezia, Porta Vittoria, Forlanini, Centro storico, Barona and Lorenteggio. These commuters use the suburban railways to reach the campus which is connected with the subway system of Milan.

To sum up, the dependence of train to reach Bovisa is due to the fact that the only mass transport available at Bovisa is train itself. The spatial distribution of students that commute to reach Bovisa is shown in the Figure 13 and the spatial distribution of workers that commute with train is shown in the Figure 14.

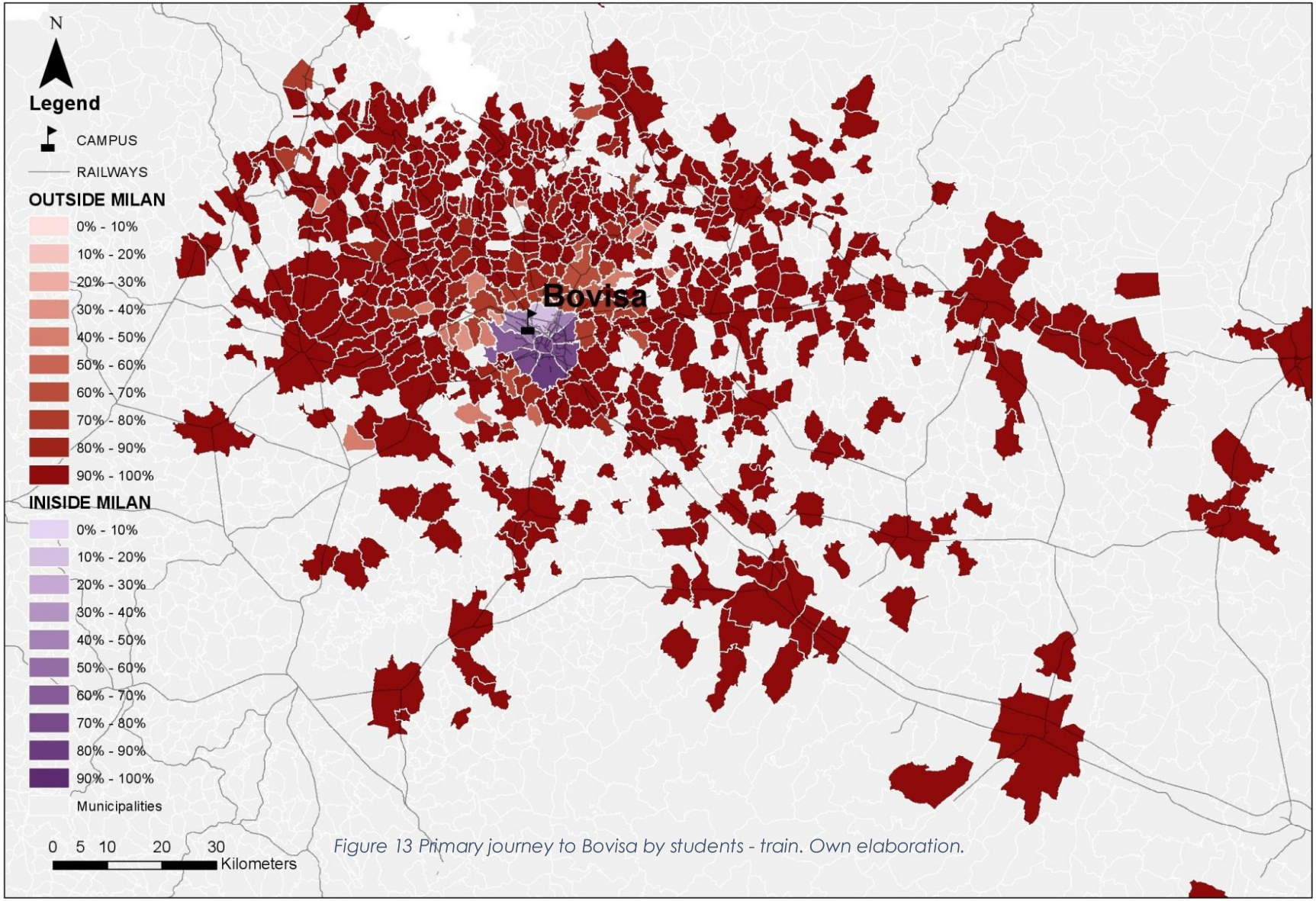


Figure 13 Primary journey to Bovisa by students - train. Own elaboration.

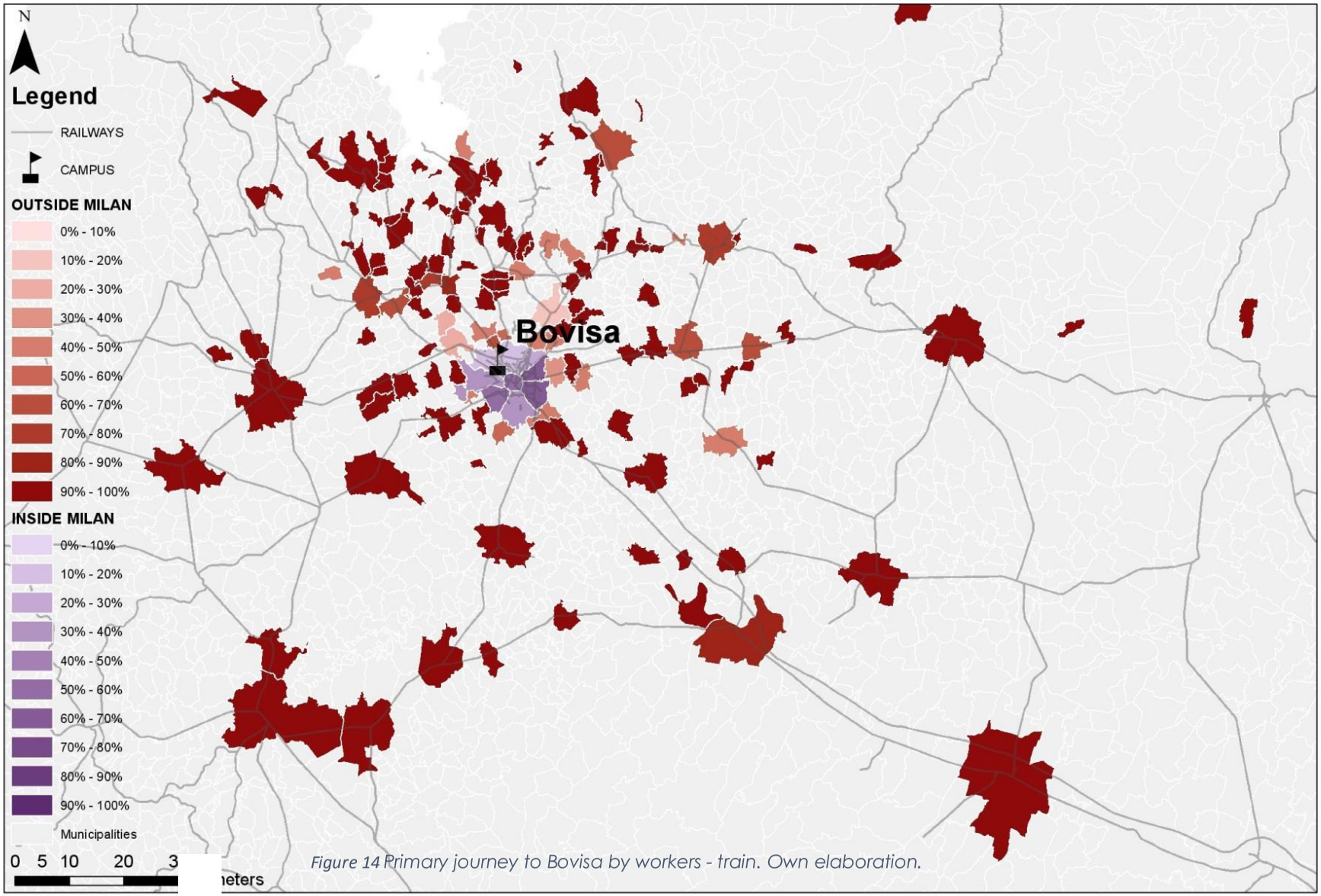


Figure 14 Primary journey to Bovisa by workers - train. Own elaboration.

Concerning to use of car to reach Bovisa can be said that the students in municipalities located at the north of the campus are mostly car dependent. In the case of students, despite the existence of a consolidated train network there are places where students prefer to use car. The pattern of distances of students car users is, however, completely different from Leonardo ones: in this case the students use car to reach Bovisa mainly come from near origins, while in Leonardo car is the option for far students.

In this case the demand of car users is attracted by the main motorway A4, as it has been said before this row connects Turin with Sistiana. The demand generated by students along this roadway begins in Novara, passes by the municipalities at the north of Milan and ends in Bergamo.

The spatial distribution of students that go to Bovisa with car is presented in the Figure 15.

On the other hand, workers in Bovisa Campus are more likely to use the car than students in the inhabit areas outside Milan. There is a strong concentration of car users in areas far away from the campus.

Similarly to Leonardo, the car users are those living near to the campus and coming from the same sector of the city. For them, the car trip skips Milan and results consequently faster. From other city sectors, it is needed to cross the city and thus public transport or train results preferred.

The spatial distribution of workers that commute with private car to reach Bovisa is shown in the Figure 16.

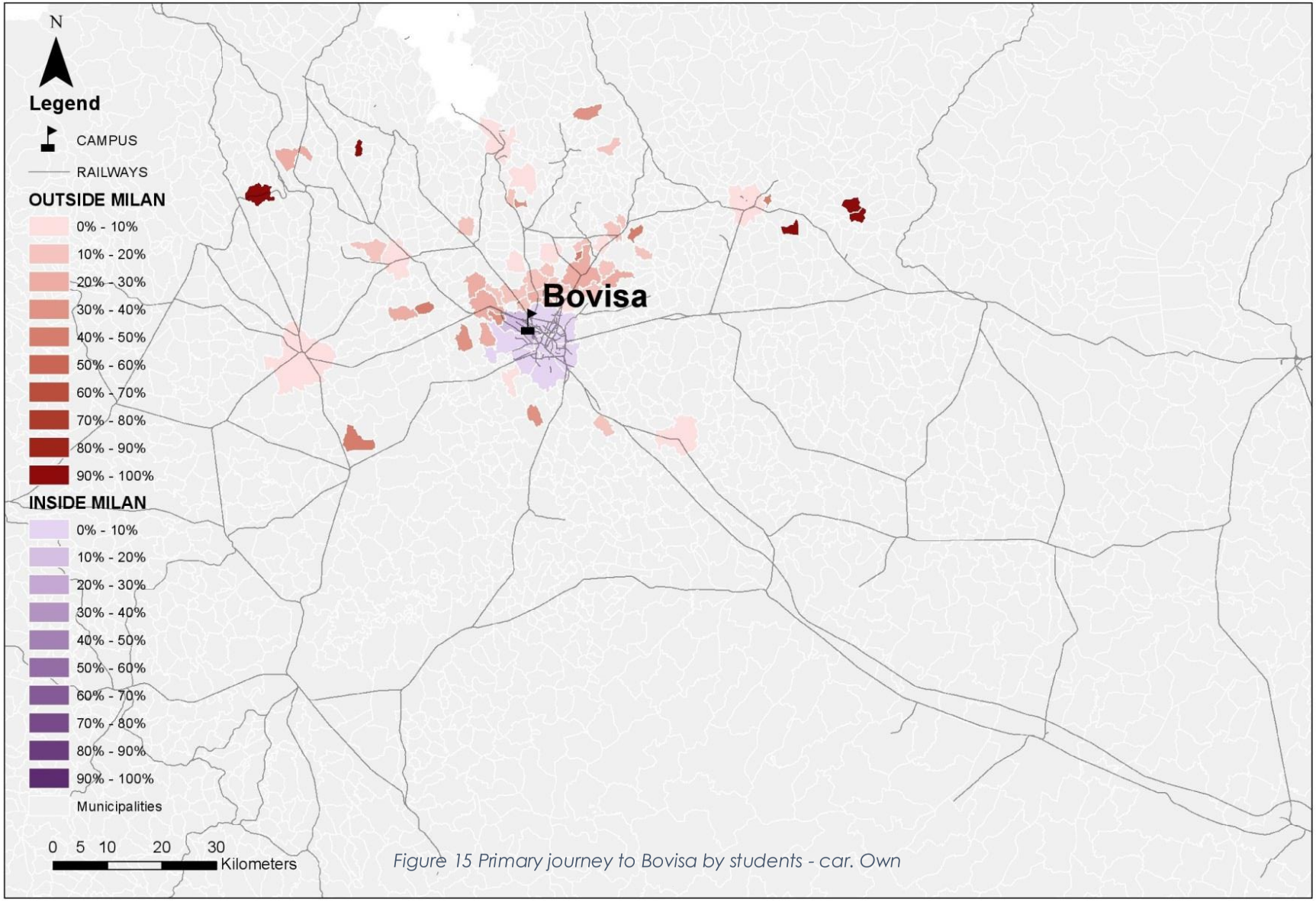


Figure 15 Primary journey to Bovisa by students - car. Own

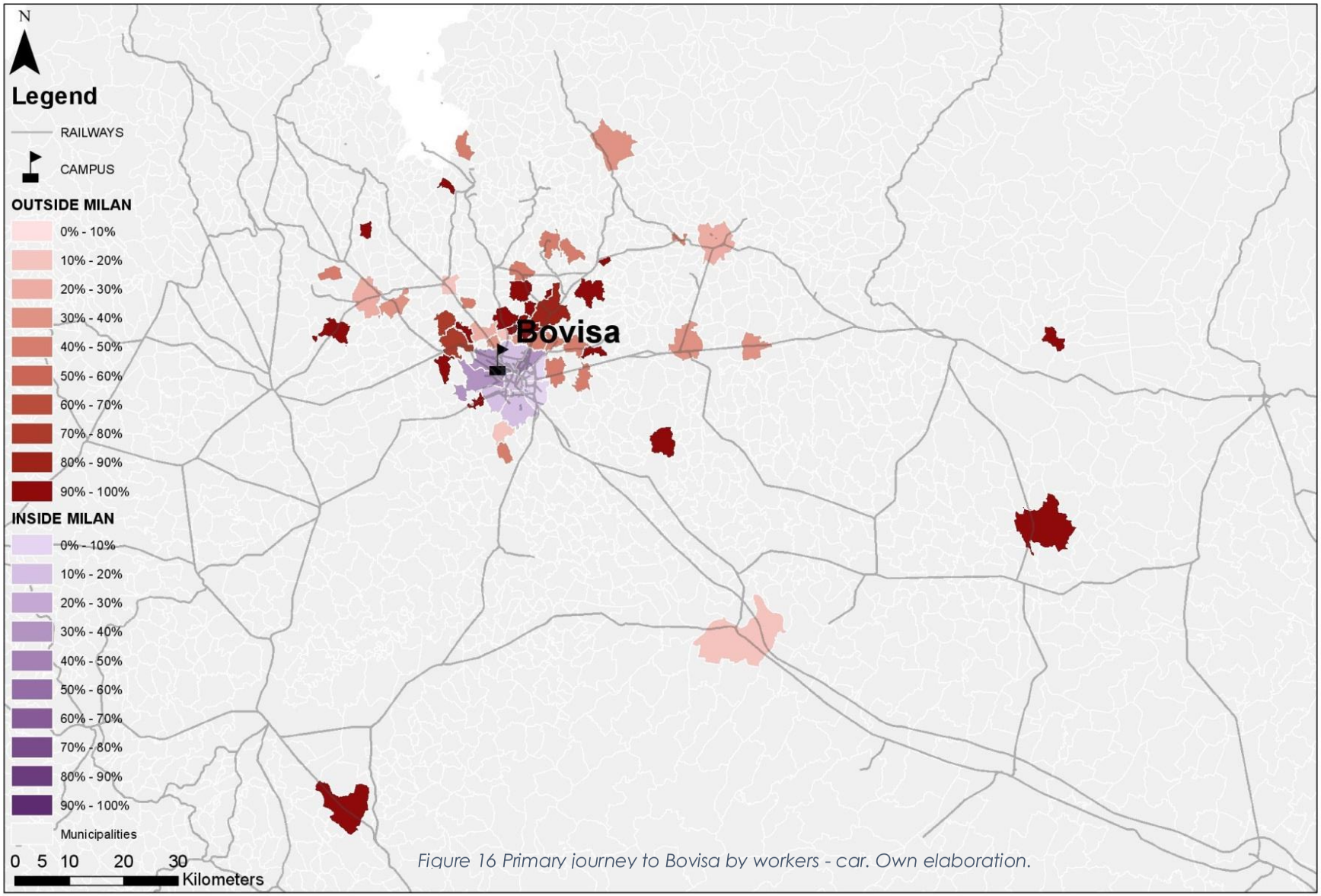


Figure 16 Primary journey to Bovisa by workers - car. Own elaboration.

Switching to transport combinations where public transportation to reach Bovisa campus, the amount of students using it is low despite a significant number of municipalities generate trips with the use of public transport. In the case of Milan, students using public transportation are mainly located in the northern part of the territory as is shown in the Figure 17.

Regarding workers going to Bovisa with public transportation, they are not so likely to use is as the students. Outside Milan only Bresso generates journeys with this mode. Inside Milan the concentration of this modal share is low; nevertheless it is present along the nine administrative zones of the city.

