POLITECNICO DI MILANO

Facoltà di Architettura e Società
Laurea Magistrale in Pianificazione Urbana e Politiche Territoriali

The Analytical Tools For Pedestrian Mobility Design

Towards a Sustainable Campus Transportation

Master of Science Thesis

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Academic year: 2010 / 2011

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With warm regards,

Your Sincerely,

Na Ziye

In Politecnico di Milano

2010-12-09

ABSTRACT:

Pedestrian mobility promoting is an important composition of sustainable transportation construction, not only at campus scale, but also at the city scale. More and more city administrations and scholars are working on encouraging walking through the enhancement of the pedestrian environment. Reviewing the experiences and methods in previous studies, the author firstly finds out that the common ways for pedestrian mobility design are “referring to experience” and “from node to node” way – ascertain the problem in some location or some kind of street, and solve them. While the tools for systematic analysis, comparison and evaluation are scarce or not widely used. So the author continues to search for the analytical tools in data collection, processing and presentation that could be applied in pedestrian mobility design, and further takes the Leonardo Campus of Politecnico di Milano as a case and practices fourteen techniques in five dimensions (flow, traces and density, accessibility, people’s consciousness of time & space and surrounding facilities estimation). Through these applications, the author not only represents the application conditions and limits of each tool, but also reveals the pedestrian mobility situations of our campus, and finally tries to propose some recommendations to improve those situations.

KEY WORDS:

Analytical Tools, Pedestrian Mobility Design, Sustainable Campus Transportation

SINTESI:

La promozione della mobilità pedonale è importante per la costituzione del trasporto sostenibile, non solo a scala universitaria, ma soprattutto a livello cittadino. Di conseguenza molte amministrazioni e studiosi stanno lavorando sulla promozione della mobilità pedonale passando tramite la valorizzazione dell'ambiente circostante. Questa tesi, si propone, in primo luogo di concludere le precedenti esperienze ed, inoltre ha scoperto un modo comune per sostenere i progetti facendo " riferimento alla esperienza" , "da nodo a nodo", metodi per accertare il problema in qualche luogo o qualche tipo di strada , e li risolvono, mentre gli strumenti per l'analisi sistematica, confronto e valutazione sono scarse o non ampiamente utilizzate. Così l'autore ha continuato a cercare gli strumenti analitici nella raccolta dei dati, l'elaborazione e la presentazione che potrebbero essere applicati nella progettazione della mobilità pedonale, e in seguito ha preso il Campus Leonardo del Politecnico di Milano come caso studio suddividendo le tecniche in quattordici metodi ed in cinque dimensioni identificabili in (flusso, traccia e la densità, l'accessibilità, la coscienza della gente e dintorni stima strutture). Attraverso queste applicazioni, l'autore non solo ha rappresentato le condizioni di applicazione e i limiti di ogni strumento, ma ha anche rivelato le situazioni di mobilità pedonale del nostro campus, e infine ha cercato di proporre alcune raccomandazioni per migliorare tali situazioni.

PAROLE CHIAVE:

Strumenti di Analisi, Design Mobilità Pedonale, Campus di Trasporto Sostenibile

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1 Introduction

1.1 Objectives

This thesis originates from the idea of planning for a "Sustainable Campus". In the whole conceptual proposal, five dimensions are considered: the outdoor space, the buildings, the transportation, waste, and the service facilities. In the transportation dimension, it is really difficult to promote policies such as green vehicle and public transport discount on a campus basis. So we start with the pedestrians system, because walking and cycling are the oldest and most basic form of transportation, and they are the transport modes with least emission: they are zero-emission. And later we can work on other aspects such as bike sharing, car zip or transport interchange etc.

As the most often-quoted definition of sustainable development defined: "it is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987)." So there is a precondition to be noticed: sustainable transportation or walking does not mean to reduce our need to travel or the distance of travel, contrariwise, our aim is to promote more accessibility – access to work, education, goods and services, friends and family (Litman, 1998). That became my original objective: **we need to promote more walking through the enhancement of the pedestrian mobility and environment**. If we start with thinking about the reasons that detract people's passion to walk, some perceptions will occur: low accessibility, unsafe walking condition, uncomfortable density or unpleasant view etc., so those will be the exact subjects that I want to improve.

Reviewing the experiences in pervious pedestrian mobility studies, we could find a lot of researches only use the "statistics curves" to explain how important walking is, and define their actions by referential experience (case of London Walk Report). There are tools to support the pedestrian environment design, but the common way is "from node to node" way – find out the problem in some location or some kind of street, and solve them (case of San Diego Pedestrian Master Plan). So I can understand that the tools for systematic analysis in this research sphere are scarce or not widely used. **So I would like to search for the tools which could be applied in the systematic analysis of pedestrian mobility,** so as to reveal the general pedestrian situation in an urban area, and help the executive bodies chose the most critical part to act on.

The thesis will have three main contributions:

- A summarization of the experiences and tools/ methods that could be applied in the data collection, processing and presentation of pedestrian mobility design from current researches and practices;
- A study about the application conditions of those tools/ methods through practicing them in our campus;

- The revelation of the pedestrian mobility situation of our campus and some recommendations to improve.

1.2 The Background of the Research

1.2.1 The Research Object

My research object is the Milan Leonardo Campus of Politecnico di Milano. This campus includes four main sites: Bonardi, Leonardo, Bassini and Golgi-Clericetti, and has a total area of 117,117 m^2. Inaugurated in 1927, this campus has been expanded as a "Città Studi" over decades. According to the 2010 statistics of the university, there are about 1,000 professors & Researchers, 19,000 students and more than 500 administrative staffs acting in this campus (Website of Politecnico di Milano).

The everyday commuting traffic is big, moreover, the pedestrian facilities are shared by the commuting flow of Polimi and that of University of Milan. Considering walk is the mean connecting public transportation with the final destinations, and the main travel mean inside the campus, the promoting of pedestrian mobility, increasing the accessibility and releasing the feeling of uncomfortable is very meaningful. Although the current pedestrian system and facilities in and around Politecnico are not bad, improving the walking environment is also good for creating the vivid social life and an active campus. And in my opinion, the interventions on pedestrian mobility are easier than those on the other transportation means, so I wish it could be the pioneer projects to respond to the sustainable transportation.

1.2.2 Universities around the world Contribute to the Sustainable Campus Transportation

Universities all over the world are taking their responsibilities and acting on their campus. The International Sustainable Campus Network (ISCN) is a network that propose the charter and guidelines of "sustainable campus", share experiences in their conferences every year, and its members are the best universities in the world. And there are some other collaborations among universities to find common goals and shared tools in the construction of a sustainable campus, such as International Alliance of Research Universities (IARU), and The Sustainable Campus (north American universities collaboration). And one interesting thing is: the promoting slogan of Princeton University "The campus as an environmental laboratory" and that of MIT "Using our campus as a living laboratory" are wonderfully consistent, which expresses an important information that the role of university in sustainability construction is not only improving the conditions, but also providing students and researchers technologies and opportunities to practice. **Here I raise the examples of Princeton University, Harvard University and a summary of mobility management measures of 9 European campuses, to show how universities act on the sustainable campus transportation.**

The Princeton Campus Plan has recommended ways to discourage single-occupant driving, enhance links to public transportation, support carpools and emergency ride home programs, and implement transportation demand management strategies. The first guideline is "Maintain a pedestrian-oriented campus". To achieve these improvements the Campus Plan proposes: <u>extending the existing pedestrian and cyclist circulation network to new areas of campus and employee residential clusters near campus</u>; <u>improving the network in areas where it is deficient</u>; <u>enhancing existing pathways</u>; and <u>instituting an extensive program of landscape design and wayfinding improvements.</u>

Figure 1- 1: In the U-Bikes Program, Students Repair Abandoned Bicycles and Loan them to the University Community

Source: The Princeton Campus Plan, 2008

In **Harvard University**, a series of "Green Campus Transportation Initiatives" has been introduced. And most of the actions are promoted by an organization named "CommuterChoice", which aims at providing faculty and staff with convenient options and financial incentives for using alternative transportation. I conclude the actions into three sorts: Physically construction and design; Incentive policies and management; Popularizing the notions.

<u>Construction and Design:</u>

- A map of bike rack locations and suggested campus-wide routes
- The Francis Avenue Bike Shelter (for 74 bikes and 2 motor scooters– interior lighting is even solar powered)

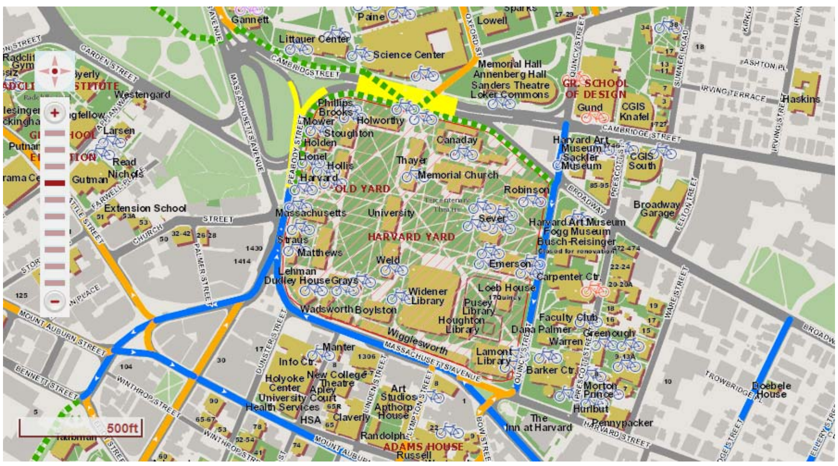

Figure 1- 2: Map of the Bike Facilities within the Campus

Source: Harvard University, 2010

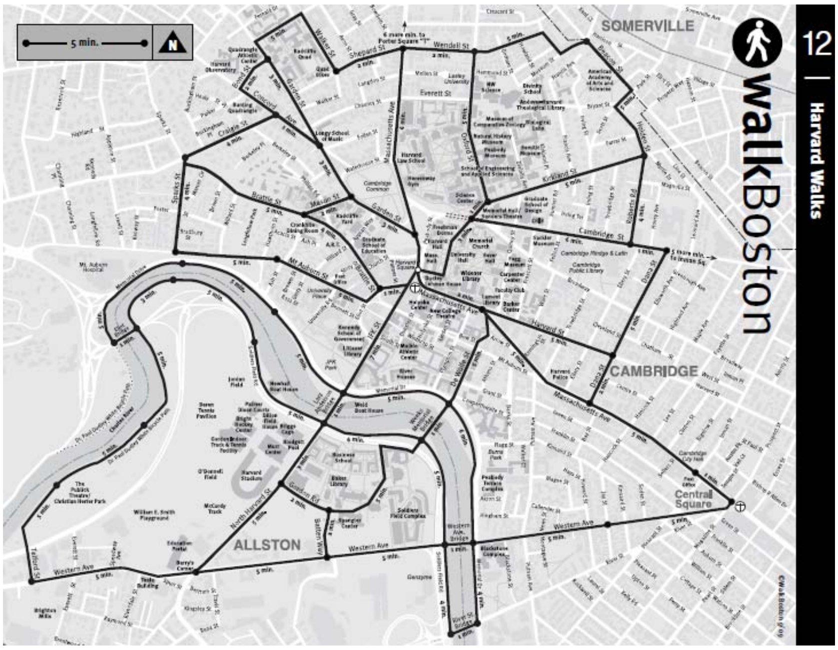

Figure 1- 3: Harvard Walk Map

Source: Harvard University, 2010

Incentive Policies and Management:

- Travel Greener with the HLS Read & Ride Bike share Program – loan out bikes the same way as they loan out books
- A Regional Bike Sharing Program - Working with the cities of Cambridge and Boston, a network of "stations" will be established where anyone could rent and return bikes just by swiping their credit card. Reimbursing faculty and staff who purchase bike related equipment such as locks and helmets.
- Public transit discount
- ZipCar or carpoolers and those who drive low emission vehicles (LEVs) enjoy preferential parking locations/ free preferred parking.

Popularizing the Notions:

- Bay State Bike Week
- Departmental Bike Program with participation from 16 University departments utilizing 37 shared bikes
- Utilizing recycled rainwater to wash hundreds of University-owned vehicles each year

Moreover, a researcher of Politecnico di Milano - Airoldi A. (2009) has studied 9 significant, innovative, and recent cases of university mobility management through Europe and Italy, and concluded 18 main measures that could be useful for sustainable campus transportation (table below).

Table 1- 1: Table of Mobility Management Measures for Universities

	MMUH Dublino	Università Poznan	Politecnico Graz	Ospedale Cambridge	UPC Barcellona	Università Bologna	Università Pisa	Roma Tre	Roma La Sapienza
Piano della mobilità	X			X	X			X	X
Tavolo di lavoro con enti locali	X			X	X	X		X	X
Istituzione servizio di trasporto pubblico/dedicato				X				X	X
Agevolazioni economiche per abbonamenti al trasporto pubblico			X	X		X	X	X	
Veicoli elettrici								X	X
Promozione car sharing				X		X			X
Promozione car pooling				X		X			
Moderazione del traffico, creazione infrastrutture ciclopedonali				X		X			
Regolamentazione e/o riduzione aree sosta, controllo accessi	X		X	X	X	X	X		
Sportello informazioni	X								
Eventi e/o campagne informative	X			X	X	X	X	X	X
Sito Web tematico				X	X	X		X	X
Tessera elettronica integrata		X							
Telelavoro, videoconferenze				X					
Rastrelliere biciclette e/o bike sharing			X	X				X	
Facility per ciclisti: spogliatoi, officina, marcatura mezzo				X			X		
Partecipazione a reti e/o progetti internazionali					X	X			
Monitoraggio e valutazione risultati	X		X	X	X	X			X

Source: Airoldi, 2009

1.2.3 Mobility Managements of Politecnico di Milano

Although Politecnico di Milano has just started to plan for a sustainable campus, it has applied the mobility management since August 2001, and has established a working group to make studies and propose for the sustainable mobility since November 2002 (Homepage of Mobility Management of Politecnico di Milano). From time to time, the group works with the other universities such as the University of Milan, Milan Bicocca University and other foundations and associations, and it seems there has been a network of research and implement for sustainable mobility among the universities in Milan.

There are initiatives and projects that have been promoted:

- Facilitating access to public transport season tickets: the students could purchase season tickets with discount, and the subscriptions will be paid to ATM , Trenitalia and FNM.
- Agreement for the purchase of bicycles with a discount: CicloPoli project encourages the increasing use of bicycles by student, staffs, and with the help of ANCMA (Association of national Cycle, Motorcycle, Accessories), the target group could buy bicycles with 20% discount in some certain shops.
- Bicycle Workshop: this project was founded by Foundation Cariplo, and the mechanical experts help students to repair and get knowledge of their bike for free.
- Messageing Service: The provincial administration of Lecco provides travelling information (the road condition, traffic difficult or incidents that affect the flow of vehicles) by SMS message.
- PoliUniPool - A system of car pooling for the Milan Polytechnic and the University of Milan: funded by the Foundation Cariplo, the project provides a car polling system designed specifically for the university, and the web platform will be able to handle the demands of travel of students and staffs so as to reduce the vehicles flow in both campus.
- Mobility Management for the university system of Milan (2005-2008): also promoted by Foundation Cariplo, this project monitors the student flow of Politecnico di Milano, Catholic, Bicocca and Bocconi University in the city scale and the final practical implementation includes agreement of tariff reduction for public transport, the implementation of measures to improve accessibility to universities through operations of transport service, and the realization of measures to improve pedestrian accessibility within universities.

The table below clearly shows the similar points and differences between Harvard case and Politecnico di Milano case: they both propose strategies of student transit discount, encouraging bicycle travelling and car pooling, but in my opinion they have different focuses: most of the Harvard actions are promoted by "the CommuterChoice Program" which is organized by the student service of the departments, so they tend to act on the projects such as the bike shelters etc.; while the mobility management of Politecnico di Miliano is basically promoted by Foundation Cariplo, so they tend to consider the situation all over the city and try to propose the general strategies. And another thing needed to be noticed, both cases put their attention on public transportation, car-sharing and even bicycle travelling, while the pedestrian mobility only remains in a strategy state, especially in Politecnico di Milano case. And that is also why I am going to focus on this topic.

Table 1- 2: Comparison of the Sustainable Transportation / Mobility Actions between Harvard case and Politecnico di Milano case

	Harvard: the CommuterChoice Program	Politecnico di Milano: Mobility Management
Strategy and Network	-	Mobility Management for the university system of Milan (2005-2008)
Promoting Public Transport	Transit discount	Discount of public transport season tickets
Encouraging Bicycle Travelling	-	Discount for the purchase of bicycles
	A map of bike rack locations and routes	-
	Construction of Bike Shelters	-
	Bike share Program – loan out bikes the same way as they loan out books	-
	A Regional Bike Sharing Program	-
	Bay State Bike Week	Bicycle Workshop
	Departmental Bike Program with participation from 16 departments	
More Sustainable Private Transport	-	Messageing Service
	Carpoolers and those who drive low emission vehicles (LEVs) enjoy preferential parking locations	PoliUniPool (Car pooling)
	ZipCar and Zip Ride	
Populization of the Notions	Transforming two metered parking spots into temporary parks	-
	Utilizing recycled rainwater to wash the University-owned vehicles	-

1.3 Key Concepts

1.3.1 Sustainability - Sustainable Transportation – Sustainable Campus Transportation

Sustainability is the capacity to endure. At the 2005 World Summit, it was noted that this requires the reconciliation of environmental, social and economic demands - the "three pillars" of sustainability (UN, 2005). But the UN definition is not universally accepted, some environmentalist think the economy is a subsystem of human society, which is itself a subsystem of the biosphere, and a gain in one sector is a loss from another. This can be illustrated as three concentric circles (Porritt, 2006). Therefore, sustainability refers to reducing negative human impacts and enhancing ecosystem while meeting peoples' needs, and there are two ways to achieve that: one is the environmental management, **and the other is the adjustments of collective and individual lifestyles to conserve natural resources**. Another thing to be noticed is that sustainability issues are generally expressed in scientific and environmental terms, but implementing change is a social challenge, so it requests the planners and urban administrations show their enough wisdom to achieve that.

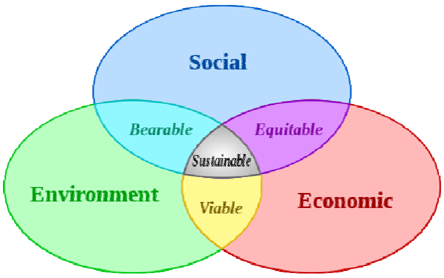

Figure 1- 4: The "three pillars" of Social, Environmental and Economic Sustainability

Source: Adams, 2006

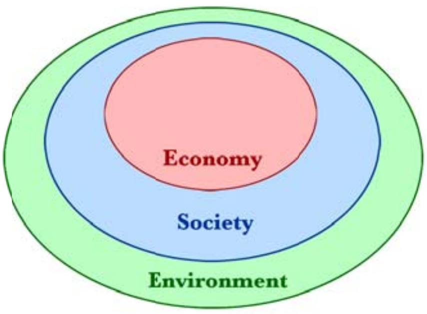

Figure 1- 5: Both Economy and Society are Constrained by Environmental Limits

Source: Ott, 2003

Transport systems exist to provide social and economic connections, while also bring the environmental cost such as energy consumption and carbon dioxide emissions, social cost such as congestion, time taken away from the family while commuting and vulnerability to fuel price increases, and the causal economic costs. Sustainable transport (or green transport) usually refers to any means of transport with low impact on the environment. Generally speaking, there are 2 threads to change our actions and achieve a sustainable transportation**: reduce individual impact – such as changing a vehicle to a bike**, **or reduce collective impacts, and promote collective transport, such as public transport**. Below is the toolbox of the main measures produced by the EU Directorate-General for Transport and Energy (DG-TREN, 2007):

Table 1- 3: The Sustainable Transport Toolbox

Clean fuels and vehicles	Collective passenger transport	Transport management
Hybrid Vehicles Biodiesel Biogas/CNG Electric Vehicles LPG Hydrogen vehicle Human-powered transport Animal-powered transport	Public transport Bus services Bus rapid transit Rail transport Intermodal transfers Integrated ticketing Marketing Park & Ride	Transportation demand management Transit oriented development Walkability New urbanism and New pedestrianism TDM Toolbox
Sustainable (green) transport infrastructure	Demand responsive transport	**Soft measures**
greenways and foreshore ways Cycleways Busways Railways	Paratransit Bus rapid transit Quality of service Security, including Transit police Accessible transport systems	Travel plan Walking school bus Travel blending Personalised travel plan
Access restrictions	**Less car intensive lifestyle**	**Sustainable Freight Transport**
Access management / Enforcement Car Restricted Zones /Living Streets Multifunctional areas Parking Management Pedestrian zone Traffic calming / Speed reduction	Car pooling Car sharing Car/ driver licence exit strategies Cycling Bike sharing	Clean vehicles / clean fleet Intermodal freight transport Transportation management system Fleet management Route planning Dry port
Integrated pricing strategies	**Travel information**	
Congestion pricing Integrated ticketing Parking Management	Public transport timetable journey planner	

Source: DG-TREN, 2007

As we found from the toolbox, the sustainable transportation is a comprehensive strategy containing vehicle dimension, infrastructure dimension, and management dimension, also it is a system containing different levels: regional level, urban level, and neighborhood level. In our case of a campus scale, which is similar with a neighborhood level, I agree with the strategy described in The British Government's White Paper on Transport - to scale up the small and scattered sustainable transport initiatives then occurring across Britain (UK Government, 2004), and it is the small, scattered, but intensive neighborhood movement that make up an efficient urban transport.

1.3.2 Pedestrian Mobility

Mobility is a general concept to describe the transportation. Even in the European Commission, they name their department (Directorates-General: DGs) as "Mobility and Transport". If the transportation mainly refers to the travelling means, then **the mobility mainly refers to the ability and frequency to move**. So the pedestrian mobility here is used as a general goal of the walking situations: as the San Diego (USA) Pedestrian Master Plan (2006) stated, in order to enhance the pedestrian mobility, they work on the dimensions of Safety, Accessibility, Connectivity and Walkability.

Safety in pedestrian mobility design is if there are sufficient street crossings, buffers protecting pedestrians from vehicles and facilities that are wide enough to accommodate peak pedestrian use.

Accessibility is defined as the measure of the capacity of a location to be reached by, or to reach different locations. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility (Rodrigue et al., 2009). Since some researches defined Accessibility as the ability of people with disabilities or special needs to access, I also take this meaning.

Connectivity is a term used to describe the connections of the street network. In my research, it is an important factor that impacts accessibility.

Walkability is a general description of pedestrian experience: if there is facilities or pleasant view etc. along the route.

1.4 The Methodology

In Chapter two, the methodologies I utilized are **literature study and case study**. I widely went through the theoretical statements, the experiences of practical cases, and the new developments of the technologies that are applied in pedestrian mobility design, in order to grasp the contents and the common & specific tools of this subject.

In Chapter three, the data came from my **field work of survey** at the end of October, the analysis conclusions came from **statistic analysis** and **various kinds of analytical tools**. More in detail, I used manual way, video-manual way and mechanical way in investigation; and Excel curve graphs, Photoshop "stacking for trails", Photoshop "time-lapse", "Ped-shed analysis", "Images in motion", Google walk score and some combination analytical method in understanding the pedestrian situation of our campus.

In Chapter four, I used **comparative analysis method** reveal the differences between theoretical statements and real applications of those tools, and pointed out the application conditions and limits of them.

1.5 The Structure of the Thesis

The thesis is composed by 4 chapters as illustrated by the diagram below:

- The first Chapter is an introduction of the whole work, includes the research objectives, working objects, backgrounds and methodologies.
- The second chapter is the theoretical and experimental preparation: defines the contents to judge pedestrian mobility such as flow, traces and density, accessibility, image in motion and surrounding facilities; and a summarization of the possible analytical tools that could be applied in pedestrian data collection, processing and presentation.
- The third chapter is the survey and analysis reflecting the current situation of pedestrian mobility in our campus, with the application of the tools mentioned above.
- The final chapter concludes the application conditions and limits of each tool, the finding and problems of the pedestrian mobility situation of our campus and the recommendations to improve.

Figure 1- 6: The Structure of the Thesis

Procedure	Contents	Methodology
1 Introduction	Objectives Research object and background Definition of the key concepts Introduction of methodology and research procedure	
2 A theoretical framework	Contents of pedestrian mobility design in a campus scale Analytical tools and methods for pedestrian mobility Design	**Literature study** **Case study**
3 Application of the analytical tools on our campus	Campus transportation background Survey of flow Study of the trace and density The accessibility Images in motion: people's consciousness Estimation of the surrounding facilities	**Field work** **Statistic analysis** **Various kinds of analytical tools**
4 Conclusions and Recommendation	Conclusion of the tools and methods applied Conclusions of the findings and problems Recommendations Limits and the extension of the research	**Comparative analysis** **Conclude**

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2 A theoretical Framework

2.1 Contents of Pedestrian Mobility Design in a Campus Scale

There are some theories and practices working on how to construct good pedestrian environment and encourage walking. But in my opinion, they could be concluded into two logics: **manipulating the urban structure** or **manipulating the urban elements** - physical (street design) or abstract (accessibility, connectivity etc.).

2.1.1 Theories and Practices on Manipulating the Urban Structure

I raise **three cases** of manipulating the urban structure here, and as we will see below, the main ideas are concentrated on public transport service, compact development and mix uses.

Figure 2-1 represents a typical model of **a walkable community**. A number of urban compositions and planning principles have been marked, and luckily most of those elements could find their counterpoints in our campus.

- A walkable community is under the service of rail link and the interchange center should be near the community center – the counterpoints are the train stations and metro stations in our campus.
- A walkable community should have road links with the metropolitan centre, along which shops and services concentrate – the counterpoints are the main urban roads and the shops along them.
- The community center and the urban parks correspond to the administrative building of Polimi and Piazza Leonardo da vince.
- The different housing opportunities could be corresponded with the departments.
- The only one without counterpoint is the facilities that contribute around the neighborhood.

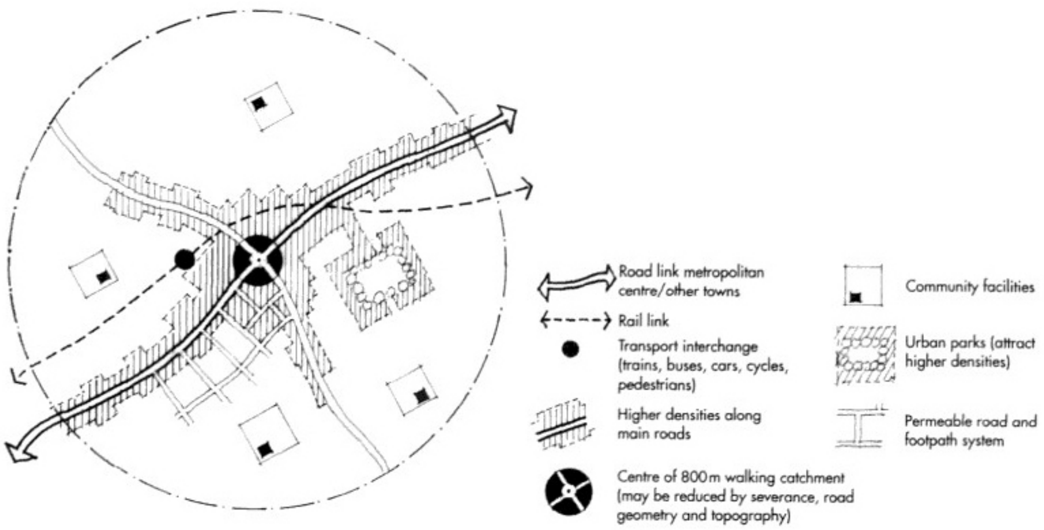


Figure 2- 1: Attributes of a Walkable Community Source: Clarke, 2008

Berkeley Urban Advantage Lab has made **a photo-realistic visualization to show "What makes a neighborhood walkable",** and similarly, they mentioned some composition principles, but also manipulation of the urban elements.

- <u>A center</u>: Walkable neighborhoods have a center, whether It is a main street or a public space.
- <u>People:</u> Enough people for businesses to flourish and for public transit to run frequently.
- <u>Mixed income, mixed use</u>: Affordable housing located near businesses.
- <u>Parks and public space</u>: Plenty of public places to gather and play.
- <u>Pedestrian design</u>: Buildings are close to the street, parking lots are relegated to the back.
- <u>Schools and workplaces</u>: Close enough that most residents can walk from their homes.
- <u>Complete streets</u>: Streets designed for bicyclists, pedestrians, and transit.

Figure 2- 2: Photo-realistic Visualization of "What makes a neighborhood walkable"

Source: Berkeley Urban Advantage Lab, 2010

Lastly, the conclusions made by Thorne and Filmer-Sankey (2008) represent general ideas of this logic: the sustainable transport requires the changes to urban design priorities:

- Higher-density development, located closed to public transport sports and interchanges.
- Mixing uses (houses, shops, workplaces, schools and public facilities) within the same area.
- Better public transport.

Summing up, the compositions which are frequently mentioned in designing a walkable urban structure are showed in Table 2-1.

Table 2- 1: The Compositions Frequently Mentioned in Designing a Walkable Urban Structure

	Research of a Walkable Community	Visualization of "What makes a neighborhood walkable"	Sustainable Transport require:
Rail Link / Public Transport	X		X
Interchange	X		X
Road Link	X		
Shops & Services (concentrated and higher density)	X		X
Community Center	X	X	
Parks & Public Space	X	X	
Different Housing Opportunities & mix use	X	X	X
Facilities	X	X	
People		X	
Pedestrian Design		X	
Complete streets		X	

2.1.2 Theories and Practices on Manipulating the Urban Elements

I raise **four cases** of manipulating the urban elements here, and as we will observe, elements of street, speed limit, sidewalk, crossing, key walking route, safety, accessibility, connectivity, and walkability are mentioned. However, in my opinion, the tools to support the systematic analysis are weak in this subject.

The **"Walkable street" section of LEED** (Leadership in Energy & Environmental Design) for Neighborhood Development (Congress for the New Urbanism et al., 2010) intents to promote walking by providing safe, appealing, and comfortable street environments. And it manipulates the urban elements as following:

- 90% of new building frontage should have a principal functional entry on the front façade faces a public space, and connect with the sidewalk;
- Ground-level retail and service uses should be at least 60% of the clear glass façades, and no more than 20% of the frontage face directly the parking;
- Design Speeds no more than 20 km/h for safe pedestrian and bicycle travel;
- At least 15% of existing and new street frontage has a minimum building-height-to-street-width ratio of 1:3;

- Continuous sidewalks or equivalent all-weather provisions for walking are provided along both sides of 90% of streets or frontage, and new sidewalks must be at least 8 feet wide on retail or mixed-use blocks and at least 4 feet wide on all other blocks, except alleys, driveways, and reconstructed existing sidewalks.

The movement of **Cittaslow** was born 1999 in Greve, a little town of Tuscany, Italy. Now they have 144 member cities. The main goals are to improve the quality of life in cities and preventing the uniformity. A good practice has been carried out in the medieval town of Enns in Austria since 2007. They set the speed limit as 20 km/h in the centre and in that case, all road users can communicate with each other by eye contact, as a result, a noticeable revival of the regional economy appears. (Cittaslow Website)

Recently, the latest "**Walking Report**" (London Assembly, 2010) has been submitted to the mayor of London. It has outlined 17 initiatives to encourage walking, and all the recommendations are concentrated on the theme of "2011 as the Year of Walking". Although they consider carefully the political and economic feasibility of each action, I can say that most of the proposals are based on experiences, but not from a systemic analysis.

- expand a Key Walking Route in 2011 and each London borough has a Key Walking Route by 2013/14;
- the mayor should report how he will support the provision of urban design surgeries by the end of 2010;
- programme of community street;
- ensure all pedestrian crossings;
- evaluation of the borough-wide pilots of 20 km/h zones design;
- The mayor should show his support for at least one large-scale infrastructure project which will have pedestrians at its core;
- Organize a major new pedestrianisation event in Central London in 2011;
- for the 2011 Year of Walking the Mayor and TfL should develop a pilot scheme that offers Londoners an incentive to undertake more journeys by foot by offering store-card type rewards;
- for the 2011 Year of Walking TfL should ensure that its Journey Planner defaults to a walking option as the first choice for any trip under 1 km/15 mins.

The final case is the **San Diego Pedestrian Master Plan** (San Diego (USA) City Government, 2006). They propose the typical problems and solutions in six dimensions: Safety at intersections, Safety along street segments, Accessibility, Connectivity, Walkability, Neighborhood character. And in my opinion, it reflects a typical "from node to node" method – researchers find the problems on some node and try to solve them – it does not give the information of a system.