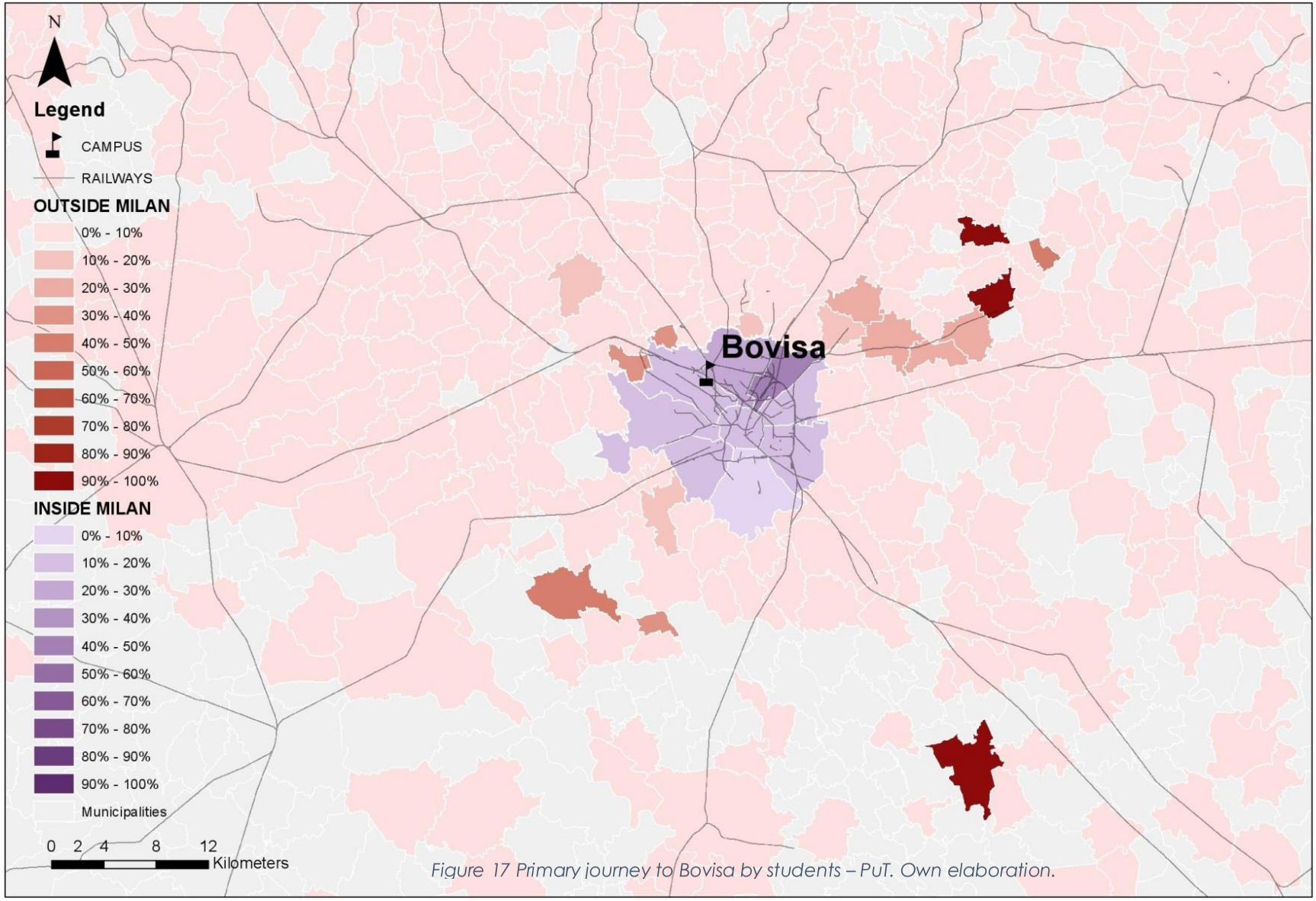


Figure 17 Primary journey to Bovisa by students – PuT. Own elaboration.

The territorial representation of survey's data makes possible to derive the next conclusions about the mobility behavior of students and workers of Politecnico di Milano:

1. Leonardo and Bovisa campuses attract the highest amount of students and workers from Politecnico population. More than 91% of the population surveyed. These results are expected based on the degree programs offered by Politecnico which are taught mostly in these two campuses.

   The population coming to these campuses is spread among the territory and among municipalities that have different transport services supply. Due to the high amount of population going to these two campuses further analysis in the present study are focused on them.

2. Students and workers going to campuses outside Milan inhabit in municipalities close to the university and primary in the municipality where the campus is located. The quantity of people who own a private car and use it to reach the different campuses outside Milan prevails over the quantity of people that use alternative transportation means. In the case of students the pattern occurs to the population going to Como, Piacenza and Cremona.

   In the case of employees, which based on the survey allows us to see that number of workers is never higher than thirty people for each one of the campuses, the pattern occurs to all the campuses outside Milan. Based on the students' results can be said that Lecco and Mantova have the railway service with highest demand. The train users that attend these two campuses prevail over the users that use car, public transportation or non-motorized means.

   In the case of Lecco campus, from 293 students 40% of them use the train and in the case of Mantova campus, from 113 students 58% of them use the train. The magnitude of private car use could be caused because of the representative size of the municipalities where the campus is located and also due to probably a lack of efficient public

transportation inside them. Lecco has a surface of 45 km^2 and Mantova a surface of 64 km^2.

3. Workers are used to transport more with a private mean than students in order to reach Politecnico. For those campuses outside Milan the share of workers going by private car is always higher than the share for students going with this mean. However, considering students and workers together it can be said that the contribution of students coming by car is more representative. For both, Leonardo and Bovisa campuses the quantity of students that use the car is higher that the quantity of workers that use it. Despite the prevail use of train to reach Politecnico di Milano by students and workers, there is a need of strategies to shift the use of private car among university population.

4.2.3 Secondary journeys attracted by Politecnico di Milano Campuses

As is has been mentioned at the beginning of this research the mobility survey considered a secondary journey, which is a less frequent alternative to reach Politecnico. This secondary journey could consider different origin and different Politecnico campus to the one considered for the main one. Thus, this section analyzes the main characteristics regarding the population that commute in a secondary trip.

To begin with, the amount of students that commute in a secondary trip attracted by Leonardo and Bovisa Campuses represent in both cases almost 19% of the amount of students that commute in a primary trip. In the case of journeys generated by Politecnico di Milano's staff the percentages are lower, 17% for trips attracted by Leonardo and 12%.

In general terms for a secondary trip there are more students that commute with public transportation than with other means. The mean that prevail for workers is the private one. For both cases the train is the transportation mean that has minimum quantity of users and in terms of non-motorized means the

share of workers is higher than the share of students. The general results about the relation of modes with secondary journey commuters for students and workers of Leonardo and Bovisa are summarized in the Table 4.

Table 4 Secondary journeys by mean. Own elaboration.

Secondary journey							
Campus	**Location**	**Students**					
		Train	**PuT**	**PiT**	**No Motorized**	**Other**	**Total**
Leonardo	**Outside Milan**	8	297	230	3	5	543
	Inside Milan	12	321	83	122	19	557
	Total	**20**	**618**	**313**	**125**	**24**	**1,100**
	Share (%)	**2%**	**56%**	**28%**	**11%**	**2%**	**100%**
Bovisa	**Outside Milan**	8	82	276	4	4	374
	Inside Milan	17	204	79	40	6	346
	Total	**25**	**286**	**355**	**44**	**10**	**720**
	Share (%)	**3%**	**40%**	**49%**	**6%**	**1%**	**100%**
Grand total		**45**	**904**	**668**	**169**	**34**	**1,820**
Share (%)		**2%**	**50%**	**37%**	**9%**	**2%**	**100%**
Secondary journey							
Campus	**Location**	**Workers**					
		Train	**PuT**	**PiT**	**No Motorized**	**Other**	**Total**
Leonardo	**Outside Milan**	0	0	0	0	0	0
	Inside Milan	1	92	59	87	0	239
	Total	**1**	**92**	**59**	**87**	**0**	**239**
	Share (%)	**0%**	**38%**	**25%**	**36%**	**0%**	**100%**
Bovisa	**Outside Milan**	20	3	44	6	1	74
	Inside Milan	1	0	1	0	0	2
	Total	**21**	**3**	**45**	**6**	**1**	**76**
	Share (%)	**28%**	**4%**	**59%**	**8%**	**1%**	**100%**
Grand total		**22**	**95**	**104**	**93**	**1**	**315**
Share (%)		**7%**	**30%**	**33%**	**30%**	**0%**	**100%**

In the case of Leonardo Campus, the share of commuters of secondary trip over primary journey commuters there are municipalities with rates above forty percent at the east side of the rail line that connects Como with Parma. Far away from Milan there are municipalities with shares above fifty percent as Desenzano del Garda. Inside Milan the overall share get at maximum fifty percent in relation with the primary journey commuters. These results are shown in the Figure 18. In the case of secondary journeys made by workers the value is not representative outside Milan and the share inside the city is higher among the administrative zones close to the campus.

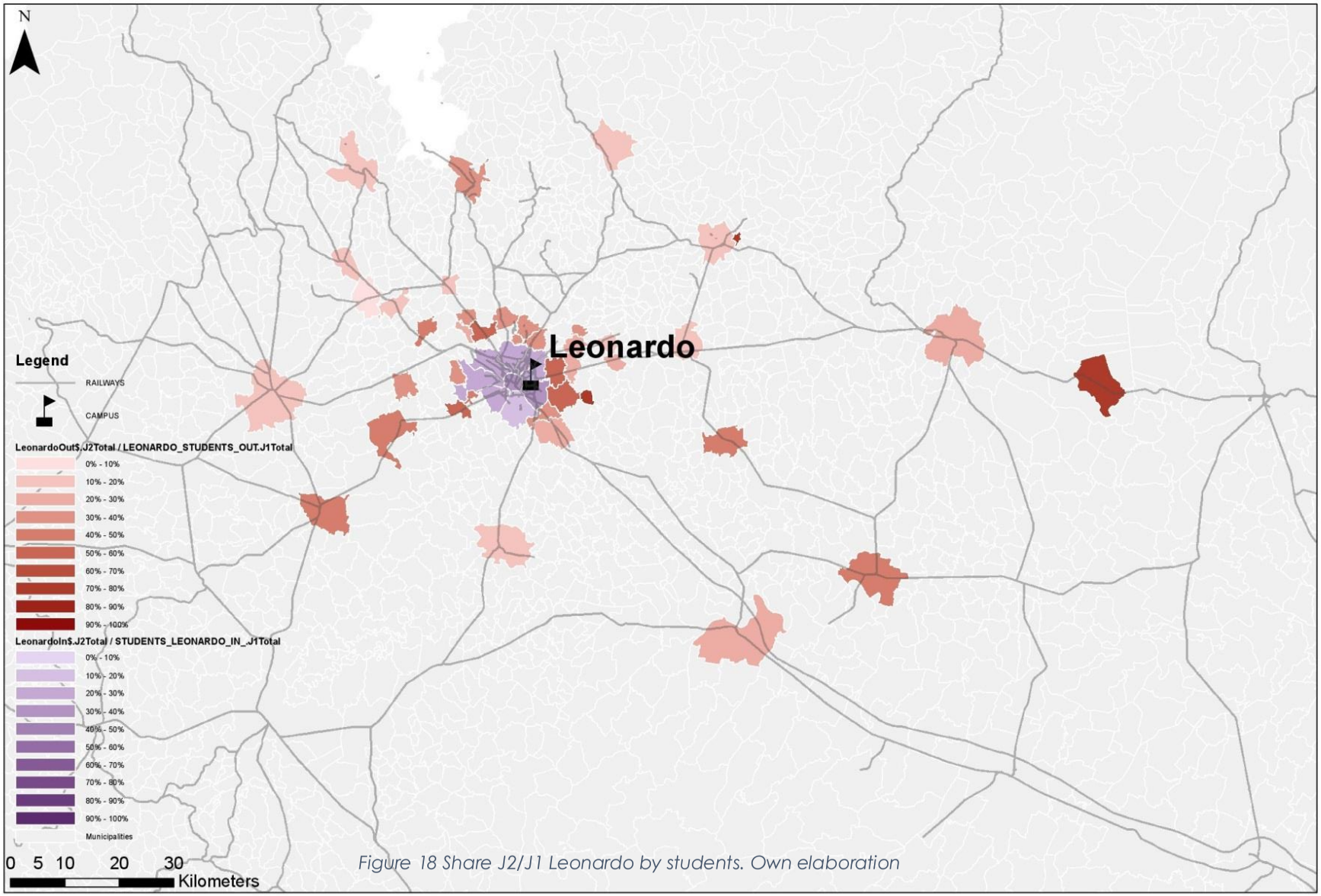


Figure 18 Share J2/J1 Leonardo by students. Own elaboration

Regarding the rate between secondary journey commuters with train and total amount of secondary journey commuters the concentrations are spread among northern Lombardy, always with low values. In the case of students going to Leonardo the values are spread along the municipalities with railway supply.

Contrary to the distribution of main trips, where the use of train prevails for secondary trips the most used transportation mode is by car, in the case of students going to Leonardo. The municipalities that generate more secondary journeys to Leonardo are located among Lombardy where the motorway A4 passes by. The results of secondary journey commuters with car to reach Leonardo are shown in the Figure 19.

The behavior of workers considering the use of car within the secondary journeys is not significant because the value is very low outside Milan and inside it the use of car does not prevail.

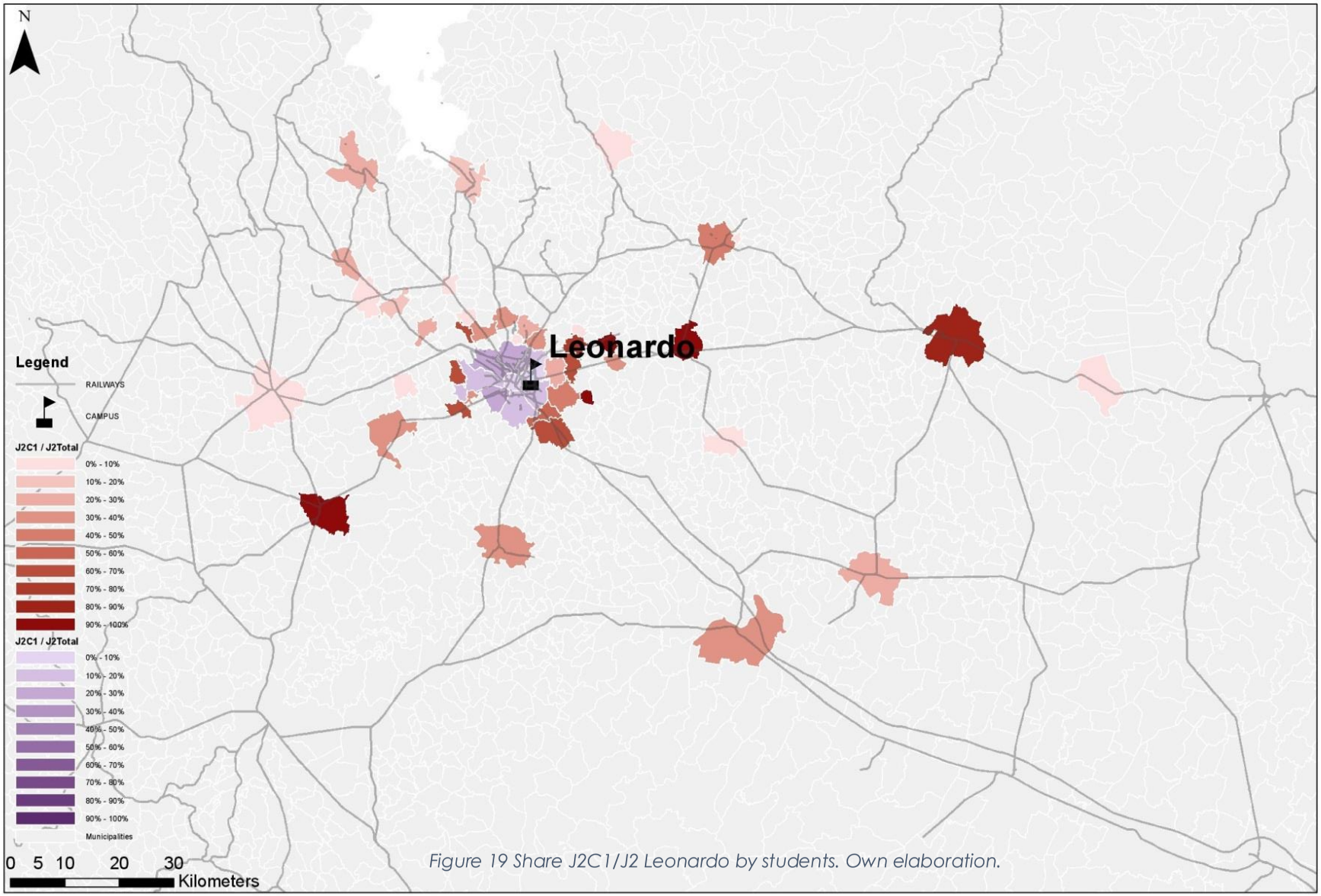


Figure 19 Share J2C1/J2 Leonardo by students. Own elaboration.

About use of public transportation within the modal share of the secondary trip of students going to Leonardo, the commuters are spread among the territory; nevertheless the concentrations are lower than ten percent where it happens. In the case of workers the results are not much significant however the share gets lower in the areas of Città Studi, Lambrate, Porta Venezia, Porta Vittoria, Forlanini Vigentino, Chiaravalle and Gratosoglio.

The share of secondary journeys commuters and primary ones attracted by Bovisa campus is different to Leonardo's case. In the case of students the concentrations are lower among the region, however municipalities like Ghedi at east, Gattinara at west and some where there are train supply the amount of secondary journey commuters and primary journey commuters attracted by Bovisa reach similar values. Inside Milan the share for each administrative zone is always lower than fifty percent. These results are shown next in the Figure 20.