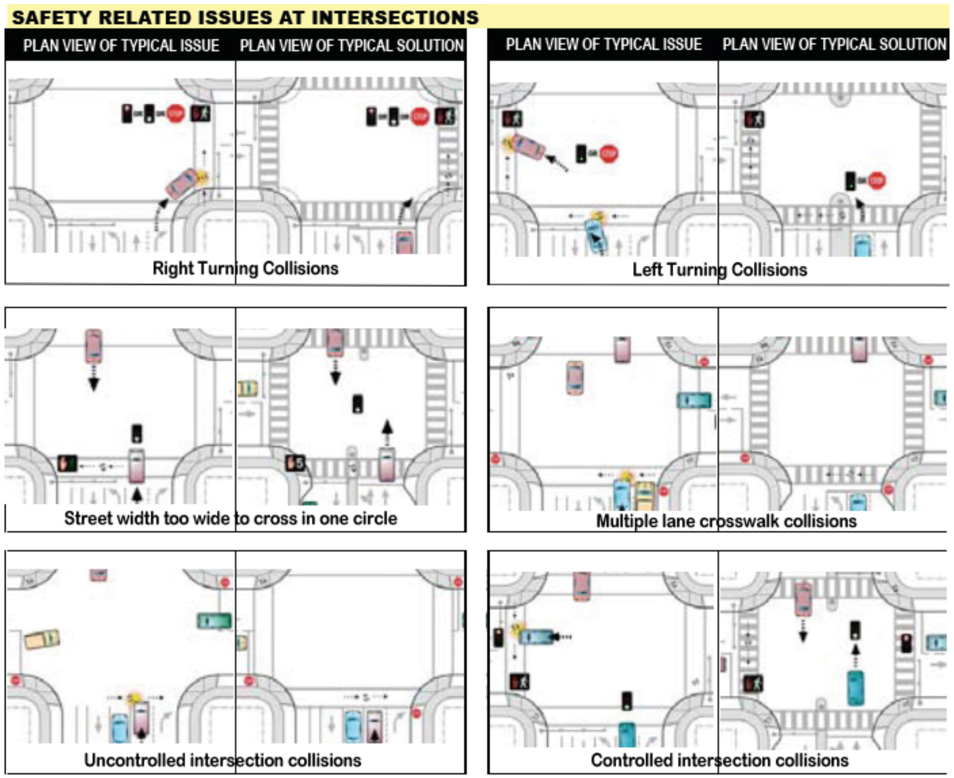


Figure 2- 3: Typical problems and solutions in "Safety at intersections" dimension

Source: San Diego Pedestrian Master Plan, 2006

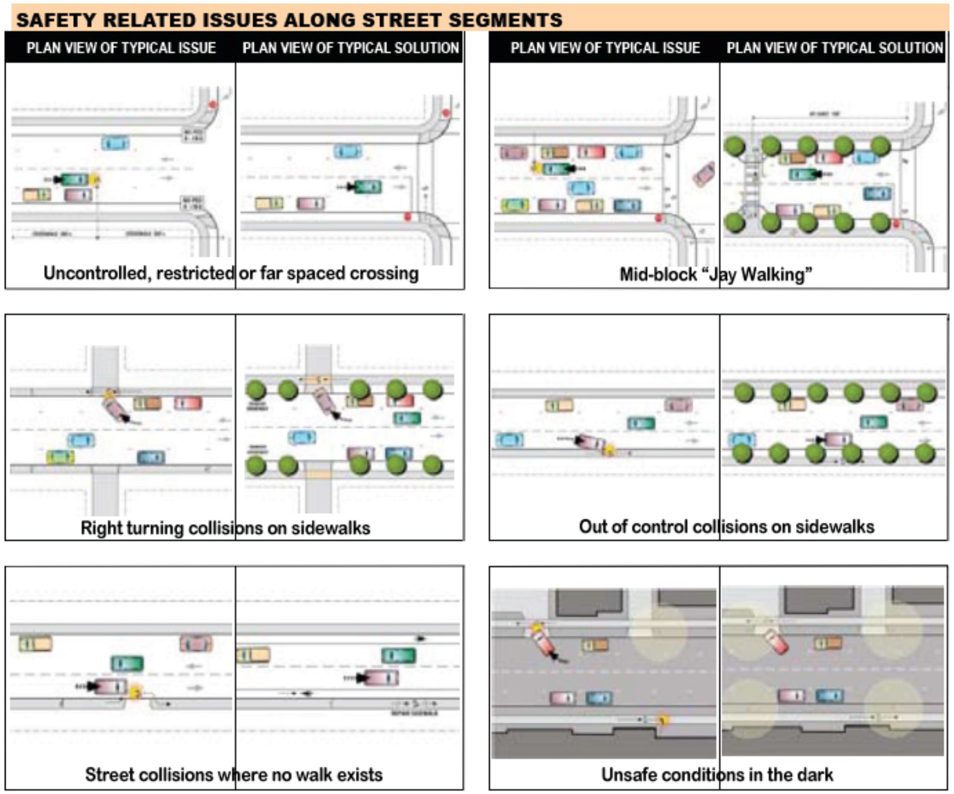


Figure 2- 4: Typical problems and solutions in "Safety along street segments" dimension

Source: San Diego Pedestrian Master Plan, 2006

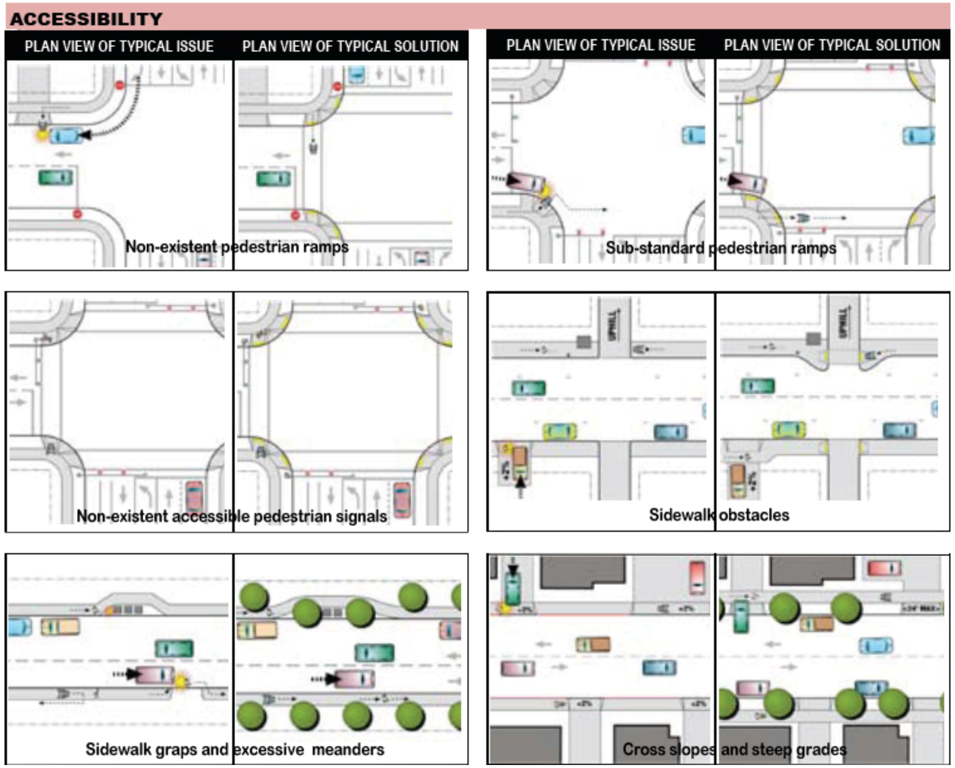


Figure 2- 5: Typical problems and solutions in "Accessibility" dimension

Source: San Diego Pedestrian Master Plan, 2006

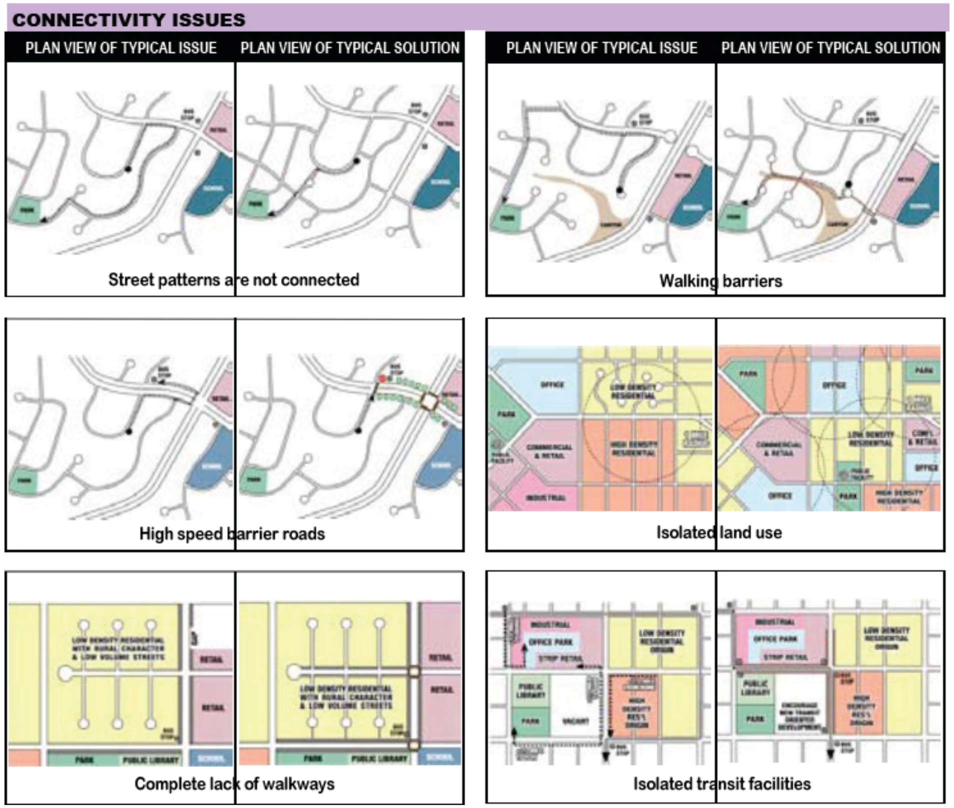
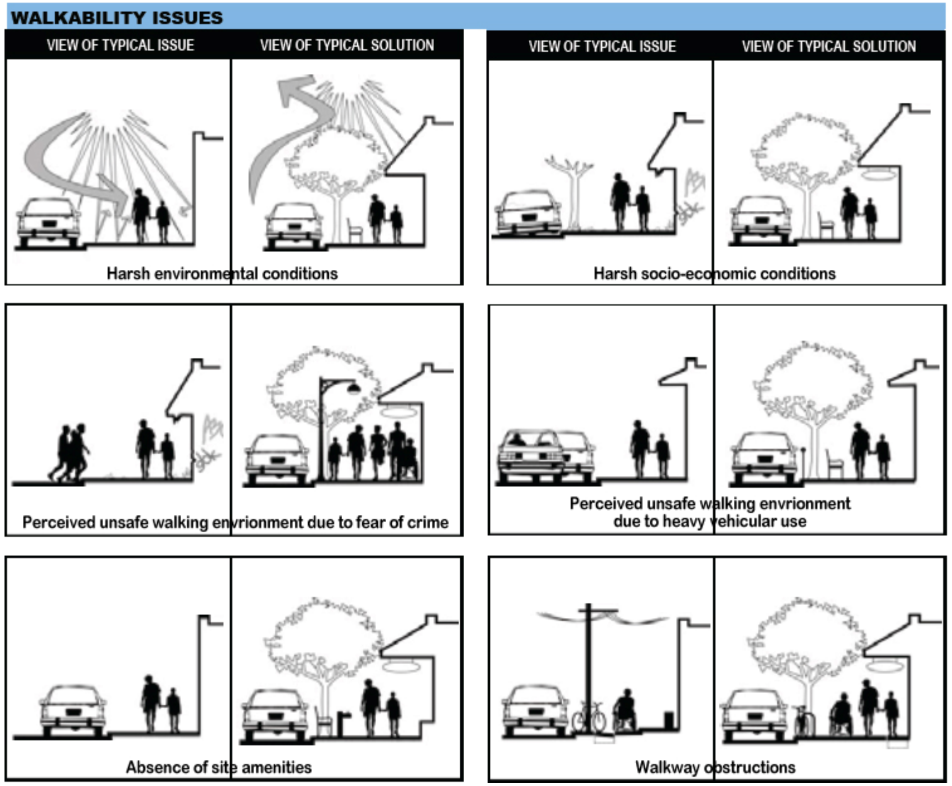


Figure 2- 6: Typical problems and solutions in "Connectivity" dimension

Source: San Diego Pedestrian Master Plan, 2006



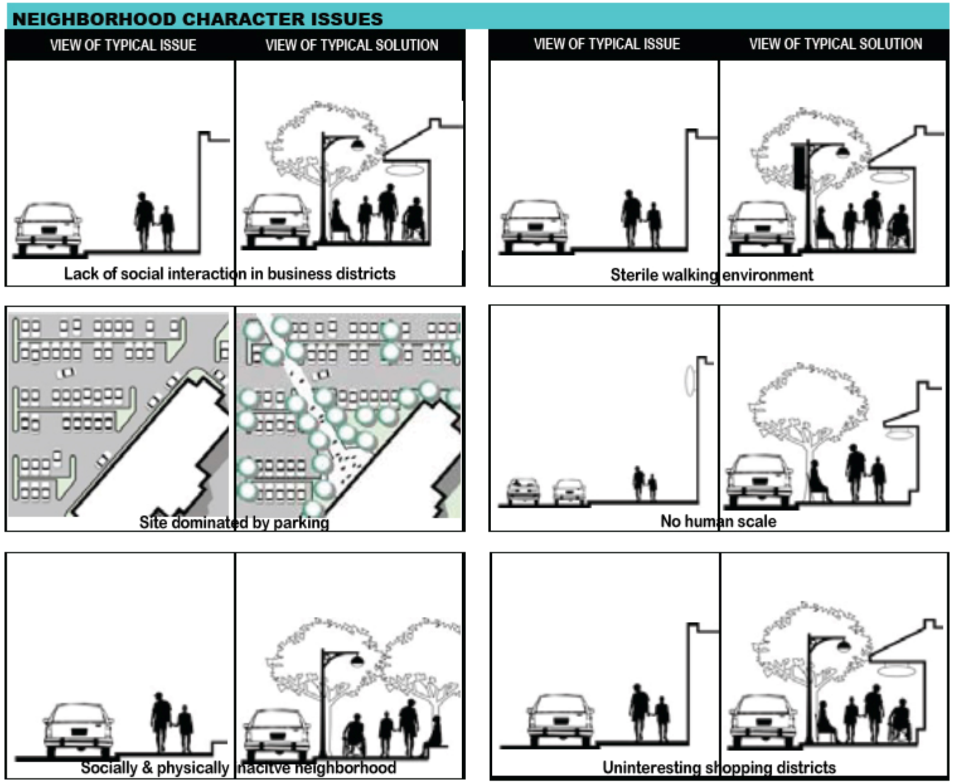


Figure 2- 7: Typical problems and solutions in "Walkability" dimension
Source: San Diego Pedestrian Master Plan, 2006

Figure 2- 8: Typical problems and solutions in "Neighborhood Character" dimension
Source: San Diego Pedestrian Master Plan, 2006

2.2 Analytical Tools and Methods for Pedestrian Mobility Design

2.2.1 Tools to Measure and Represent the Flow

Pedestrian flow surveys have been widely carried on in retail, commercial and public premises for business uses since last 2 or 3 decades, but most of them are suitable for interior environment. But the Technicians never stop looking for tools that are suitable for multiplicative environments and with higher Accuracy. **As going through cases, we found 4 main ways to measure the people and vehicle flows**: The manual way, the mechanical way such as a hand tally counter, infrared beams, thermal imaging and pressure-sensitive mats, the digital way such as computer vision, face identification, and the real-time way such as GPS and cell phones information platform. We are going to reveal the advantages and disadvantages of them below, and of course we need to chose an ideal cost effective way of collecting flow data for specific environments (outdoor space, doorways and interior spaces etc.).

The manual way is the traditional way to get the flow information and also detail information about people' behaviors, such as when and where they leave the shops. It takes workforce, but it is easy to carry out. Even now manual flow survey is the main business of some survey company.

The mechanical way requests sensitive instruments such as pressure sensitive mats and infrared equipments (figures below), and in order to fix those instruments, the mechanical way is much more suitable for indoor application. But it has the advantage of automatically calculating the data and presenting the curves.

Figure 2- 9: A Hand Tally Counter Works Though People Click it

Figure 2- 10: Pressure-sensitive Mats Feel the Weight

Source: Eco-compteur Website

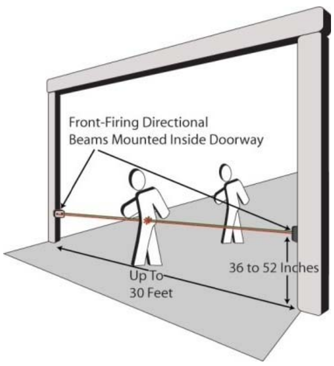


Figure 2- 11: Infrared Beams Measure Flow When People Pass by

Source: People Counter Website

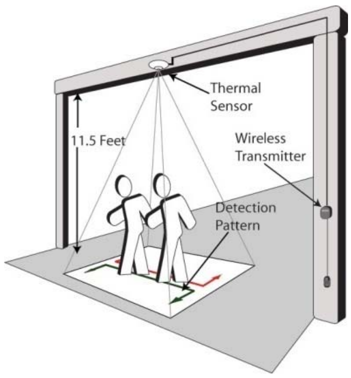


Figure 2- 12: Thermal Imaging Counts Flow and Direction by Thermal Sensor

Source: People Counter Website

The digital way not only requests a closed-circuit television camera or IP camera to feed a signal into a computer or embedded device, but also requests the specific software to achieve an accurate result. But it has the advantage of automatically data collecting and processing and being suitable for flexible environments.

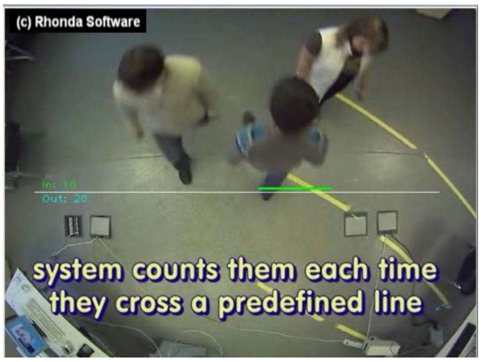


Figure 2- 13: Software that Recognizes and Counts Moving Objects from a Video

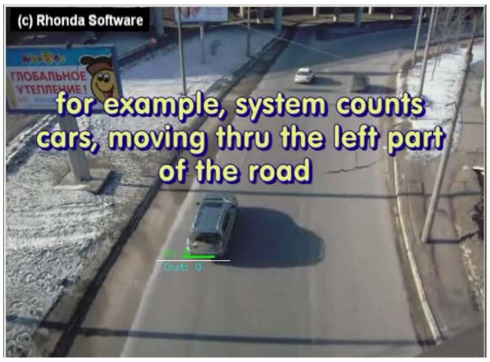


Figure 2- 14: The Same Software can be Used Outdoors to Count Vehicles from Both Sides

Figure 2- 15: Face Identification Software Recognizes Faces and could be Applied Outdoors

Source of Figure 2-13, 2-14: Computer-vision-software Website

Source of Figure 2-15: Face Identification Software Technology Support

The last method is the real-time data collecting and processing. Below are the successful examples of applying it. The first one of "Traffic on GoogleMaps" is based on GPS enabled on the phones. When people choose to enable Google Maps with his Location, the phone sends anonymous bits of data back to Google describing how fast he/she is moving. Across thousands of phones moving around a city, the picture of real-time traffic conditions is produced. The second case and the third one are working with the same mechanism of GPS, but reveal much more aspects of the same data, such as the traffic speed, density and the concentrations. The second case of "24h of Traffic Evolution in Lisbon" are produced by GPS which are fixed on 400 taxis running in the city for a whole day. The third case of "Real Time Rome" is the MIT SENSEable City Lab's contribution to the 2006 Venice Biennale. The project aggregated data from cell phones (Telecom Italia's innovative Lochness platform) and GPS fixed on buses and taxis in Rome, to show the urban dynamics in real time. The final case is proposed by Polimi, and it analyzes and represents urban dynamics and study the movement of individuals through telephone traffic data.

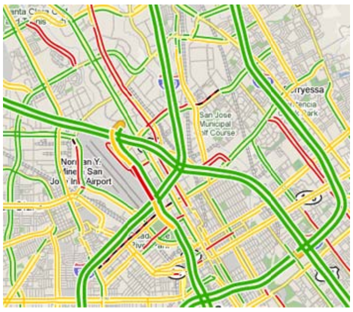


Figure 2- 16: Traffic on GoogleMaps

Source: Datavisualization Website

Source of Figure 2-17 until 2-20:Datavisualization Website

Figure 2- 17: Lisbon Traffic Evolution during 24h (from 0:00 to 23:59)

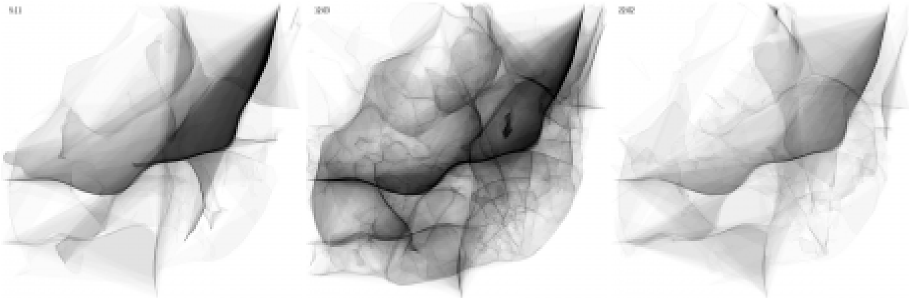


Figure 2- 18: Lisbon Intense Traffic Area Evolution during 24h

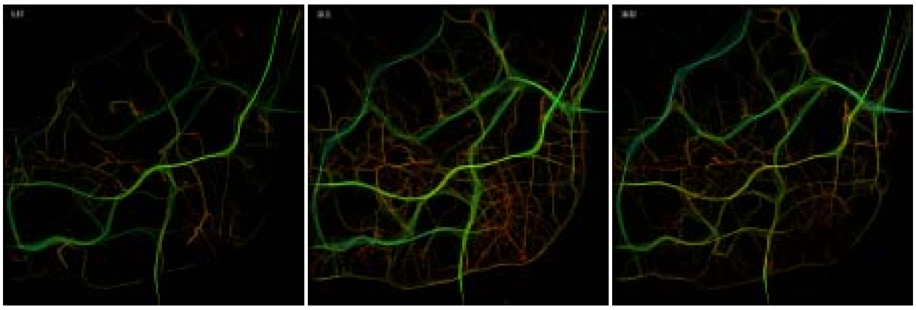


Figure 2- 19: Lisbon Vehicles Speed during 24h

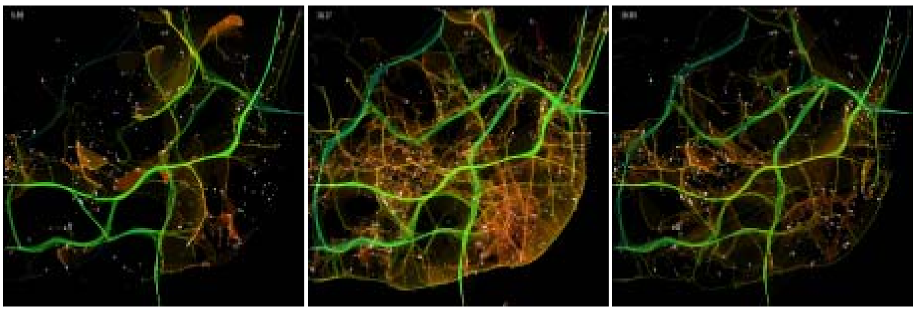


Figure 2- 20: Lisbon Traffic Problems Area during 24h

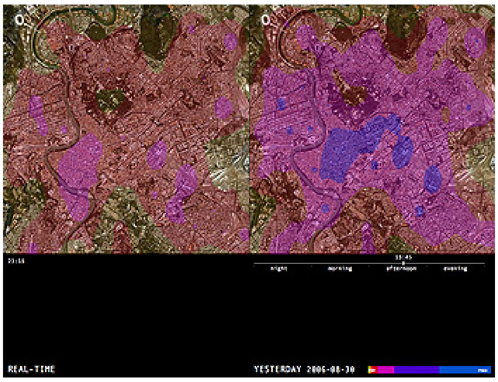


Figure 2- 21: Pulse - the intensity of mobile phone calls in Rome at different time

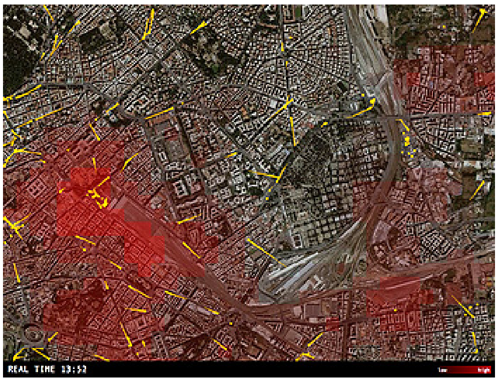


Figure 2- 22: Connectivity between people and public transport – the positions of the buses and the distribution of mobile phone users

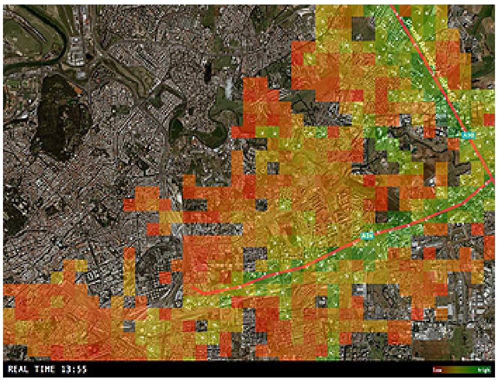


Figure 2- 23: Flow - mobile phone callers traveling in vehicles

Figure 2- 24: Incons - the density of people using mobile phones at different historic attractions in Rome

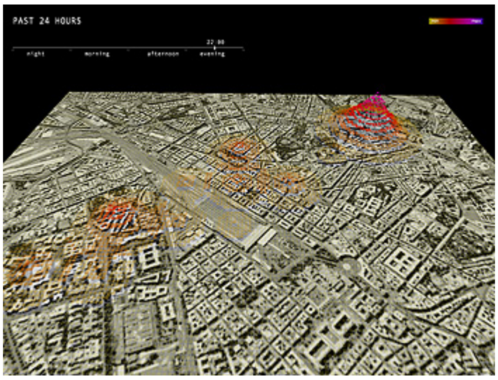


Figure 2- 25: Visitors - the locations around the Stazione Termini of Rome where tourists are speaking on mobile phones

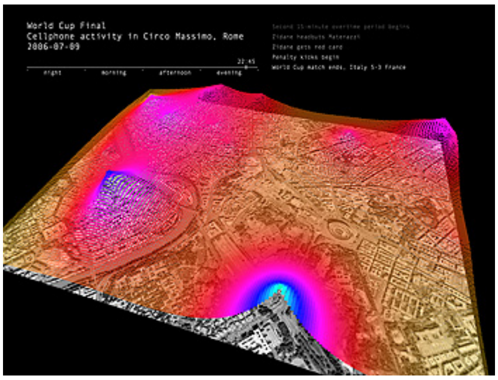


Figure 2- 26: Special Events - calling distribution during Madonna's concert in Rome on August 6, 2006

Source of Figure 2-21 until 2-26: MIT Senseable City Lab Website

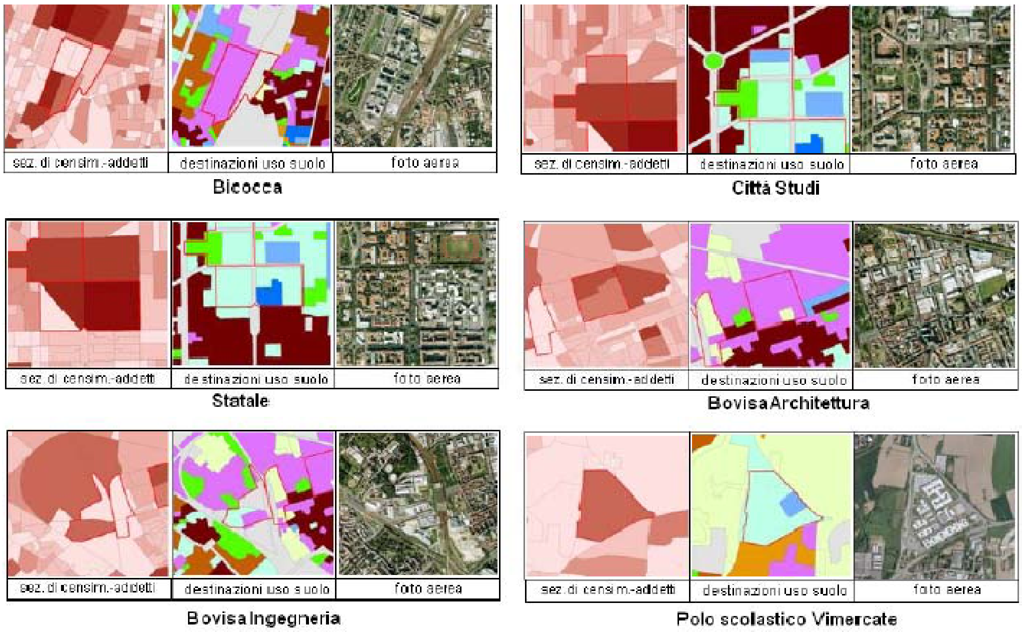


Figure 2- 27: Cell Phone Connections in Different Universities which are with Different Physical Forms

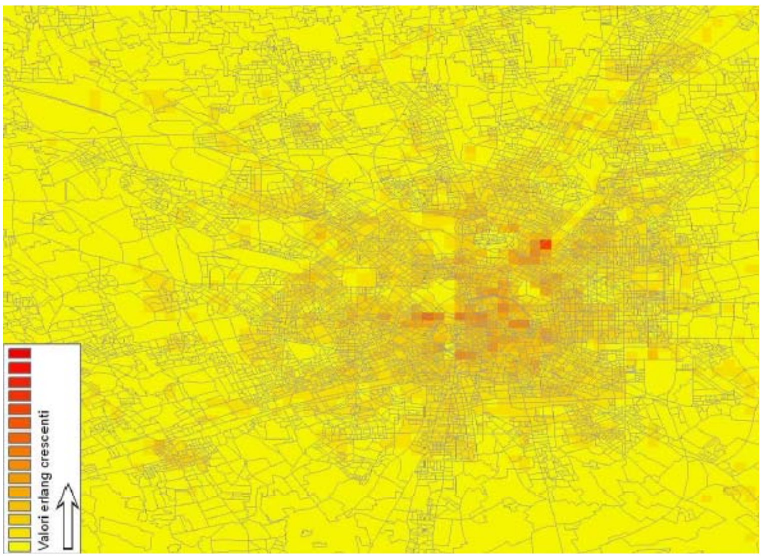


Figure 2- 28: Map of the Telephone Traffic Between 17.00 and 18.00 on the Day of the Salone del Mobile 24/4/2009 (Events)

Source of Figure 2-27 & 2-28: Manfredini et al., 2010

Another way to get the flow data is the formula simulation way. The example below is the Simulation of Visitors' Flow and Time-space distribution in the World Expo 2010 Shanghai based on Internet Survey (Ma, 2006). The author finds out the factors that influence visitors distribution through internet survey, they are walking distance, the area of the pavilion, the character of the pavilion, if the location is on the river bank, if the location is near an exit. And then he uses the discrete choice model to make a formula. Finally he utilizes the GIS spatial interpolation technology to produce the time-space distribution maps.