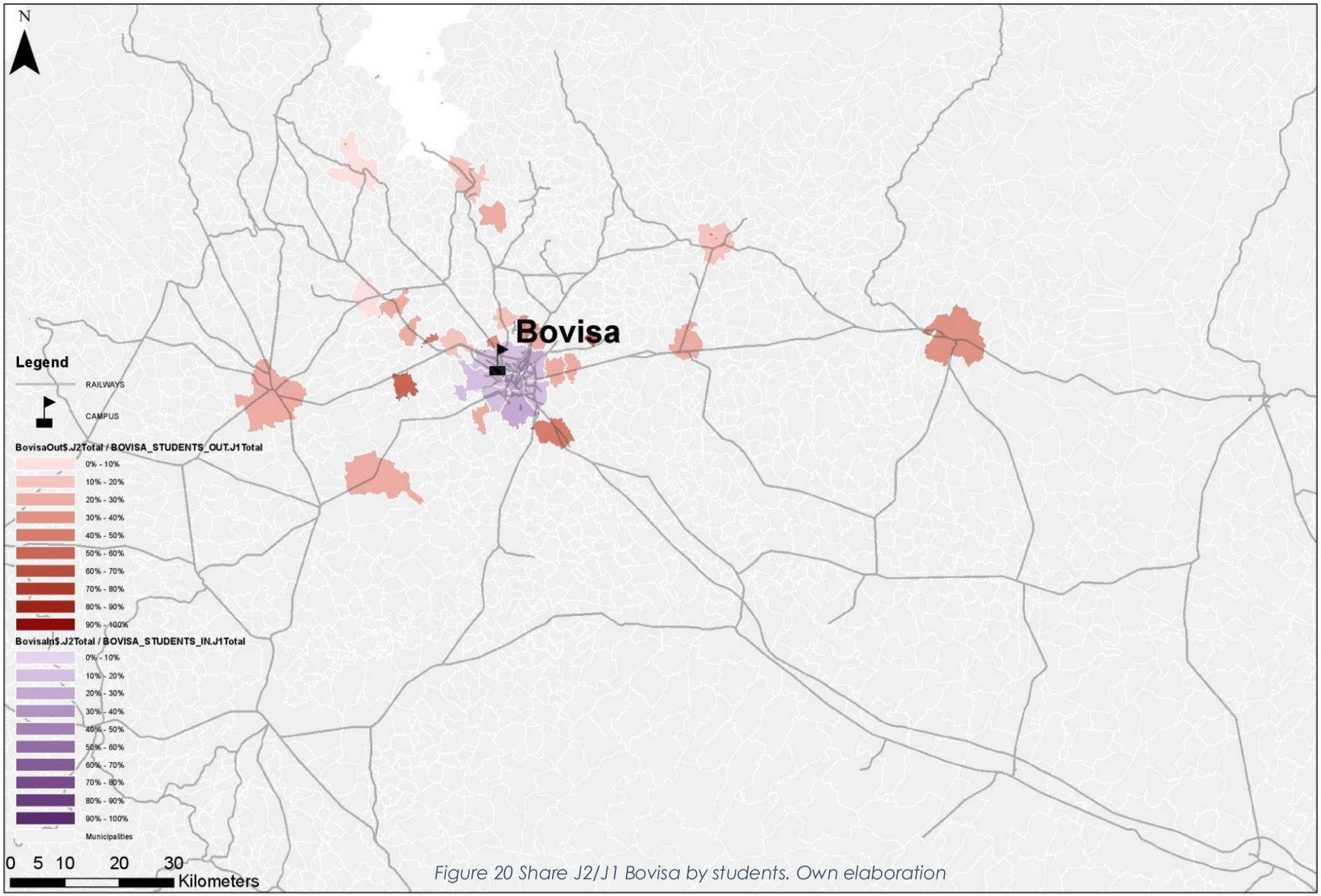


Figure 20 Share J2/J1 Bovisa by students. Own elaboration

The workers going to Bovisa with a secondary journey are more active than those going to Leonardo. Not all municipalities generate secondary journeys however close to the city; more at north there are areas where the quantity of secondary trip commuters is almost the same as the primary ones.

The quantity of secondary journey commuters that are students attracted to Bovisa, when the train prevails in the modal share of transportation is low among the territory. There are just three municipalities with representative percentages, all of them at the north of Milan. These are Treviglio, Brescia and Missaglia. Neither the behavior inside Milan is representative.

The behavior for workers is more representative, secondary trips made with train to reach Bovisa are significant in some municipalities where there is railway supply. At north of Milan we have, for instance, Monza, Cantú and Gallarate, at west Iseo and at south Lodi, Crema and Piacenza. Inside Milan the administrative zones that are closer to Bovisa campus have lower quantities.

Like secondary trips made by students attracted by Leonardo with private car the quantity of commuters going to Bovisa is significant among the municipalities in northern Lombardy. The concentration is higher at the northern-west from Milan and in almost all the cases the share is between seventy percent and eighty percent of the total number of commuters of secondary journeys generated by each municipality. Inside Milan the areas of Baggio, De Angeli, San Siro have the higher concentrations. The spatial distribution regarding this relation is shown in the Figure 21.

In the case of workers, the amount of secondary trip commuters that use private car to reach Bovisa is low; however the majority of municipalities where they are present have high values of percentages. The pattern is more present from north to south and mostly in the western area outside Milan. Inside the city of Milan the quantity of commuters is higher than students that commute. All in all, the results for workers, in terms of secondary journey are not representative.

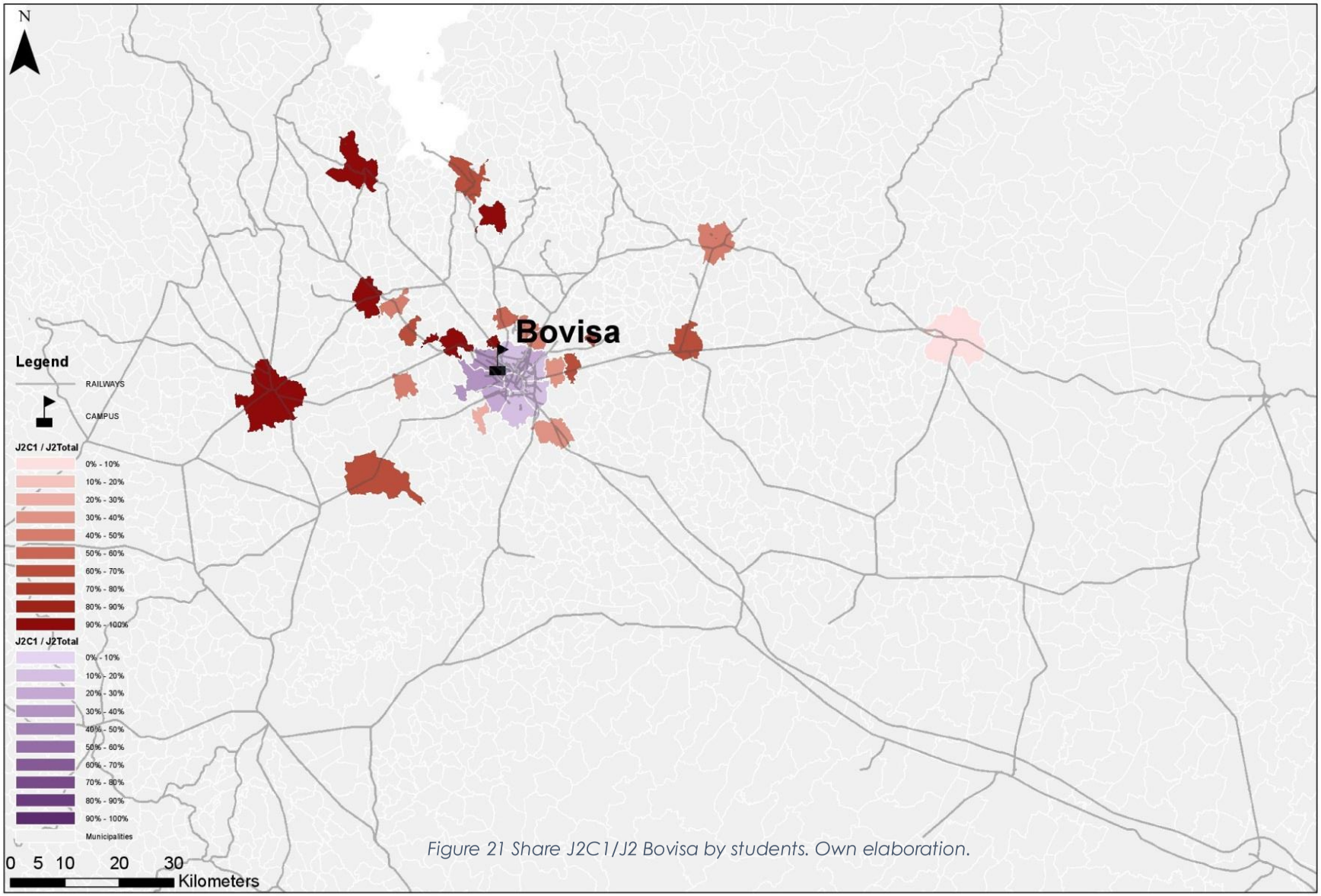


Figure 21 Share J2C1/J2 Bovisa by students. Own elaboration.

In the case of secondary trips attracted by Bovisa and made with transport combinations where public transport prevails there is a similar behavior for students and workers. The commuters are segregated among the territory, inside and outside Milan, always with low values. In the case of workers, municipalities like Vignate and Fiesco have percentages higher than ten percent.

In both cases, commuters attracted by Leonardo and Bovisa with no motorized means are low. Thus, the behavior of primary and secondary trips is similar; but in the second case the amount of journeys is less and less frequent. The main difference between primary and secondary journeys is related with the most used transportation mean which in the first case is train and in the second one is public transport for students and private car for employees. The share of students that commute with private car is higher in this case. The amount of students that commute with public transportation and private car reach more than eighty percent of the total quantity of students that commute for a secondary journey.

4.2.4 Relation between availability of season ticket and primary journeys attracted by Politecnico di Milano Campuses

Politecnico di Milano's population is used to reach the campuses with the use of different modal shares where the train prevails. Thus in this section is presented the relation between the availability of train season ticket by students and workers and the number of users that declared their preference to use the train as mean of transportation.

The high amount of train users attracted to Leonardo is related with the availability of the train season ticket. In the case of students the behavior of primary trip commuters with this mean and the behavior of the availability of season ticket among the territory are similar.

Students with train season ticket are spread among the territory and the concentration among the different municipalities is representative, almost every time above thirty percent. Overall the concentration inside Milan is much lower than outside as is shown in the Figure 22.

In the case of workers, despite the high amount of primary trips attracted by Leonardo with train the availability of season ticket is low, concentrated mostly outside Milan, at the north west of the city. Inside Milan the availability of season ticket is presented in areas as Fiera, Gallaratese and Quarto Oggiaro. The spatial distribution in this case is shown in the Figure 23.

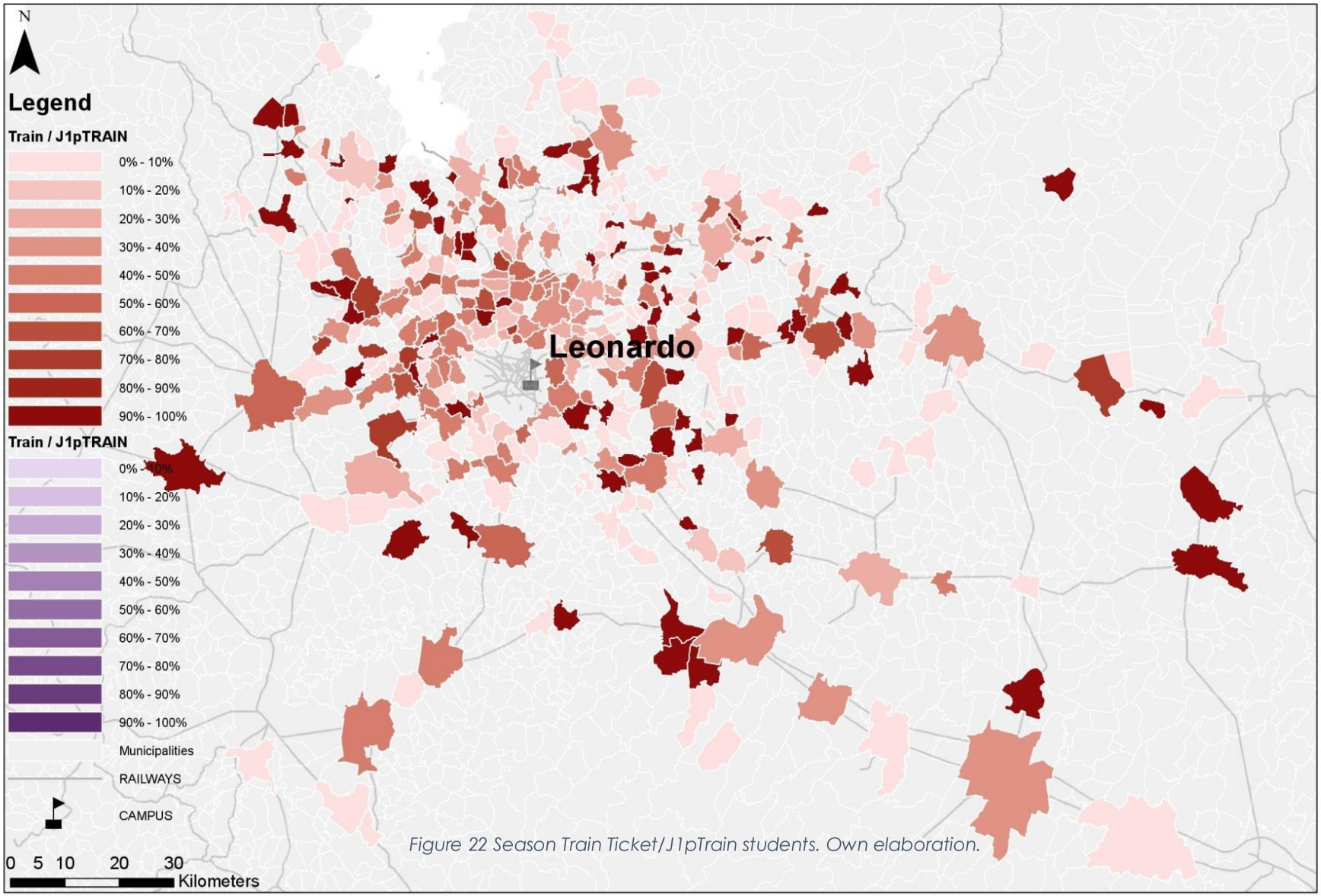


Figure 22 Season Train Ticket/J1pTrain students. Own elaboration.

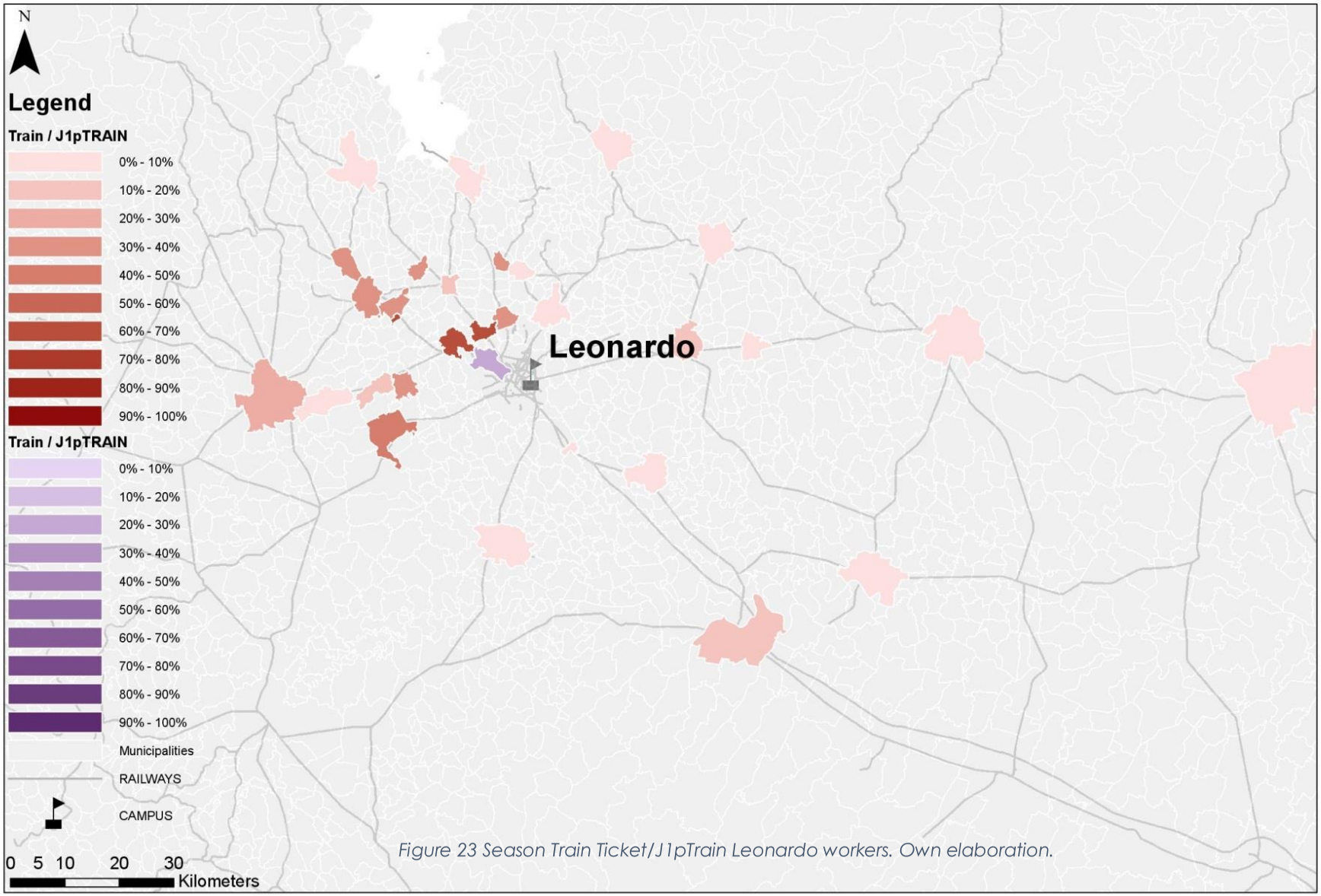


Figure 23 Season Train Ticket/J1pTrain Leonardo workers. Own elaboration.

In the case of students going to Bovisa the amount of people that use the service is significantly higher than the amount of people with season ticket (See Figure 24).

The behavior of workers is similar to students' outside Milan and inside Milan there is not a representative sample of workers that use a season ticket for the train service (See Figure 25).

The relation between availability of train season ticket is quite different for the analyzed campuses. In the case of students that use the train to reach Leonardo campus it is almost one to one and in the case of staff half of the quantity of workers that use the train has season ticket. In the case of Bovisa almost the third part of students that use the train to reach the university have season ticket and the eighty percent of workers that use this mean to reach the campus have a season ticket.

The latest statement could have different reasons: One related with the use of singular tickets to reach Politecnico or with the availability of ATM season pass inside Milan. The outcome from the mobility survey in connection with quantity of train users and availability of season ticket is shown in the Table 5.

Table 5 Season ticket and use of train. Own elaboration.

Leonardo	**Season Ticket**	**Train users**	**Share**
Students	1,369	1,636	84%
Workers	234	431	54%

Bovisa	**Season Ticket**	**Train users**	**Share**
Students	1,069	2,922	37%
Workers	290	362	80%

Leonardo + Bovisa	**Season Ticket**	**Train users**	**Share**
Students	2,438	4,558	53%
Workers	524	793	66%

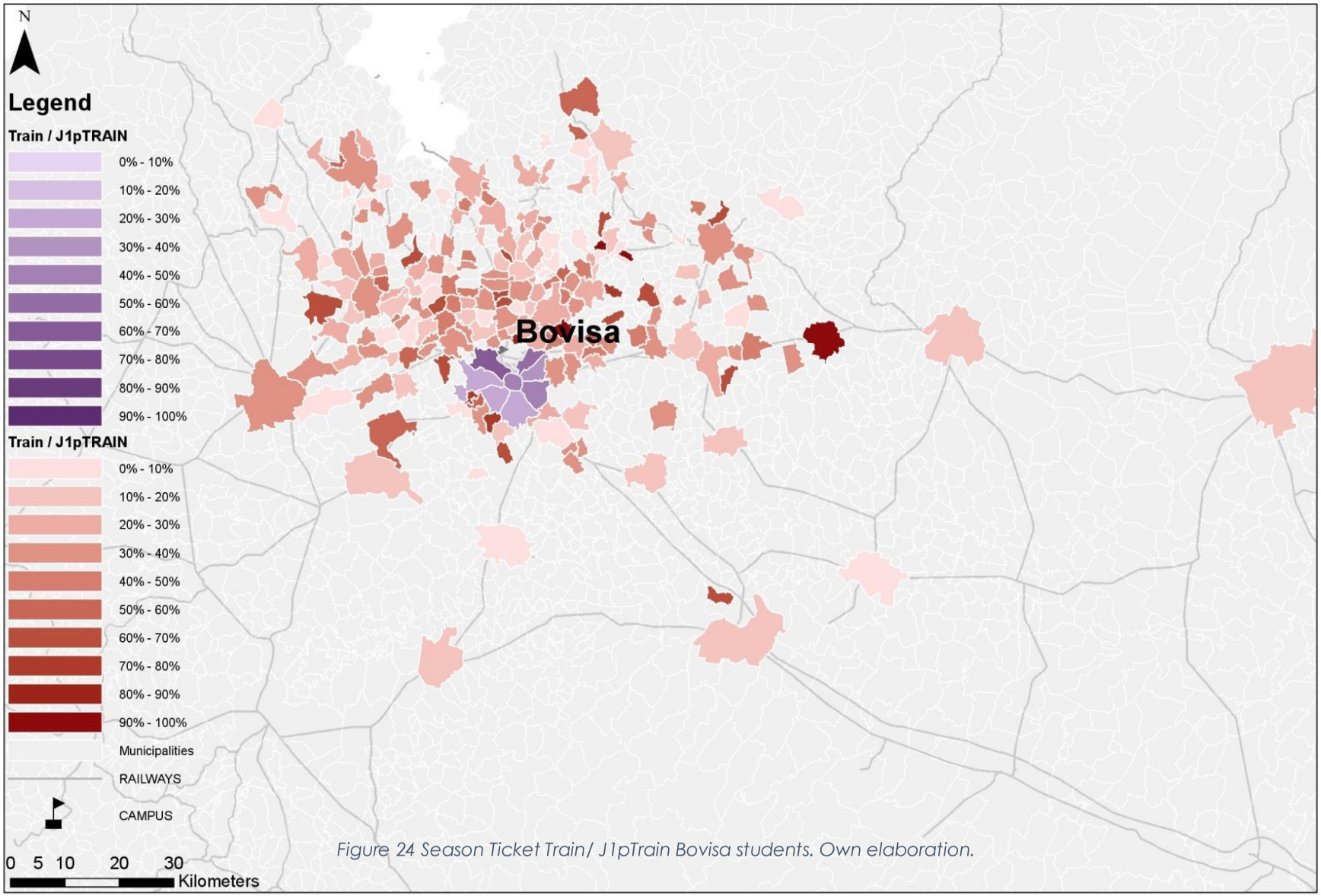


Figure 24 Season Ticket Train/ J1pTrain Bovisa students. Own elaboration.

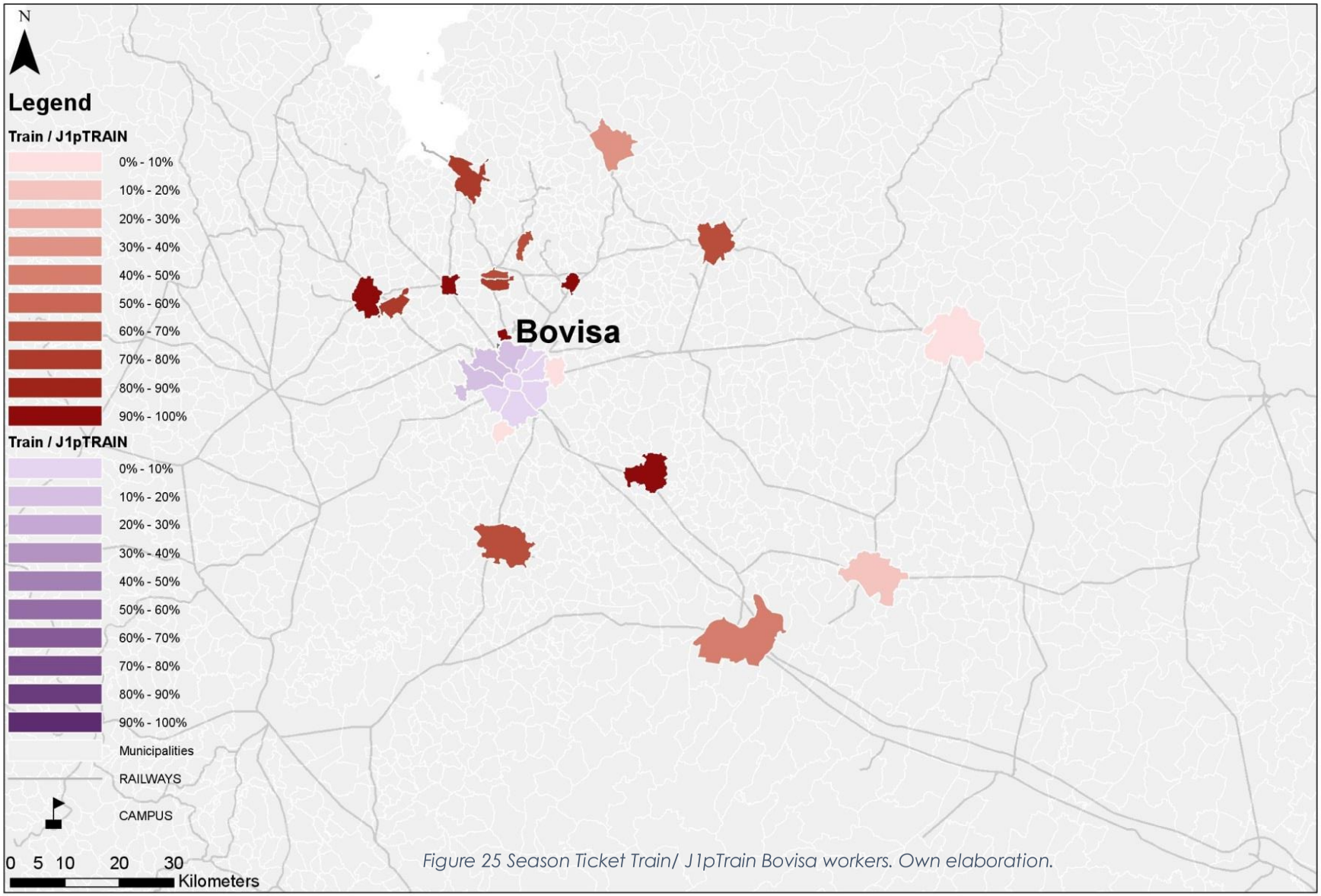


Figure 25 Season Ticket Train/ J1pTrain Bovisa workers. Own elaboration.

4.2.5 Relation between frequency and journeys attracted by Politecnico di Milano Campuses

In order to develop policies that decrease the use of private transport it has to be understood the pattern of use of this mean, which is possible if we consider the frequency of the trips made by car to Leonardo and Bovisa.

It has been said that Politecnico di Milano's staff uses more the private transport to reach the university than students (See Figure 2) and that part time professors are the ones who use private car the most. The first statement can be considered true however the second one changes if the frequencies of the trips are taken into account. In this sense, for Leonardo as well as for Bovisa, the categories of employees that use private transport the most are technical, administrative and research staff. Part time professors use private transport the most when low frequencies are considered which means trips made between cero percent and fifty percent of lectures time. In respect of the behavior of the students, the majority of primary trips generated by Leonardo and Bovisa with car are made in an interval of high frequency.

So far, we have been talking about **quantity of commuters** that have declared their modal share to reach one of the campuses, nevertheless if we consider the frequency declared by these users during the lectures time as well as the declared secondary trips with their respective frequency we would be able to compute a weighted sum of primary and secondary journeys to each one of the campuses, in other words the **quantity of journeys** and an estimated **modal share** among Politecnico commuters.

The analysis related with private car use is explained as follows:

Although the share of students that use private car is less than workers' the quantity of the trips produced are representative too. The weighted results show that **students generate almost 40,000 trips during the period of lessons**. In

the case of **employees the quantity of trips reaches more than 40,000 trips during the period of lessons.**

The outcome of the computation of journeys only with private car is shown below:

Table 6 Weighted private car trips. Own elaboration.

Category	Leonardo	Bovisa	Total	Share /trips
Students	**17,262**	**20,684**	**37,947**	**47%**
assegnista di ricerca	812	928	1,740	2%
assegnista di ricerca; cococo	109	145	254	0%
cococo	283	239	522	1%
Dottorato	1,646	827	2,472	3%
Support staff	**2,849**	**2,139**	**4,988**	**6%**
Docente a contratto	2,023	2,610	4,633	6%
Part time professors	**2,023**	**2,610**	**4,633**	**6%**
Personale Tecnico-Aministrativo	15,283	4,038	19,321	24%
Technical and administrative staff	**15,283**	**4,038**	**19,321**	**24%**
Professore associato	4,104	2,255	6,358	8%
Professore ordinario	2,226	1,088	3,313	4%
Ricercatore legge 240/10 - t.det.	827	210	1,037	1%
Ricercatore universitario	957	1,639	2,596	3%
Research staff	**8,113**	**5,191**	**13,304**	**17%**
Total workers	**28,268**	**13,978**	**42,246**	**53%**
Total trips/year	**45,530**	**34,662**	**80,192**	**100%**
Total trips/day	**314**	**239**	**553**	**0.7%**

The distribution of private car journeys made by students is higher for Bovisa than for Leonardo and the trips generated by workers are more distributed in the case of Bovisa. The distribution of private car journeys for both campuses is shown in the next figures.

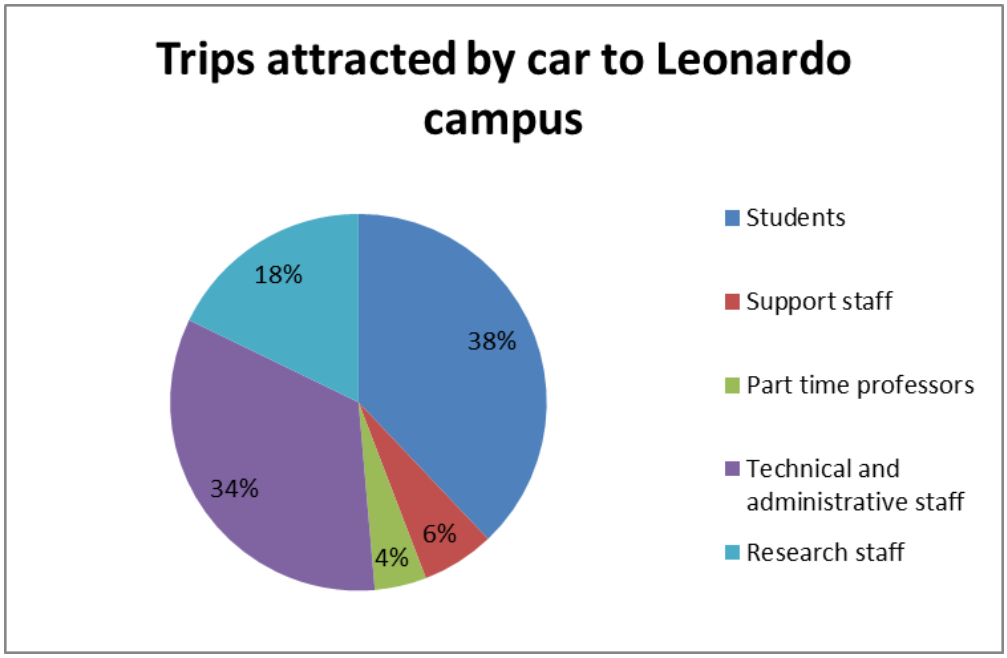


Figure 26 Weighted trips attracted by car to Leonardo. Own elaboration.

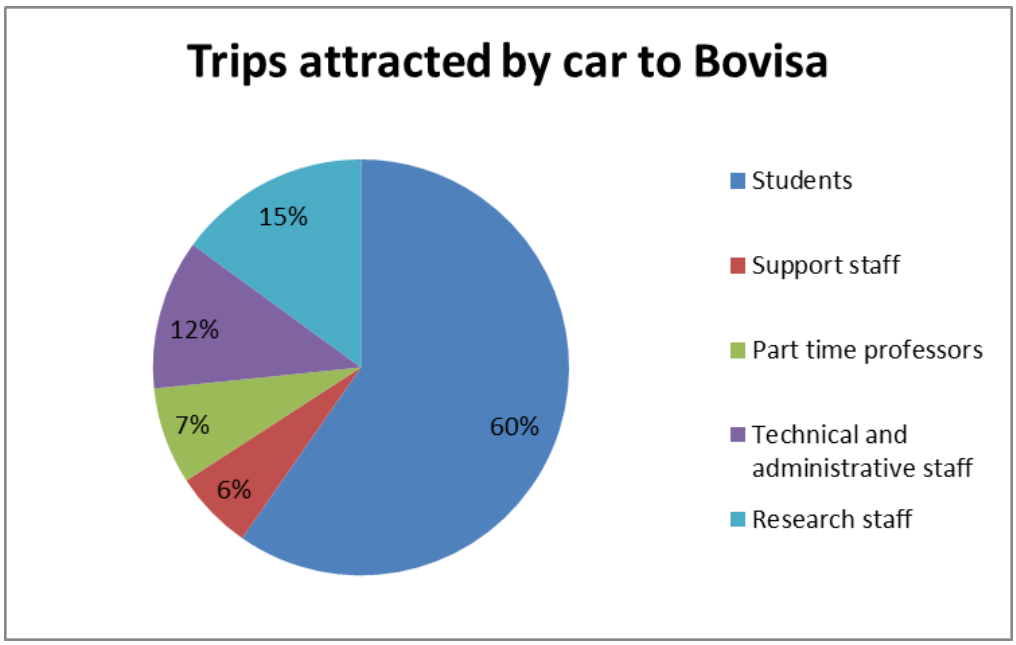


Figure 27 Weighted trips attracted by car to Bovisa. Own elaboration.

The amount of trips attracted by Milan during lessons time could reach a value up to 80,192 according to the data set, which represent 553 trips by private car/day, 314 trips/day attracted by Leonardo and 239 trips/day attracted by Bovisa.

About the spatial distribution of high frequency primary trips by students by car attracted by Leonardo campus it can be said that are generated mostly in municipalities that don't have direct access to a rail line. Examples of it are Manerba del Garda, Ripalta Cremasca, Vistarino and Zibello.

Low frequency primary trips by car are generated in low quantities and spread among the territory; nevertheless municipalities with railway infrastructure generate high number of trips with private transport like Piacenza and Cremona due to the fact of their size. There is a similar pattern for private transport journeys to Bovisa by car but in this case the spatial distribution is mostly located at the north of Milan contrary to Leonardo case which is spread among Lombardy.

The spatial distribution of high frequent journeys generated by workers attracted by Leonardo campus is concentrated in municipalities at west of Milan, like Peschiera Borromeo, Segrate and Zelo Buon Persico. In the case of Bovisa the trips are spread among the northern part of Milan with representative quantities in municipalities like Lecco and Monza.

On the other hand, the analysis related with exclusively public transport use, which considers subway, tram, trolley or bus, is explained as follows:

Among the academic year students generate more than the eighty percent of trips exclusively with public transportation. The Politecnico employees that generate more trips with public transportation are the technical and administrative staff with eight percent over the total.

During the academic year **Politecnico attracts almost 240,000 trips made exclusively with public transportation**. Almost eighty percent of these trips are attracted by Leonardo where the journeys made with high frequency are generated in the area bounded between Monza and Bergamo. At the north of the rail line that connects Milan with Brescia.

Inside Milan these trips are mostly generated in the areas of Centro storico, StazioneCentrale, Gorla, Turro, Greco, Crescenzago, Barona, Lorenteggio, Baggio, De Angeli, San Siro, Fiera, Gallaratese, Quarto Oggiaro Porta Garibaldi and finally Niguarda.

The quantities of journeys by students and the different categories of workers are summarized below:

Table 7 Weighted PuT trips. Own elaboration.

Category	Leonardo	Bovisa	Total	Share /trips
Students	**148,582**	**46,175**	**194,757**	**81%**
assegnista di ricerca	2530.25	406	2936.25	1%
assegnista di ricerca; cococo	137.75	0	137.75	0%
cococo	652.5	0	652.5	0%
Dottorato	6626.5	1000.5	7627	3%
Support staff	**9,947**	**1,407**	**11,354**	**5%**
Docente a contratto	2472.25	688.75	3161	1%
Part time professors	**2,472**	**689**	**3,161**	**1%**
Personale Tecnico-Aministrativo	18219.25	696	18915.25	8%
Technical and administrative staff	**18,219**	**696**	**18,915**	**8%**
Professore associato	4712.5	464	5176.5	2%
Professore ordinario	2987	246.5	3233.5	1%
Ricercatore legge 240/10 - t.det.	543.75	21.75	565.5	0%
Ricercatore universitario	2022.75	456.75	2479.5	1%
Research staff	10,266	1,189	11,455	5%
Total workers	**40,905**	**3,980**	**44,885**	**19%**
Total trips/year	**189,486**	**50,156**	**239,642**	**100%**
Total trips/day	**1,307**	**346**	**1,653**	**0.7%**

The share of trips by students that use public transportation is higher for Bovisa than for Leonardo despite Leonardo attracts the highest amount of journeys. The distribution of trips associated exclusively with public transportation is shown in the following figures.