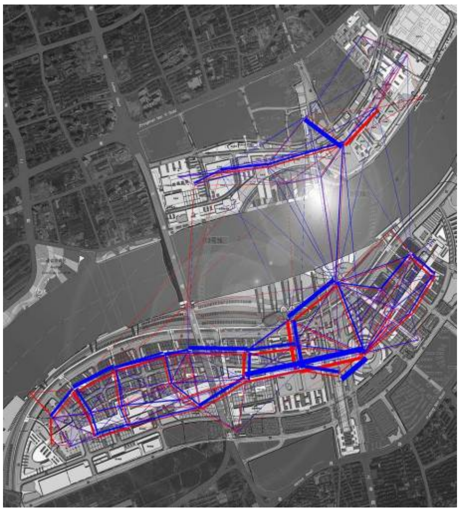


Figure 2- 29: Visiting Path Simulation

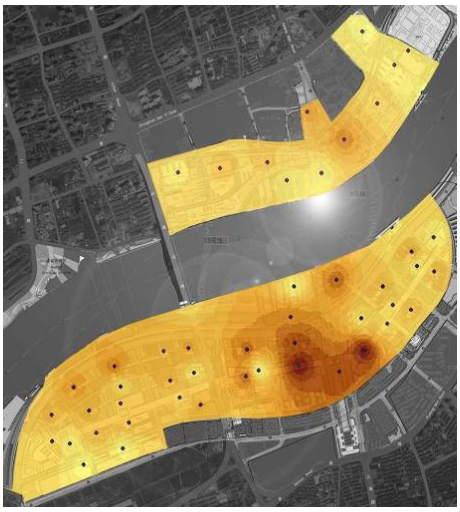


Figure 2- 30: Visiting intension

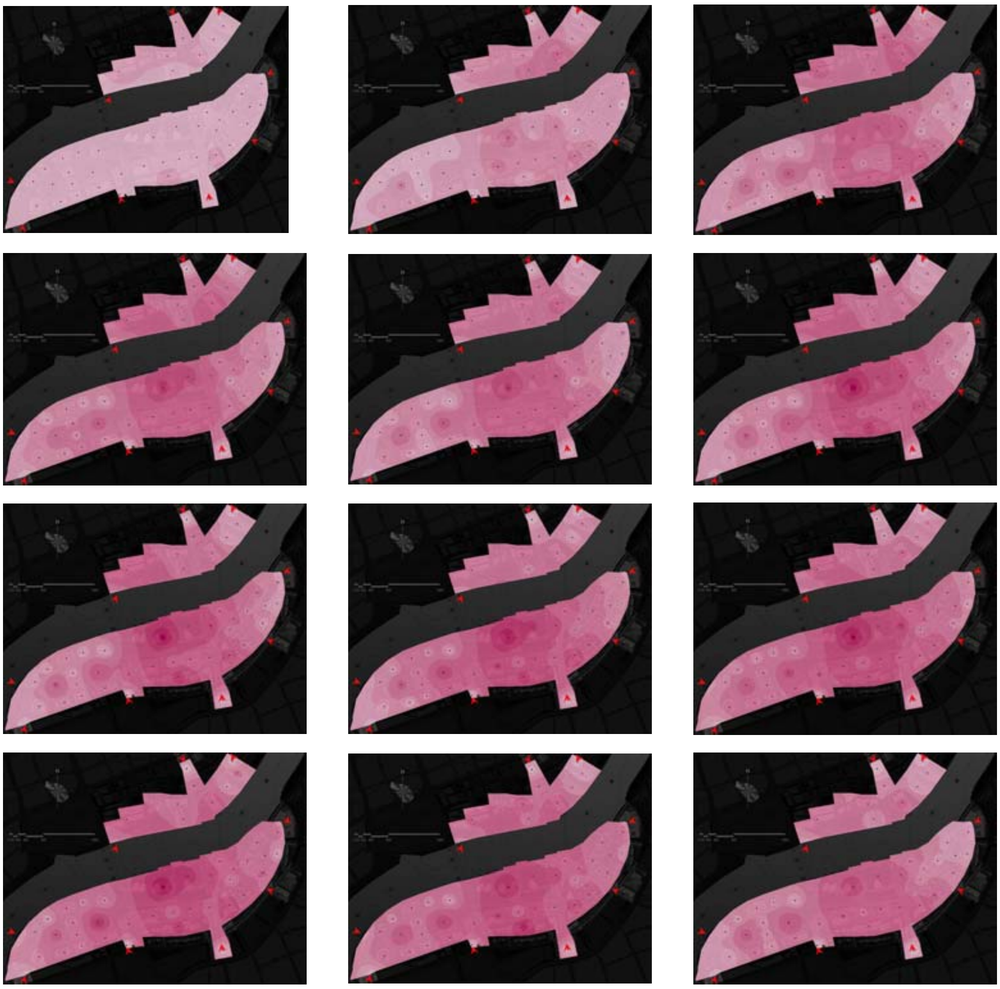


Figure 2- 31: A whole day time-space distribution simulation (9:00 -21:00)

Source of Figure 2-29 until 2-31: Ma, 2006

2.2.2 Tools to Study the Origins and Destinations

I propose two cases here to study this subject. The first case of "flow map" displays the relationship between origins and the destinations, and the second case of "San Diego Pedestrian Priority Model" uses origins and the destinations to define the critical area and communities to be improved.

Figure 2-32 is an example of flow map that shows the traffic movement from one location to another. The advantage of flow maps is that they reduce visual clutter by merging edges. The researchers from Stanford University presents a method for generating flow maps using hierarchical clustering given a set of nodes, positions, and flow data between the nodes. Their techniques are inspired by graph layout algorithms that minimize edge crossings and distort node positions while maintaining their relative position to one another.

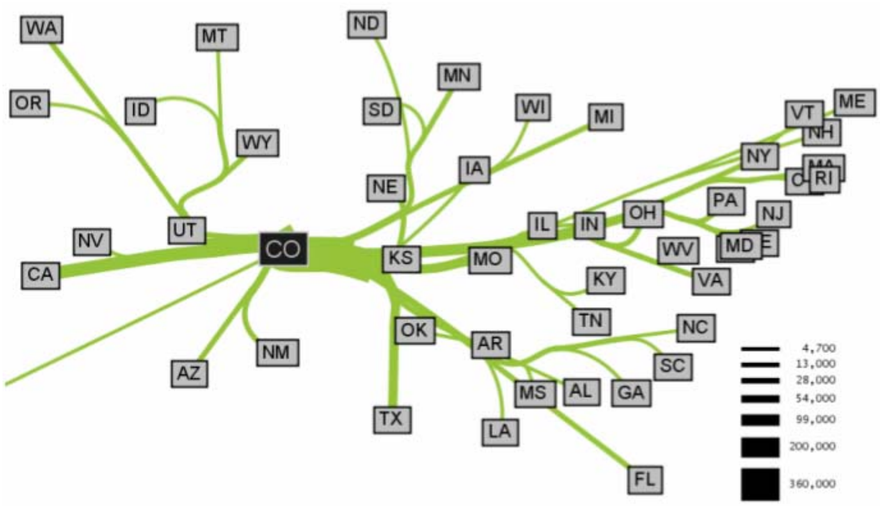


Figure 2- 32: Example of Generating Flow Maps

Source: Datavisualization Website

Figure 2-33 until 2-37 are the process to produce the "San Diego Pedestrian Priority Model". Combining the factors of pedestrian attractors, pedestrian generators and pedestrian detractors, the city government gets the pedestrian improvement priority area and the community ranking.

- Pedestrian Attractors are Schools, Transit stations, Parks and recreation facilities including beaches, Neighborhood and community retail, and Neighborhood and community serving destinations.
- Pedestrian Generators are decided by Walk to work (census), Population density, Employment density, Senior age density, Household income, Youth age density, Disability density, Existing mixed use areas, Programmed mixed use areas
- Pedestrian Detractors are considered as Pedestrian / Vehicular Collisions, ADT (Average Daily Trips), Street Lighting, Speed Limits, Slope, Railroads and Freeways.

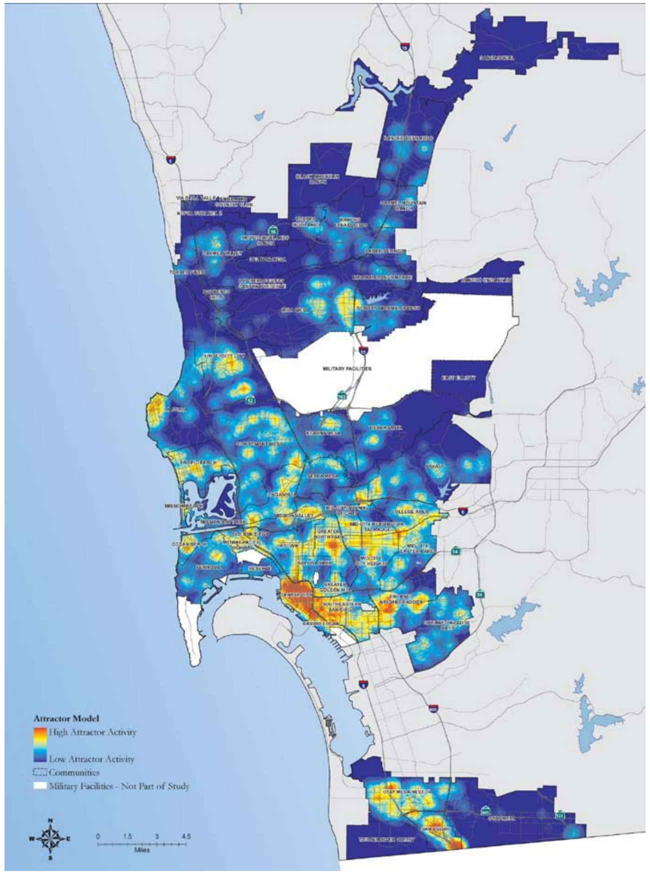


Figure 2- 33: Pedestrian Attractors Map

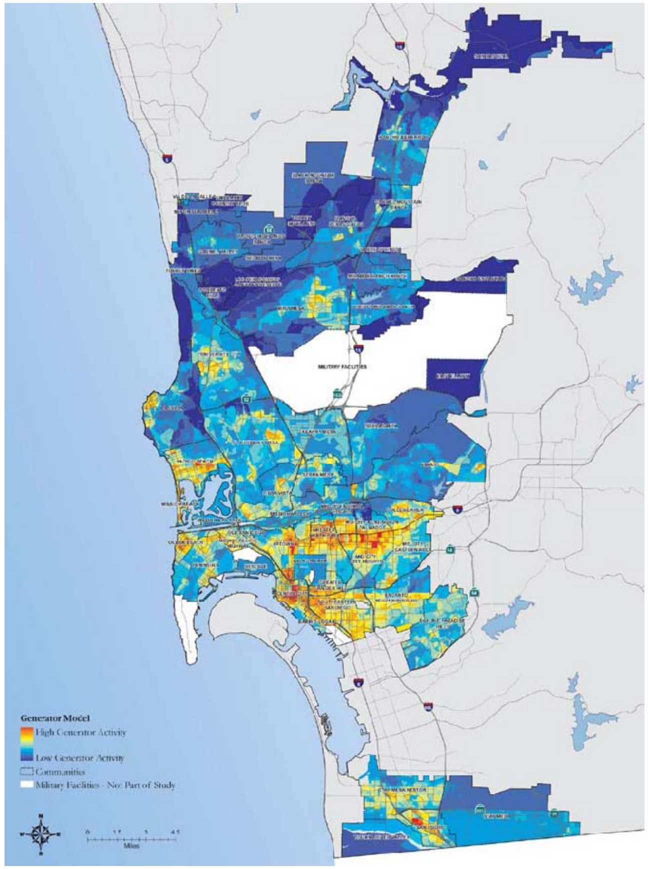


Figure 2- 34: Pedestrian Generators Map

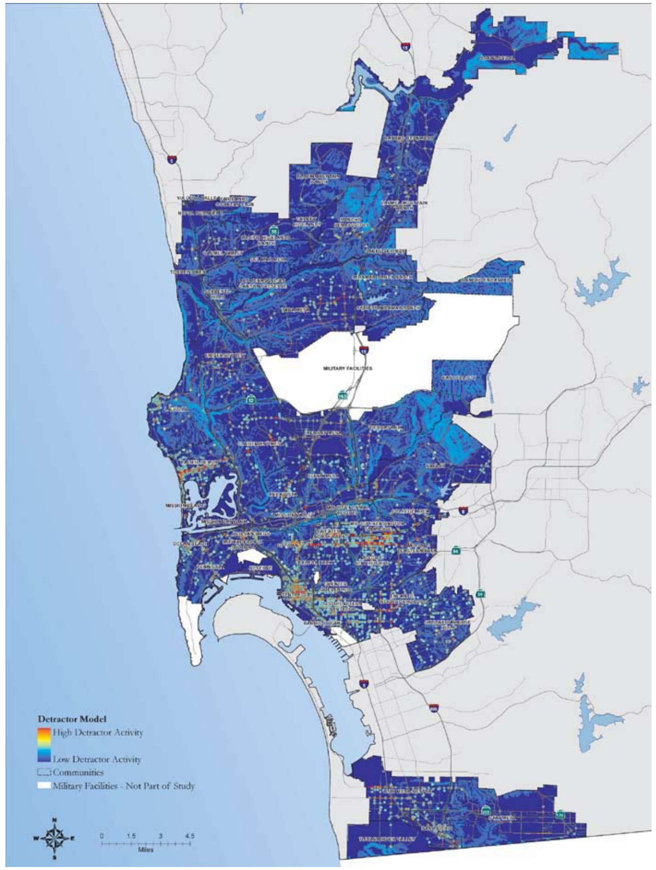


Figure 2- 35: Pedestrian Detractors Map

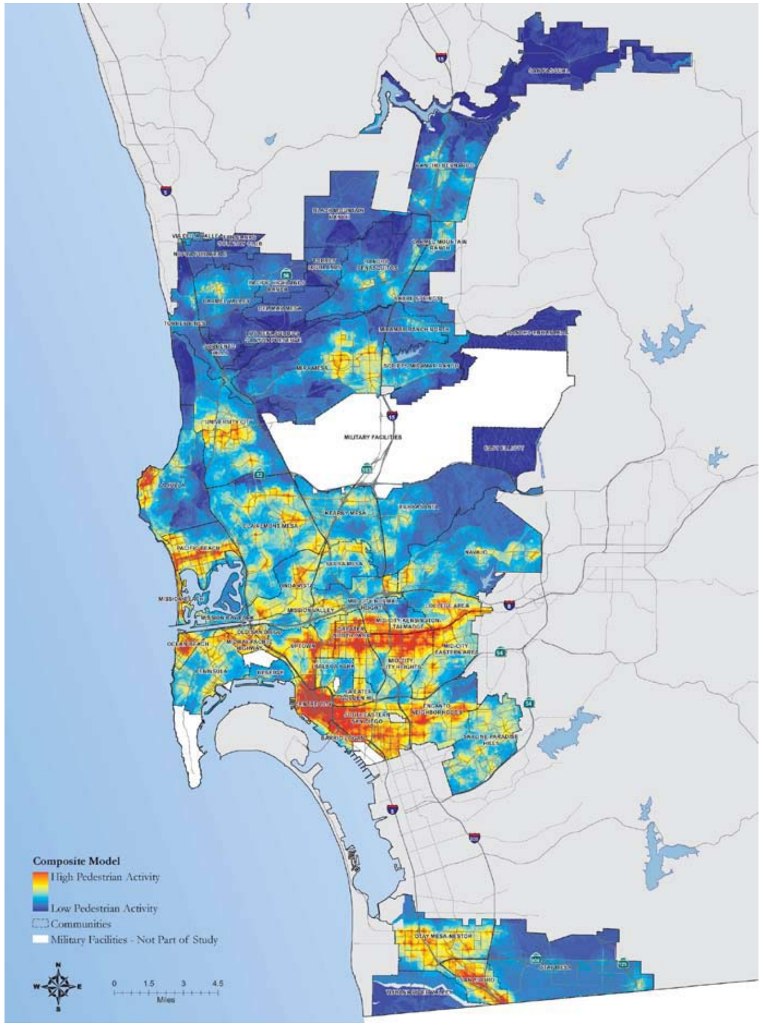


Figure 2- 36: Composite Model Result

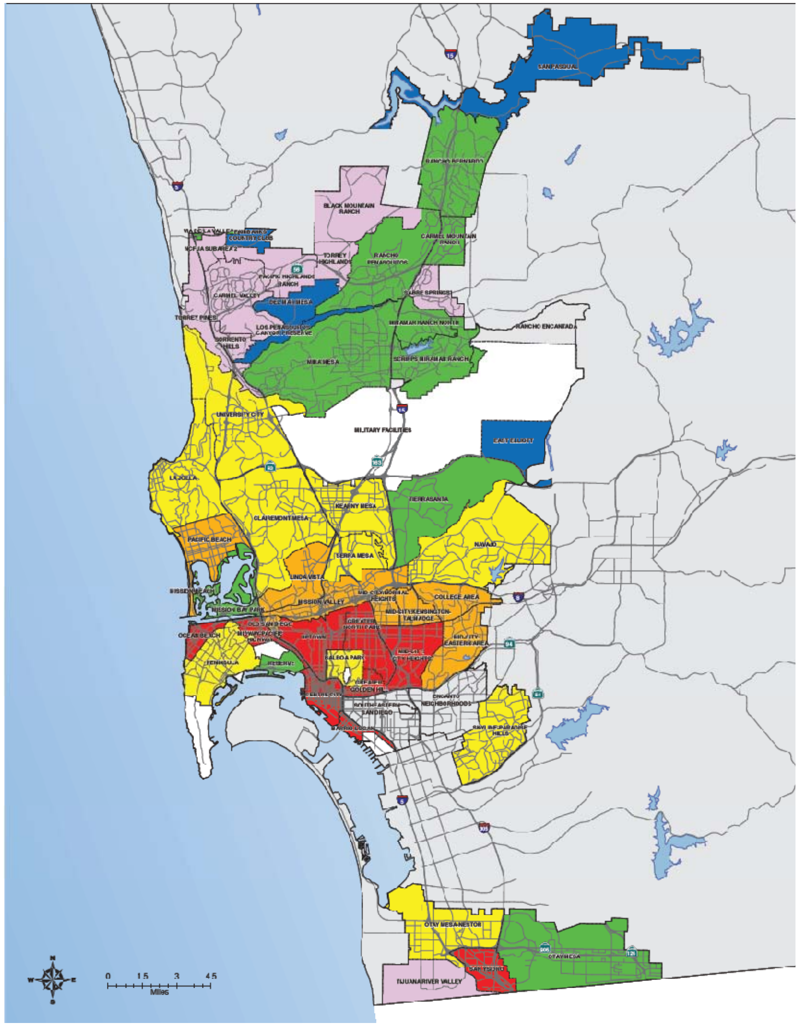
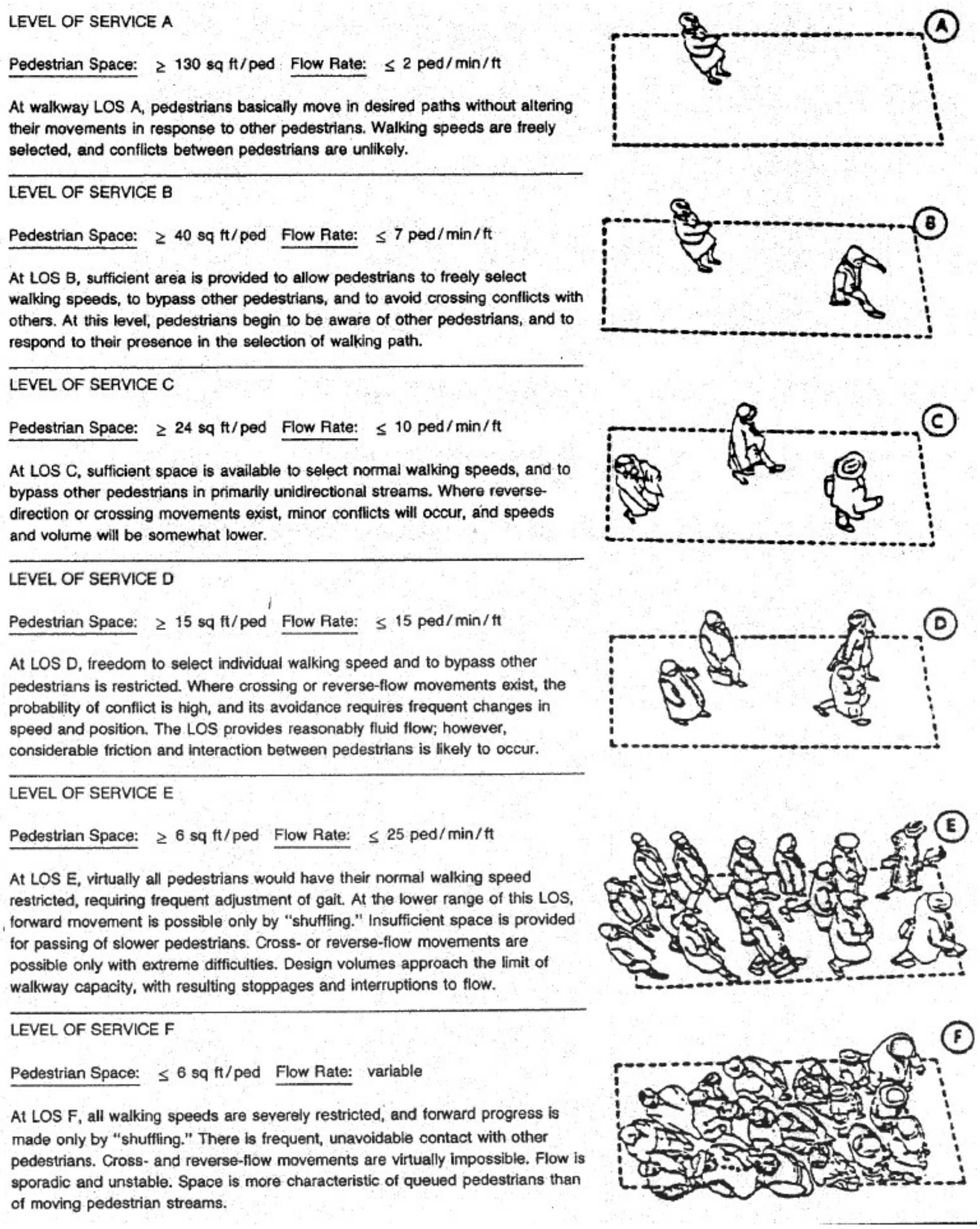


Figure 2- 37: Community Ranking

Source of Figure 2-33 until 2-37: San Diego (USA) City Government, 2006

2.2.3 Tools to Measure and Represent the Traces and Density

I focus on two dimensions for this subject. Figure 2-38 gives us a quantitative criteria to evaluate the service level of a pedestrian sidewalk, and the images representing the trails give us qualitative impression of the situation on pedestrian facilities.



LEVEL OF SERVICE A

Pedestrian Space: ≥ 130 sq ft/ped Flow Rate: ≤ 2 ped/min/ft

At walkway LOS A, pedestrians basically move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.

LEVEL OF SERVICE B

Pedestrian Space: ≥ 40 sq ft/ped Flow Rate: ≤ 7 ped/min/ft

At LOS B, sufficient area is provided to allow pedestrians to freely select walking speeds, to bypass other pedestrians, and to avoid crossing conflicts with others. At this level, pedestrians begin to be aware of other pedestrians, and to respond to their presence in the selection of walking path.

LEVEL OF SERVICE C

Pedestrian Space: ≥ 24 sq ft/ped Flow Rate: ≤ 10 ped/min/ft

At LOS C, sufficient space is available to select normal walking speeds, and to bypass other pedestrians in primarily unidirectional streams. Where reverse-direction or crossing movements exist, minor conflicts will occur, and speeds and volume will be somewhat lower.

LEVEL OF SERVICE D

Pedestrian Space: ≥ 15 sq ft/ped Flow Rate: ≤ 15 ped/min/ft

At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Where crossing or reverse-flow movements exist, the probability of conflict is high, and its avoidance requires frequent changes in speed and position. The LOS provides reasonably fluid flow; however, considerable friction and interaction between pedestrians is likely to occur.

LEVEL OF SERVICE E

Pedestrian Space: ≥ 6 sq ft/ped Flow Rate: ≤ 25 ped/min/ft

At LOS E, virtually all pedestrians would have their normal walking speed restricted, requiring frequent adjustment of gait. At the lower range of this LOS, forward movement is possible only by "shuffling." Insufficient space is provided for passing of slower pedestrians. Cross- or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with resulting stoppages and interruptions to flow.

LEVEL OF SERVICE F

Pedestrian Space: ≤ 6 sq ft/ped Flow Rate: variable

At LOS F, all walking speeds are severely restricted, and forward progress is made only by "shuffling." There is frequent, unavoidable contact with other pedestrians. Cross- and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams.

Figure 2- 38: Walkway Service Level

Source: Transportation Research Board (TRD), 2000

Figure 2-39 introduces the tool "Photoshop Image Stacking for Day Trails", and its result for representing the path of the traffic and the most utilized sections of the sidewalks. Figure 2-40 illustrates how to grab the individuals moving trace by the tool "Intelligent Video Analytics for people traces". Figure 2-41 shows the process of pedestrian distribution analysis by "Timelapse + GIS". The researcher firstly take a video of pedestrian moving and use timelapse technology to replay it, then all the pictures are imported into GIS. After unskewing the perspective, the movement data becomes a distribution map. With the application of a grid, we will have the map showing which part of the sidewalk are most be used.

And the time-lapse technique could capture frames at a rate much slower than they exactly are, and help to replay a slow change into an onslaught of activity. This technique has been used to photograph celestial bodies, plants for few decades, and in these years, it has been applied in landscape and traffic observations and studies.

Figure 2- 39: Photoshop Image Stacking for Day Trails
Source: Digitalurban Website

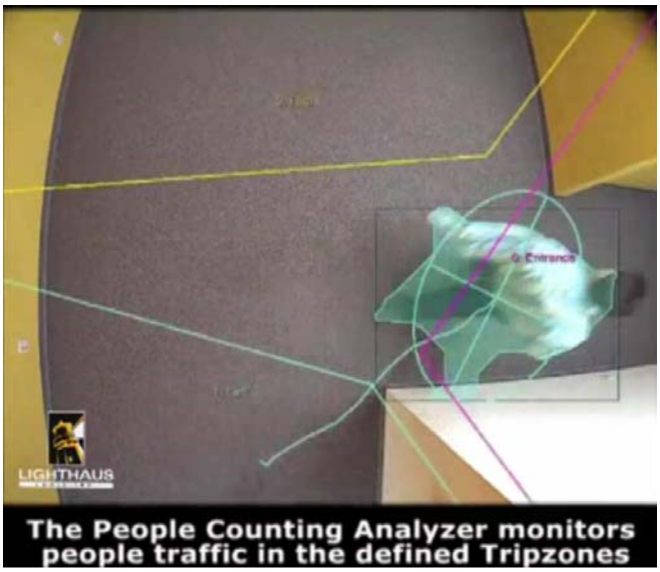


Figure 2- 40: Intelligent Video Analytics for people traces
Source: The Lighthaus logic Company Website

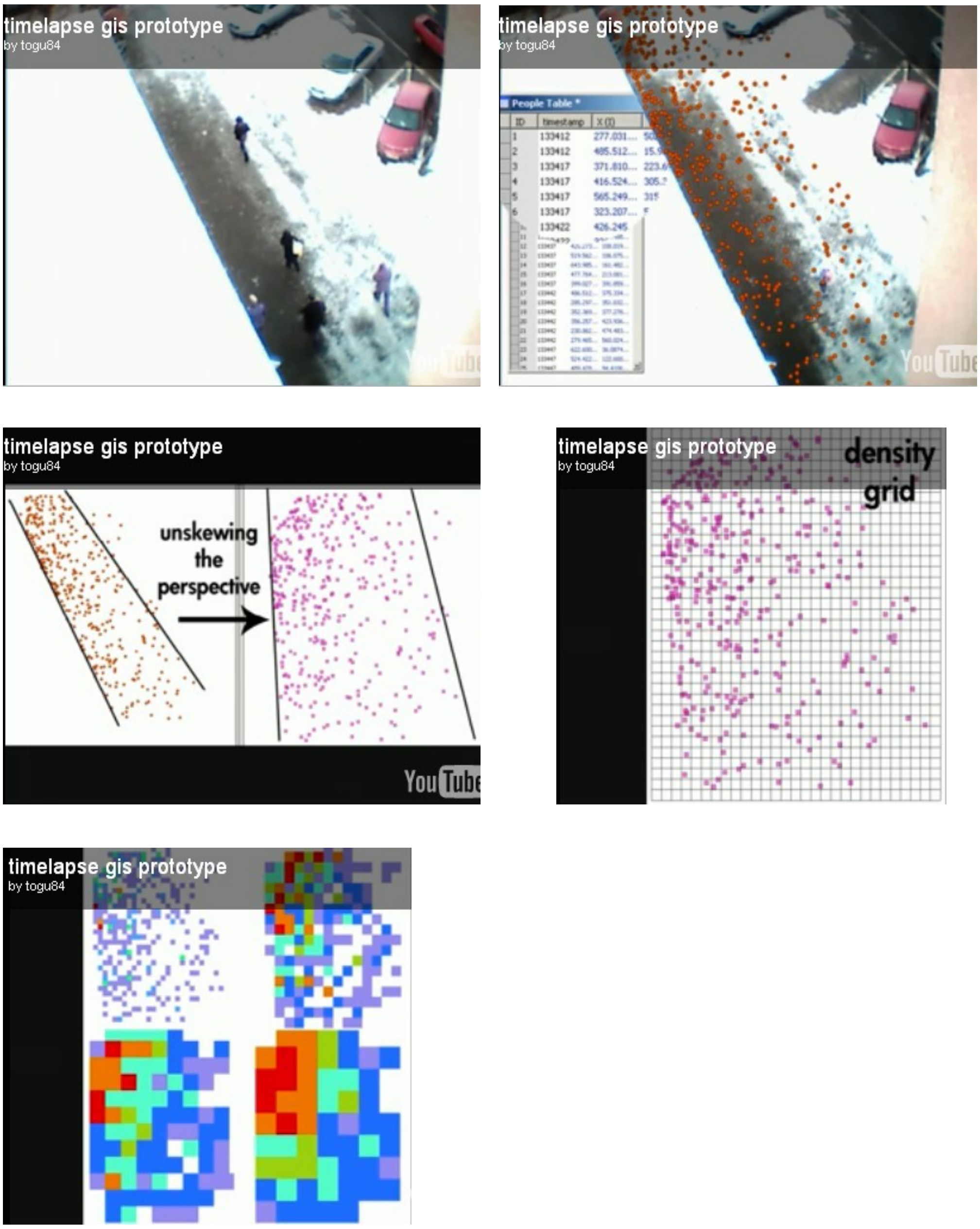


Figure 2- 41: Timelapse + GIS for Pedestrian Distribution Analysis

Source: Digitalurban Website

2.2.4 Tools to Measure and Represent the Accessibility

Here I find two method to represent the accessibility. The first one is a calculation formula proposed on wikipedia, the second one is evaluating the accessibility basing on the real street network, and it has been developed as a method called "Ped-shed Analysis".

A measure that is often used is to measure accessibility in a traffic analysis zone i is:

$$Accessibility_i = \sum_j Opportunities_j \times f\left(C_{ij}\right)$$

where:

i = index of origin zones

j = index of destination zones

f (C ij) = function of generalized travel cost (so that nearer or less expensive places are weighted more than farther or more expensive places). For a non-motorized mode of transport, such as walking or cycling, the generalized travel cost may include additional factors such as safety or gradient. (Wikipedia Definition of Accessibility)

Hawkins (2007) has pointed out that the different kind of street network lead to different connectivity. He further raised a comparison of the same a one-mile walk in Seattle's Phinney Ridge and Bellevue, WA. The Seattle's Phinney Ridge has a grid-like street network, and takes people to wide area; while Bellevue, WA with cul-de-sacs and winding streets, leads people achieve much less area.