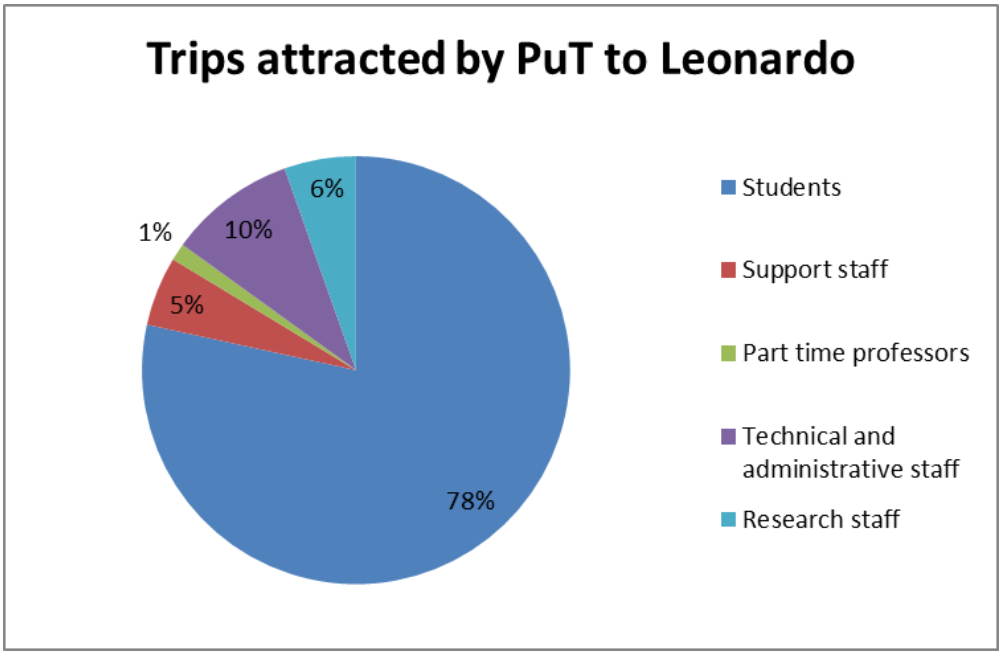


Figure 28 Weighted trips attracted by PuT to Leonardo. Own elaboration.

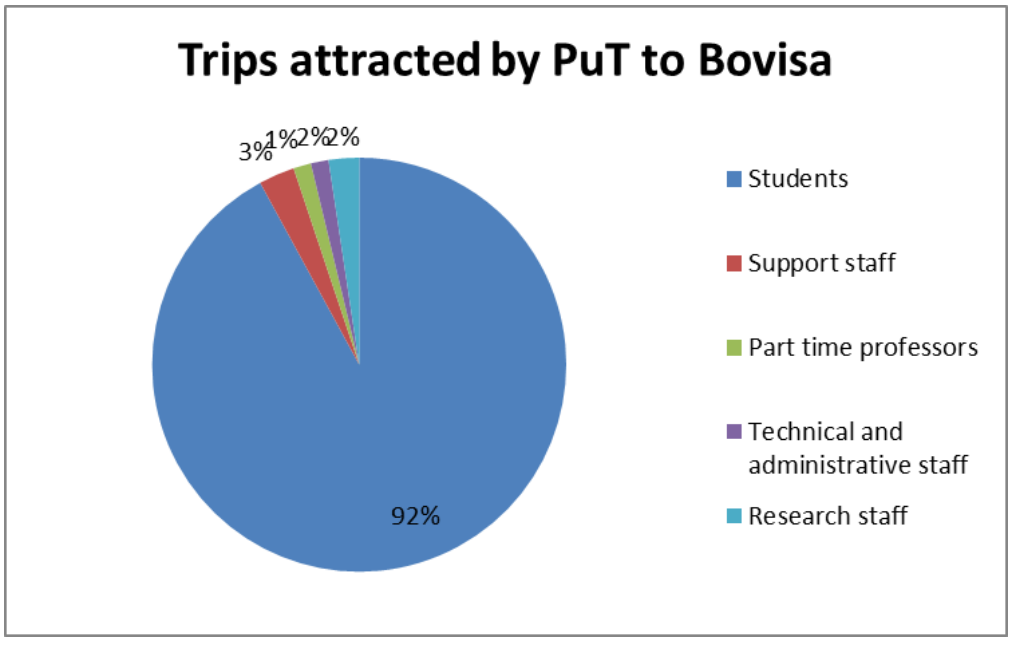


Figure 29 Weighted trips attracted by PuT to Bovisa. Own elaboration.

In connection with journeys exclusively with train and suburban railways there has been made the following statements:

Every year Leonardo and Bovisa attract **more than 170,000 trips made exclusively by train**. More than eighty percent of these trips are made by

students. Students going to Bovisa generate more than sixty percent of these trips.

In terms of trips made by workers, the support staff category is the one that generates the most with a non-representative value over the total, which is lower than ten percent. The quantifications regarding trips made exclusively with train are shown below.

Table 8 Weighted Train trips. Own elaboration.

Category	Leonardo	Bovisa	Total	Share /trips
Students	**36,830**	**113,318**	**150,148**	**85%**
assegnista di ricerca	935.25	3132	4067.25	2%
assegnista di ricerca; cococo	7.25	398.75	406	0%
cococo	493	130.5	623.5	0%
Dottorato	1769	3132	4901	3%
Support staff	**3,205**	**6,793**	**9,998**	**6%**
Docente a contratto	928	1022.25	1950.25	1%
Part time professors	**928**	**1,022**	**1,950**	**1%**
Personale Tecnico-Aministrativo	3719.25	3719.25	7438.5	4%
Technical and administrative staff	**3,719**	**3,719**	**7,439**	**4%**
Professore associato	1914	1558.75	3472.75	2%
Professore ordinario	754	1131	1885	1%
Ricercatore legge 240/10 - t.det.	696	282.75	978.75	1%
Ricercatore universitario	1196.25	464	1660.25	1%
Research staff	**4,560**	**3,437**	**7,997**	**5%**
Total workers	**12,412**	**14,971**	**27,383**	**15%**
Total trips/year	**49,242**	**128,289**	**177,531**	**100%**
Total trips/day	**340**	**885**	**1,224**	**0.7%**

Although Leonardo campus does not have a train station as Bovisa does, the share of employees that uses exclusively this mean of transportation is higher in the first case. As it is expected, the share of students that use exclusively train is

higher for Bovisa than for Leonardo. The share about trips made by the different categories of population inside each one of the campuses is presented in the next figures.

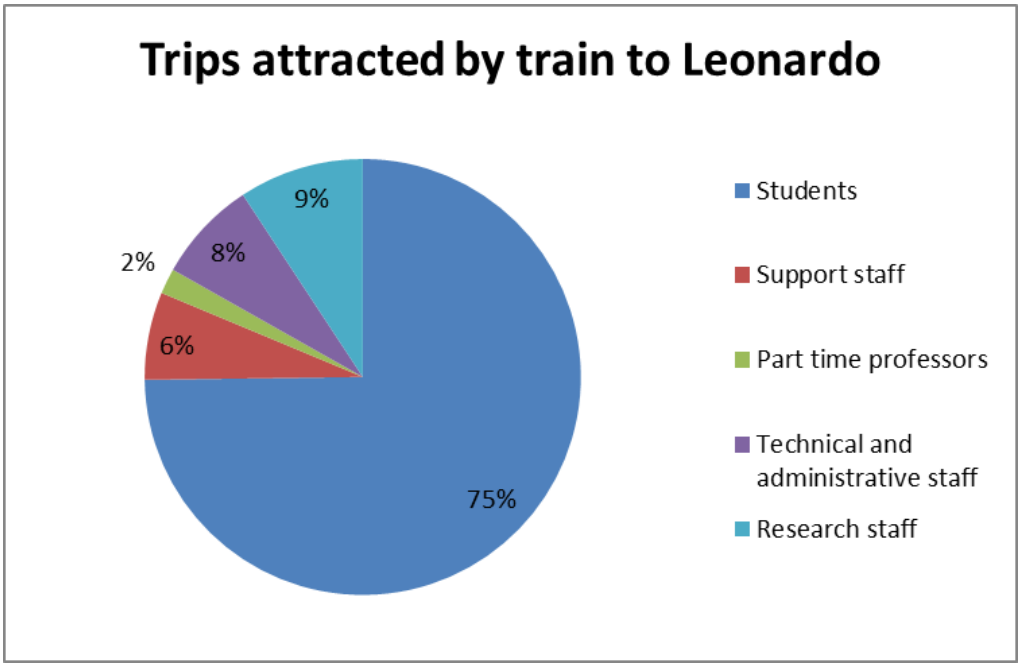


Figure 30 Weighted trips attracted by train to Leonardo. Own elaboration.

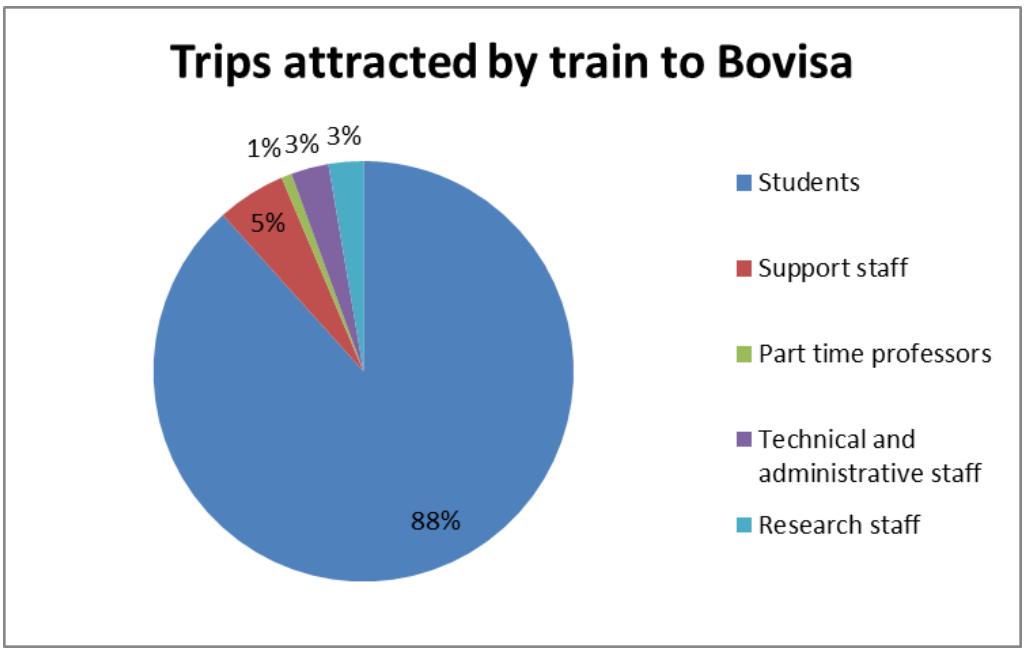


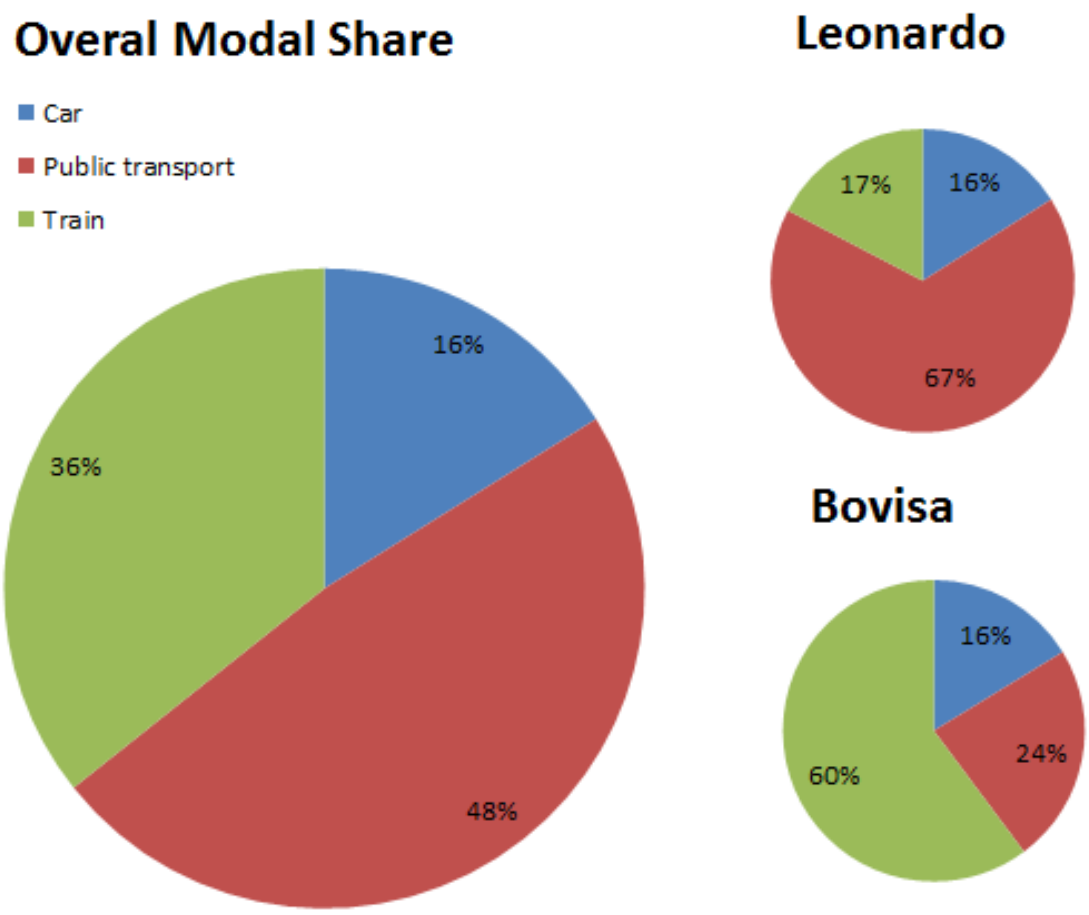
Figure 31 Weighted trips attracted by train to Bovisa. Own elaboration.

As it has been said, the latest interpretation only consider the journeys produced by commuters that **exclusively** use either private car, public transportation which can be subway, tram, trolley, bus; or train to reach Politecnico. This interpretation has left out the different transport combinations that consider the mentioned means. For example it does not consider the trips made by those users who reach the train station with a private car and afterwards use the rail system or those users that use public transportation after use the train. It has been done in this way in order to skip more journeys than the ones that Politecnico di Milano really attracts.

Although there is a higher amount of commuters that use train to reach Politecnico, the results of the present section have shown that the higher amount of trips is made with public transportation, followed by train and finally car.

Leonardo and Bovisa attract almost half million trips with motorized means every academic year. The share of journeys exclusively with private car reaches almost the fifth part of the total. The distribution of these private car journeys is the same for both campuses however there are notorious differences in terms of use of public transportation and train. The first one is more used by Leonardo commuters and the latest by Bovisa ones, which is natural due to the high availability of public transportation for Leonardo commuters and train services for Bovisa ones.

It has to be kept in mind that the previous results are based on the mobility survey, which represents almost the fourth part of Politecnico population. They are summarized in the next figure.



Modal Share/year	Leonardo	Bovisa	Total
Car	45,530	34,662	80,192
Public transport	189,486	50,156	239,642
Train	49,242	128,289	177,531
Total	**284,258**	**213,107**	**497,365**

Figure 32 Modal share. Own elaboration.

5. Policy proposals

5.1 Context

An urban environment is related with the livability of residents and this environment is affected with issues as traffic congestion, air and noise pollution. Nowadays places with urbanized environments or cities are suffering due to these mentioned issues and Italian cities are experiencing severe damage because of it (Rotaris and Danielis, 2014).

In terms of traffic congestion, the average speed of vehicles during rush hours in Italy could be lower than 30 km/h (TomTom, 2016). Confcommercio has said that the reason of traffic congestion in Italy dates back to 1970. Over the last forty years the vehicle fleet has increased at a point where there are Italian cities with a rate of 700 cars/1,000 habitants (ISTAT, 2012). There are also attributed facts as inadequate urban infrastructure, inefficient public transport, lack of parking lots and low accessibility in terms of connection between urban centers and roadway network.

Considering $PM_{10,}$ Italy has been through periods where the PM_{10} emissions are higher than accepted values. In 2010 there were on average forty five days in which the PM_{10} average daily concentration threshold was exceeded (ISTAT, 2012). The statistics of average annual value of PM_{10} in Milan reach 43 $\mu g/m^3$ and the threshold is 40 $\mu g/m^3$ (Cittá Metropolitana di Milano, 2016). It has been identified that one of the main responsible of PM_{10} is the traffic which combined with the combustion of diesel produces 44% of the total (l'Espresso, 2015). Regarding noise pollution limits rose from 42.8% in 2009 to 57.2% in 2010 on average, among Italian cities (Rotaris and Danielis, 2014).

Despite the contribution of a university to an urban environment is related with a notorious increase in the prestige of the area, there are negative impacts, for instance the attraction of traffic which produces the damages mentioned above: traffic congestion, PM_{10} emissions and noise pollution, among others. Regarding the data set analyzed in the present study there are more than

80,000 trips/academic year made by car attracted to Milan campuses. More than five hundred journeys per day.

One of the statements made by Havlik and Toor (2004) in their work titled *Transportation and Sustainable Campus Communities* is that daily movement of people back and forth to campus in automobiles burning fossil fuels, this is one of the repercussions that an institution imposes over the life support systems in the planet, besides it is one of the reasons to balance the pros and cons of the urban location of the Politecnico campuses as large traffic generators of spots which are essential for the livability of the city, particularly Milan.

Currently the city of Milan has options to enhance the use of public transport within the city, not only through investments, but also by means of different set of policies. One key issue is that of fare system. The main transport provider in the city, ATM (Milan Transport Company) is partially integrated with other provincial operators through a system called "SITAM" and with the regional transport, mainly trains, under the fares "IoViaggio". Limiting to urban transports of ATM, numerous subscriptions exist: (abbonamenti urbani) for travel inside the urban network, intercity subscriptions for travel on a long distance network from Milan (abbonamenti interurbani) and cumulative subscriptions that consider the ones mentioned before (abbonamenti cumulativi). ATM also offers different kind of subscriptions depending on the age of the user. There are special discounted fees for students, young and elderly. For example people under 26 years could pay a monthly ticket of €22 or an annual ticket of €200 that make them able to use the urban ATM network (Bus, Tram or subway) and the train inside the city (Passante Ferroviario) instead of pay for a ticket able for only ninety minute which cost €1.5 or a daily ticket that has a value of €4.5.

Inside Milan there are also available services of bicycle sharing, for instance BikeMi, and car sharing, like Enjoy, Car2Go or GuidaMi available for everyone. All these services have decreased the use of private vehicle inside the city, which is evident in the analyzed data set where less than 10% of the commuters going from the Milan's different administrative zones to Leonardo and Bovisa use these means of transportation.

In terms of options related with the use of train in northern Lombardy the company responsible for it, Trenord, has besides the option of one singular ticket subscriptions for an entire week, month or year just depending on the traveled distance and the class where the user would travel. In alternative, season tickets integrated with urban tickets of the cities have been recently introduced (*IoViaggio*).

Coming back to the use of private transport, the parking lots inside Leonardo and Bovisa facilities do not have a using fee and are available only for Polimi employees. There are also parking spots nearby the campuses without fee and available for everyone. The allowance of only workers inside campuses parking might solve the parking problem for employees; nevertheless create an increase of demand of parking spots by students and residents.

There is a necessity of balance the pros and cons of an educational institution inside an urban environment because of if capacity of being a large traffic-generator. Supplying this necessity is important for the success of the habitability not only in the neighborhood where the institution is located, but in the entire city. This success could be achieved shifting the modal share of private car towards public transport or active modes such as bikes and walking.

In the following, it is considered the approaches mentioned by Holden (2015) in order to achieve a sustainable mobility: Efficiency, Alteration and Reduction and discuss them applied to Politecnico's mobility based on the results of the spatial distribution of trips shown in previous sections.

5.2 Parking meters

In order to reduce the private car use to reach Leonardo and Bovisa campuses it could be proposed, in analogy with many other areas in Milan, setting of an hourly parking tariff in the streets nearby the university with the implementation of parking meters in spots that today work as free and public. For the purpose of this program we have checked the document "*Piano Urbano Mobilità Sostenibile*" issued in February 2015. There is a classification of the areas in which are located both Leonardo and Bovisa campuses, according with this

Leonardo is located in the "*Cerchia Bastioni",* corresponding to the XX-Century city. In these areas of Milan city there are a total number of 58,100 parking spaces in which 31,500 out of the total are for residents and 26,600 have to be paid if are used. Bovisa Campus is located in an area called in the document "*Ambiti Sosta Progammata/ In Attuazione*". It means this area is under the development for the implementation of parking fees. The delimitation of areas is described in the Piano di Mobilità:

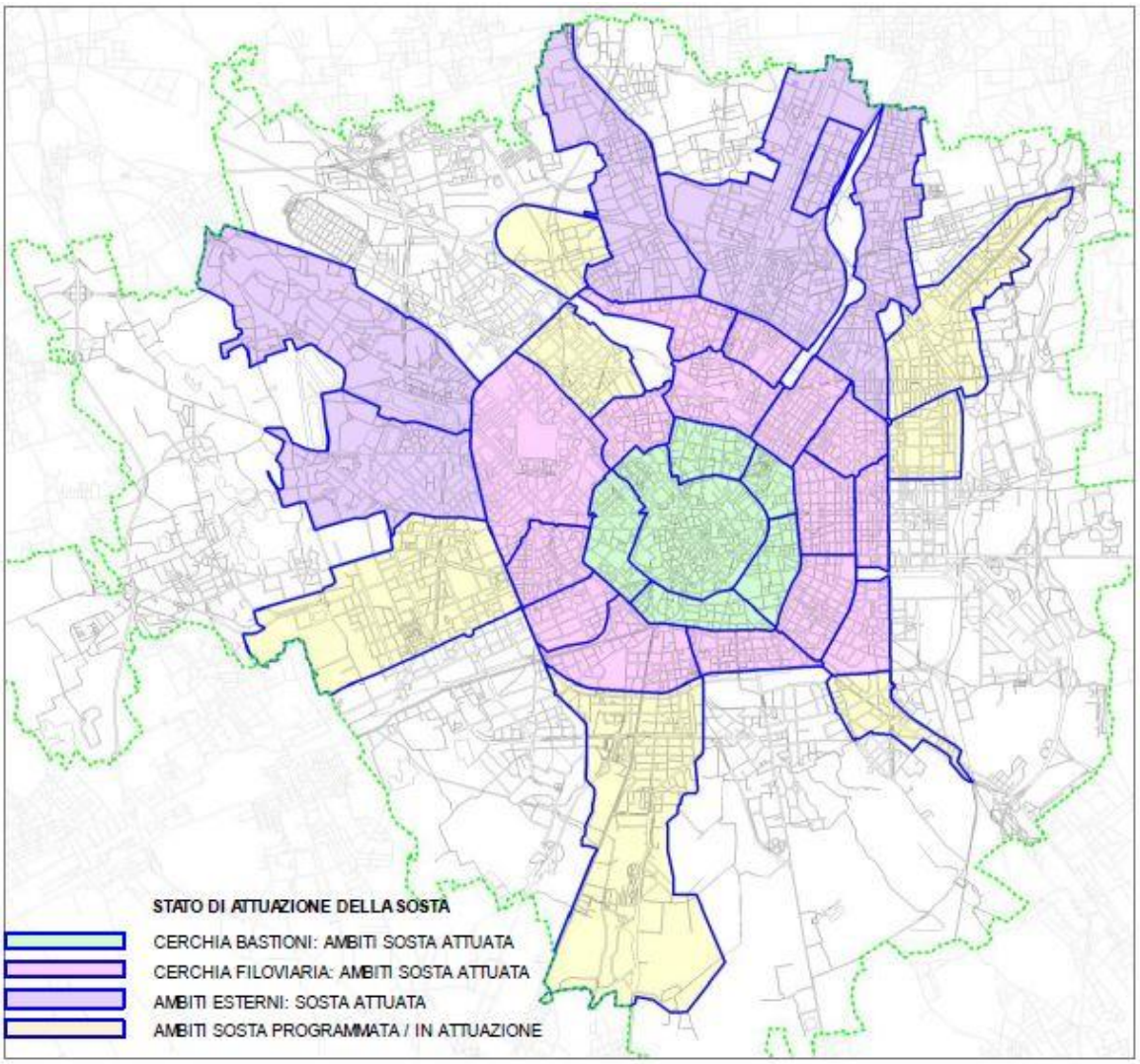


Figure 33 Parking areas in Milan. Comune di Milano, 2015.

For the formulation of this this strategy, we considered a circular area with a 400 m radio centered in the principal building of every campus, both Leonardo and Bovisa. Our proposal for this strategy is to impose a parking fee on people using

the car, willing to park their cars within the circular area. The following principles rule the strategy:

1. This strategy gives special attention to principal roads that have two senses since are the most desired places for parking, especially for occasional users.

2. Residents of the neighborhood will have the right to use these parking spots for free in any location.

3. Parking spots in the 400 m buffer have to be paid for those who are not inhabitants of the neighborhood.

4. On the secondary roads, parking space could be offered without charge by a maximum period of two hours.

5. Parking spots located outside the 400 m buffer can be offered for free during the first four hours.

For the development of this strategy we have considered the total number of street parking spaces available within the 400 m. The idea with these figures is to calculate which will be the rate of occupation based in state of art provided by Citta Studi-Campus Sostenible survey and finally get an approximate amount of money that could be raised. In the case of Leonardo Campus almost 900 parking spaces could be involved in the strategy (See Figure 34), while for Bovisa 990 spots, 760 spots from Durando campus (See Figure 35) and 230 spots from La Masa (See Figure 36).

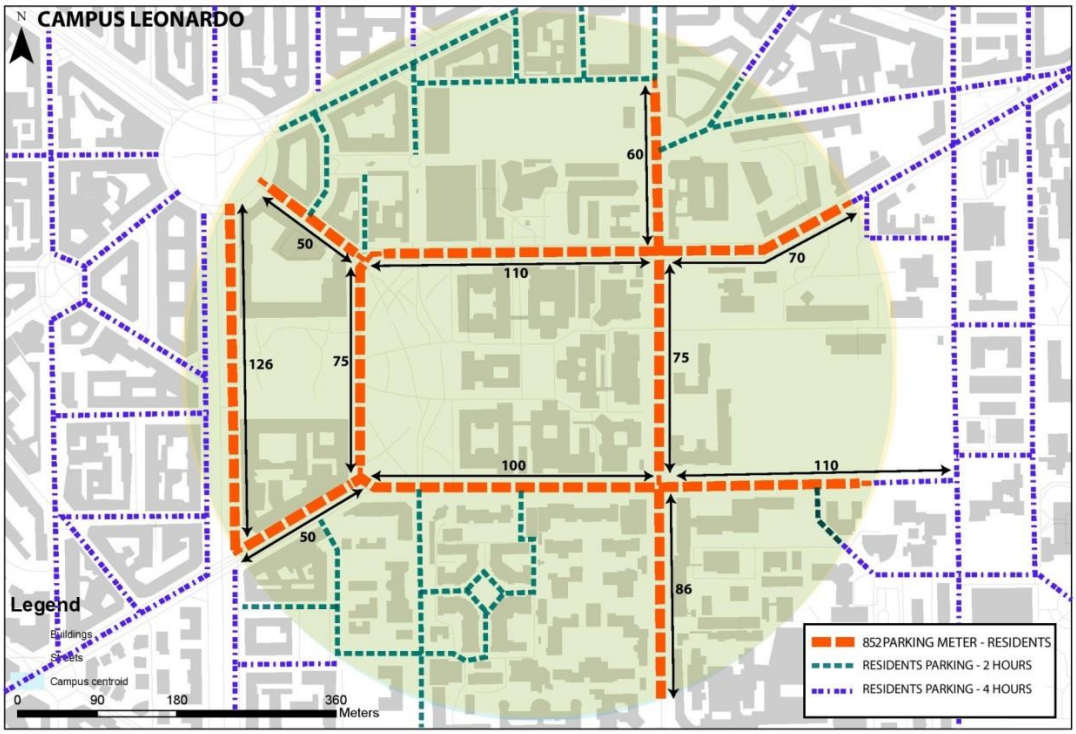


Figure 34 Parking streets spots Leonardo. Own elaboration.

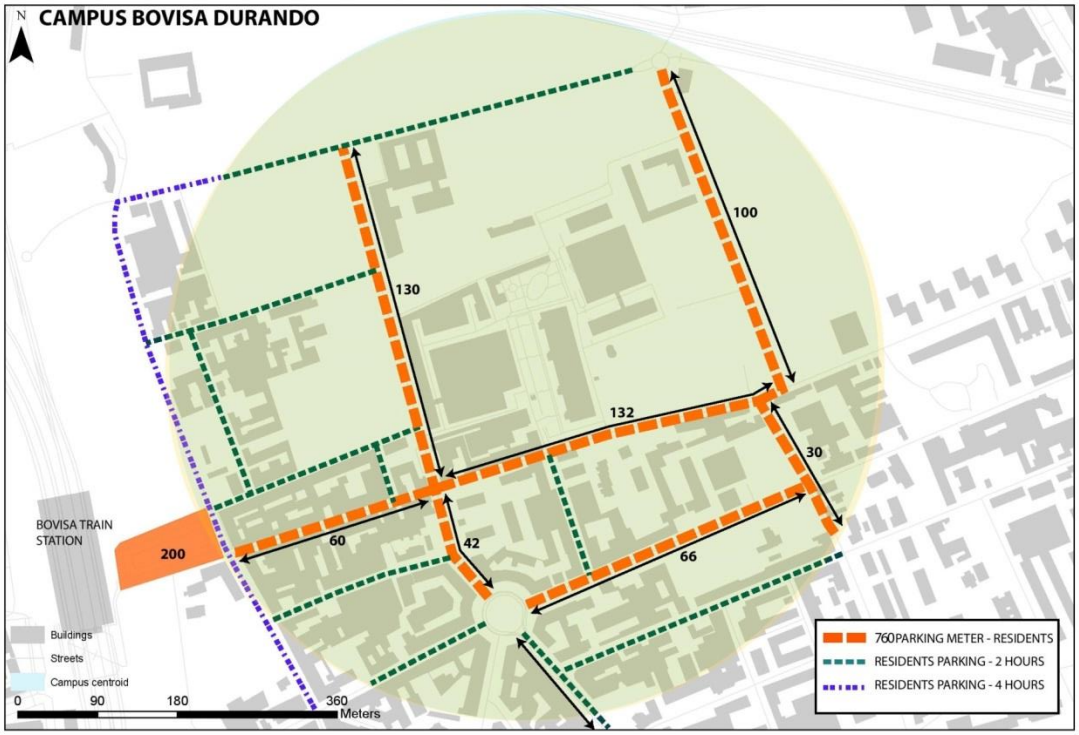


Figure 35 Parking streets spots Bovisa-Durando. Own elaboration.

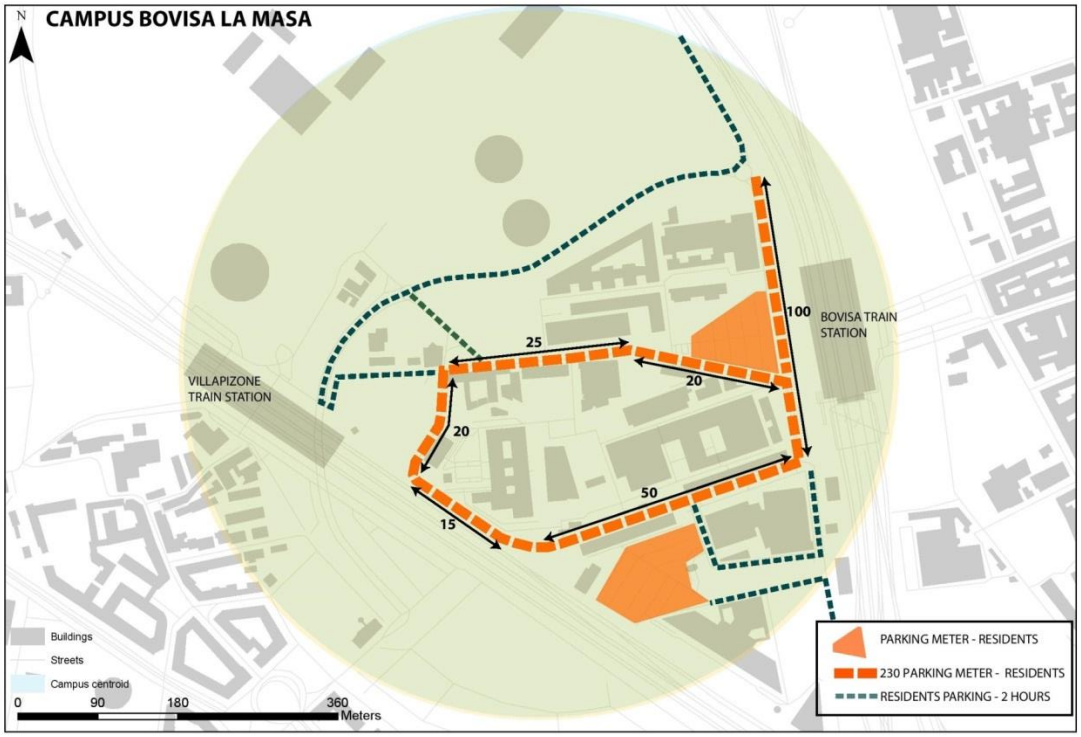


Figure 36 Parking streets spots Bovisa La Masa. Own elaboration.

The parking spots with fee, as already said, will not interfere with the spots of the residents in the neighborhood and the revenues obtained by the Municipality with it could ideally be earmarked to support policies specific for the University, such as public transport improvement or subscriptions discounts.

For the calculation of the possible scenarios we considered the data collected by Citta Studi-Campus Sostenible survey in order to figure out the total number of cars that goes every day to the campus, during the academic year. The total amount of weighted trips (primary and secondary) declared in the survey is recalled:

Table 9 Car trips Leonardo. Own Elaboration.

Category	Academic year trips	Daily trips	Percentage
Students	17,262	119	38%
Support Staff	2,849	20	6%
Part Time Professors	2,023	14	4%
Technical and Administrative Staff	15,283	105	34%
Research Staff	8,113	56	18%
TOTAL	**45,530**	**314**	**100%**

The results obtained show us a total amount of 45,530 trips made by car going to Leonardo during the academic year, compound by 145 days of lessons. It means there are more than three hundred vehicles every day. In this particular case, students represent the 38% of users going by car. Technical and administrative staff is the 34%, while research staff represents the 18%. Others like support staff, are lower than 10%. And finally it is remarkable to notice that part time professors are just the 4% of these figures, having into account that this group is not completely dedicated to the university.

In the case of Bovisa Campus we have made the calculations as well to find out the number of cars going there and here the results show us that 60% are represented by students, again we can notice that are the highest population coming by car. It also can be explained due to the simple fact that they are the bigger group among the university population. While research staff represents the 15%, technical and administrative staff is the 12% and others groups are lower than 10% each one of them (See Table 10). These quantities represent the weighted trips declared in the survey, quantities not extrapolated to the whole Politecnico population.

Table 10 Car trips Bovisa. Own Elaboration.

Category	Academic year trips	Daily trips	Percentage
Students	20,684	143	60%
Support Staff	2,139	15	6%
Part Time Professors	2,610	18	8%
Technical and Administrative Staff	4,038	28	12%
Research Staff	5,191	36	15%
TOTAL	**34,662**	**240**	**100%**

To perform the calculation about the implementation of this policy it has been considered parking spots and daily occupancy rate in order to notice how much could be obtained from students with park pricing. There have been estimated three scenarios with the aim of compute a range of policy revenue along the academic year. The results are shown below for both campuses: Leonardo and Bovisa, respectively.

Table 11 Street parking spots Leonardo. Own elaboration.

Leonardo			
Slots	852	852	852
% Residents (not paying)	50%	50%	40%
Hours per day	12	12	10
Occupancy rate	100%	80%	50%
Hour price	€ 1.00	€ 1.00	€ 1.50
Total daily revenue (€/day)	€ 5,112	€ 4,090	€ 2,556
Total academic year revenue (145 days)	**€ 741,240**	**€ 592,992**	**€ 370,620**

Table 12 Street parking spots Bovisa. Own elaboration.

Bovisa (La Masa and Durango)			
Slots	990	990	990
% Residents (not paying)	50%	50%	40%
Hours per day	12	12	10
Occupancy rate	100%	80%	50%
Hour price	€ 1.00	€ 1.00	€ 1.50
Total daily revenue (€/day)	€ 5,940	€ 4,752	€ 2,970
Total academic year revenue (145 days)	**€ 861,300**	**€ 689,040**	**€ 430,650**

The considered scenarios keep constant the quantity of slots and change the occupancy rate by Politecnico commuters as well as the fee of the service, always considering occupancy by residents in the area.