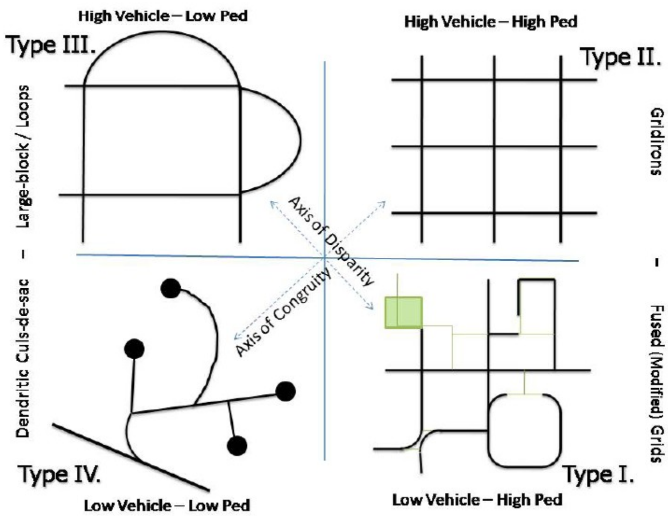


Figure 2- 42: Different Types of Street Networks and their Performance on Connectivity

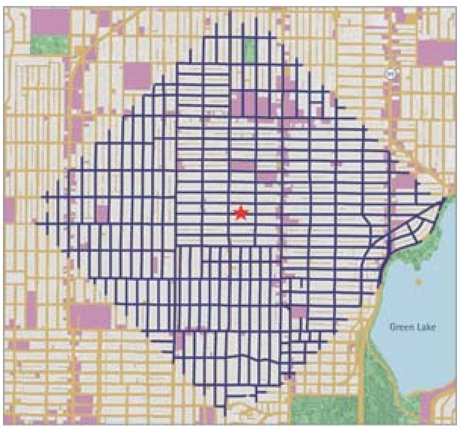


Figure 2- 43: One-Mile Walk in a Compact Neighborhood

Figure 2- 44: One-Mile Walk in a Sprawling Suburb

Source of Figure 2-42 until 2-44: Hawkins, 2007

Pedestrian Shed (Ped Shed) Analysis aims at identifying the permeability of the street network for pedestrian, it will help show how far you can achieve by walking 400m (5 minutes) / 800m (10 minutes). Researchers firstly outline all the routes could be taken from your origin (step 1) and measure 400m/ 800m along the routes (step 2). Then we can build the perimeter that includes all the reachable places (step 3). Compared with the theoretical accessible area, the percentage of the reachable area can be know (step 4).

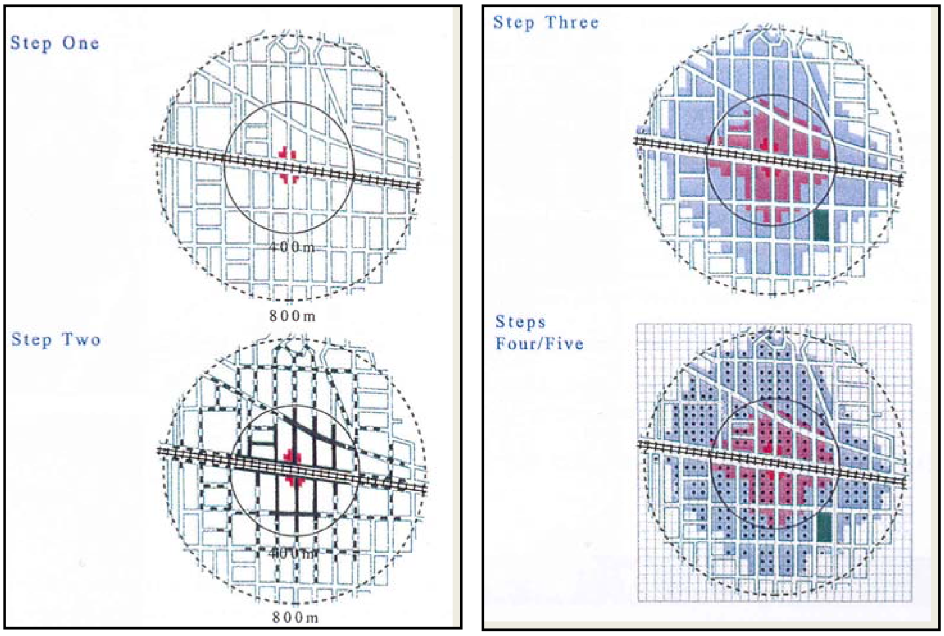


Figure 2- 45: The Procedure of PedShed Analysis

Source: ISTP Murdoch University and Western Australia Ministry for Planning, 2001

An application case is the comparative analysis of the disastrous effects of the fences in Central Westfield community, Australia. As we can see, with the removal the fence, the accessible area of the facilities is widely enlarged.

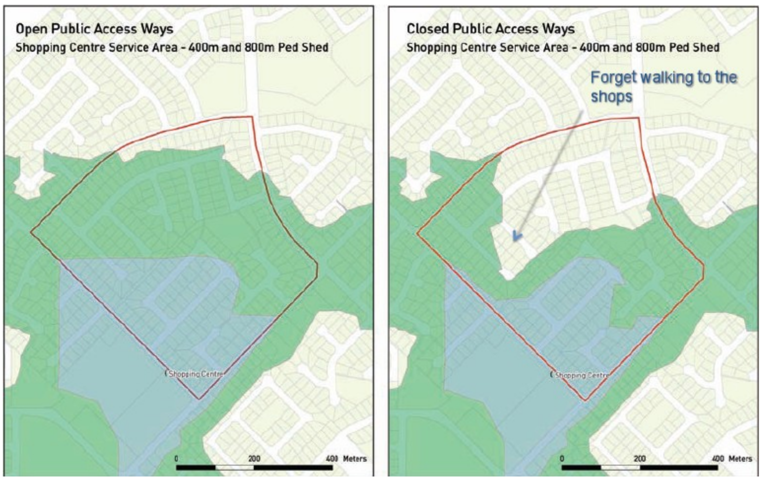


Figure 2- 46: A Comparative Analysis of the Disastrous Effects of the Fences

Source: Australia Department for Planning and Infrastructure, 2008

2.2.5 Tools to Represent People's Consciousness of Time & Space

Prof. Bosselmann P. has discussed about how urban elements influence people's consciousness of time & space as "Images in motion" in his book <Representation of places: reality and realism in urban design> in 1998. Basing on his walking experience in Venice, he took the same-time (distance) walk in 14 different cities with different urban scales, and he felt that the same-time walks seems to take different amounts of time. In most cities, traveling the distance that is actually equivalent to the walk in Venice appeared to take less time, while in some cities such as Kyoto and Barcelona, it came close to the time it took to walk in Venice. And his conclusion is "awareness of change is the condition on which our perception of time's flow depends" and "pedestrians tell the length of their walks by the rhythmic spacing of recurring elements". More concrete, he pointed out "**The dimensions of the physical objects and the setting of these objects in space influence the sense of time. Designers thus have remarkable power to affect the perception of time by arranging objects in space, by setting dimensions, designing textures, selecting color and manipulating light**" (Bosselmann, 1998). So his tool of "Images in motion" also could be applied in our campus, to represent or even measure in quantity people's consciousness of time, space, feeling of safety, etc.

2.2.6 Tools to Estimate the Surrounding Facilities

The common way to represent the concentration and the contents of the shops and services around some location is the field survey + mapping. And there is no other tool to evaluate the services in different locations as I know. But Google utilizes its advantage of owning the amenities (business lists, parks, etc.) information, creates an algorithm to evaluate the concentration of them and produces the Google Walk Score. This tool are firstly used in real estate business and hotel location ranking.

Table 2- 2: The Rating of Walk Score

Walk Score	Description
90 - 100	**Walker's Paradise** — Daily errands do not require a car.
70 - 89	**Very Walkable** — Most errands can be accomplished on foot.
50 - 69	**Somewhat Walkable** — Some amenities within walking distance.
25 - 49	**Car-Dependent** — A few amenities within walking distance.
0 - 24	**Car-Dependent** — Almost all errands require a car.

Source: Google Walk Score, 2010

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3 Applications of the Analytical Tools on our Campus

3.1 Campus Transportation Background

3.1.1 Campus Transportation Background

My research object is the Milan Leonardo Campus of Politecnico, except some single buildings distributed in the city. This campus includes four main sites as below: Bonardi, Leonardo, Bassini and Golgi-Clericetti. The four sites have a total area of 117,117 m^2, and host the main management and administrative structures of the university (the ones in purple color) and all Schools of Engineering, the School of Architecture and Society, the departments and most of the research institutions (the ones in blue color). According to the 2010 statistics of the university, there are about 1,000 professors & Researchers, 19,000 students and more than 500 administrative staffs acting in this campus (Website of Politecnico di Milano). It means there are big traffic flows arriving and transferring among the locations every day. Considering walk is the mean connecting public transportation with the final destinations, and the main travel mean inside the campus, the promoting of pedestrian mobility is very meaningful.

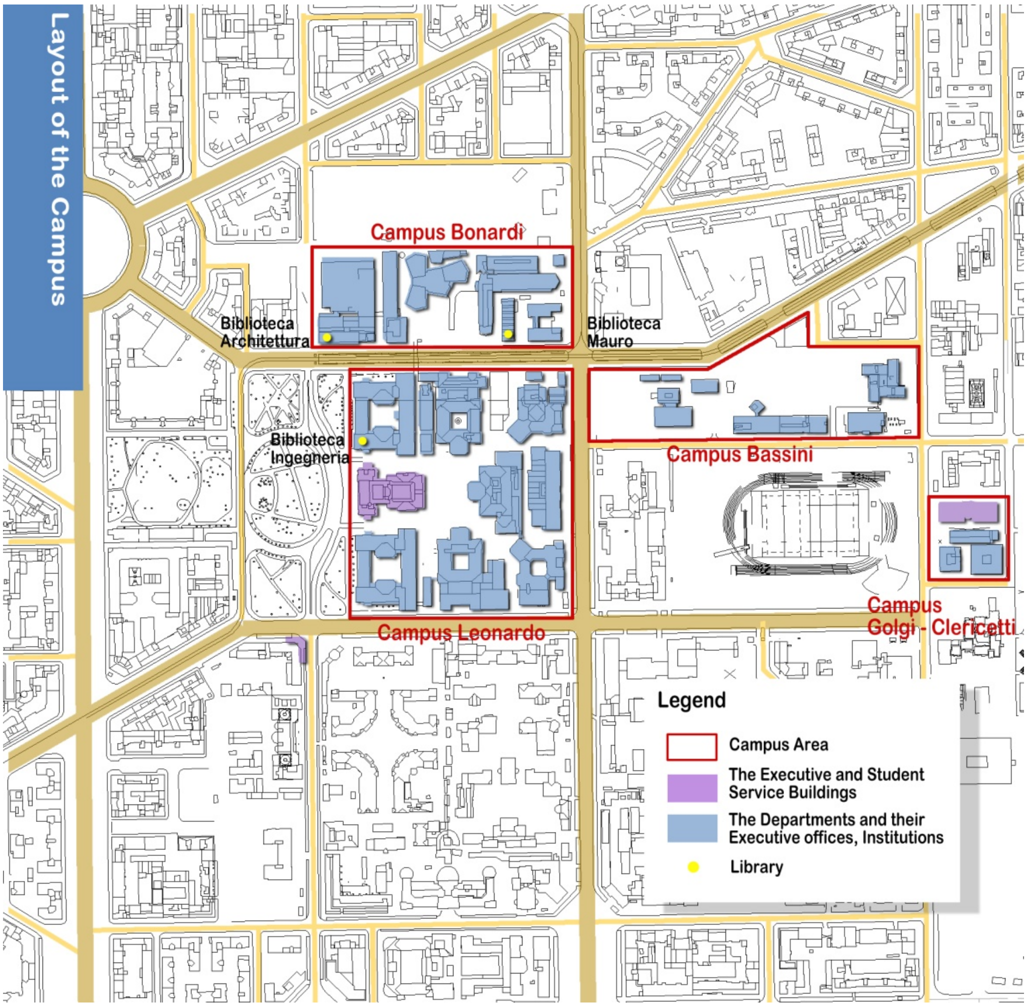


Figure 3- 1: The Layout of the Campus

Together with the campus, other urban functions form the walking environment. I picked out four categories of them: the public open space, the public facilities and student services, the University of Milan and the metro/bus/tram stations. The main public open space that attracts students is Piazza Leonardo Da Vinci, where they could buy (necessary activities) and have (optional activities) their lunch, could have a rest in good weather (optional activities) or could gather to have some events (optional/social activities). The public facilities and student services include the swimming pool, the sport yard and hospital “Carlo Besta” serving for both inhabitants and students, the two student residences, and some commerce along the street where students could buy food or print their documents. From the map below we could find they are almost concentrated around the metro station or at least to the west of the Piazza Leonardo, and it means the trend of student flow will be northwards and westwards. The university of Milan is located on the south of our campus, and the impact of it is that there are lots of their students sharing the pedestrian space and facilities with our students every day. And the strong elements affecting the student flow are the public transport stations, they could be considered as the “origin” of the flow – the place with highest density, so they are definitely the key points of the walking system.

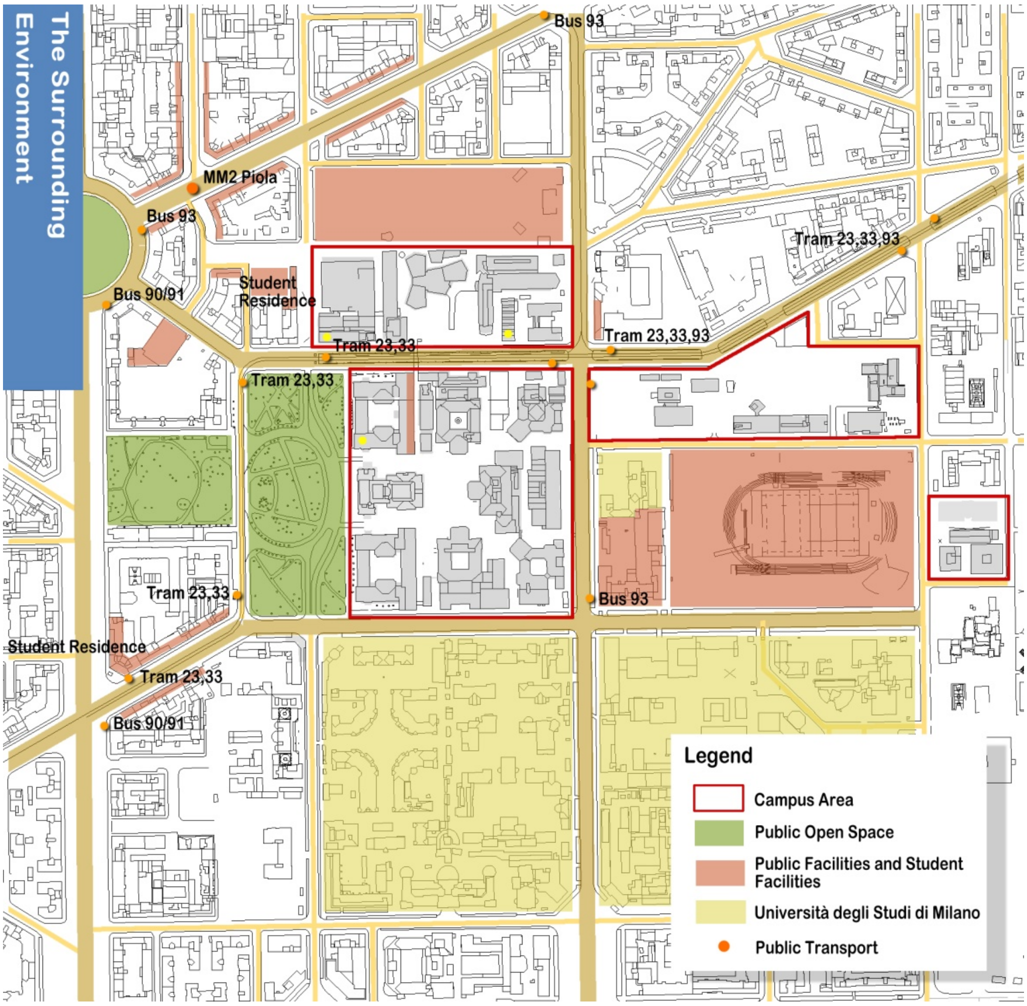


Figure 3- 2: The Surrounding Environments of the Campus

Summing up, the map below constructs the attractive points for the pedestrians: the nearest public transport stations, the departments, Piazza Leonardo and some services. What we need to do is proposing a good connect (high accessibility, safe environment, comfortable density and pleasant view) among them.

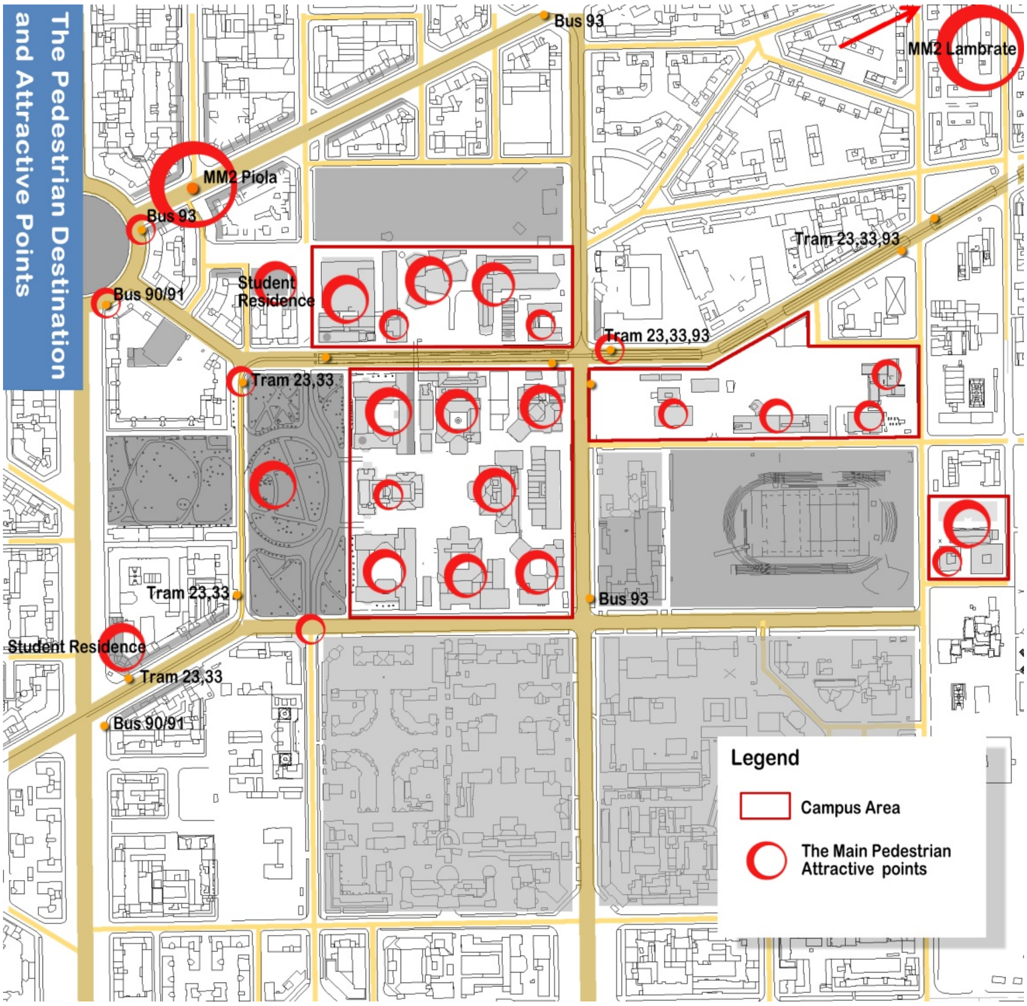


Figure 3- 3: The Pedestrian Destinations and the Attractive Points of Polimi

Knowing the attractive points, we would like to learn the routes that the pedestrians could choose. The map below represents the walking area within the campus. The pedestrian area takes about 28% of the total campus area, but it would be actually lower: this area is shared by vehicles and pedestrians, and some space was taken by parking. Although the speed within the campus will not be high enough to endanger the pedestrians, the pedestrians are the week ones in this condition.

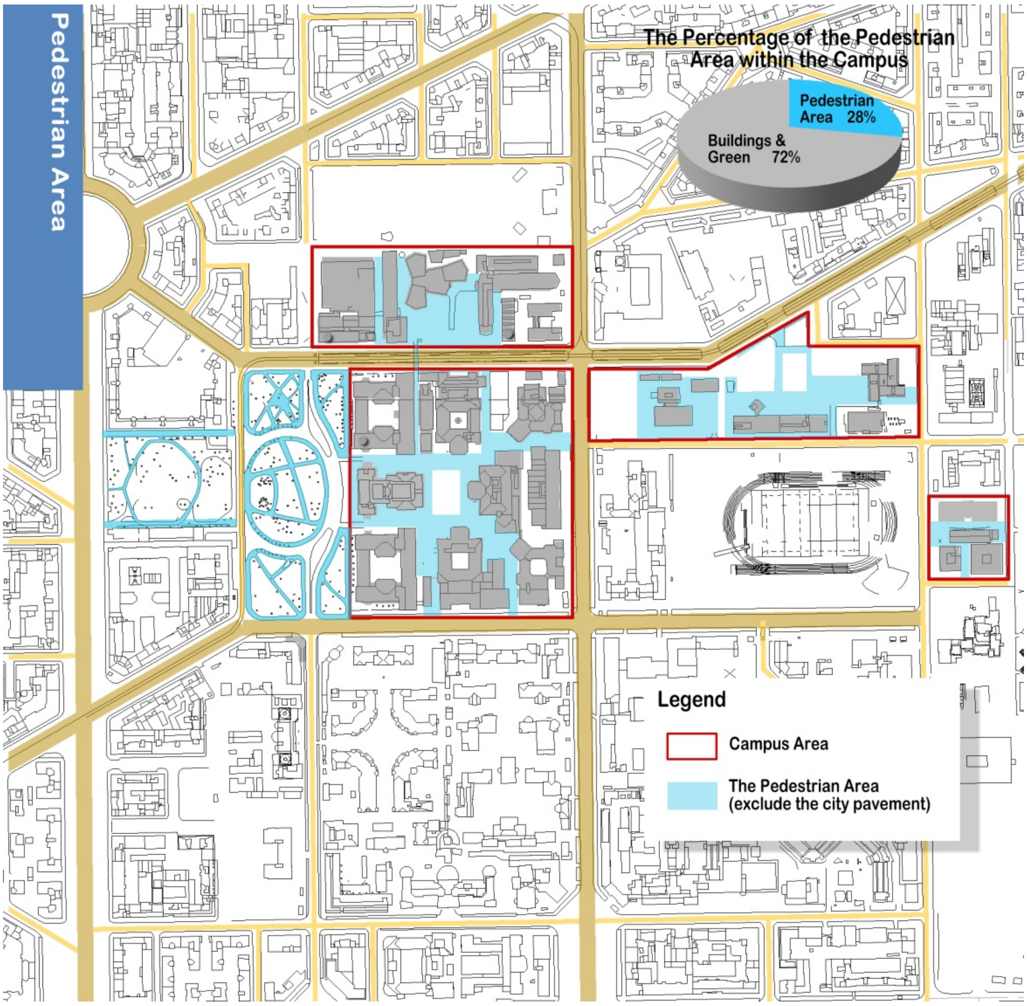


Figure 3- 4: The Map of Pedestrian Area

Figure 3-5 represents the crosswalks around the campus, because they are the critical points in the walking system – where the pedestrian flow would directly have the collisions with the urban vehicles flow. From the map we can find that on every intersection of the main urban road, there is a crosswalk. Some are set with the traffic lights while some are without, except the point with the question mark in the map: it is on the intersection of a main road and a secondary road. Maybe we could explain the absence with the reason that the nearest crosswalk is only 75m away from here, but the high speed in the main road really brings potential dangers to the pedestrians.

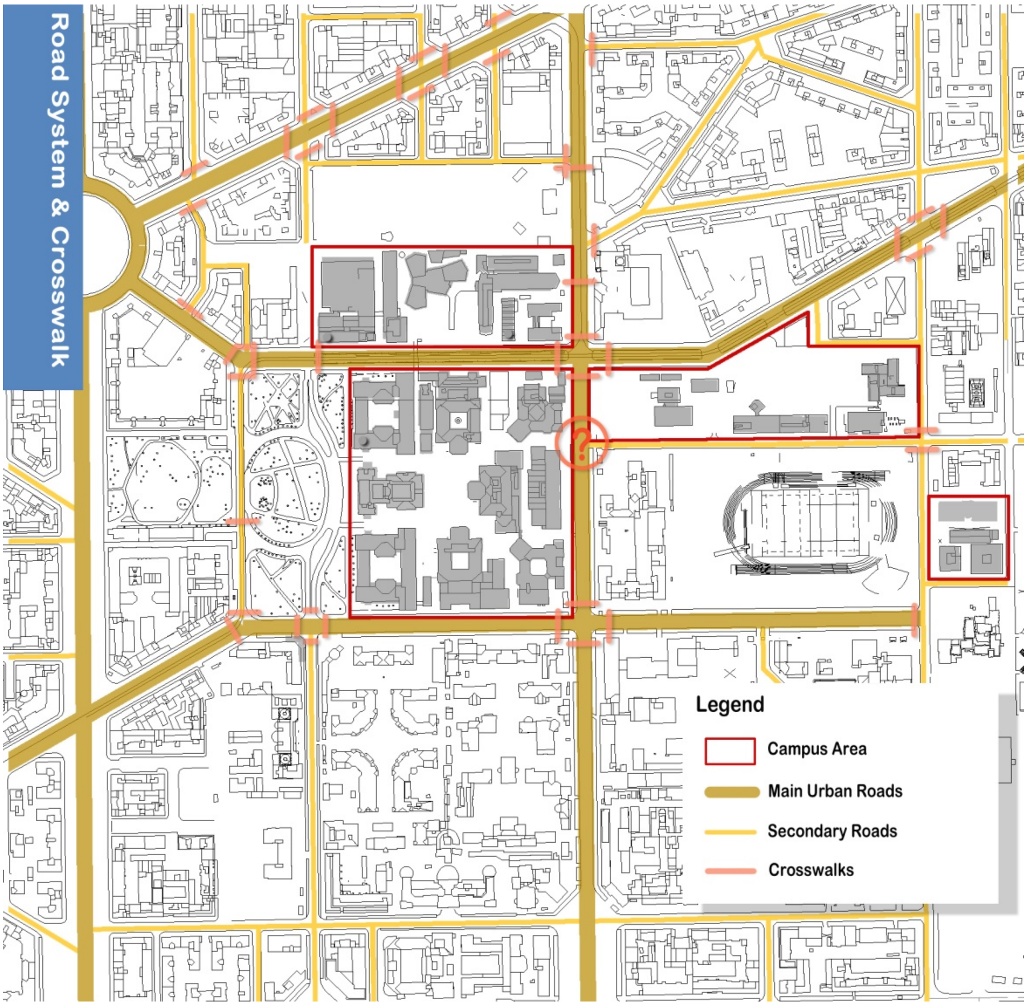


Figure 3- 5: The Road System and the Crosswalks

A research was carried out by Laboratrio Mobilità e trasporti of Politecnico di Milano (2008), studying the accessibility of the campus considering the distribution of the residences. They produced the distribution map of the residences of students and employees (Leonardo campus and Bovisa campus) with the tool of GIS, draw the isochrones of 30 and 60minutes through the use of the public transport, and lastly found out the residences which are one-station away from the campuses, 5km in bicycle or 1km on foot, and the potential users of Politecnico through the use of public transport combined with 0.6km walk or 3km cycling.

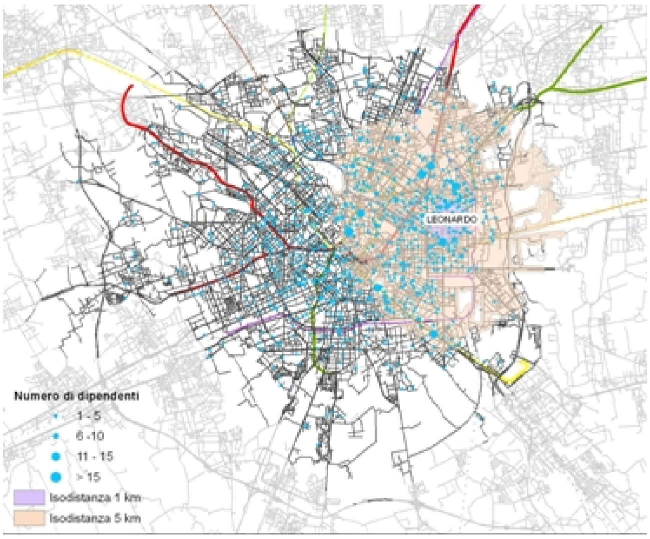


Figure 3- 6: Accessibility of the Campus & the Distribution of the Residences

(Source: Laboratrio Mobilità e trasporti of Politecnico di Milano, 2008)

Referring to the travel means from home to the university, there were two surveys carried out by the Politecnico di Milano, in coordination with Statale, Bicocca, Bocconi University and Catholic in 2006 and 2007. In the one-month survey period of 2007, there were 4500 students who completed the questionnaires on line, which was 13% of the total students. The result showed that the most commonly used transportation from home to university was **metro** for students who live in Milan, while the **train** for students living outside of Milan, and the car was also used as the prevailing mean: 5,5% for suburban students and 4,2% for urban students (Figure 3-7). But when they consider the entire chain of the trip, 41% students who live outside of Milan use the car to make the first part of their route until they arrive the train or metro. The average duration of trip to university was 58 minutes for students to arrive Città Studi, however, the journey time varied depending on the origins and the transportation used (Table 3-1).

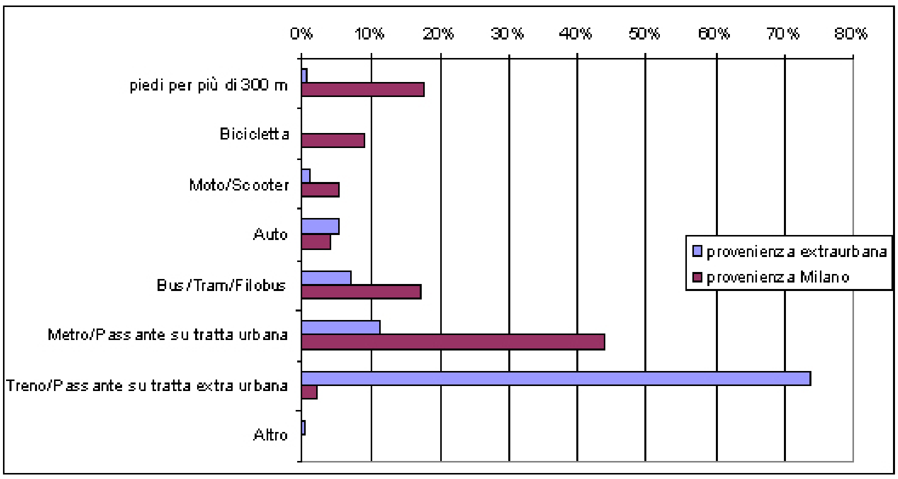


Figure 3- 7: Means of Transportation from Home to University

(source: Mobility Management Group of Politecnico di Milano, 2007)

Table 3- 1: Average Journey Time

Città Studi	Mezzo utilizzato	Durata del viaggio (minuti)
A piedi per più di 300 m	7,4%	16
Bicicletta	3,5%	16
Moto/Scooter	2,3%	23
Auto	4,9%	46
Bus/Tram/Filobus	10,5%	49
Metro/Passante su tratta urbana	21,5%	40
Treno/Passante su tratta extra urbana	49,6%	80
Altro	0,2%	49

(source: Mobility Management Group of Politecnico di Milano, 2007)

In the questionnaire the student could express a qualitative assessment from 1 to 10 on their degree of satisfaction with their journey to and from the universities. The average rating was 5 for suburban students and 6.5 for urban students. The transportations with high satisfaction were motorcycles, cycling and walk, while the one with the lowest satisfaction was the rail.

Table 3- 2: Average Ranting of the Trip to Universities

Mezzo prevalente	Voto
A piedi per più di 300 m	6,70
Bicicletta	7,56
Moto/Scooter	8,01
Auto	6,41
Bus/Tram/Filobus	5,53
Metro/Passante su tratta urbana	5,97
Treno/Passante su tratta extra urbana	4,94
Altro	5,22

(source: Mobility Management Group of Politecnico di Milano, 2007)

And there was also a survey about the travel behaviors of the employees proposed by the Committee for Equal Opportunities of Politecnico di Milano in 2001. Based on 500 available questionnaires, the report pointed out that the total public transportation and the total private transportation were in the majorities of means to work, and these two means together took 85%, while walking was the top of the rest three means. In order to encourage the motorists to switch to a more sustainable mode, the questionnaire explored the expected incentives.