The scenarios with lowest revenue for Leonardo and Bovisa consider an occupancy rate of fifty percent, with an implementation of it the city of Milan could gain during the academic year, besides almost half million euros for each campus, a decrease of trips made by car due to the implementation of a parking fee.

In both cases the best scenario, in terms of economic income, reaches an annual revenue close to one million euro, however it consider a fully occupancy rate.

There is moderate scenario which reduces the occupancy rate of the parking slots in a representative rate (20%) and gives annual revenue higher than half million euros per campus.

All in all, the implementation of this policy could decrease the use of private car and could bring incomes to finance sustainable transport strategies as it has been mentioned before; however it requires further analysis about the occupancy of these slots that could be done with a study of the willingness to pay of commuters for an spot close to the university.

5.3 Parking fees inside the campuses

First we want to present a description about the situation of the parking facilities inside the Leonardo university campus. This is based on a work developed by Prof. Paola Pucci, to the Citta Studi-Campus Sostenible project. The main goal of this project was quantify the patterns of use for parking spots inside the university facilities.

This strategy considers the existing situation of parking slots inside the campuses. In the case of Leonardo campus the computations related with this strategy would not be accurate if the "green proposal" made by the Architect Renzo Piano (2016) is implemented[1].

To begin with, Leonardo campus has 362 parking spots, which are offered for free to the staff in the following distribution (See Figure 37):

- Leonardo historic buildings has 110 spots,
- Via Bonardi parking area has 80 spots,
- Via Bassini has 105 spots,
- Via Clericetti has 52 spots
- Mensa Viale Golgi has 15 spots.

[1] http://www.archiportale.com/news/2015/11/architettura/le-prime-bozze-di-renzo-piano-per-il-campus-del-politecnico_48829_3.html

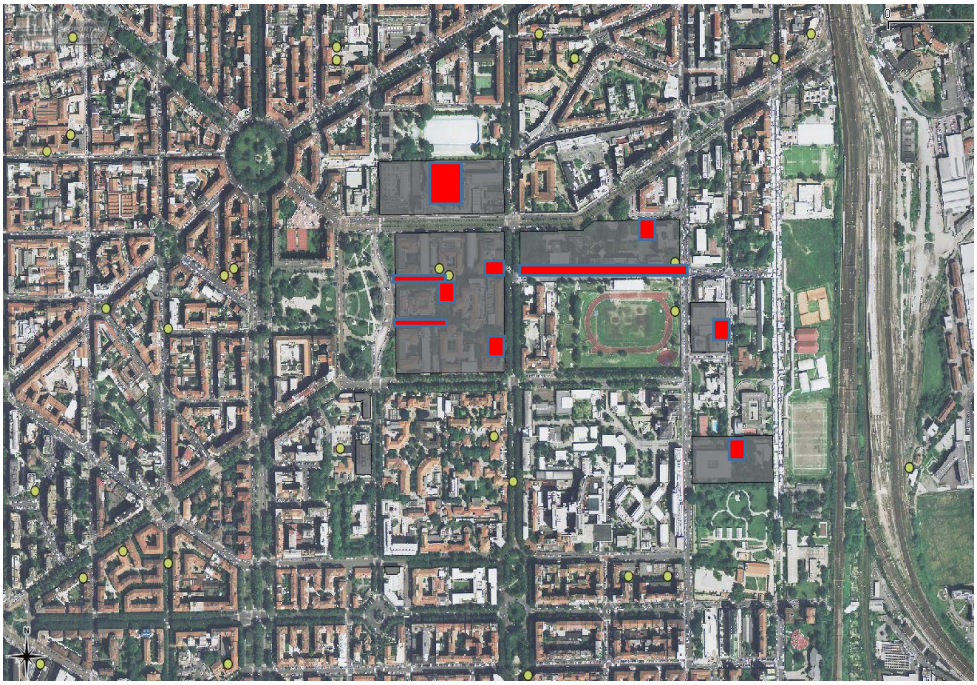


Figure 37 Parking spots Leonardo. Campus Sostenibile – Prof. Paola Pucci.

The fact that staff population has free access to the parking facilities generates in this specific case a non-sustainable practice among the staff working at Leonardo campus. As it has been shown before, among the car-users belonging to Politecnico staff, there is a concentration of origins close to the university like Lambrate neighborhood and areas in the east part of Milan. To the contrary, the quantity of users coming from the rest of the Lombardy or even from Milan West side is few.

Obviously this can be explained because it is more comfortable to use the car in a short distance and then having the easiness to park their vehicles in a closed area with no charge. The car produces a variety of senses among users like: sensation of liberty, due to instantaneous availability compared against schedules of public transport. Seems to be more convenient, since offers the possibility of reach several places and satisfy the needs of the commuters.

Appears to be an economic way of transportation, because those users who already have a car and assume the financial, maintenance and operation do not count these expenses on every journey and finally. These kinds of advantages produce a psychological resistance to the reduction of car use.

According with some scholars who have made surveys and projects in this field, if car users are requested to voluntarily reduce their private means of transportation habits through some method of influence like direct feedback about environmental and financial consequences and personal self-commitment, a very low likelihood of success is possible to obtain (Tertoolen & Kreveld, 1998). Having this into account, a better strategy to reduce car dependence among university population is the installation of parking meters inside the university facilities.

Based on the data set from the mobility survey, considering the frequency of the trips made with car to Leonardo and Bovisa and considering the assumptions presented in the previous section about parking fees per hour and days of an academic year, here is a policy proposal that just involve employees and for the calculations we will use just the Leonardo Campus since there is an existing detailed information about it.

From the data set there is information about 29,268 trips made by car among the staff population which represent 62% of the total amount of trips attracted by Leonardo Campus with private car. If we extrapolate this figure assuming that transportation habits are proportional on the universal population the number of workers making trips by car to Leonardo campus is 74,453 in the academic year compound by 145 days and 513 daily trips. On the other hand, students use less the car, just with 38% from the total population sample in Leonardo.

To sum up, workers are more used to use private mean of transport than students do. A reasonable cause for this behavior is the availability of free parking spots. Hence, this policy attempts to implement a fare for the parking spots for employees.

The calculations related with the policy efficiency consider, on the one hand parking spots and daily occupancy rate in order to notice how much could be obtained from park pricing, an income that could be used in other sustainable transport policies. There have been estimated three scenarios with assumptions on the average load factor to obtain a range of policy revenue among the

academic year. The results are shows that the revenue could be between one hundred euros and four hundred euros per academic year as is shown below.

Table 13 Employees parking Leonardo Campus. Own elaboration.

Leonardo			
Slots	362	362	362
Hours per day	8	8	8
Occupancy rate	80%	50%	20%
Hour price	€ 1.00	€ 1.00	€ 1.50
Total daily revenue (€/day)	€ 2,317	€ 1,448	€ 869
Total academic year revenue (145 days)	**€ 335,936**	**€ 209,960**	**€ 125,976**

However, reduce the quantity of parking slots could be, additional to implement a parking fee, a strategy to decrease the amount of private car journeys attracted to Leonardo. The revenues for three different scenarios reach values with a similar magnitude order to the previous ones. In this case the scenarios consider a reduction in space of 10%, 20% and 30%. These results are presented in the next table:

Table 14 Reduce parking Leonardo Campus. Own elaboration.

Leonardo			
Slots	326	290	253
Hours per day	8	8	8
Occupancy rate	100%	80%	50%
Hour price	€ 1.00	€ 1.00	€ 1.50
Total daily revenue (€/day)	€ 2,606	€ 1,853	€ 1,520
Total academic year revenue (145 days)	**€ 377,928**	**€ 268,749**	**€ 220,458**

If this kind of policy have an acceptance by university administrators suddenly employees will lost a benefit acquired from the fact of being employees, therefore the occupation in the parking and the number of people using cars is likely to decrease. In addition, the made scenarios shows that the revenues obtained from a strategy like this one would reach a range between two hundred thousand and more than four hundred thousand; which could be used in the implementation of more transport demand policies.

5.4 Transit pass discount

The aim of the transit pass discount strategy is to increase the use of train to reach the two campuses inside Milan in order to decrease the routine of private car use. The strategy proposes a discount of the train pass for Politecnico users.

In principle the discount rate is equal for all the commuters, however it increases as the train users does. Politecnico could make an agreement with Trenord, the company that deals with public transport by train of Lombardy, in order to provide the benefit for Politecnico commuters.

In this sense the university would buy directly from Trenord the train passes. In exchange Trenord would apply a discount on the final price according to the total number of subscriptions purchased that will increase as the number of subscriptions does. The university could develop a survey in order to know how many train commuters would have if the strategy is implemented and decide if they subsidize the program completely, partially or charge the cost to the train commuters.

This strategy is not new in Italy, in Milan ATM has introduced in a group of tariff called *Key*. The public transport company offers a special discount for a group of users on base of specific agreement with private or public entities (http://www.atm.it/it/ViaggiaConNoi/Pagine/grandiclienti.aspx). ATM considers three kinds of passes, two related with commuting and one with use of parking slots. The passes of transport are divided in passes for free mobility inside Milan (Hinterlands included) and passes just for "home-job" displacement. The

discount is applied when the subscription includes at least one hundred users and it could reach a percentage of 11.30% from the conventional price.

Nowadays Trenord offers a monthly pass ticket which price increases according to its distance from Milan. The fare is estimated until 180 km from Milan; however train users are able to purchase a yearly pass for the entire region that costs €1,028. Get this yearly train-pass becomes more accessible than get a yearly pass when the municipality of origin is more distant than 101 km to Milan. If we consider a discount of 11.30% for all the yearly Trenord passes we will have the yearly fares shown next in the Table 15.

Table 15 Transit pass discount Own elaboration.

From (km)	Until (km)	Trenord yearly fare	Yearly fare with discount (11.3%)
0	5	€ 251.00	€ 222.64
6	10	€ 321.00	€ 284.73
11	15	€ 390.00	€ 345.93
16	20	€ 447.00	€ 396.49
21	25	€ 512.00	€ 454.14
26	30	€ 569.00	€ 504.70
31	35	€ 627.00	€ 556.15
36	40	€ 677.00	€ 600.50
41	50	€ 769.00	€ 682.10
51	60	€ 849.00	€ 753.06
61	70	€ 900.00	€ 798.30
71	80	€ 941.00	€ 834.67
81	90	€ 967.00	€ 857.73
91	100	€ 992.00	€ 879.90
101	120	€ 1,036.00	€ 911.39
121	140	€ 1,081.00	€ 911.39
141	160	€ 1,135.00	€ 911.39
160	180	€ 1,178.00	€ 911.39

As it has been said the aim of the present strategy is to shift the behavior of car users, however the outcome of a policy could not be totally effective, thus

there have been estimated three possible effects of the transit pass discount among Politecnico commuters:

1. The private car commuters do not change their behavior. No one of them get the transit pass.

2. The private car commuters change completely their behavior. All of them obtain the transit pass.

3. The strategy has a partial success; just three quarters of the private car commuters obtain the transit pass.

The mentioned scenarios have been considered in order to estimate a possible cost of the policy per year for Politecnico. The computations consider the distance from each one of the municipalities that generates private car trips as well as those municipalities that have existing train users, in order to have an accurate estimation of the policy cost. In addition, the cost has been extrapolated to the whole Politecnico community considering that the transportation behavior declared in the mobility survey can be widespread. The results are summarized in the next table:

Table 16 Cost transit pass policy Own elaboration.

Scenario	Commuters	Policy cost/year
1	22,054	€ 4,910,129
2	28,914	€ 6,437,382
3	27,199	€ 6,055,569

Subsidize the existing train commuters per academic year could have an investment around five million euros. From the made computations it is notorious that change the behavior of private car users represent more than thirty percent the mentioned quantity, if all private car users accept to use the transit pass instead of a private mean. All in all, it can be said that change the behavior of private car users would have an annual cost around one million euros.

The implementation of this strategy should be considered with a more detailed study in order to know better the willingness to shift the mean of transportation

of private car users and the availability of resources of Politecnico to finance the policy, totally or partially.

5.5 Bus lines

The supply of public transportation to reach Milan is not provided to everyone. There are commuters that must use the private car to reach the university because of the quality of the public transportation services and their distance to reach the closest train station.

The municipalities where this issue happens are spread among the territory, mostly at east of Milan. The criteria to identify them has been the quantity of private car users that they have which go to Leonardo and Bovisa with low frequency during the academic year, between cero and fifty percent of lessons time. It seems that these users use private car because of lack of public transport and lack of access to the closest train station.

These municipalities are shown next in the Figure 38 with red, as well as the existing bus lines among the territory that could connect almost most of these municipalities with the rail lines. Due to the quantity of bus lines seems that there is a service to connect some of the mentioned municipalities with the rail line, however the service provided by these bus lines is not continuously available or its frequency during lessons hours is insufficient.

It could be a strategy to improve the public transportation supply based on the mentioned results; nevertheless it has to be proposed by the different municipalities to the respective public transportation companies. Overall it would benefit the whole territory and mostly municipalities where seems to be a significant lack of public transport service like Cologno al Serio, Morimondo, Spino d'Adda or Sant'Angelo Lodigiano.

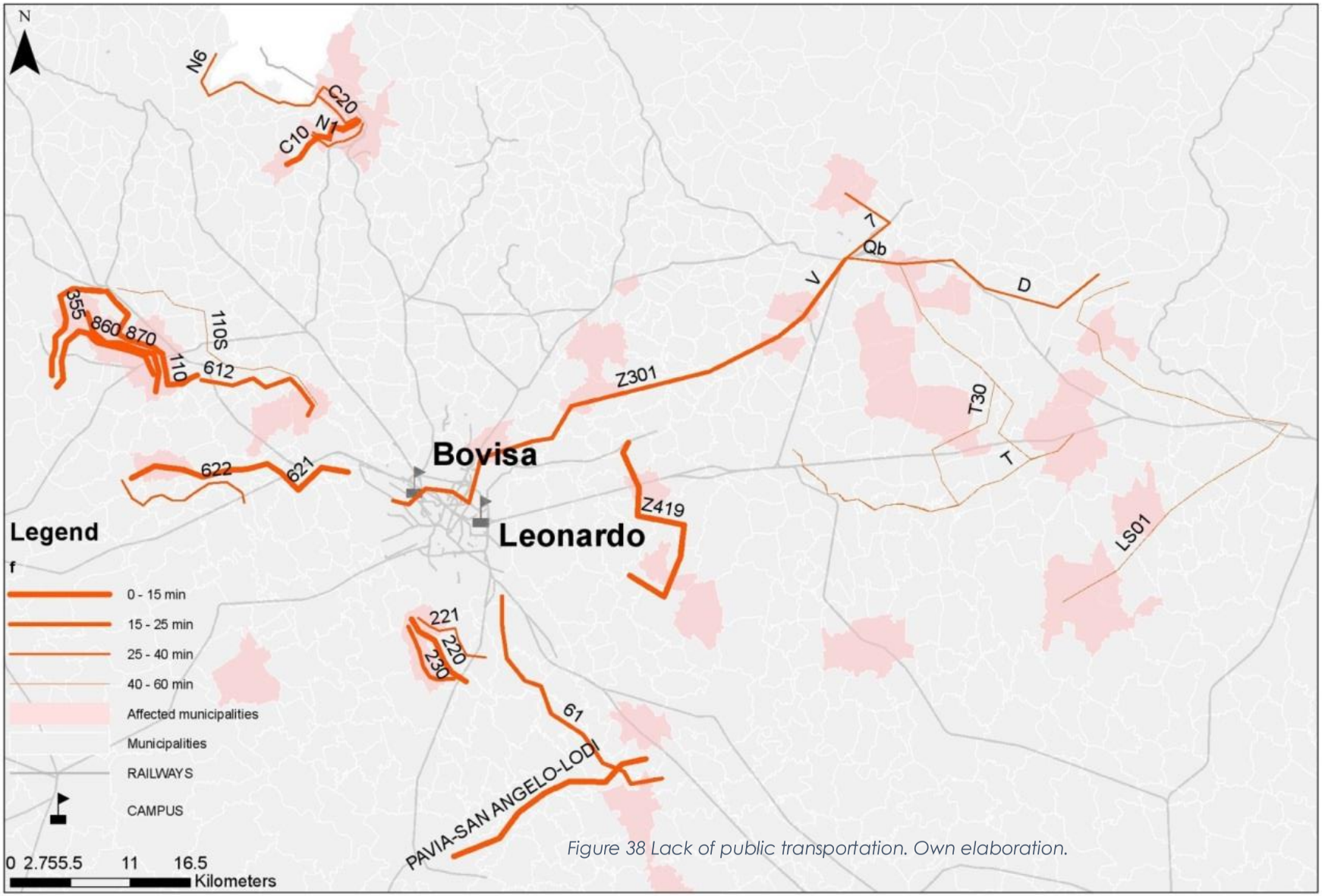


Figure 38 Lack of public transportation. Own elaboration.

5.6 Carpooling

Colorni (2011) defines carpooling as a transport system based on a shared use of private cars for single trips. The most known and common example of it is BlaBlaCar which is a community that connects commuters and travelers with same Origin-Destination by means of drivers offering empty seats to passenger looking for a ride.

Some universities around the world have implemented internet platforms to facilitate carpooling in an exclusive way just for members of the community. As driver or passenger, these platforms allows save routes and locations to offer and search a fast, safe and easy trip from or to the university. With the platform the users receive notifications when an offer arrives from a driver or from a passenger.

The platform also could include internal chats to ease the communication between passengers and drivers and sometimes allow filtering the made offers based on the destination area. It is provided with a GPS service and Google Maps interface.

One example of the platform was developed in Colombia by University of Los Andes, the name of it is *Portal Viaje* (Travel Gate). It also has apps for smartphones and with a friendly interface allows the user to:

- Filtering the trips based on location, date and time of departure.
- Receive notifications from drivers and passengers.
- Chat with drivers and passengers.
- Reduce the emissions of CO_2 and traffic congestion.

This strategy is not new in Italy; it has been promoted in 1998 in the national legislation with a law on sustainable mobility by Environmental Ministry. The mobility managers of the Universitá Statale and Politecnico di Milano have tried a carpooling program in 2011 named PoliUniPool. The program target students due to their interest of choosing transportation means which reduce private car use (Gärling et al., 2000). The main characteristics of PoliUniPool were:

- Its use was restricted to employees, faculty and students of the two universities.
- The system provided the expected schedule for their trips.
- Besides the campus premises, users could pick the main railway and subway stations.
- Users were informed in case of delay or changes.
- The system was able to estimate the cost for each user, in order to let the users know how to share them.
- The system website has some social network functionalities.