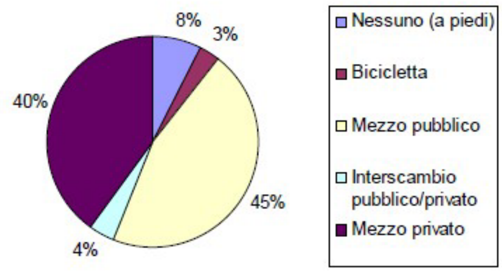


Figure 3- 8: The Means of Transportation to Politecnico di Milano (the average of those who live in Milan and those do not)

(Source: Committee for Equal Opportunities of Politecnico di Milano, 2001)

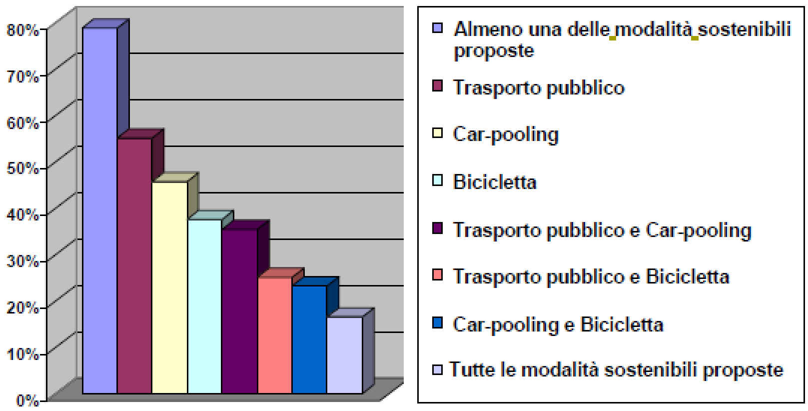


Figure 3- 9: Motorists' willing if switching to a mode with lower environmental impact

(Source: Committee for Equal Opportunities of Politecnico di Milano, 2001)

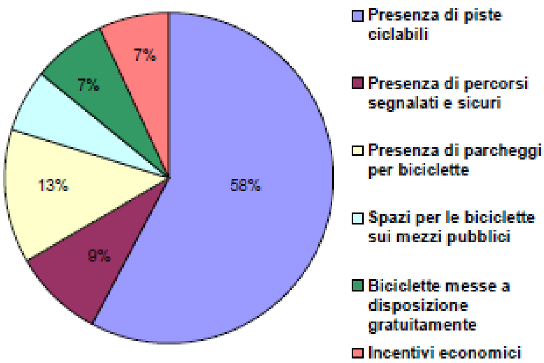


Figure 3- 10: Conditions to which you are willing to leave the use of the car for a bicycle

(Source: Committee for Equal Opportunities of Politecnico di Milano, 2001)

Those surveys release some facts. Although the percentage of walking to school is not high – average 7.4% for the students and average 8% for the employees, if we consider nearly a half of the students and employees are travelling by public transportations and they need to achieve their destinations on foot, it becomes important to create good walking environment from the public transportation stations (metro, bus and train stations) to the departments. The students who are now walking to school hold a good satisfaction with walking and cycling, and it is a very good start point to promote the pedestrian mobility. What's more, reviewing "the conditions to which you are willing to leave the individual use of the car for a bicycle" – the first expectation is creating bicycle lanes, and the second one is providing bicycle parking, we can say that we can also promoting walking by improving a better pedestrian environment.

3.1.2 Define the Important Nodes

Basing on the information above, we have learnt that: the campus is composed by four parts and the transits among them are achieved by crossing two urban main roads – Via Bonardi and Via Ponzio and a secondary road – Via Golgi; the nearby public transport stations, student service facilities, Piazza Leonardo and University of Milan are the main attractive points outside of campus territory; and from the quantity point of view, the walking areas share a good percentage of the total campus area. So I define four nodes to learn details of the pedestrian situation: **they obey the trend of people flow, and they are on the transit surface among the campuses**.

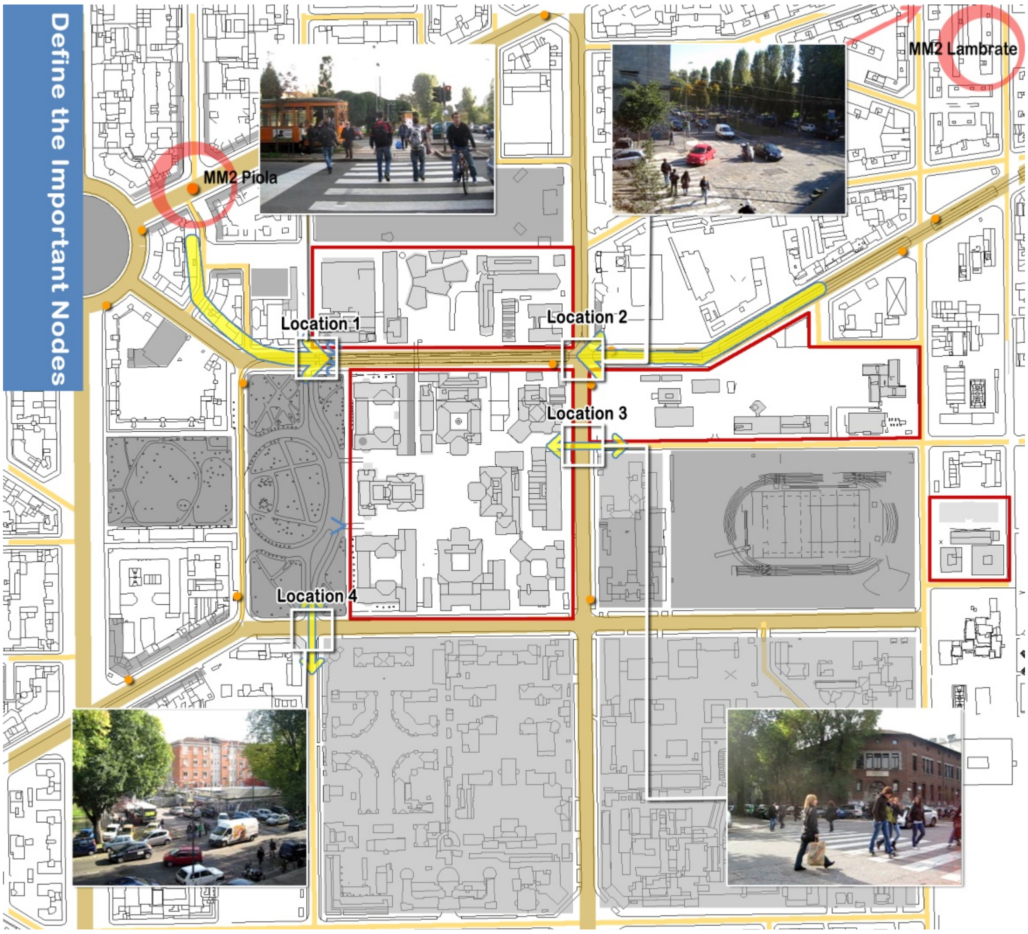


Figure 3- 11: Definition of the Survey Nodes

Location 1 is the crosswalk between the architecture faculty and Piazza Leonardo

– one of the necessary routes between Campus Bonardi/ Metro Station Piola and Campus Leonardo. This crosswalk is divided by the buffer belt of the tram as three parts, and is combined with a tram station. Because every divided parts is short, the illegal cross (cross when the traffic light is red) become a problem of this location. The red lines below represent the vehicle routes, and the yellow ones represent the pedestrian routes (the figures below follow the same legends).

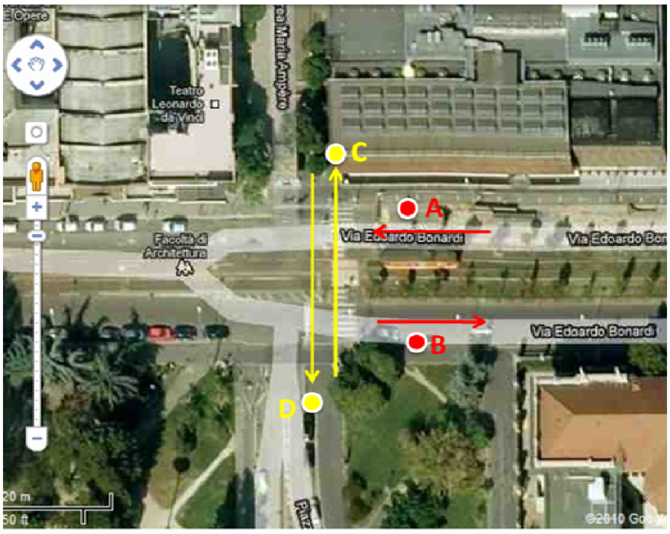


Figure 3- 12: Plan of Location 1

Location 2 is the intersection on the east boundary of Campus Bornardi – one of the necessary routes between Train Station & Metro Station Lambrate and Campus Bornardi & Leonardo. This is a intersection with crosswalk, traffic lights and heavy traffic flow, so the illegal crosses are not so common. But it presents a phenomenon of continue cross: people cross the east-west side, and then cross the north-south side and things like that.

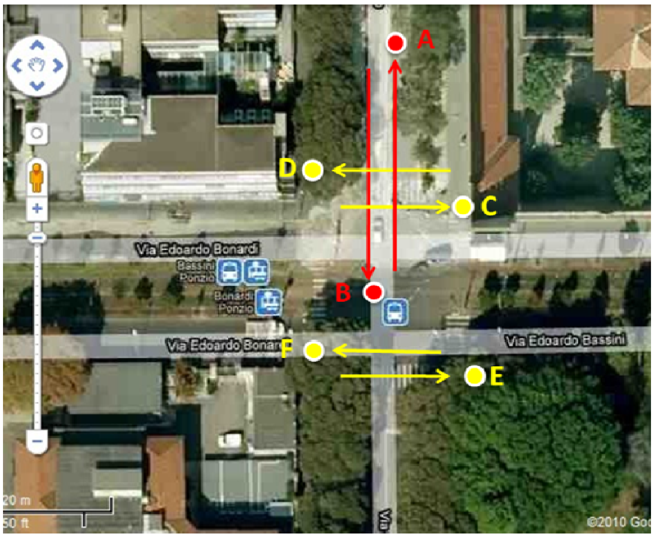


Figure 3- 13: Plan of location 2

Location 3 is a cross place on via Ponzio – the necessary route between Campus

Leonardo and Campus Bassini. This cross place is with neither crosswalk nor traffic lights, but with heavy traffic flow. People always need to find a chance to cross the street in the high speed flow, and it means the safety is not guaranteed.

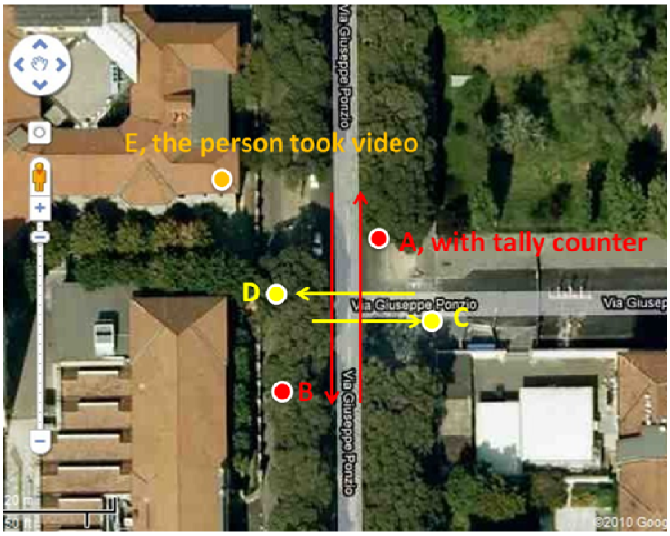


Figure 3- 14: Plan of Location 3

Location 4 is the intersection to the south of Piazza Leonardo – the main path connecting Metro Station Piola and University of Milan, and also the route chosen by some students who walk to school. It is an intersection with crosswalk, but without traffic lights. It has the similar situation with Location 3: a pedestrian need to grab a chance to cross the road. But the difference is: the people flow here is heavier than the one in Location 3, so frequently the vehicle need to stop once or twice.

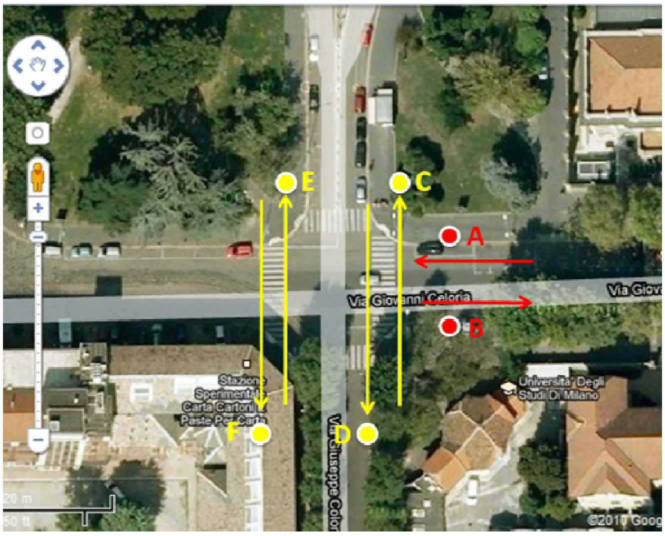


Figure 3- 15: Plan of Location 4

3.2 Survey of the Flow

The flow is a basic element of pedestrian mobility design: it releases when and to where people walk, which means it releases when and where we can act; it is an indicator of walking comfort; and it is also a critical element to support the surrounding services and further influence the feeling of safety and images in motion. So it is meaningful to put the study of flow as the first research subject.

3.2.1 The Methods to measure the flow

As we mentioned above, there are five ways that could actually measure the flows (except the formulae simulation way). And we have carried out an experiment to check the application conditions of the manual way, the video-manual way and the mechanical way on Location 3. There were three students counting the vehicle and people flows manually, one student counting with a tally counter, while the final one taking a video, and counting the flow manually later (see appendix 1). **The experiment revealed that those ways have their own advantages and disadvantages in the aspects of the specific requests we have (application limits or further usage), the assumed flow, the survey duration, expected accuracy, the available human resource and the time for result collation.**

Table 3-3 concludes the characters of all the five ways. Considering the human resource would be taken by the manual way, the equipments requested by the mechanical and digital way, and the assumed flow of our campus, I carried out the further surveys in video-manual way.

Table 3- 3: Comparison of the Five Ways (Take a 15-minute survey as an example)

	Manual way	video-manual way	Mechanical way	Digital way	Real-time way
People needed	4	1	4 (with tally counter) or 0 (with sensitive instruments)	0 (except the people setting the equipments)	0
Equipment needed	A pen & A paper	A tripod & A camera	sensitive instruments	A fixed IP camera & specific software	Real-time information platform
Time request to get the result	15 mins for counting + 1 min for outcome collating	15 mins for video + 1.5 hours for outcome collating	Automatically result collating	Automatically result collating	Automatically result collating
Accuracy	High accuracy with less than 5% deviation, but the accuracy drops when the flow increases.	High accuracy. If be checked again, the data will be exact.	High accuracy with less than 5% deviation, but the accuracy drops when the flow increases.	Accuracy varies among systems and installations	High accuracy
Suitable flow & survey duration	Not be suitable for big flow (below 200) and long duration counting	No limits	No limits	No limits	No limits
Application limits & Further usage	Widest application range, also could get details during the survey	Wide application range, It could lose some details because of the location setting. But we can get information not only of the flow, but also of the time, speed, space distribution etc.	The sensitive instruments are needed to be fix in some specific environment (indoor…) and sometimes it does not recognize the directions of flow, and the usage is only for this purpose	Accuracy varies between systems and It needs technical supports, the further usage is the same as the video-manual way	It is a professorial way which needs a lot of technical supports, and the usage is only for this purpose

3.2.2 Time-flow Distribution

Time-flow distribution maps are used to describe the flow variety during a day in a certain location. We can easily get the information of **the amount**, **the degree of fluctuation**, **the peak hour and low point** from this map, **handle the common flow rules**, and **learn the relationships between flow and flow** in this location.

Figure 3-16 until Figure 3-19 are the timeline based explorations of flow in the four survey nodes during the working hours of a day. I represent the data by two methods: **the diagram way** and **the curve graph way**. The diagrams are very good at showing changing trends – how the peak hours transit to low hours, and the watch-look design implies the idea of circulation of flow for days. They are usually more vivid than the curve graphs. They are produced manually with software auto CAD and Photoshop. While the curve graphs could also represent clear degree of fluctuation and the relationship between flow and flow as the diagram way, but it has an advantage of showing the exact number. And they are produced by software Excel automatically.

Figure 3-16 reflects the flow change from 9:30 to 17:30 in location 1. The red and yellow circles represent **the motorized amounts** (cars, motors and public transportations): the amount of vehicles from west to east (they are on the driveway on the Piazza Leonardo side and be presented by the yellow circle in the figure) are always a little bit less than the amount from east to west (they are on the driveway in front of architecture faculty and be presented by the red circle in the figure). **Their fluctuations** are similar – there are few fluctuation, and the amount of vehicles are very stable in the working hours of a day. The green areas represent the nonmotorized flows (pedestrians and bicycles): **the amount** from south to north (leave the architecture faculty and go to the Piazza direction) are basically more than the ones go from north to south, we can consider the fact as more people leaving the architecture faculty through this crosswalk than arriving, or the fact that this crosswalk is an important path that is used by the architecture students to go to the Piazza or the Campus Leonardo. The south to north flow has two obvious **peak durations**: 12:30 until 13:30, 15:30 until 16:30, while the north to south flow has only one peak hour: 12.30. Interestingly, they reach their peaks at the same time – around 12:30, and the amounts are similar, which means the people exchanges at noon are balance, and 12:30 is the extreme time of this location. In the curve graph, the red line represents the total motorized flow, while the green line represents the nonmotorized flow from both directions. This graph reflects the same fact: the extreme time of nonmotorized movement is around 12:30, the total amount reaches 447, while the lowest point is on 10:30. Since this is a cross place with the control of traffic lights, I do not focus on the time when the people flow curve and vehicles flow curve have a junction.

Comparatively, the vehicles flows in Figure 3-17 are in bigger **amounts**: the area of the circles are bigger, while **the fluctuations** are similarly smooth during the day. The total pedestrians seem less than the ones in location 1 for the whole day, because the total area representing pedestrians in Figure 3-17 is less than the one in

Figure 3-16. The pedestrians flows have obvious **peaks**: flow from west to east have the peaks at 13:30 and 16:30; flow from east to west have peaks at 9:30 and 13:30; again, the overlapping peaks reasoning to the extreme hour at 13:30.

Figure 3-18 shows similar **amount of motorized flow** as Figure 3-17, while the pedestrians amounts are much less: the flow from both direction are basically less than 50 for the whole day, except at their **peak hour** of 12:30, both amounts slightly exceed 50. It is a cross place without traffic lights, so it's useful to check if there is collision hour between vehicle flows and pedestrian flows. From the curve graph, we can see the peak hour of motorized flow is 9:30 and from 14:30 until 17:30, while the low hour is around 13:30; the peak hour of nonmotorized flow is 12:30 and the low hour is 9:30, so we can consider it is an optimize situation: the extreme hours of vehicles and pedestrians stagger each other. Although the pedestrian flows are comparatively less than those in location 1 and 2, this position is important because here is the only exit on the east boundary of the Campus Leonardo. Although the extreme hours do not overlap, the motorized flows are big enough and their speed are high enough to influence the pedestrians' mobility. So the construction of traffic lights or some managements should be considered.

Compared with Figure 3-18, **the amounts of motorized flow** in Figure 3-19 are less, while **the amounts of pedestrian flow** are much bigger. **The fluctuation of motorized flow** is smooth, and the pedestrian flows have their own **peaks**: flow from south to north reaches its peaks at 12:30 and 17:30, while flow from the contrary direction has busy hour at 9:30, 12:30 and 13:30. But the amounts are less the south to north direction (the ones walk towards the Piazza). The same as Location 3, this is a intersection without traffic control, but differently, the big vehicles flow holds up the pedestrians in location 3, while it is the big pedestrian flow here blocking the vehicles.

Concluded, the time-flow distribution study is very helpful for studying the amounts, the fluctuations and the relationships between flow and flow, and for making flexible managements which depend on the time.

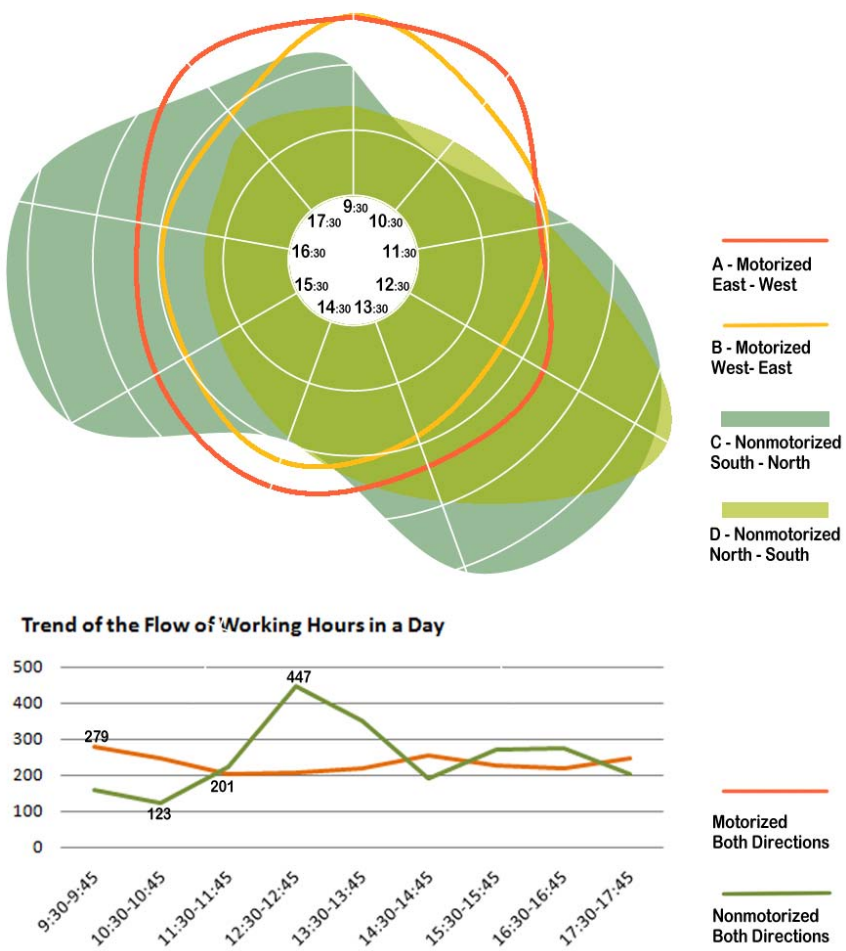


Figure 3- 16: Timeline Based Exploration of Flow in Location 1

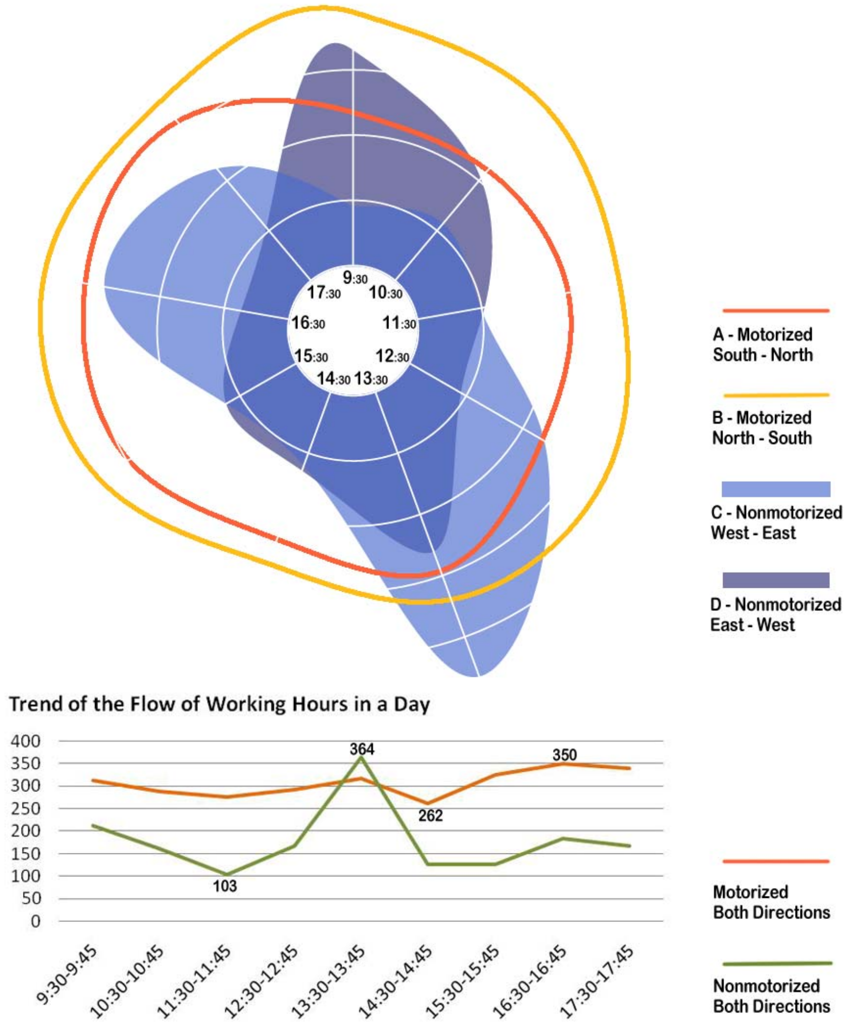


Figure 3- 17: Timeline Based Exploration of Flow in Location 2

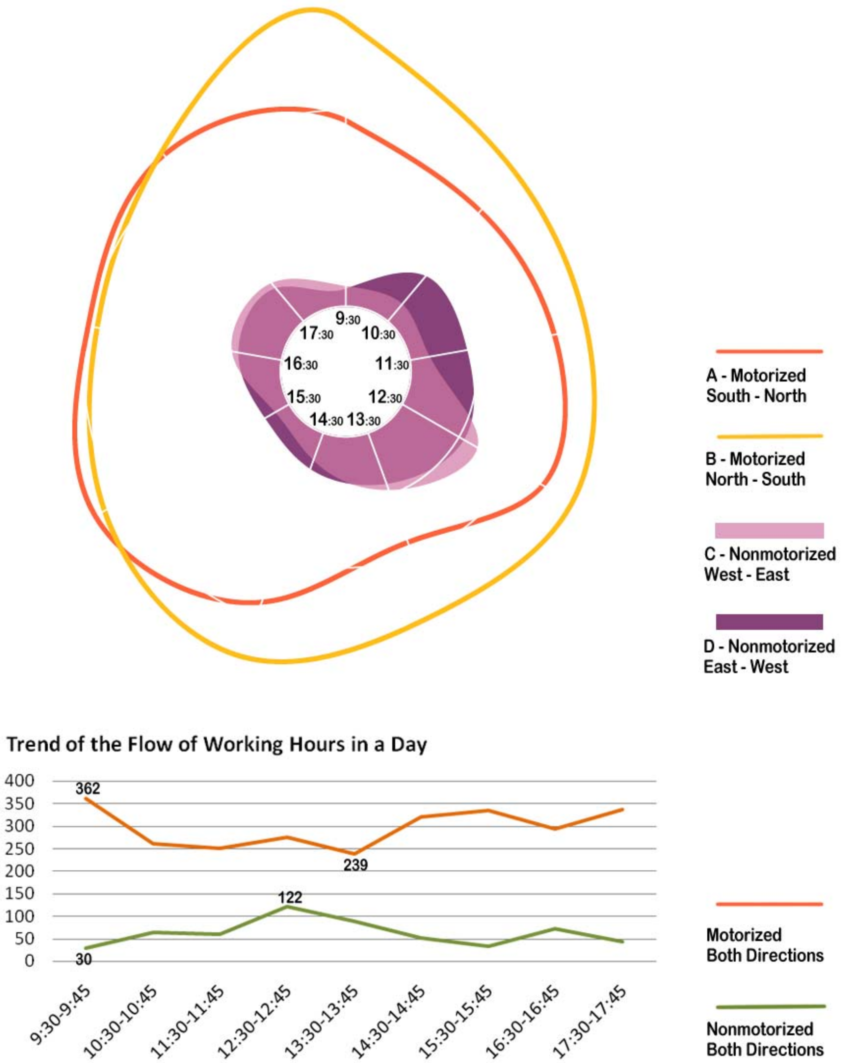


Figure 3- 18: Timeline Based Exploration of Flow in Location 3

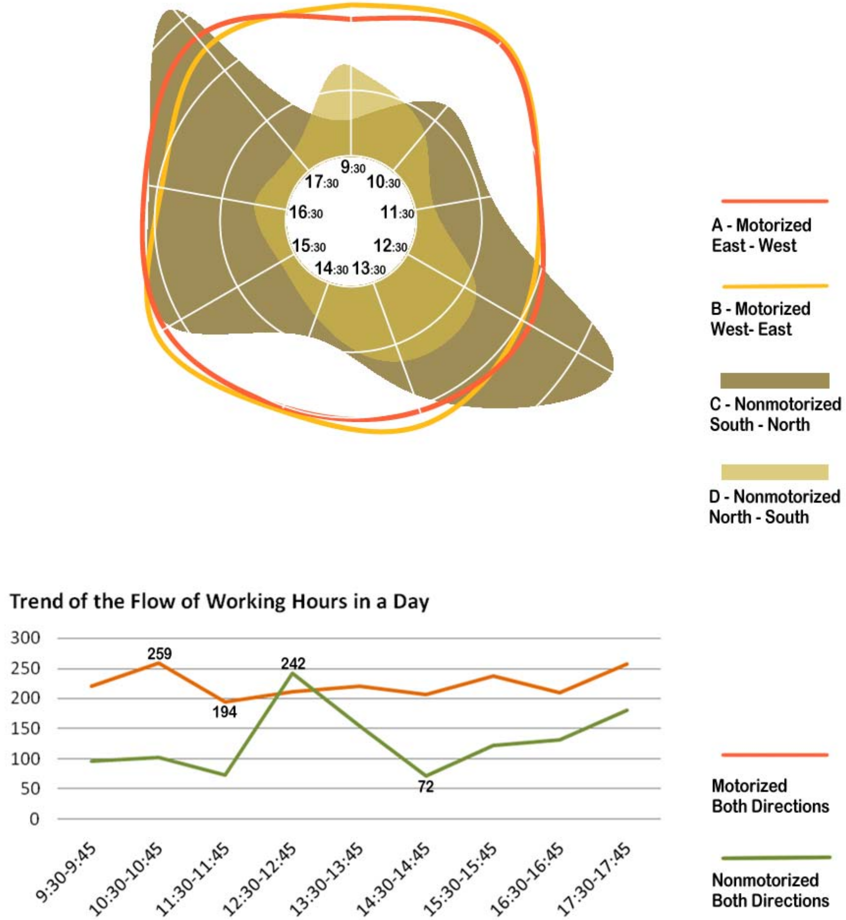


Figure 3- 19: Timeline Based Exploration of Flow in Location 4

3.2.3 Space-flow Distribution and Pulse of the Campus

The space-flow distribution maps are used to describe the amounts of flow in different locations at the same time, and they could help us to find out the "hot points/ area" in our campus. Again I applied two ways to represent the distribution: **the spatial interpolation way** and **"flow-on-road" way**.

GIS is one of the tools to produce a spatial interpolation map. Figure 3-20 is the space-flow distribution map of our campus at about 12:30, it was produced manually, but based on the idea of spatial interpolation. I did some complementary surveys, and collected the 15-minute flow data of 8 locations (make sure that the data is not interconnected). Then I used a circle to represent 80 persons, and assuming bigger amount of flow would spread in bigger area, the background circle in the location with bigger data would be larger. The overlapping result is Figure 3-20, and we can observe the "hot area" is the one within the yellow line. But this method could not differentiate the direction of the flow.

The "flow-on-road" way sources from the idea "Traffic on GoogleMaps". As Figure 3-21 shows, I visualized the survey data basing on the road structure, and we can judge the "hot points" depending on the thickness of the lines. But this way is much more suitable for representing the vehicles flow, which could be linear, while for the pedestrians data, we could only present it on the nodes.

And the pulse map is an extension of the space-flow distribution concept. Figure 3-22 is a series of images showing the vehicle and pedestrian flows in every hour, and the pie charts express the composition of the vehicles – the blue one represents the car, the red one represents the motor, and the green one represents the bus. We can find out the varieties of flows (pedestrians, cars, motors and buses) during a day. At 9:30, the trend of people flow goes into our Campus from two stations, but in location 4, more people go to the direction of University of Milan. At 10:30, the spread of pedestrian is quite equal in the campus. At 11:30, pedestrians start to concentrate around location 1. At 12:30, nearly all locations reach their peak hour, especially the people exchange in location 1 is huge, and also there are big amount of people go in to Piazza Leonardo through Via Colombo. At 13:30, the amounts of pedestrians in each location slightly decrease, except the pedestrians leaving the campus through Via Bassini increase. At 14:30, the amounts in each location continue decreasing correspondingly. At 15:30, there are small peaks of people going into Piazza Leonardo through Via Colombo, people going to architecture faculty direction in location 1 and people leaving the campus through Via Bassini. At 16:30, the major trends to the three directions continue increasing, and the pedestrian exchange in Location 3 increases and equals on the both direction. At 17:30, the two main trends in Via Colombo and Via Bassini continue increasing while the main trend in front of architecture faculty slightly decreases.