PoliUniPool was not successful and closed after four months of it implementation. The developers of the program have identified three main failures in the design and implementation of it:

- Lack of a strong communication strategy among university population. Not all university commuters knew about PoliUniPool basically because during the design step there were not included the students.
- Application with too many options regarding schedule, destinations and possible options that made difficult the matching between commuters and routes.
- It considered a bigger territory than the one it was able to manage.

Based on the experience with PoliUniPool, there are some strategies to reborn a carpooling project for Politecnico di Milano commuters:

- Use of a powerful communication strategy of the program through social networks, university events and workshops taught by the university where students and professors can work on the design of the program itself. In this way the university population would be involved in the project since the very beginning of the project, during the design phases and during it implementation.
- Create a rewarding system for those commuters that use carpooling like parking spots for drivers inside the campuses and incentives like local restaurant coupons, cultural tickets pass, discount on books and so on.

- Address the program to municipalities with huge car dependence and lacks of accessibility in order to defined paths for carpooling. However, carpooling could not be schematized for single routes due to its nature, where drivers are independent and can decide any route and time of departures according to their own needs.

Also, a recent study about ridesharing in the context of the University of Maryland (Erdogan et. al, 2015) was developed by an analysis of commuter survey data. It has shown the interest in ridesharing by commuters, who are possibly interested in being drivers to those who wish to be passengers. The study has given effects that should be taken into account by universities interested in programs aimed at reducing carbon-intensive travel activity. The main conclusions of this study are:

- People who never or rarely carpool are not likely to be interested in a ridesharing program.
- There are four main aspects that affect ridesharing: Supply of a friendly online application, cost of parking, cost of gas and good company in the case of driver.
- In the case of passengers; not having a car, need to pick up/drop off children and independence are potential barriers to carpooling.
- In the case of drivers only independence is a barrier to carpooling.
- Longer residential distance to target negatively impacts the propensity to carpool from a driver perspective while positively affects passenger behavior. Results from previous studies indicate that long-distance (higher than 24 km) are more likely to rideshare.
- Commuters who drive most days of week to university have a higher propensity to fill the role of driver.

The present study pretends to introduce carpooling as an alternative of Politecnico commuters' considering the lessons learned with PoliUniPool experience and the recommendation made by Erdogan (2015).

The strategy in Politecnico would be focused on student's population due to increase in the likelihood of choosing carpooling and other private car-reduce

measures by young people populations (Gärling et al., 2000). It also would consider municipalities far away from Milan in a radius of thirty kilometers and municipalities with commuters that use car to reach the campuses in a high frequency along the academic year.

In order to be successful among Politecnico population, it should be considered with a campaign of carpooling, in order to make the people notice about these kind of strategies, as is explained in the *Reduction Policies* section.

Besides campaigns the strategy should consider marketing and communication in order to enlarge the catchment area of the strategy. To achieve this goal Politecnico could do several actions like inform the students about the total number of commuters from their municipalities to their campus suggesting that if they travel together with a single vehicle they can save money. The spread of this kind of information can be developed by mail or with the use of the carpooling platform.

Nowadays the cost of a trip by car is well known by route planners available on the internet, therefore Politecnico is able to share this information with students as well. Examples of possible carpooling routes that can be shared with students are shown in the next figure. They include the operational costs and tolls (Michellin Route Planner, 2016) that a single car has to pay to reach the university in order to make the students notice about how they could save with this strategy in monetary terms.

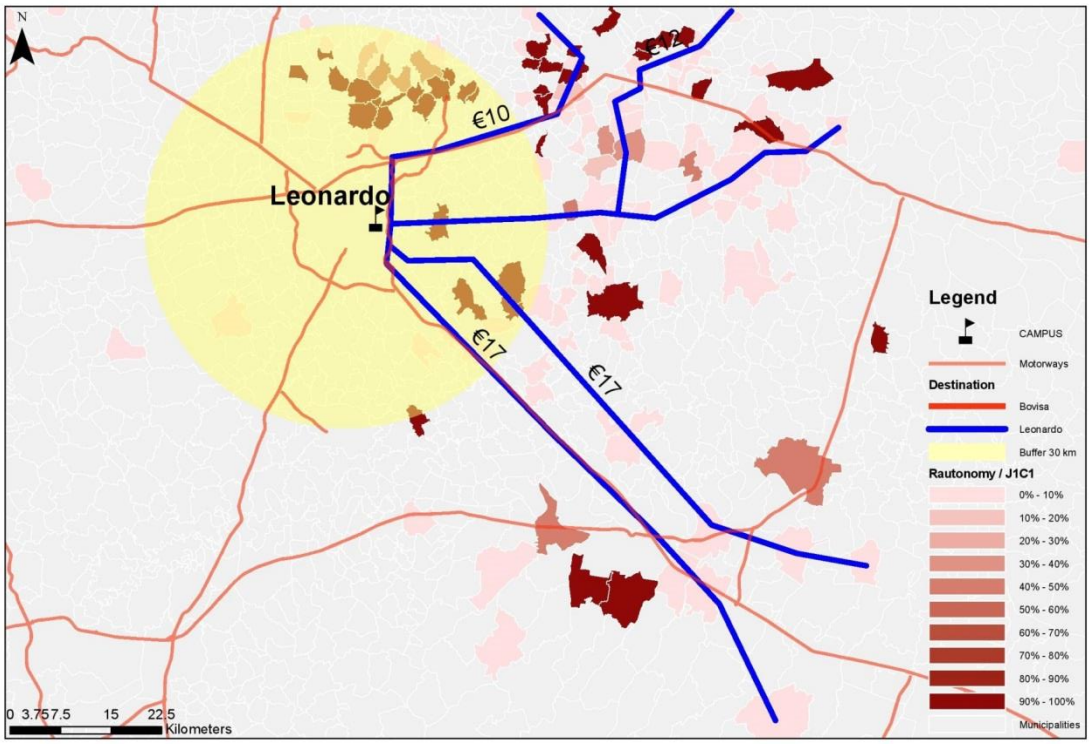


Figure 39 Carpooling Leonardo. Own elaboration.

Carpooling should be considered with parking policies. As Erdogan (2015) mentioned, providing parking incentives, such as priority parking and cheaper parking options to rideshare program members will help increase interest and discourage single occupant vehicle and emissions of greenhouse gases.

Finally, its implementation for Politecnico could consider an agreement with an already existing carpooling community to use their critical mass and online platform. There different options to implement this strategy, nevertheless the present study recommends to focus in the lessons learned with PoliUniPool and the results found by Erdogan (2015). A more detail survey focused on carpooling would bring better decisions about the implementation of the strategy as well as a detailed study about this field in Politecnico di Milano.

5.7 Reduction Policies

The cost of non-sustainable transportation schemes is very large for the society, represented in the following phenomena: Production of CO2, congestion cost and a very big gap between the accessibility in peripheral areas compared with central areas. These three phenomena have a common cause which is the emergence of a very powerful mean of transportation in the last century: the automotive industry and its super star product, the car.

Many factors like low accessibility to public transport and the spread urbanization of land had endorsed the use of the car. This is the case of the Milan conurbation in the Lombardy territory. Nevertheless, as we have seen with the territorial representation made in this work, there are commuters who actually decide to use the car despite being located in areas with a good railway network, even areas whit direct connection to the *Passante Ferroviario,* which offer a direct connection to inner Milan city.

One of the most important assumptions related for the choice of mean of transportation is the following: commuters well informed about the cost of using private transportation, negative impacts on the environment and availability of more sustainable means for commuting are supposed to make decisions more acceptable for the society and the environment. Hence, with this assumption is implicit that will not be necessary the prohibition of car use since it could be perceived against the concept of freedom to choice (Banister, 2008).

The idea in here is to propose policies that can be able to reduce car dependence appealing to the commuter awareness. Involving the people to accomplish better levels of engagement and encourage more sustainable ways of transportations turns out to be an alternative, these are the so called *soft transport measures*. Conventional examples of these policies are: public transport marketing, travel awareness campaigns, movements supporting the use of bicycle within urban centers among others (Moser & Bamberg, 2008).

The implementation of measures like the ones described in previous chapters of this work: parking fees, transit discounts and so one need to be implemented

together with this kind *soft transport measures*. Nowadays social networks appears to be a highly useful and efficient resource to endorse this policies because the concepts that plays an important position in the transformation of social habits like perception of values, green attitudes, self-responsibility with the environment, and social norms attempting to promote a better urban atmosphere. British government had invested financial resources in the creation of *soft transport measures* at various scales in the territory (Moser & Bamberg, 2008).

Commuter's opinion on the implementation of policies like parking fees implementation or transport subsidies need to be taken into account very seriously. For instance if the community is warned about the fact that funds raised on parking fees will be used to support of transport subsidies this has a higher acceptance than if it is used for a common fund in the city.

There is also a crucial aspect to be taken into account when implementing Transport Demand Policies which is to provide a wide variety of options to commuters rather than just prohibiting the car use since it will be perceived as a restriction and a violation of basic rights derived from citizenship (Erikson & Garvill, 2008). These give us an important clue about a key aspect in the accomplishment of reduction of the car dependence: It is necessary to have in mind the personals needs of commuters related with their journeys, hence to offer them another options able to fulfill them.

A very accurate case suitable to propose for this kind of issue is to create a personalized travel planning awareness campaign, where users can find travel advice and information to improve their transportation habits. Examples of this sort of program are: public transport timetable screens installation inside the university facilities, distribution of a free public trial ticket for those people who are not used to ride in a tram or the metro or the bus and the creation of center dedicated to the transportation information and help for students and staff members. This campaign could be linked with proposals of an implementation of services as new public transport lines in order to increase the supply of public transport.

We could think about an agreement between the ATM and Politecnico di Milan to set up an office inside the campus to provide attention for university population on procedures like the expedition of new ridership cards, tickets sales and basic information about the transportation functionality.

It is also necessary to create awareness among the population about the relation between health and transportation. Particularly in university population compound mostly by young people to create the culture of walking and biking as a manner for being healthy but also people need to understand the harmful effects produced by CO_2. Thus students and staff must have the knowledge about the benefits derived of sustainable mobility.

Many times the feeling of need for change among a community is highly influential in the decision making process of a controversial measure like the implementation of parking fees on the university facilities since nowadays it is perceived by employees as earned right, however if students get sufficient moment and strength asking the administration of University for this change then implement this strategy will appears to be a legitimate action.

Information campaign should be based in two aspects: first one is offering help to commuters in order to choose the best option available for them, this is to a certain extend a permanent effort since normally people probably already know all the possibilities that can take to reach their destinations however they do not know which one better fits to their needs, for instance the lapse of time spent, the timetables of buses, overcrowding subway lines hours and so forth.

The second aspect is the effective involvement of population into the programs (Bamberg, Fujii & Friman, 2011). As we have seen in the car pooling experience carried out by Politecnico di Milano in 2011, a key fail in the formulation of this program according to its director, Prof. Colorni, was the lack of communication during the construction phase which derives in a low recognition among the students and employees. Based on this experience we can affirm that it does not matter how good developed is a project in its technical characteristics, it will not be successful, if would not consider the most important input that are the users.

Finally we want to summarize and numerate the different solutions that we have mention in this part of the work to provide a framework of ten different strategies and programs that can be implemented in the reduction policies field and their main goals.

- **Information campaign:** The main objective of this strategy is to provide commuters with detailed information about the travel alternatives they have to reach their destinations. Also key information that should be provided is the impacts in terms of CO_2 derived from each choice aiming to create a green attitude as well as the information related with the money they can save in case they decide to shift from private car to more sustainable means of transportation as public transport and carpooling.
- **Promotion of biking and walking:** Bicycle turns out to be a good solution for those commuters who live in the city. However it may need to be endorsed with the creation of networks especially in social media to create a community of users sharing routes, activities and events which might make see this activity more appealing form a social point of view. Health benefits should be also a good strategy to sell the walking option. Also the city should work on infrastructure that increase the road safety of bicycle users and work on promote road safety among non-motorized users.
- **Attention Point ATM & Politecnico di Milano:** Having an ATM attention point inside the university would be an advantage for those who need to acquire their memberships, buy tickets and so forth. But also through agreements both institutions could launch strategies and promotions to attract users.
- **Installation of travel schedules screens:** Information about times, delays, frequencies, strikes and so on. It could be provided to university population with the installation of screens in crucial points of circulation and exits of building. This strategy could be important to make more comfortable the public transport experience.
- **Personal journey information:** Every user has a different need, different destination and different secondary journeys. To satisfy these aspects the promotion of applications or the distribution of personal maps or schedulers turns out to be a way to help people to solve their personal need with public transport.

- **Involvement of community in development of projects:** In the creation of a project that will touch the community and its need with a service like transportation it is necessary to involve people in since the very first creation phases of the projects to assure its recognition and future success.
- **Events selling the benefits:** This an important strategy to accomplish the awareness among commuters of the results and benefits caused by the increase in the sustainable mobility. People need to be informed about the progress of ongoing projects likewise university has to make control and tracing of the goals and objectives.
- **Creation of workshops:** There is a wide variety of workshops created on different periods of the academic year focused in topics urbanism, architecture and design. Nevertheless more workshops and academic activities should be created around the sustainable mobility and the transportation to guarantee a deeper knowledge among students.

6. Conclusions

The present research has been done to support the hypothesis that although the large network of public transportation in the city of Milan and the vast system of trains serving Lombardy, Politecnico di Milano attracts a representative amount of private car commuters.

The mentioned statement has been proved with the results of the mobility survey made by Città Studi Sustainable Campus (2015) which has shown that Leonardo and Bovisa attracts more than eighty thousand private car journeys during the period or lessons or academic year. In fact, these two campuses attract more than ninety percent of Politecnico trips, reason why they are analyzed in this research.

In the first part of this work has been presented a spatial distribution of commuters among the territory, which has been done with the use of a valuable tool to visualize, interpret and analyze the mobility patterns of Politecnico commuters. This is the set of SHAPE files created for the research based on the results of the mobility survey. This data set can be used in further researches. It nomenclature and way of use it is explained in the present document.

A first analysis has indicated that employees are more used to transport with private means than students however the quantity of commuters which mobilize with train occupy the first place in the rank for students and workers due to the majority of Leonardo and Bovisa population inhabit municipalities in northern Lombardy that are supplied with railway services.

Regarding the campuses outside Milan: Lecco, Como, Mantova, Piacenza and Cremona it can be said that their population inhabits in municipalities close to each one of the campuses and mainly in the municipality where the university is located.

A second approach, that instead of consider quantity of commuters considers quantity of trips, has demonstrated that the highest value within the modal

share is presented by public transportation, followed by train and finally private car. The situation is the same in the case of Leonardo but in the case of Bovisa the use of train is predominant.

The quantities associated to private car use are high, extrapolated the results, just Leonardo and Bovisa could reach more than 300,000 journeys/academic year. In other words, the quantities can reach more than 2,000 journeys/academic year. The hypothesis that has generated this research could be considered and affirmative sentence. Therefore there is a need to reduce the increasing use of private car.

In order to achieve this reduction there have been proposed different Transport Demand Policies (TDP):

- Implementation of an hourly parking fee in the streets nearby Leonardo and Bovisa.
- Parking fees inside the campuses.
- Increase of train use with the implementation of a transit pass discount which is based on an agreement between Trenord and Politecnico.
- Improvement of existing bus supply in the municipalities with higher car dependency.
- Carpooling exclusively for Politecnico di Milano commuters.
- Reduction policies.

The analyzed strategies consider an estimation of the costs involved in their development, however there is a need of further researches to decide their implementation.

These strategies have many benefits. Some of these benefits have been considered by the University of British Columbia in 1999 in a program to assess the implementation of a package of strategies to increase the sustainable mobility:

- **Benefits for the university population:**

With this regard in the Politecnico di Milano study case, it can be estimated considering the information provided by the Campus Sostenibile survey, where the distance to the campus of destination from the origin of every member can be calculated likewise the mean of transportation. Thus it is possible to compute the actual transportation cost and the correspondent savings with implementation of a sustainable transport strategy. The benefits are not only financial; they could include improvements in quality of space, reduction in CO_2 emissions and less congestion.

- **Mode shift benefits:**

If students change their mean of transportation as a consequence of the transport demand policy encouragement it means they are better off, otherwise they would not made the change. In transportation economy the consumer surplus, based on the *Rule of Half* (Winkler, 2013), is the 50% of the change in price. Therefore if an urban ticket in Milan cost €1.5, the estimated incremental consumer benefit for new users will be €0.75. With the data of the Campus Sostenibile survey it would be possible to compute this benefit considering the exact location of every person who answered the questionnaire.

- **Parking cost savings:**

Politecnico di Milano has a number of parking places located in their facilities which are used by staff members. These facilities are currently offered for free to the staff; nevertheless it requires maintenance and operational costs that have to be covered by the university infrastructure department since there is not a pricing parking established. In addition, these parking contribute to the scarce quality of urban space inside the campus. The implementation of a parking strategy would produce savings in the mentioned costs, in addition to the contribution to overall car use reduction.

- **Congestion reduction and road cost savings:**

This is an evident consequence of the implementation of transit demand policies. Value of time is usually calculated in the generalized cost of a

particular mean of transportation, thus the reduction in the use of car by commuters going to Leonardo or Bovisa Campus will have a positive impact in the reduction of the generalized cost.

- **Reduction of pollution and accidental risk:**

The first goal of the Campus Sostenibile project is to estimate the cost of pollution based in the calculation of CO_2 produced by a passenger depending in the mean of transportation chosen, where the trains, since are electrically powered and have a wide capacity like the buses, have a better results than the private car. Also the decrease in the car dependence will have a positive impact in the downturn of accident risk.

- **Equity impacts:**

Private car users have benefits like independence, comfort and so forth. However this people are forced to share the drawbacks of the private car use alike the pollution, noise and risk of accidents in the roads (Shirmohammadli, Louen & Vallèe, 2016). Whit the implementation of transport demand management strategies this inequality will be reduced.

To sum up, the prepared data and the suggested strategies in the present work would be useful for further analysis in order to decrease the use of private car which has been demonstrated as the most used by Politecnico di Milano commuters, either students or workers.

To conclude with, the present research has studied the modal share and has given an input related with strategies to shift the car dependence into a more sustainable mobility among Politecnico population. It could be a beginning of further analysis with, gives valuable tools and strategies to reach the goal of sustainable transportation.

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