Concluded, the space-flow distribution is helpful for us to learn the "hot points" of the territory. And if we make them dynamic, they could illustrate the directional trends of people's moving and the pulse of a day.

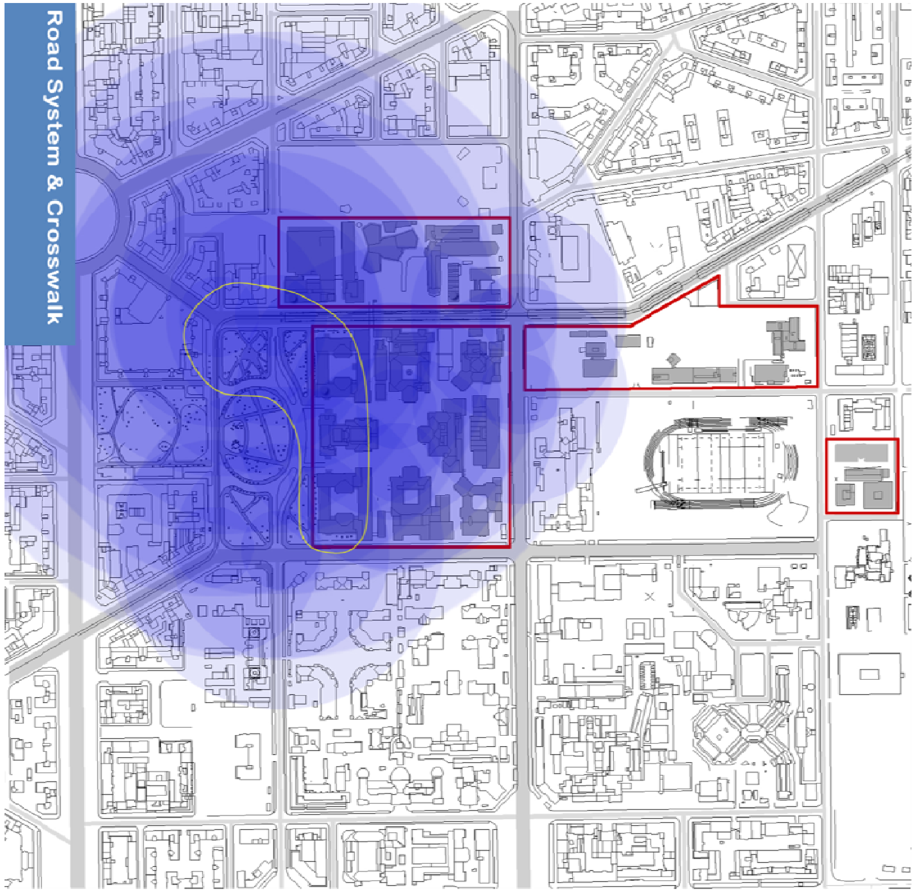


Figure 3- 20: The Space-flow Distribution Based on Spatial Interpolation Concept

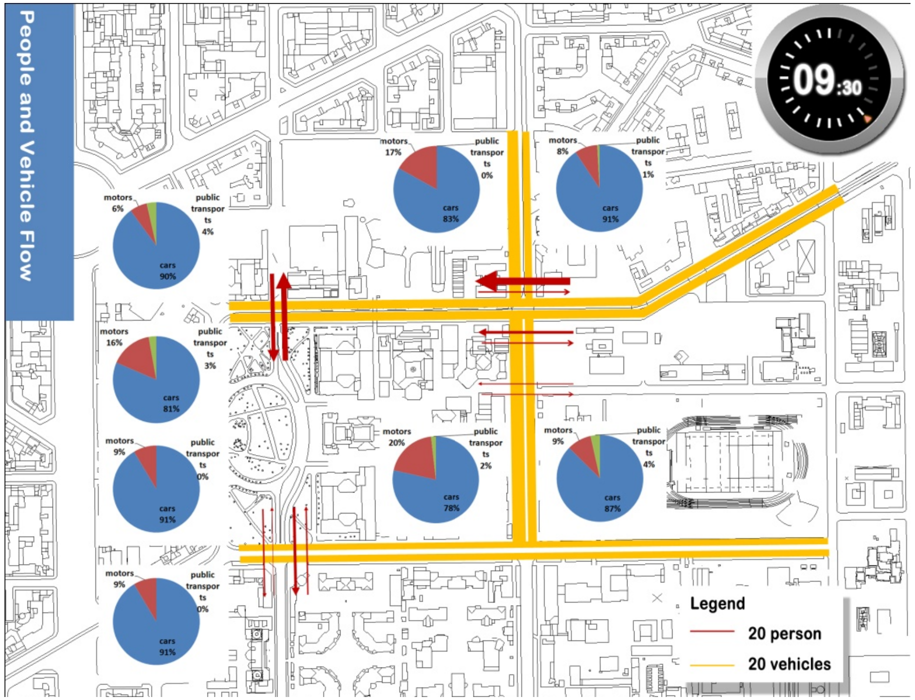
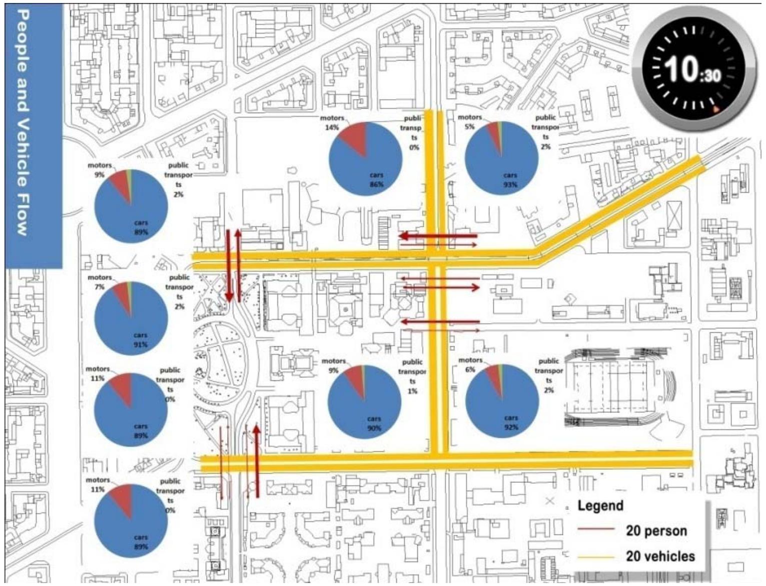
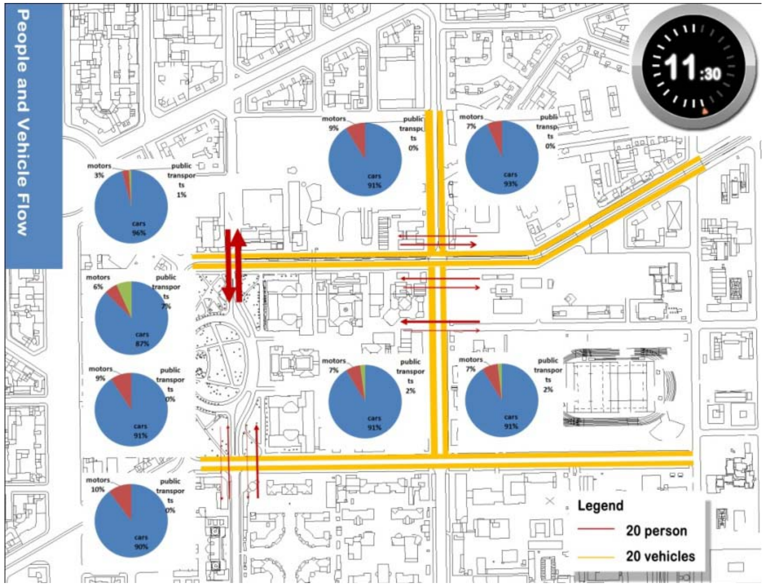
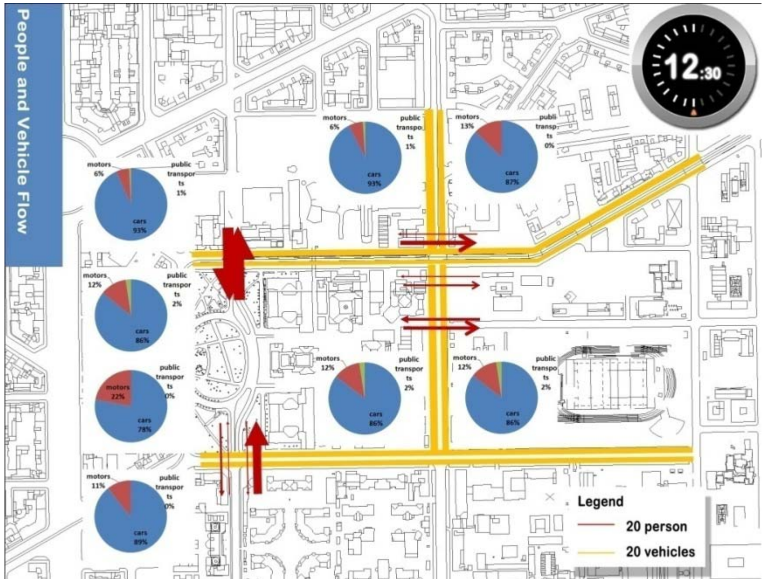


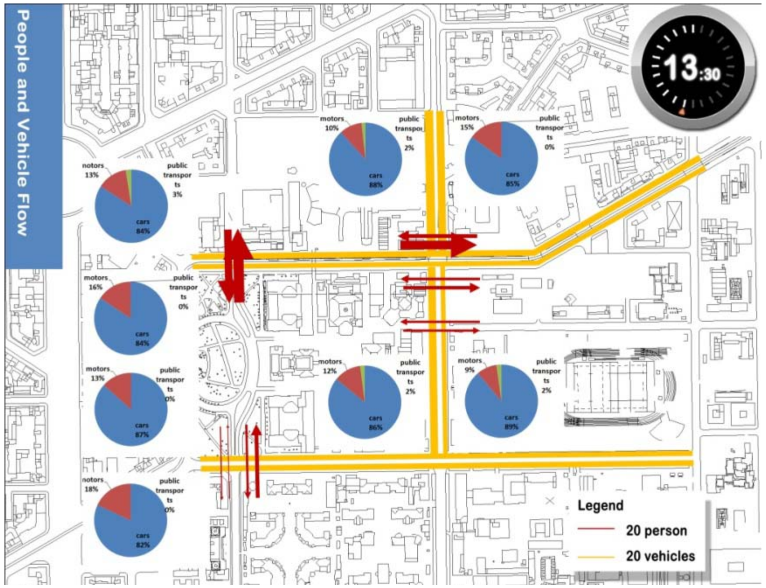
Figure 3- 21: The Space-flow Distribution Based on "Flow-on-road" way

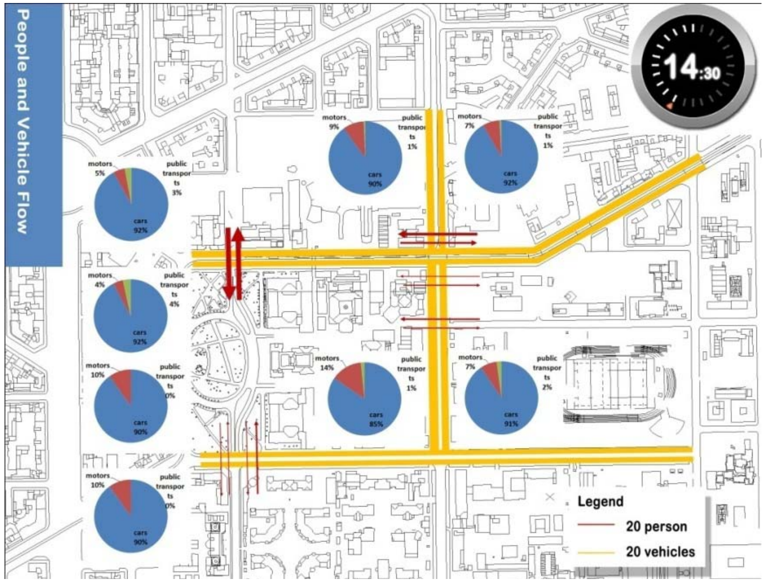
Figure 3- 22: The Pulse of the Campus in Working Hours of a Day


People and Vehicle Flow
10:30
Legend
20 person
20 vehicles

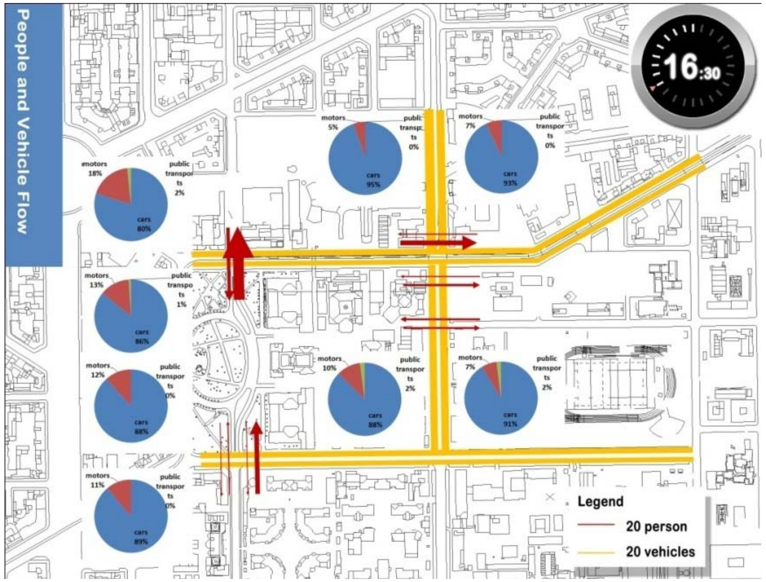

People and Vehicle Flow
11:30
Legend
20 person
20 vehicles

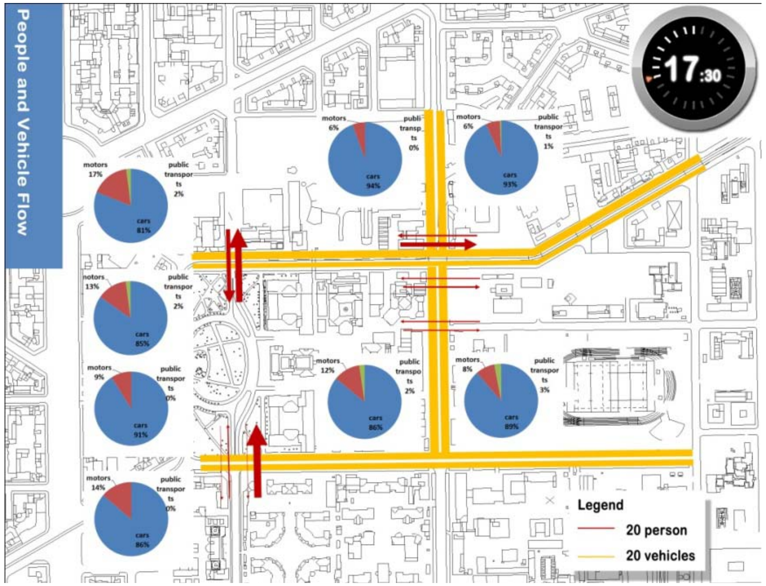

People and Vehicle Flow
12:30
Legend
20 person
20 vehicles


People and Vehicle Flow
13:30
Legend
20 person
20 vehicles


People and Vehicle Flow
14:30
Legend
20 person
20 vehicles


People and Vehicle Flow
15:30
Legend
20 person
20 vehicles


People and Vehicle Flow
16:30
Legend
20 person
20 vehicles


People and Vehicle Flow
17:30
Legend
20 person
20 vehicles

3.2.4 Attraction-Flow Map

The attraction-flow map has a similar nature with the space-flow distribution map, because they both represent flows on route system: in Figure 3-21, the vehicle flows are represented on road structure, while in Figure 3-23, the pedestrian flows are represented on pedestrian system. But consider with the attractive points, the pedestrian flow map becomes more specific: the space-flow distribution maps illustrate the "hot points" or the direction trend, while **the pedestrian flow map illustrate which routes are more commonly chosen between the same origin and destination, and how flows spread and gather together**.

In Figure 3-23, the biggest origin is Metro Station Piola, and the pedestrians spread through three routes. Then one of the streams meets with the flow from Via Spinoza and from Via Bonardi, and together form two agglomerative points in the intersections of Via Spinoza and Via Bonardi and in front of architecture faculty. After that, the flows spread again into the Piazza Leonardo and the different faculties. In front of the gate on the right side of the "Rettorato Building", there is a small agglomeration, except that, there are not obviously gathering.

About the routes chosen between the same origin and destination, we observe that when people arrived the north-west corner of Piazza Leonardo, they use to cross athwart the Piazza, but do not choose the vertical or horizontal way; in front of the "Rettorato Building", people use to take the gate which is more near to Via Bonardi; and the flow on the branch of Via Ponzio is not less than the flow on the main urban road – Via Bassini.

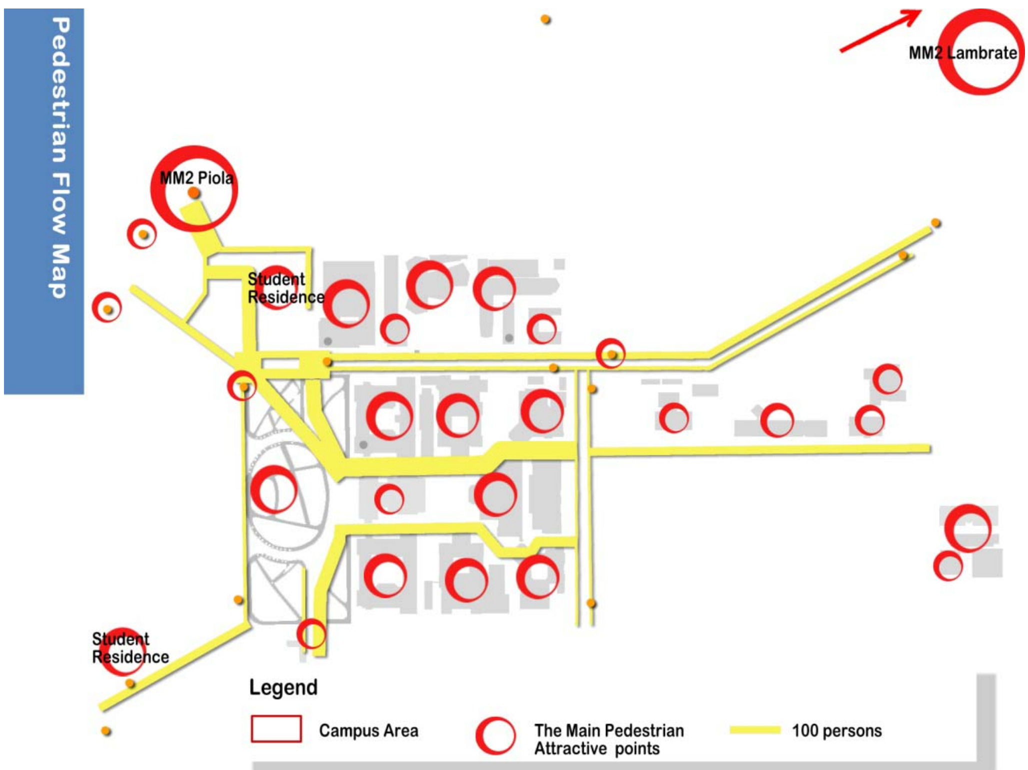


Figure 3- 23: Attraction-Flow Map at about 12:30

As the spatial interpolation way, survey data on four nodes is not enough to produce a pedestrian flow map. So complementary surveys were carried out on the other 7 locations (Figure 3-24). The surveys cover six days (each day at around 12:30, I survey 1 or 2 locations). Although the difference is less than 20% in different days, you can consider it is a map providing just a glance. On the other hand, in order to reach higher accuracy and more efficiency, it is better to use mechanical, digital or real-time approaches.

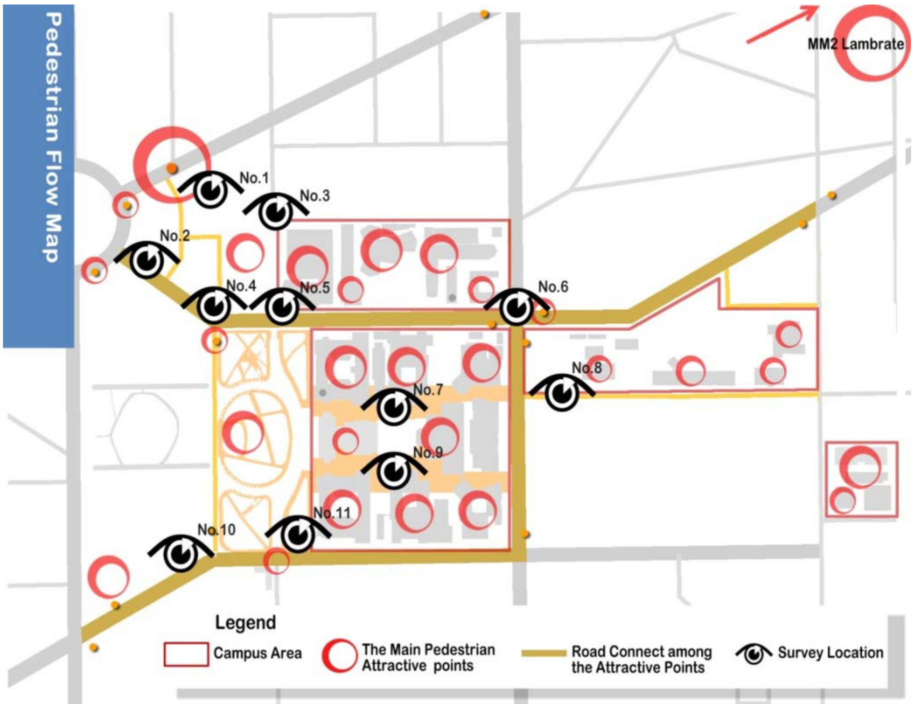


Figure 3- 24: 11 Survey points of Attraction-Flow Map

Figure 3- 25: Photos of the 11 Survey Points

3.3 Study of the Traces and Density

The traces and density study links directly people's behaviors with the space, and helps us understand how people use the space during a period of time. Here I applied three approaches to study it: the mail tool is "stacking for trails", and the complementary ways are "photos for traces" and "time-lapse".

3.3.1 Stacking for Trails

It is a tool to illustrate the traces (distribution) of people' and vehicles' moving during a period of time by overlapping the frames captured from a video every 2 seconds, and the application software is Photoshop. But in my application of it, I found some conditions that should be obeyed, so as to get an optimal result.

The first one is that the researchers should have a top enough position to have a plan view of our space. Figure 3-26 & 3-27 are the stacking results of the same location from different positions, and neither of them is good enough to represent the pedestrians' traces. Because there is perspective in Figure 3-26, we differentiate the pedestrian flow and traces from the vehicle flow, even through the amount of pedestrians are bigger than the amount of vehicles. Figure 3-27 stacks the sectional views of the same location, and from this image, we can only tell the density (the density in red circle is higher than other parts, which means it is a critical point).

Figure 3- 26: Stacking for Trails in Location 1 (A)

Figure 3- 27: Stacking for Trails in Location 1 (B)

The second condition is a dark background. It relates with the nature of this tool: if one frame has lighter color than another, the lighter color will be kept and the dark color will be deleted. As showed in Figure 3-28, the background is the crosswalk and it is in white color, so the traces are not kept. And if we modify the nature of the tool – the darker frames are kept, the result is Figure 3-29. Although we can not exactly tell the pedestrian traces, we can say that the pedestrians distribute homogeneously: there is no space with extremely density while others without.

Figure 3- 28: Stacking for Trails in the intersection of Via Spinoza & Via Bonardi (A)

Figure 3- 29: Stacking for Trails in the intersection of Via Spinoza & Via Bonardi (B)

Figure 3-30, 3-31 & 3-32 are the stacking images of Location 2,3,4. The stacks of vehicle flows work well, but the stacks of pedestrian flows are not so perfect. Figure 3-30 has the same weakness with Figure 3-28, but the stack in the yellow circle somehow represents the amount of pedestrians. In Figure 3-31, the amount of pedestrians are not big enough to be obviously stacked or they are covered by the heavy vehicle flow. Figure 3-32 recalls the disordered situation in Location to us: there is no clear traces of vehicles, because they stop, go ahead and turn, and mix with the pedestrian flow. In a word, the tool "stacking for trails" could be useful in the condition of a top view and a dark background, and it could help us at least grab the general situation of a space.

Figure 3- 30: Stacking for Trails in Location 2

Figure 3- 31: Stacking for Trails in Location 3

Figure 3- 32: Stacking for Trails in Location 4

3.3.2 Photos for Tracess

Since the “stacking for trails” way could not clearly describe pedestrians traces, I use photos to illustrate it. As I observe, there are two situations in which people will go beyond design area of the crosswalk.

Figure 3-33, 3-34 & 3-35 show the first situation: if there are destinations on the other side of the crosswalk, people use to take the "quick routes", but not follow the crosswalk. In Figure 3-33, a lot of people walk directly towards the entrance of the nearby building on the driveway; in Figure 3-34, some people walk athwart from the engineering building to the greenbelt; in Figure 3-35, people walk directly to the bus stop on the right and the commerce on the left. Realizing this fact, designers have two kinds of choices: do not put the attractive points horizontal with the end of the crosswalk, or put signals to remind the drivers to watch out for those people.

The other situation is showed in Figure 3-36 and 3-37: people need to make detours to avoid the cars on their way. It is a typical phenomenon in the cross place without traffic control. In this case, if the amount of vehicles is big enough as Location 3 or the amount of pedestrians is big enough to make this phenomenon very common, the measures should be made.

Figure 3- 33: Traces in an intersection

Figure 3- 34: Traces in Location 1

Figure 3- 35: Traces in Location 2

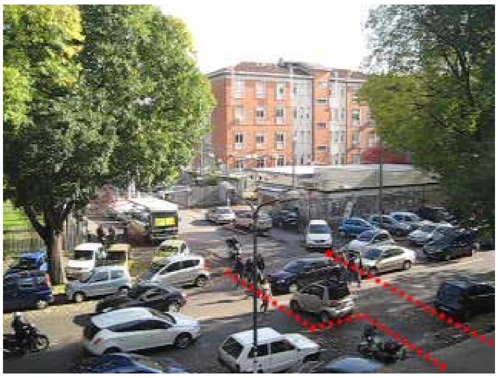


Figure 3- 36: Traces in Location 3

Figure 3- 37: Traces in Location 4

3.3.3 Time-lapse

As mentioned in Chapter 2, the time-lapse is a dynamic presentation that shows slow changes in a short time. It does not overlap frames, so it overcomes the disadvantage of mixing the different tracess together. In my case, I use it to **replay the busy scene of a crosswalk, represent the trend dynamically and give the audiences the impression of the tracess**. The result in GIF format will be attached. There are specific photography to produce it, but I made it with the software of Photo. There was research studying the pedestrians' density and distribution with time-lapse combining GIS (refer to 2.2.2), and it could be seen as the further step of my study.

3.4 The Accessibility

In analyzing the pedestrian accessibility of our campus, the main concept/tool applied is "Ped-shed". It shows the comparison of how far you can actually reach by walking 400m (5 minutes)/ 800m (10 minutes) within the current street network with the theoretical 400m/ 800m accessible area from your destination. The software utilized are Auto ACD and Photoshop. In this section, I apply this tool with two logics: **external – which part of the campus is within 400m / 800m metro service,** and **internal – which part of the campus is with negative accessibility.**

3.4.1 Campus Area within 400m/ 800m Metro Service

There are two metro station near our campus. Figure 3-38 shows the accessible area by walking 400m/ 800m from metro station Piola, and Figure 3-39 shows the situation of metro station Lambrate (the 800m accessible area in both images are not completed because they are out of our study territory). Overlapping the two images, we can get the result: **16% of the campus area is within 400m metro service –a piece of north-west part of the our campus; and 94% of the campus area is within 800m metro service – only Campus Golgi-Clericetti is out of it**.

There could be two ideas to improve the accessibility: enlarging the 400m/ 800m walking accessible area or providing assisting travel means. And **there are two main factors influencing the accessible area – the road fabric and the fences.** The oblique or curvilinear road add the walking distance, and also the fences make people detour. We can find cases in Piola situation and Lambrate situation respectively. As Figure 3-41 shows, if we follow the urban road fabric, the distance is 1070m, and if we take another route going through the campus and which seems more directly to our destination, the distance is 970m – **the vertical and grid road structure provide more accessibility**. As Figure 3-42 shows, if there is no fence, it would be 464m from our origin to the destination, but it is actually 800m with the fence. So the measures would be: cutting down some fences, adding some paths to minimize the impacts of not grid road network, or providing assisting travel means for Campus Golgi-Clericetti.

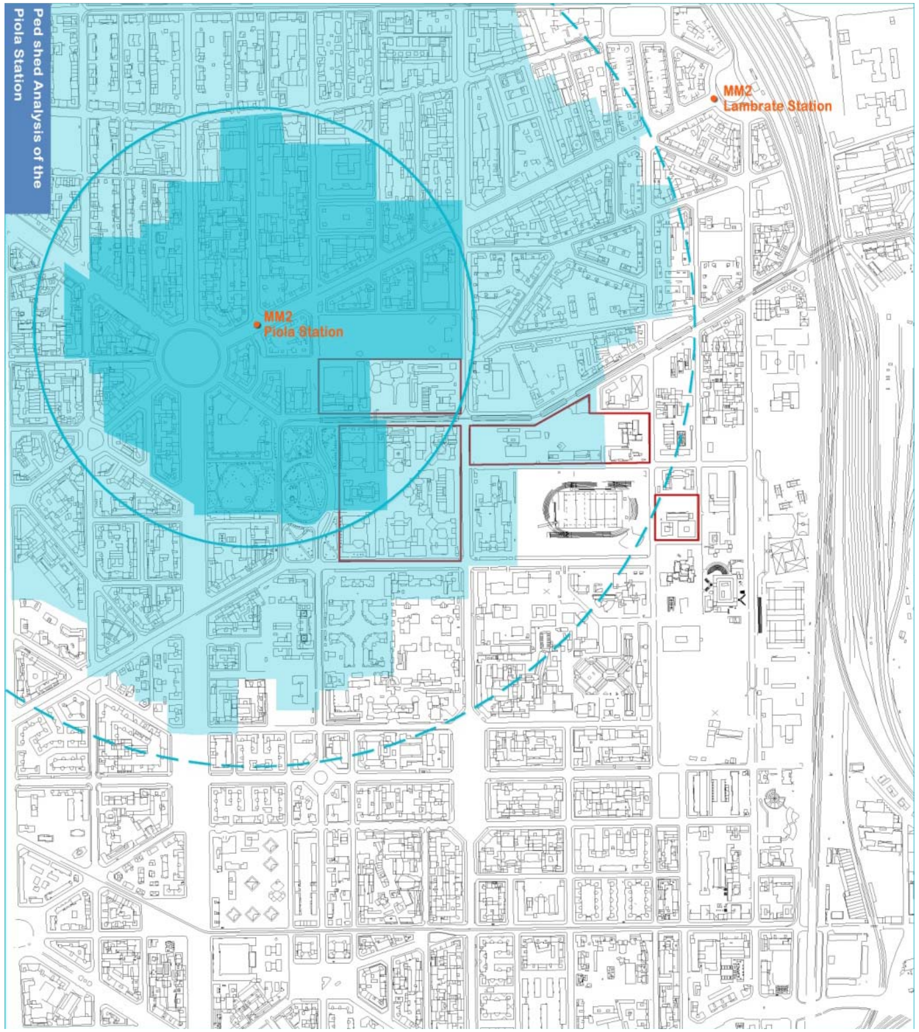


Figure 3- 38: Ped-shed Image of Metro Station Piola

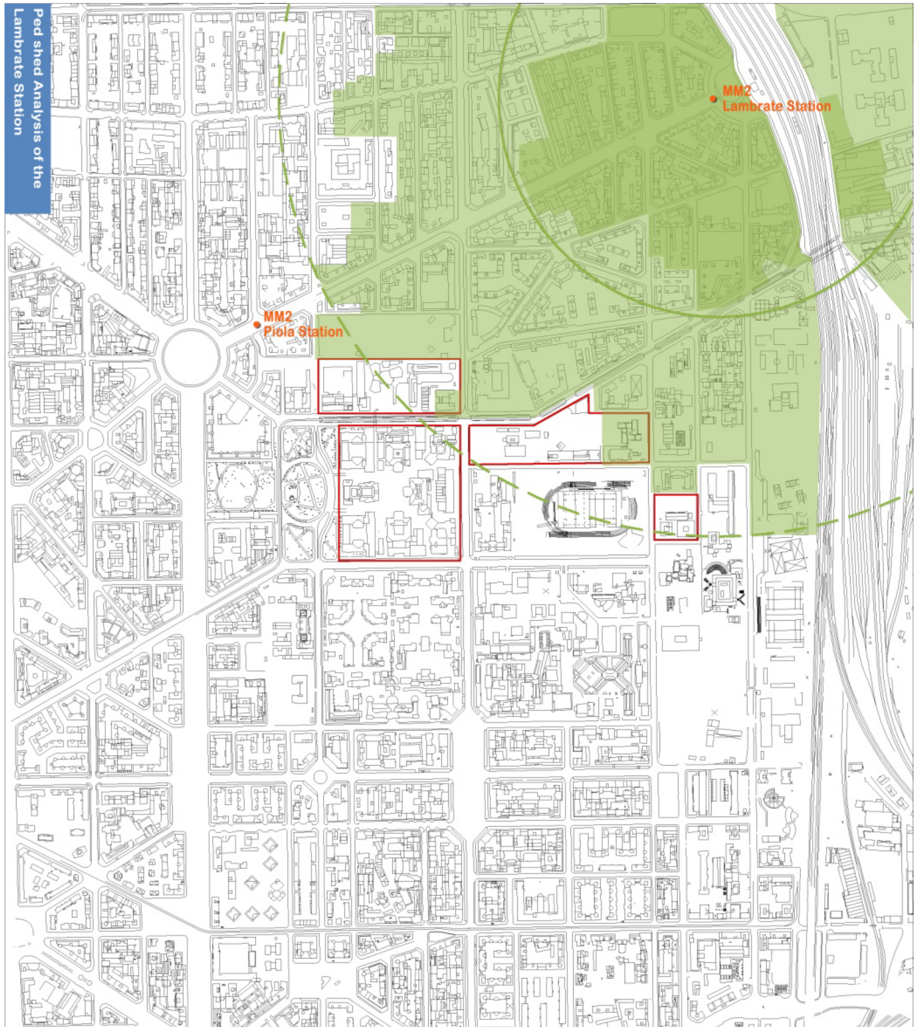


Figure 3- 39: Ped-shed Image of Metro Station Lambrate

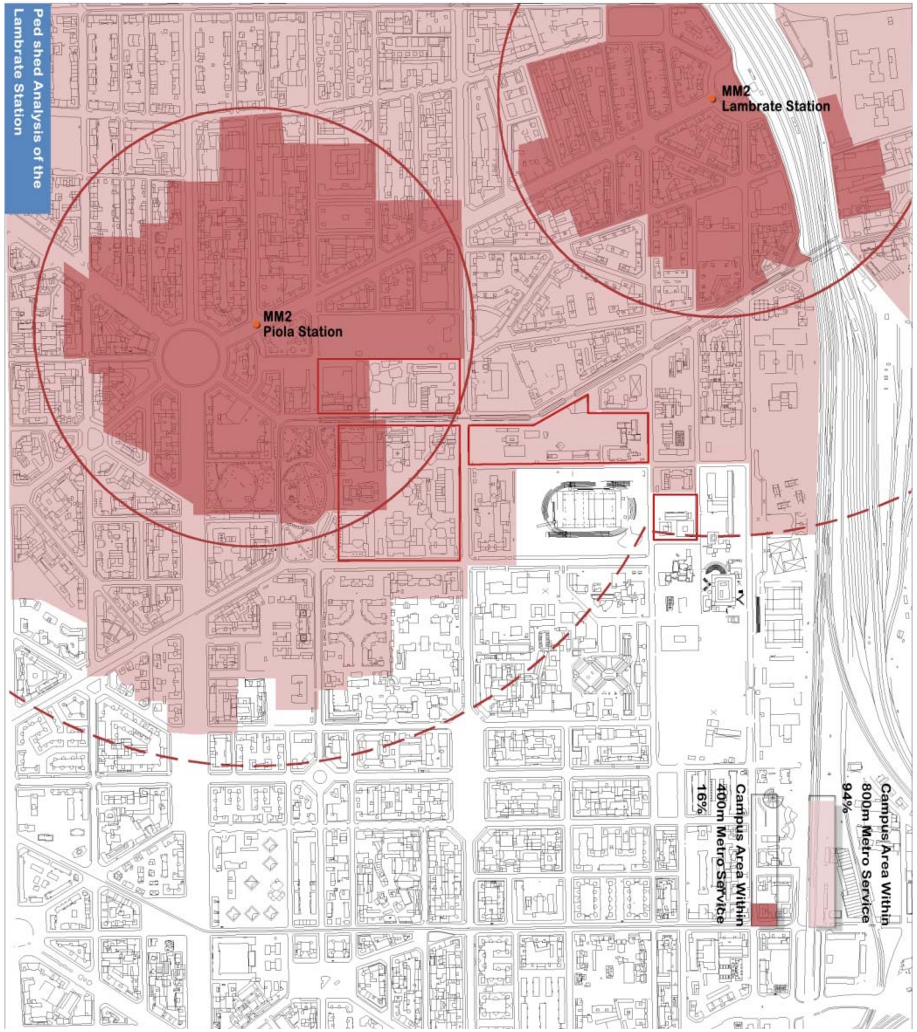


Figure 3- 40: Campus Area within 400m / 800m Metro Service

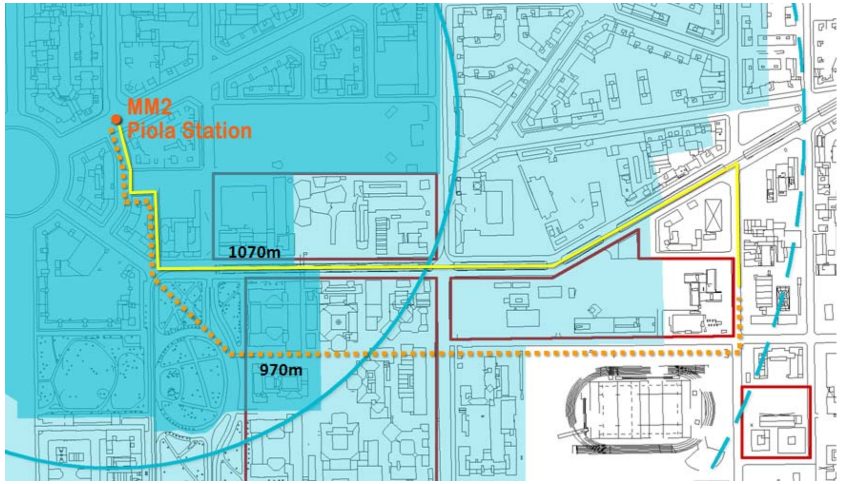


Figure 3- 41: The Road Fabric as a Factor Impacting Accessibility

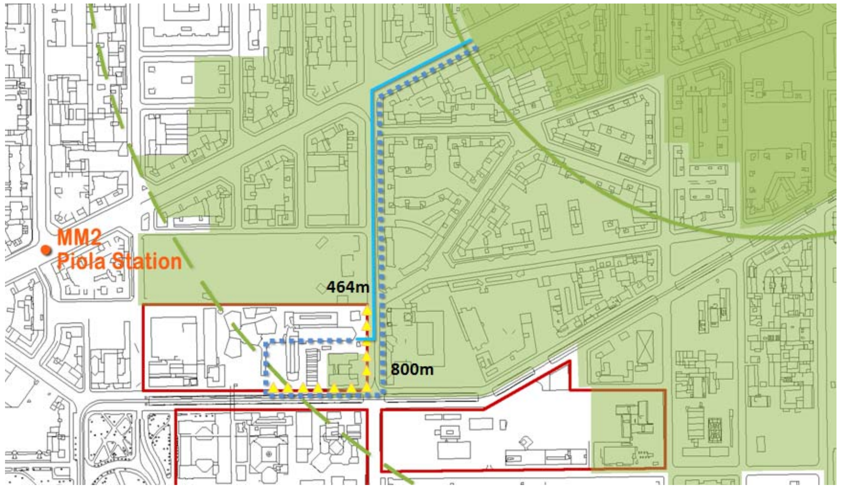


Figure 3- 42: The Fence as a Factor Impacting Accessibility

3.4.2 Campus Area with Negative Accessibility

Figure 3-43 is an experimental study of how far we can reach by walking 400m/ 800m if we depart from the central of "Rettorato" Building: **66% of the 400m walking theoretical area is accessible, and 67% of the 800m walking theoretical area is accessible** (although part of the 800m walking theoretical area is out of our research area, the actual accessible area is ended up by the research boundary). Actually it is not a bad result, because the Piazza Leonardo somehow decreases the impacts of the road fabric (you can choose the shortest way in an open space); and the roads near our study point are basically symmetrical, that decreases the impacts of the fences. So I change my logic, and want to find out which part of the campus is with negative accessibility based on the study of the fences and the entrances.

Figure 3-44 are the images of fences around our campus, and there is also a kind of fence needed to be noticed: as the 4th image shows, the high differences go backwards the accessibility as virtual fences. More concretely, Figure 3-45 figures out the positions of the entrances and the walls. The blue lines represents the gates on the south side of Campus Leonardo, which are not used even during the working hours, and Figure 3-46 are images of them.

If we calculate the proportion of the length of the entrances and the fences, we can get the table below. **The proportion would be an indicator to describe the accessibility.** Assuming each gate is similar in width, in Campus Golgi-Clericetti there are 10.8m fence corresponding to per meter entrance, therefore it means there will be more paths available, and the accessibility will be bigger. While in Campus Bassini, there are 15.4m fence corresponding to pre meter entrance. People need to make detours to reach the departments especially from its north side, and this situation decreases the accessibility.

After being aware of all the fences and entrances, I start with the finding of the area with negative accessibility (Figure 3-47, 3-48, 3-49). Firstly I abstract the entrance & the main foot paths. And then I applied a grid and give a node in the central of each frame, so as to calculate the move. Lastly I evaluate how many steps are needed if we depart from each frame (manually), as the legend shows, if the steps needed are within 3, I color the frame green, and if they are from 4-7, I color it yellow, 8-11 steps is orange, 12-15 steps is red, 16-19 steps is purple and 20-23 is grey. Each frame is 14m * 14m, it means the farthest position access to the entrances is about 300m. I name this method as "Steps to the entrance". **With this method, I get the analytical image to illustrate the area with low accessibility: they are the north-east part of Campus Bonardi, the south-east part of Campus Leonardo and the north-west part of Campus Bassini.**

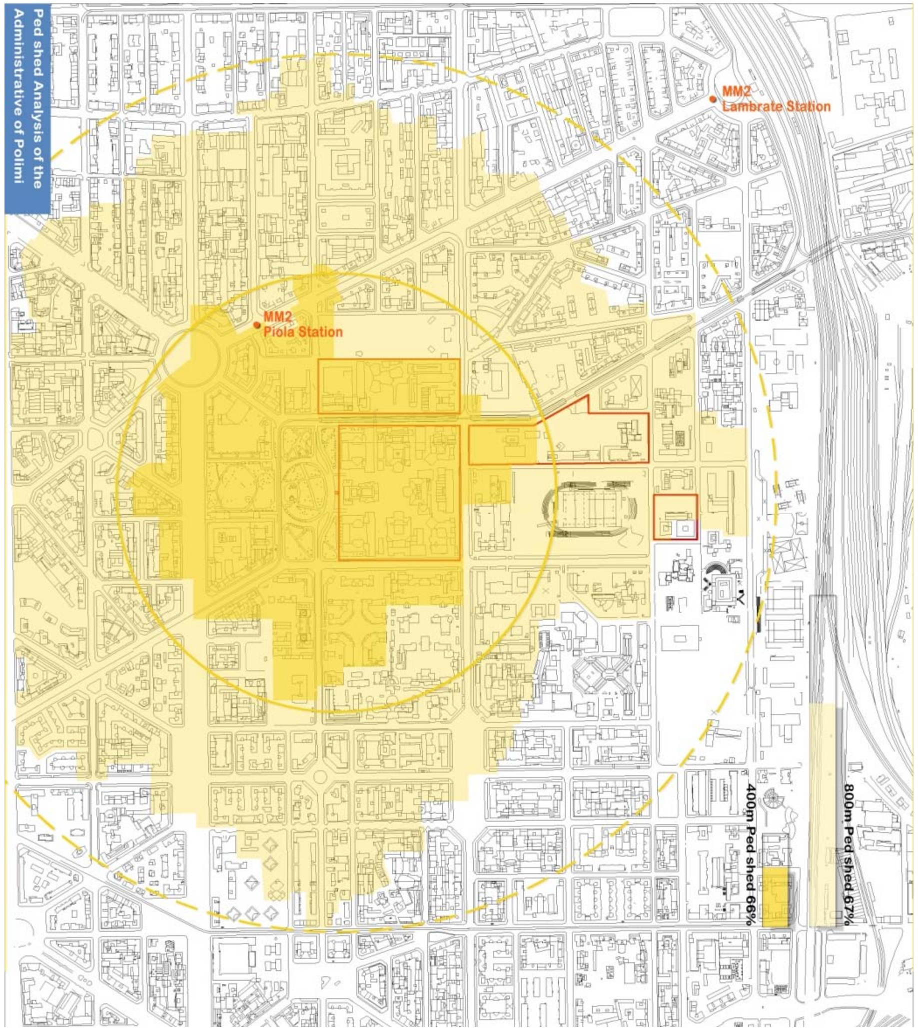


Figure 3- 43: Accessible Area if Departing from our Campus

Figure 3- 44: Images of the Fences (correspond to the number 1-9 in Figure 3-45)

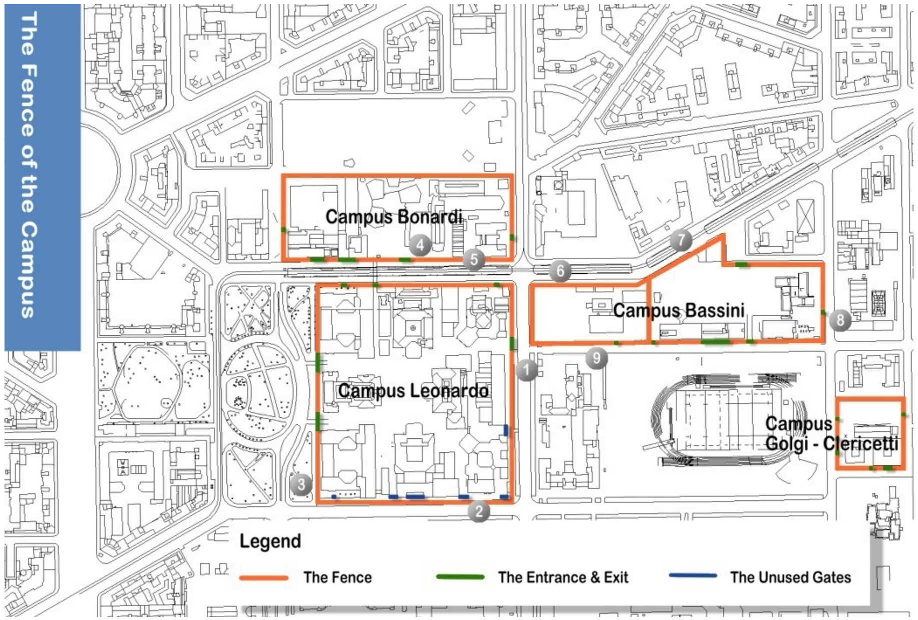


Figure 3- 45: The Fences around our Campus

Figure 3- 46: The Unused Gates on the South Side of Campus Leonardo

Table 3- 4: Distance of the Fences and the Proportion with the Entrances

	Open (m)	Closed (m)	Proportion
Campus Bonardi	57	632	1: 11.1
Campus Leonardo	62	844	1: 13.6
Campus Bassini	55	848	1: 15.4
Campus Golgi-Clericetti	25	270	1: 10.8

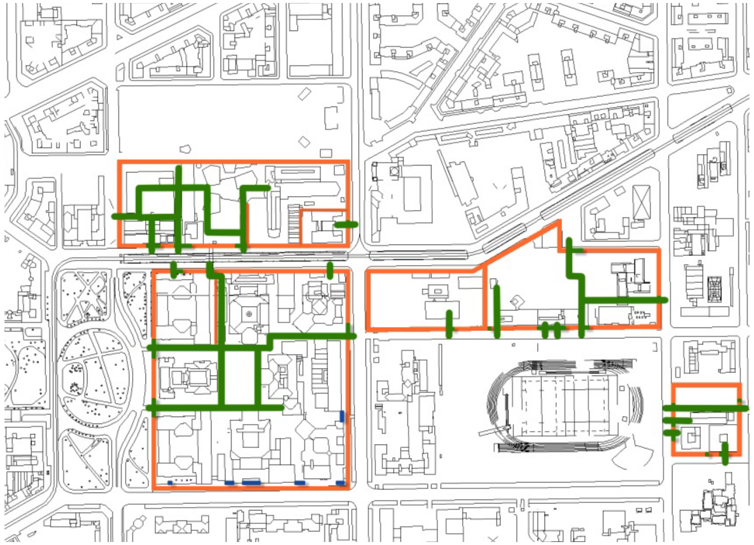


Figure 3- 47: Step 1 - Abstracting the Entrance & Foot Paths

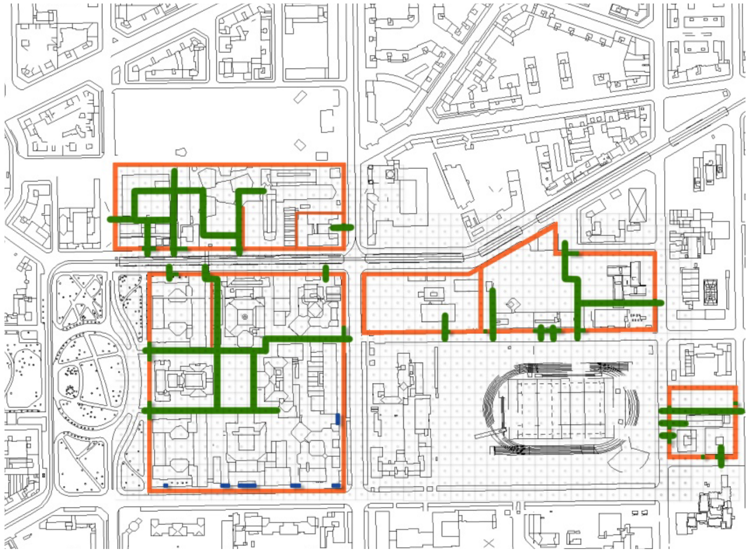


Figure 3- 48: Step 2 – Giving the Grid and a Node in the Central of Each Frame

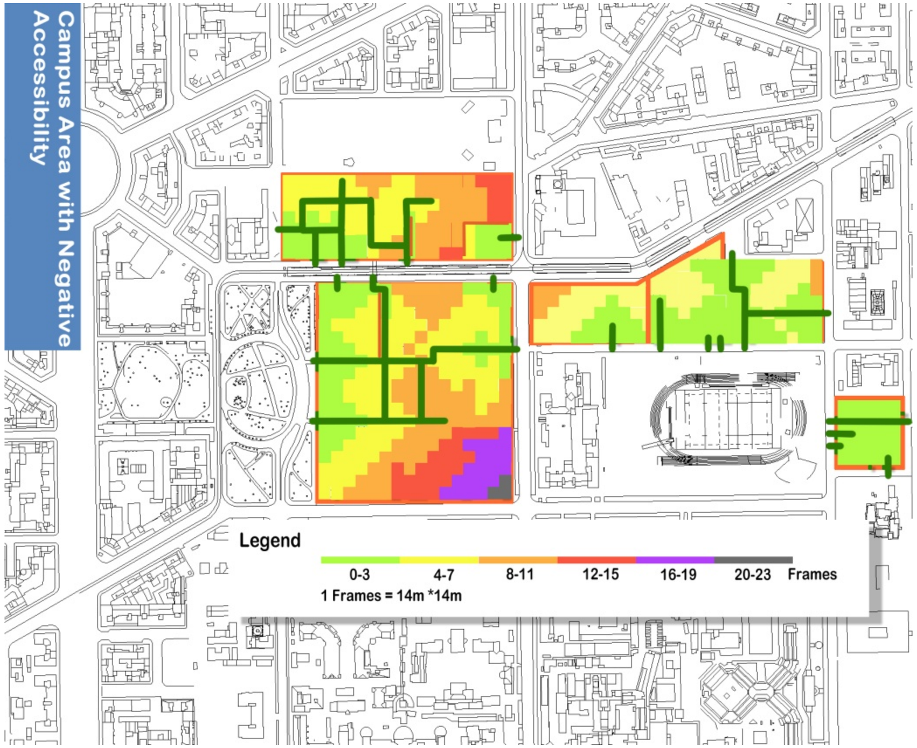


Figure 3- 49: Step 3 & Result – Evaluating How Many Frames are needed if We Depart from Each Frame

3.5 Images in Motion: People's Walking Experience

As mentioned in 2.2.4, we could use Prof. Bosselmann's method of "Images in motion" to represent or even quantify people's consciousness of time, space, feeling of safety, etc. His concluded "awareness of **change** is the condition on which our perception of time's flow depends" and "Designers thus have remarkable power to affect the perception of time by **arranging objects in space**, by **setting dimensions**, **designing textures**, **selecting color** and **manipulating light**" (Bosselmann, 1998). The perception of time is a dimension of "Images in motion", and if we want to promote pedestrians' mobility through providing better walking experience, I would like to consider more perceptions, such as perception of safety. Because we all dream of walking on a path which is so interesting that let us feel time past quickly, and which make you feel safe. In order to measure those perceptions, we could measure the "changes" or "settings, textures, colors of the objects" as Prof. Bosselmann suggested, but the measure of "change" is too general and the measure of "objects" is too detail, so I focus on four dimensions: unpleasant fences, shops, possible flow and negative environment.

Unpleasant Fences: fences could be treated as common landscape in our campus. But there are some unpleasant fences which are down the side and out the back. They do not get loved and looked after, what's more, if there is a back fence, there will not be a certain number of "eyes on the street", so the safety decrease. So the present of fence is considered as negative element.

Shops: shops do not only mean the available services, they also mean "eyes on the street", changes of landscape and flow. They make pedestrians feel interesting and safe, so they are considered as positive elements.

Possible Flow: a certain amount of flow provide changes and safety, so it is considered as a positive element.

Negative Environment: the negative environments make people unable to walk or have bad feelings (dirty or broken pavement, and as Prof. Bosselmann mentioned, the unpleasant textures, color and light) could be consider as negative elements.

Figure 3-50 illustrates my experiment routes to quantify people's walking experience. Route 1 & 2 are with the same origin and destination, so as route 3 &4. I will first present the "Images", and then give them evaluations depending on the positive or negative elements presented as the description of "Motion", by calculating the points, we will know the situation of people's walking experience. The experiment was carried out in the beginning of November, on a working day afternoon at about 15:00. The time intervals of taking those images are 30 seconds. And what needed to say is that the judgment of certain flow and negative environments are quite personal, I didn't consider the weight among the dimensions, and the judgment would change depend on the time (the square is a positive element in the day, while a negative element in the night),so the situations I will present also could be consider as a glancing.

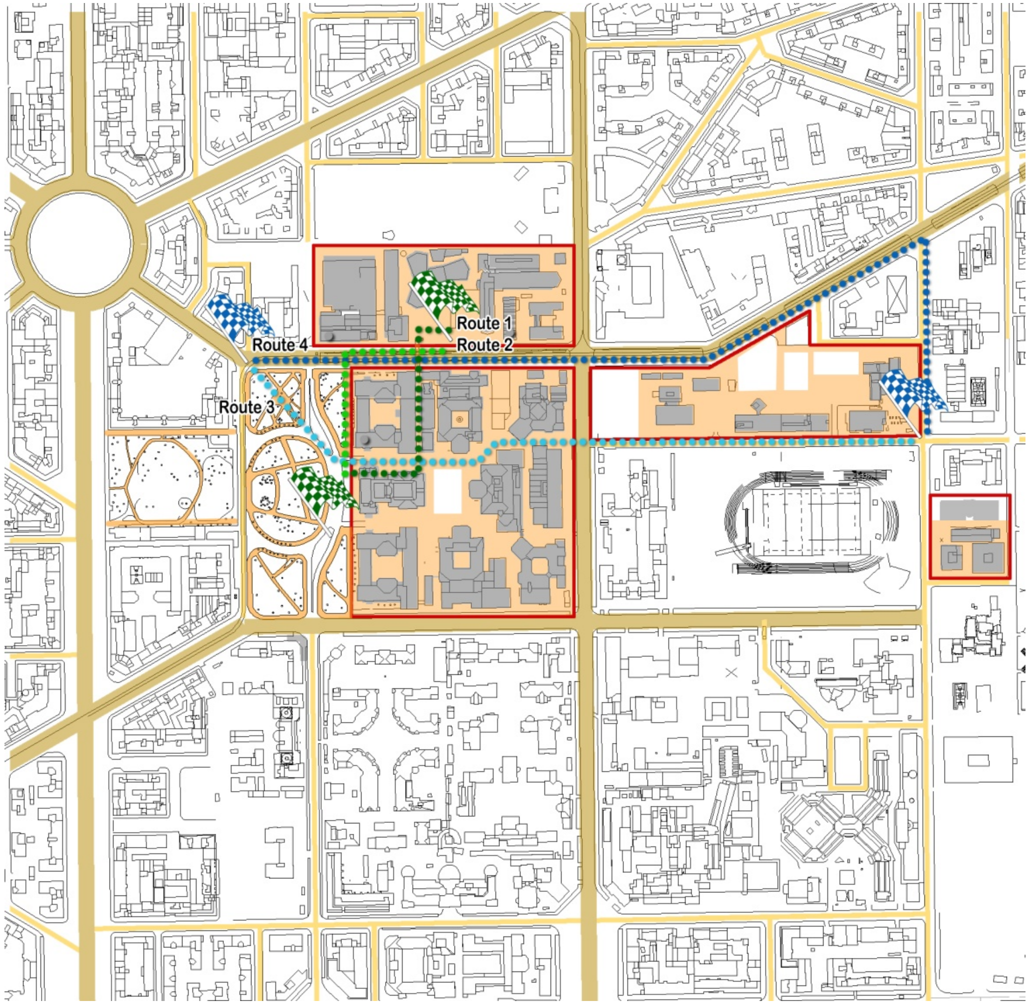


Figure 3- 50: The map of experiment routes

Figure 3- 51: Images of Route 1

Figure 3- 52: Images of Route 2

Table 3- 5: Comparison of Route 1 & Route 2

Image		1	2	3	4	5	6	7
Route 1	**Dimension**	No special element	certain flow	Change of view, certain flow	Shop, certain flow	No special elements	No special elements	Certain flow
	Evaluation	0	+1	+1, +1	+1, +1	0	0	+1
	Total							+6
Route 2	**Dimension**	Certain flow	Certain flow, buffetcar, entrance	Certain flow	No special element	Fence of trees	Certain flow	No special element
	Evaluation	+1	+1, +1, +1	+1	0	-1	+1	0
	Total							+5

Figure 3- 53: Images of Route 3

Figure 3- 54: Images of Route 4

Table 3- 6: Comparison of Route 3 & Route 4

Image		1	2	3	4	5	6	7
Route 3	**Dimension**	Certain flow	Too muddy to walk	Certain flow	No special element	Certain flow	Change of view	Certain flow
	Evaluation	+1	-1	+1	0	+1	+1	+1
		8	**9**	**10**	**11**	**12**	**13**	
	Dimension	Certain flow	Certain flow, buffetcar	Fence	Entrance, change of view and flow	Fence	No special element	
	Evaluation	+1	+1,+1	-1	+1	-1	0	
	Total							**+6**
Route 4	**Dimension**	Fence	Fence	Fence	Intersection and certain flow, Fence	Fence	No special element	Fence
	Evaluation	-1	-1	-1	+1, -1	-1	0	-1
		8	**9**	**10**	**11**	**12**	**13**	
	Dimension	Fence	Intersection and certain flow, Fence	Fence	Fence	Entrance, change of view and flow	Certain flow, buffetcar	
	Evaluation	-1	+1, -1	-1	-1	+1	+1,+1	
	Total							**-5**

Summing up, **at about 15:00, the walking experience in route 1 and route 2 is similar**, because there are a certain amount of flow, shop/buffetcar to provide food, and change of view in both cases. **But the situations in route 3 and route 4 are quite different**, because there are certain flow in front of the departments, change of view at some time and buffetcar in route 3, while there are always negative elements of fence and the flows are not so big in route 4. **If we apply the judgment of four dimensions (Unpleasant fences, Shops, Possible flow and Negative environments) within the campus area, we will get the walking walking experience map at 15:00 below**. At a glance, the paths in the north & west side give people better perception while the paths in the south & east side make pedestrian feel worse.

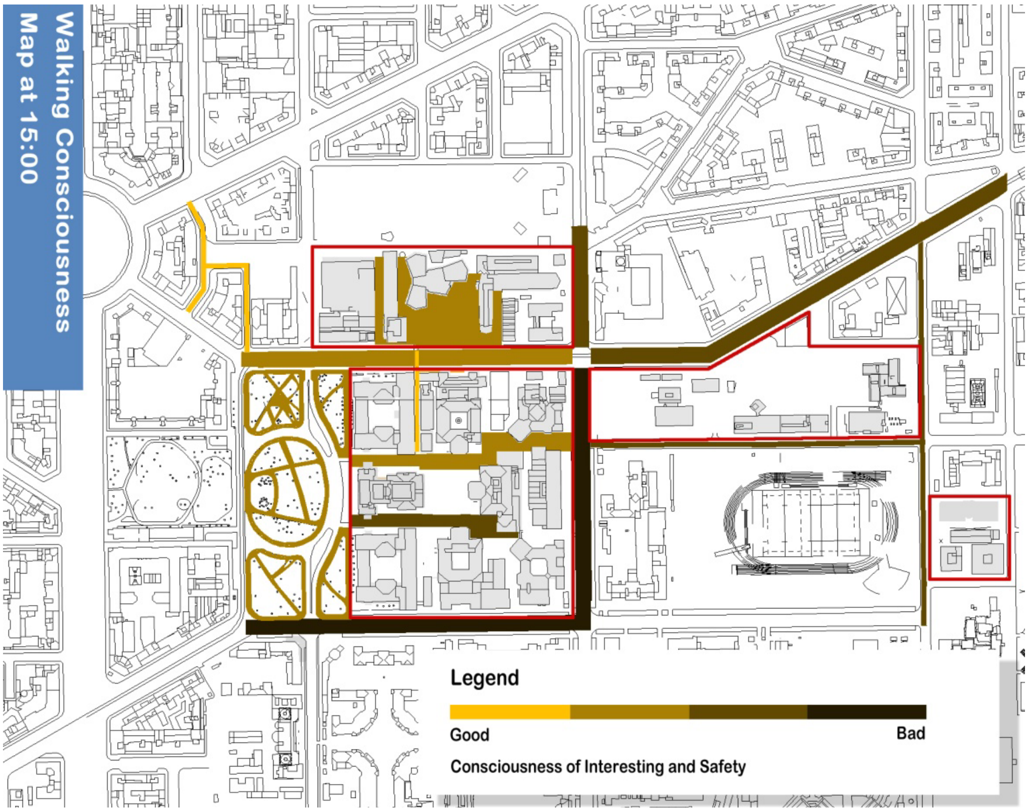


Figure 3- 55: Walking Walking Experience Map at 15:00

3.6 Estimation of the Surrounding Facilities

The function of surrounding facilities in pedestrian mobility is not only providing destinations, but also providing an atmosphere of walk: enough people, the feeling of security and interesting views. Here I applied a convenient and efficient tool to evaluate the surrounding environment – Google Walk Score. It utilizes the Google Local Search API to retrieve nearby amenities (business, parks, etc.), and relieves our workforce of marking the facilities and some land use and giving a set of criterion to evaluate them. Figure 3-56 until Figure 3-59 are the result of estimating the surrounding facilities of each campus.

Figure 3- 56: Campus Bonardi is Very Walkable from the Aspect of Surrounding Environment

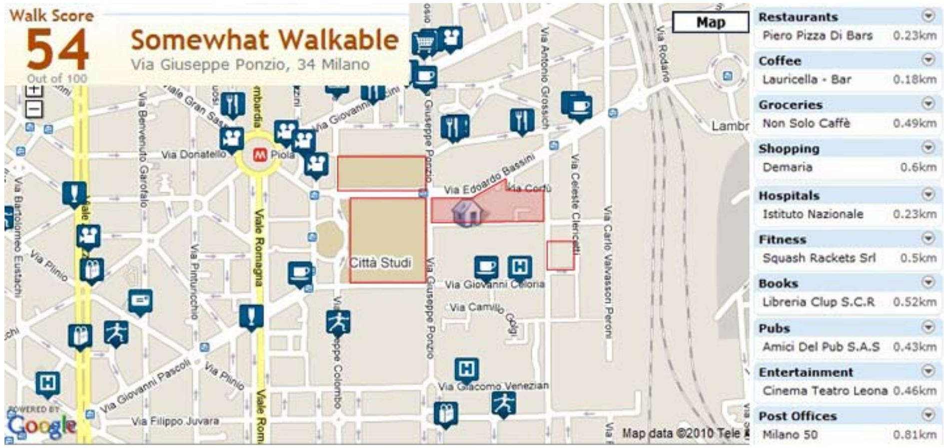


Figure 3- 58: Campus Bassini is Somewhat Walkable from the Aspect of Surrounding Environment

Figure 3- 57: Campus Leonardo is Very Walkable from the Aspect of Surrounding Environment

Figure 3- 59: Campus Golgi-Clericetti is Somewhat Walkable from the Aspect of Surrounding Environment

Reference

Bosselmann, P. (1998), *Representation Of Places: Reality And Realism In Urban Design,* University of California Press, Berkeley and Los Angeles.

Committee for Equal Opportunities of Politecnico di Milano (2001), *Indagine Sugli Spostamenti Dei Lavoratori Del Politecnico Di Milano*, 2001. http://www.mobility.polimi.it/studi/spostamenti_lavoratori.htm

Mobility Management Group of Politecnico di Milano (2007), *Indagine Sugli Spostamenti Degli Studenti*, 2007. http://www.mobility.polimi.it/studi/spostamenti_studenti.htm

Internet Links

Laboratorio Mobilità e trasporti of Politecnico di Milano (November, 2010)

http://www.trasporti.polimi.it/Mobilità%20Sostenibile.html

Politecnico di Milano (October, 2010)

http://www.english.polimi.it/university/organization/facts-at-a-glance/

4 Conclusion and Recommendation

In Chapter Three, I have applied a few tools to analyze five dimensions of pedestrian situation in our campus, trying to understand the facts and characters, and to reveal problems. Since my research objectives are not only to study about the possible tools/ methods which could be used in pedestrian mobility design, but also to study about the walking situations of our campus, I will conclude both the useful tools and the facts about pedestrian mobility in our campus below.

4.1 Conclusion of the Tools and Methods Applied

Table 4-1 concludes the fourteen tools/ methods applied in the five dimensions (more than seven sub-dimensions) of the study. And below explains all their application conditions: why and how to use them.

Table 4- 1: Study Dimensions and Tools/ Methods Applied

	Dimension	Tools / Methods Applied
Flow	Measure of flow	Manual way, video-manual way, Mechanical way
		Digital way, Real-time way
	Time-flow Distribution	Diagram
		Curve graphs
	Space-flow Distribution	Spatial interpolation
	Pulse of the Campus	“Flow-on-road”
	Attraction-Flow Map	Manual counting way + “Attraction-Flow” method
Traces and Density		Stacking for Trails
		Photos for Tracess
		Time-lapse
Accessibility	Campus Area within 400m/ 800m Metro Service	Ped-shed Analysis
	Campus Area with Negative Accessibility	“Steps to the entrance”
People’s Walking Experience		Images in Motion + “General evaluation of fences, shops and flows” method
Surrounding Facilities		Google Walk Score

Annotation: the method in double quotation marks are named by the author.

<u>Flow</u>

<u>Manual way, video-manual way and Mechanical way</u> is suitable for survey of flow

which is not big (below 200 in 15 minutes), not long duration (less than 20 minutes), and request certain amount of workforce and time involved, but they are the ways easily to carried out, with high accuracy, and with the advantage of capture details.

Digital way and Real-time way are especially suitable for big amount of flow survey, and they do not have the limit of survey scale and duration. If combined with the statistics or spatial analysis software, they could be very helpful and convenient to reveal the relations among data and the distribution of data. But those methods requests specific equipments and software & information platform support.

Diagram way for Time-flow study is very good at showing changing trends – how the peak hours transit to low hours, and the watch-look design implies the idea of circulation of flow for days. It is usually more vivid than the curve graphs.

Curve graphs for Time-flow study could also represent clear degree of fluctuation and the relationship between flow and flow as the diagram way, but it has an advantage of showing the exact number.

Spatial interpolation is a method to produce a continuous data surface through discrete points. In this case, we can convert the survey data on the nodes into a distribution map of the whole campus area, and find out the “hot points” in some certain moment. As a precondition, we need a certain number of independent “node data”. GIS and a software called “Surfer” are the common tools to produce a spatial interpolation map.

“Flow-on-road” way visualized the survey data basing on the road structure, and we can judge the “hot points” depending on the thickness of the lines. But it is more suitable for representing the linear data such as the amount of vehicles.

“Attraction-Flow” method has a similar nature with the ”flow-on-road” way, but it represents the pedestrian flows on pedestrian system. And considering the attractions, this method has a specific advantage of showing the agglomerative position and the routes chosen between the same origin and destination.

Traces and Density

Stacking for Trails is a set of Photoshop actions to overlap the frames captured from a video every 2 seconds, so as to illustrate the traces (distribution) of people’ and vehicles’ moving during a period of time. But this tool could be useful in the condition of a top view and a dark background, and its applications on vehicles flow stacking are usually better than those on pedestrian flow stacking.

Photos for Tracess is a complementary ways to describe pedestrians traces, because sometime the overlapping images could not give clear tracess. The producing method is simple: take some typical pictures which illustrate people’s walking habit, and mark the traces.

Time-lapse is a dynamic presentation that shows slow changes in a short time. It does not overlap frames, so it overcomes the disadvantage of mixing the different tracess together. The audiences will get the impression of tracess themselves just by watching. There are specific photography to produce it, but we can also make it with the software of Photo or QuickTime.

Accessibility

Ped-shed Analysis is a method which could help to define how far you can actually reach by walking 400m (5 minutes)/ 800m (10 minutes) within a current street network, and shows the comparison of the theoretical 400m/ 800m accessible area and the actual reachable area. There is no limit to use this method, but the researcher need to have a very clear view of the fences and entrances, so as to define if a place is accessible.

"Steps to the entrance" is a method developed by myself to study the accessibility of internal area. With two information basis of the fences & entrances and the available walking path, we could calculate how many steps are needed from any place to an entrance by applying a grid. If we give the frames different colors depending on the steps needed, we can learn the area with negative accessibility.

People's Walking Experience

Images in Motion is a method used by Prof. Bosselmann to find out what influence pedestrians' perception of time by replaying a series of pictures. With his conclusion, we could compare and tell which route will give people better walking experience.

"General evaluation of fences, shops and flows" method is an extended study method based on Prof. Bosselmann's conclusions, and it is also developed by myself. We could give scores to each path on the dimensions of fences, shops and possible flows, by adding the scores, we could find out the ways which give pedestrians more interesting and safe perceptions.

Estimate the Surrounding Facilities

Google Walk Score is a convenient and efficient tool to evaluate the surrounding facilities based on Google data base of nearby amenities (business, parks, etc.). It could be used in almost any location and projects.

4.2 Conclusion of the Findings and Problems

Time-flow Distribution Study

In location 1, **the motorized amounts** from west to east are always a little bit less than the amount from east to west, and both are with few **fluctuation**: and the amount of vehicles are very stable in the working hours of a day. The **amount of nonmotorized flows** from south to north are basically more than the ones go from north to south, we can consider the fact as more people leaving the architecture faculty through this crosswalk than arriving, or the fact that this crosswalk is an important path that is used by the architecture students to go to the Piazza or the Campus Leonardo. The south to north flow has two **peak durations**: 12:30 until 13:30, 15:30 until 16:30, and the north to south flow has only one peak hour: 12.30. The **peak hours coincidence** at about 12:30, and the amounts are similar, which means the people exchanges at noon are balance, and 12:30 is the extreme time of this location.

In location 2, the **vehicles flows** from both directions are bigger than those in location 1, but the **fluctuations** are similarly smooth during the day. The **total pedestrians** seem less than the ones in location 1. The pedestrians flow from west to east have the **peaks** at 13:30 and 16:30, and the flow from east to west have peaks at 9:30 and 13:30. Again, the **overlapping peaks** reasoning to the extreme hour at 13:30.

In location 3, the **amounts of motorized flow** are similar as those in location 2, while the **pedestrians amounts** are much less. Since it is a cross place without traffic lights, the **peak of motorized flow** comes at 9:30 and from 14:30 until 17:30, while the low hour is around 13:30; the **peak hour of nonmotorized flow** is 12:30 and the low hour is 9:30, so we can consider it is an optimize situation: the extreme hours of vehicles and pedestrians stagger each other. This position is important because here is the only exit on the east boundary of the Campus Leonardo. And the motorized flows are big enough and their speed are high enough to influence the pedestrians' mobility. So some managements should be considered.

In location 4, **the amounts of motorized flow** are less than location 3, while **the amounts of pedestrian flow** are much bigger. **The fluctuation of motorized flow** is smooth, and the pedestrian flows from south to north reaches its **peaks** at 12:30 and 17:30, while flows from the contrary direction has busy hour at 9:30, 12:30 and 13:30. The same as Location 3, this is a intersection without traffic control, but differently, the big vehicles flow holds up the pedestrians in location 3, while it is the big pedestrian flow here blocking the vehicles.

<u>Space-flow Distribution & Pulse Study</u>

Based on the spatial interpolation way, the area from the intersection of Via Spinoza and Via Bonardi to the two entrances near the "Rettorato building" is the "hot area" at about 12:30.

Although the time-flow distribution figures could provide amount comparisons between two locations, the series of space-flow distribution maps give us more systemic impression of the flow. At 9:30, the trend of people flow goes into our Campus from two stations, except in location 4, more people go to the direction of University of Milan. 10:30 could be consider as a peace moment when the spread of pedestrian is quite equal. Pedestrians start to concentrate from 11:30, until 12:30, nearly all locations reach their peak hour, especially the people exchange in location 1 is huge. From 13:30 until 14:30, the amounts of pedestrians in each location decrease correspondingly, except the pedestrians leaving the campus through Via Bassini start to increase. At 15:30, the other peak moment of people going into Piazza Leonardo through Via Colombo, people going to architecture faculty direction in location 1 and people leaving the campus through Via Bassini starts. The major trends to these three directions continually increase during 16:30, and gradually go peace until 17:30. **Based on the description, the morning trend (9:30-10:30) is the flow goes into our Campus from two metro stations, the flows are on Via Bonardi and Via Bassini; the noon trend (11:30-14:30) is the pedestrian moving around Piazza Leonardo; the afternoon trend (15:30-17:30) is the northward and eastward in Piazza Leonardo and Via Bassini.**

Attraction-Flow Map

There are four agglomerative points of the flow where people spread and gather together again: Metro Station Piola, the intersections of Via Spinoza and Via Bonardi, the crosswalk in front of architecture faculty and the gate on the right side of the "Rettorato Building".

About the routes chosen between the same origin and destination, we observe that when people arrived the north-west corner of Piazza Leonardo, they use to cross athwart the Piazza; in front of the "Rettorato Building", people use to take the right gate; and the flow on the branch of Via Ponzio is similar with the flow on the main urban road – Via Bassini.

Traces and Density Study

With the tool Stacking for Trails, we can say that the north part of the crosswalk in front of architecture faculty is a critical point, because the density there could be observed higher than other parts. The pedestrians flows in the intersection of Via Spinoza and Via Bonardi are high and their distribute are homogeneous in space. The vehicle flows have inundated the pedestrian flows in location 3 even in the peak moment, and the vehicle flows were blocked by the pedestrian flows in location 4.

With the illustration of Photos for Traces, we could find two situations in which people will go beyond design area of the crosswalk. The first one is that if there are destinations on the other side of the crosswalk, people use to take the "quick routes", but not follow the crosswalk, and the case is the intersection of Via Spinoza and Via Bonardi, location 1 and location 2. The other situation is people need to make detours to avoid the cars on their way, the case is location 3 and location 4, neither of where have traffic light control.

The impression of traces given by Time-lapse will be similar the results I describe above. And all these studies could help decide the width and pattern of the crosswalks and if the someplace is so disorderly that need to be controlled.

Accessibility Study

With the method of Ped-shed Analysis, we could know 16% of the campus area is within 400m metro service –a piece of north-west part of the our campus; and 94% of the campus area is within 800m metro service – only Campus Golgi-Clericetti is out of it. And the experimental study shows: if we depart from the central of "Rettorato Building", 66% of the 400m walking theoretical area is accessible, and 67% of the 800m walking theoretical area is accessible.

In my practice, I think the main factors influencing the accessible area are the road fabric and the fences: the vertical and grid road structure provide more accessibility, and less fence means more available paths and higher route density. Therefore, in order to improve the campus accessibility, we could cut down some fences, add some paths to minimize the impacts of not grid road network, or providing assisting travel means to enhance people's capability to travel.

In the study of the accessibility of internal area, I applied the "Steps to the entrance" method, and found out the area with low accessibility: they are the north-east part of Campus Bonardi, the south-east part of Campus Leonardo and the north-west part of Campus Bassini.

People's Walking Experience Study

Basing on the consideration of fences, shops and possible flows, the paths in the north & west side of our campus give people better perception while the paths in the south & east side make pedestrian feel worse.

Surrounding Facilities Estimation

Basing on the consideration of nearby amenities, the walk score of Campus Bonardi and Campus Leonardo are 72 and 75, they are in a level of "very walkable" (most errands can be accomplished on foot), but the scores have been close to "somehow walkable" (Some amenities within walking distance). And both walk score of Campus Bassini and Campus Golgi-Clericetti are 54, it is in a level of "somehow walkable", but near the situation of "car-dependent" (A few amenities within walking distance).

4.3 Recommendations

Recommendation 1

Since there is big amount of people frequently passing some crosswalk in the peak hour, aggravating the danger of illegal crossing and the collisions between people and vehicles, so we could consider to **stagger the peak hours through for example making different schedules for different schools, and arranging the classes equally in the week** (because it is obvious the pedestrian flow on Friday is about 80% of that on Tuesday or Wednesday). In that case, the illegal crossing becomes bearable (it is almost impossible to forbid illegal crossing, but we could decrease this behaviors if few people did it) and collisions relieve.

Recommendation 2

If we think about the reason why the pedestrians agglomerate in some certain place, we will find out it is because there are few entrance could be used, and they need to gather together around the entrances. So the second recommendation would be **breaking some fences, and providing more pedestrian entrances**.

Recommendation 3

Thinking about the specific situations in the important nodes, from the space-flow distribution maps, we learn that the pedestrian flows are big in location 1 and the intersection of Via Spinoza and Via Bonardi for the whole day; and from the traces study, we observe people use to spread outside of the area of the crosswalks. So this is **the critical area to carry on wider crosswalks for the big pedestrian flow and traffic calming design to avoid high speed vehicles**.

Recommendation 4

From the either the time-flow study or the traces study of location 3 and location 4, **the constructions of traffic lights or pedestrian priority facilities are needed**.

Recommendation 5

From the study of attraction-flow map, we could find an existing route with big pedestrian flow (route from metro station Piola - Piazza Leonardo – right gate of the Campus Leonardo – branch road of Via Ponzio), so we can **promote this route as the key walking route in our campus, and enhance the walking environments as the pioneer project**.

Recommendation 6

From the accessible study, we know that only 16% and 94% of the campus area is under 400m and 800m metro service, so it would be useful to **provide assisting travel means** to enlarge the service area in our campus. For example, within 400m of Campus Golgi-Clericetti, there is no bus stops, maybe we could consider here as the priority place of bike-sharing project or bus-enhancing project.

Recommendation 7

The feeling for pedestrian paths is inseparably interconnected with the flow: if there is certain amount of flow, there will be more shops and people's perception will be better. So again we need to **break some fences (or even change them with the "senseless fences"), and add some pedestrian entrances and exits, so as to bring flows and commercial activities** and finally improve people's walking experience.

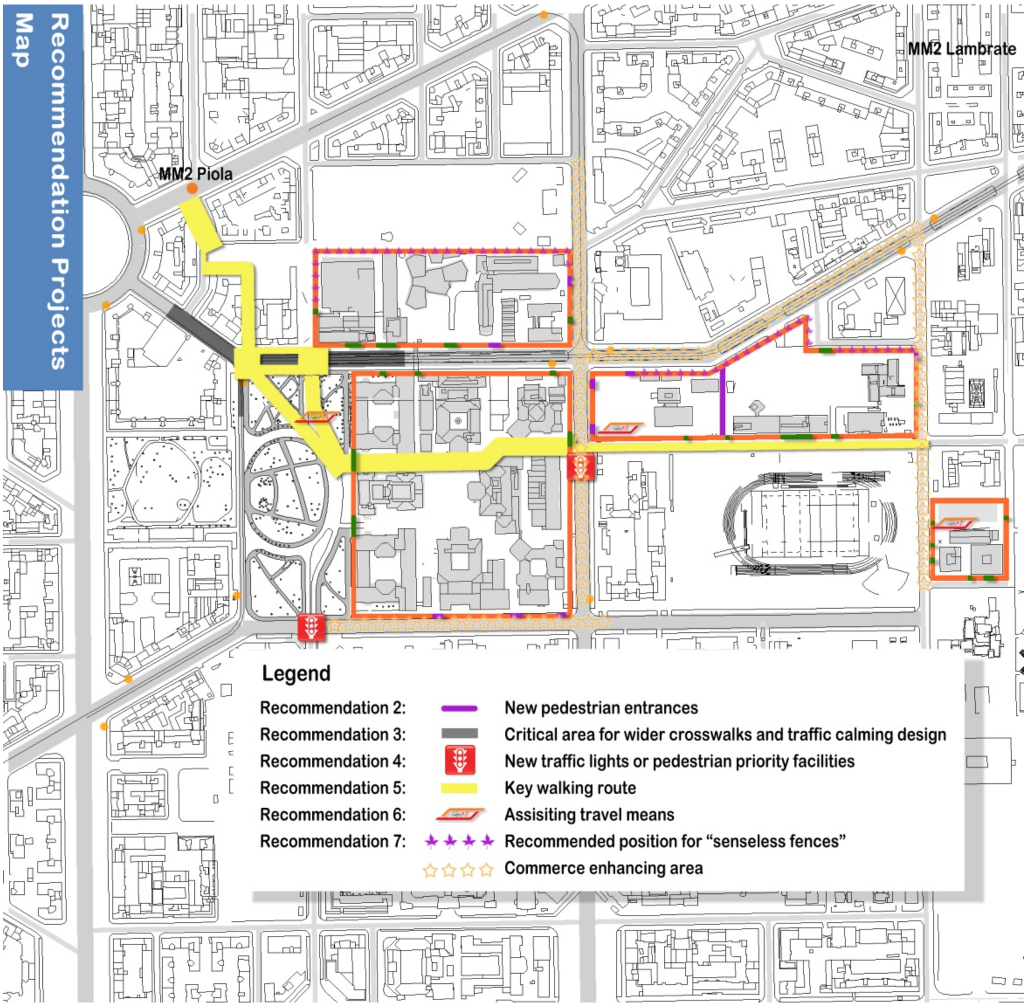


Figure 4- 1: Map of Recommendation Projects

4.4 Limits and the Extension of the Research

Reviewing the whole research, there are some limits and perspectives that should be declared.

The extension of the research contents: Some other dimensions that are related with pedestrian mobility promoting are not included in my research, such as the frontage / façade design for streets, and the building-height-to-street-width ratio control etc.. Even for the referred dimensions, there are contents could be developed more deeply, such as the research about the style of fence and the property of a piece of land. And the presented recommendations need to be defined more carefully. The time to carry out the measures, the resources and actors needed and other feasibilities are need to be studied, so there are still distances between those recommendations and the practical guidelines.

The limit in capturing the data: What I did is just a “one-day survey” in each location, so the data could not be considered as average flows in a working day. More exactly, even the “one-day surveys” are not carried out on the same day, and the data represented in one flow map are data around half of each hour (for example, I count the flow in location 1 at 9:15-9:30, and in location 2 at 9:35-9:50), because this is a study about tools, but not a study about the feasibility of real traffic managements.

The extension of research tools: Some tools which should be very useful are not practiced, such as the digital and real-time flow measure and presentation, the analytical tool of GIS and some other statistical tools. And also if some analysis is represented by 3D models, the outcome and the result for communication will be better.

The extension of application: Most of analytical tools presented in the thesis need to be carried out manually, but it is possible to program some tools (Ped-shed, “Steps to the entrance” and “General evaluation of fences, shops and flows”) as some analytical software, and transit the manual calculation into computer calculation. Although my research aims to quantify the accessibility and the feelings, I still insist that designers could not decide people’s lives (styles) just by the indicators, and my quantitative results are just used for comparing situations in different locations. From this aspect, those tools are always need to be developed depending on different cases.

Appendix

1 The experiment to check the application scope of three flow-measure ways

We carried out the flow survey by three ways - the manual way, the video-manual way and the mechanical way - at the same time in location 3.

Day: 27/10/2010 **Time duration:** 10:30 – 10:45

Description of the location:

Location 3 is a connect point of two parts of the campus (Figure below). It is on a busy urban road – Via Giuseppe Ponzio, with heavy use, but without a crosswalk or traffic lights, and it is where we consider as the weak point of the campus pedestrian system.

Figure Appendix 1: Location 3 as the experiment location

Preparation for the experiment:

1. A task-arrangement map as showed below;
2. 5 students: A – counts the South to North vehicle flow with a tally counter; B - counts the North to South vehicle flow manually; C&D - count the pedestrian and cyclist in East – West direction; E- takes a video, and counts the flow manually later.
3. A fixed camera in a place where he/she can have a general view of the crosswalk;
4. A survey table for vehicle flow survey, and a survey table for pedestrian flow survey, each table with a duplicate copy;
5. 5 watches which are adjusted as the same time, 3 pens.

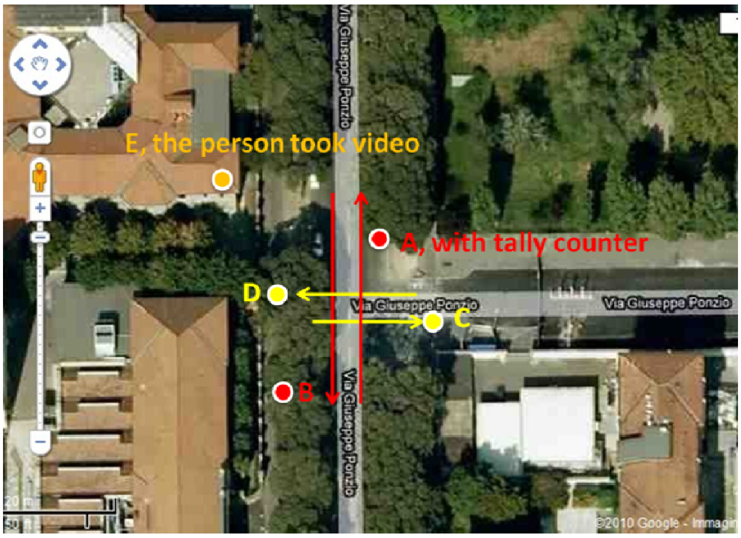


Figure Appendix 2: Arrangement of the task

Table Appendix 1: The survey table for vehicle flow survey

Investigator:		Date:	Weather:
Time		The Record of the Amount	Total
10:30-10:45	cars		
	of whichbrakes		
	motors		
	of whichbrakes		
	public transports		
	of whichbrakes		

* The amount of braking is considered as a potential collision.

Table Appendix 2: The survey table for pedestrian flow survey

Investigator:		Date:	Weather:
Time		The Record of the Amount	Total
10:30-10:45	Pedestrians		
	Bikes		

Results:

Table Appendix 3: Result of South to North Direction

10:30-10:45	**Date:** 27/10/2010		**Weather:** Good	
South – North	Student A: with a tally counter		Student E: the video-manual way	Difference
	Total	Of which brakes		
cars	102	6	101	1%
motors	7	0	8	-12%
public transports	2	0	2	0

Table Appendix 4: Result of North to South Direction

10:30-10:45	**Date:** 27/10/2010		**Weather:** Good	
North - South	Student B: Manual way		Student E: the video-manual way	Difference
	Total	Of which brakes		
cars	136	15	133	2%
motors	13	10	13	0
public transports	2	1	2	0

Table Appendix 5: Result of East to West Direction

10:30-10:45	**Date:** 27/10/2010	**Weather:** Good	
East - West	Student C: Manual way	Student E: the video-manual way	Difference
	Total		
Pedestrians	17	17	0
Bikes	1	1	0

Table Appendix 6: Result of West to East Direction

10:30-10:45	**Date:** 27/10/2010	**Weather:** Good	
West -East	Student D: Manual way	Student E: the video-manual way	Difference
	Total		
Pedestrians	45	47	4%
Bikes	1	1	0

Conclusion:

From this experiment, we can notice some advantages and disadvantages of these possible methods:

Assuming that we use **the manual way** as a datum, it is a way with randomness, because the accuracy depends on the proficiency of the surveyors, the amount of the flow and the duration of the survey. But from my experiment, for surveys within 15 minutes and the flow below 200, the accuracies are higher than 95%. And it needs a team of surveyors to exactly be there, but the collation of the result is quick (about 1 minute). And it has a specific advantage of detail survey: all the surveyors could accomplish the survey of times that the vehicles brakes, while the surveyor who carried out the video-manual way could not.

Then **the video-manual way** is a way which has nearly 100% accuracy (if we check the video for times), does not need people to be exactly in the location, but need a lot of time-spending to manage the data (take the 15-minute survey for example, the time needed for data collecting is 1.5 hours). But if we compare the total time spent with the manual way – they are similar.

Lastly, **the mechanical way of tally counter** is similar with the manual way: it is also a way with high randomness, and the situations of accuracy, people needed and time needed are similar. But compared with the manual way, the mechanical way is much suitable for big flow & long duration counting.

In a word, we can choose the appropriate method depending on the specific requests we have, the assumed flow there will be, the survey duration we request, expected accuracy, the human resource we have and if there is enough time for result collation.

2 The Results of the Whole-day Flow Survey around the Campus

Considering the human resource would take by the manual way, the equipments requested by the mechanical and digital way, and the scale of our campus, I carried out the further survey in video-manual way. The survey day was 27th (Wednesday), 28th (Thursday) and 29th (Friday) October 2010. The survey hour is from 9:30 to 17:30, 15 minutes per hour. Although the data is not collected at the same day, as I observed, the differences are within 20%, because basically the arrangements of classes are equal; and although the survey hours are not exactly at 9:30/10:30… (they are around :30), I use the data to produce the flow maps as they are at the same time. About the description of the locations, please refer to 3.1.2 Define the Important Nodes.

Table Appendix 7: Survey Results of Location 1

28/10/2010								Good weather		
Time		9:30-9:45	10:30-10:45	11:30-11:45	12:30-12:45	13:30-13:45	14:30-14:45	15:30-15:45	16:30-16:45	17:30-17:45
A: East - West	cars	125	122	94	113	101	126	108	96	120
	motors	9	12	3	7	16	7	16	22	25
	public transports	5	3	1	1	3	4	3	2	3
	Total	***139***	***137***	***98***	***121***	***120***	***137***	***127***	***120***	***148***
B: West - East	cars	114	99	90	72	81	107	89	85	83
	motors	22	8	6	10	15	5	9	13	13
	public transports	4	2	7	2	0	4	2	1	2
	Total	***140***	***109***	***103***	***84***	***96***	***116***	***100***	***99***	***98***
C: South-North	Pedestrians	76	50	116	216	200	93	193	204	116
	Bikes	13	3	4	2	4	5	7	7	8
	Total	***89***	***53***	***120***	***218***	***204***	***98***	***200***	***211***	***124***
D: North-South	Pedestrians	68	68	97	227	143	91	62	64	75
	Bikes	1	2	7	2	4	4	7	1	4
	Total	***69***	***70***	***104***	***229***	***147***	***95***	***69***	***65***	***79***

Table Appendix 8: Survey Results of Location 2

29/10/2010								Good weather		
Time		9:00-9:15	10:00-10:15	11:00-11:15	12:00-12:15	13:00-13:15	14:00-14:15	15:00-15:15	16:00-16:15	17:00-17:15
A: South - North	cars	107	103	110	103	125	111	137	148	149
	motors	10	6	8	15	22	9	12	11	10
	public transports	1	2	0	0	0	1	0	0	1
	Total	***118***	***111***	***118***	***118***	***147***	***121***	***149***	***159***	***160***

B: North - South	cars	162	152	144	161	150	127	160	181	170
	motors	33	25	14	11	17	13	15	10	10
	public transports	0	0	0	2	3	1	1	0	0
	Total	***195***	***177***	***158***	***174***	***170***	***141***	***176***	***191***	***180***
C: West - East	Pedestrians	21	19	30	80	166	35	41	95	82
	Bikes	0	1	1	2	3	0	1	2	3
	Total	***21***	***20***	***31***	***82***	***169***	***35***	***42***	***97***	***85***
D: East - West	Pedestrians	119	65	25	23	73	48	44	19	28
	Bikes	3	5	0	2	2	4	0	1	1
	Total	***122***	***70***	***25***	***25***	***75***	***52***	***44***	***20***	***29***
E: West - East	Pedestrians	25	36	18	37	62	25	19	43	25
	Bikes	0	2	1	1	2	1	2	4	3
	Total	***25***	***38***	***19***	***38***	***64***	***26***	***21***	***47***	***28***
F: East - West	Pedestrians	42	32	27	20	55	12	18	18	24
	Bikes	2	1	1	1	1	1	1	1	1
	Total	***44***	***33***	***28***	***21***	***56***	***13***	***19***	***19***	***25***

Table Appendix 9: Survey Results of Location 3

27/10/2010								**Good weather**		
Time		9:30-9:45	10:30-10:45	11:30-11:45	12:30-12:45	13:30-13:45	14:30-14:45	15:30-15:45	16:30-16:45	17:30-17:45
A: South - North	cars	125	102	103	107	80	126	151	138	148
	motors	13	7	8	15	8	10	19	10	14
	public transports	5	2	2	3	2	3	2	3	5
	Total	***143***	***111***	***113***	***125***	***90***	***139***	***172***	***151***	***167***
B: North - South	cars	172	136	126	139	128	155	143	126	146
	motors	43	13	9	9	18	25	20	15	20
	public transports	4	2	3	3	3	3	1	3	4
	Total	***219***	***151***	***138***	***151***	***149***	***183***	***164***	***144***	***170***
C: West - East	Pedestrians	16	17	14	67	46	22	13	32	24
	Bikes	0	1	2	0	1	1	0	7	0
	Total	***16***	***18***	***16***	***67***	***47***	***23***	***13***	***39***	***24***
D: East - West	Pedestrians	14	45	45	52	41	30	21	33	20
	Bikes	0	1	0	3	1	0	1	1	1
	Total	***14***	***46***	***45***	***55***	***42***	***30***	***22***	***34***	***21***

Table Appendix 10: Survey Results of Location 4

28/10/2010								Good weather		
Time		9:30-9:45	10:30-10:45	11:30-11:45	12:30-12:45	13:30-13:45	14:30-14:45	15:30-15:45	16:30-16:45	17:30-17:45
A: East - West	cars	96	114	88	85	91	92	102	98	122
	motors	9	14	9	24	14	10	13	13	12
	public transports	0	0	0	0	0	0	0	0	0
	Total	***105***	***128***	***97***	***109***	***105***	***102***	***115***	***111***	***134***
B: West - East	cars	96	114	87	91	95	90	104	87	106
	motors	20	17	10	11	21	15	19	11	17
	public transports	0	0	0	0	0	0	0	0	0
	Total	***116***	***131***	***97***	***102***	***116***	***105***	***123***	***98***	***123***
C: South-North	Pedestrians	15	56	34	161	71	32	106	86	138
	Bikes	5	3	1	2	6	0	2	2	3
	Total	***20***	***59***	***35***	***163***	***77***	***32***	***108***	***88***	***141***
D: North-South	Pedestrians	45	14	7	25	43	12	8	12	10
	Bikes	1	1	0	0	0	0	0	0	0
	Total	***46***	***15***	***7***	***25***	***43***	***12***	***8***	***12***	***10***
E: South-North	Pedestrians	6	6	19	18	13	11	1	19	20
	Bikes	2	0	5	0	0	1	1	0	1
	Total	***8***	***6***	***24***	***18***	***13***	***12***	***2***	***19***	***21***
F: North-South	Pedestrians	21	22	8	35	21	14	4	12	8
	Bikes	2	1	0	1	0	2	1	1	1
	Total	***23***	***23***	***8***	***36***	***21***	***16***	***5***	***13***	***9***