Introducing water sensitive design into Traffic infrastructure systems

Case study: Itaim Paulista Bus Corridor, São Paulo

REAP - Resource Efficiency in Architecture and Planning

Paula Saldaña - Master Thesis

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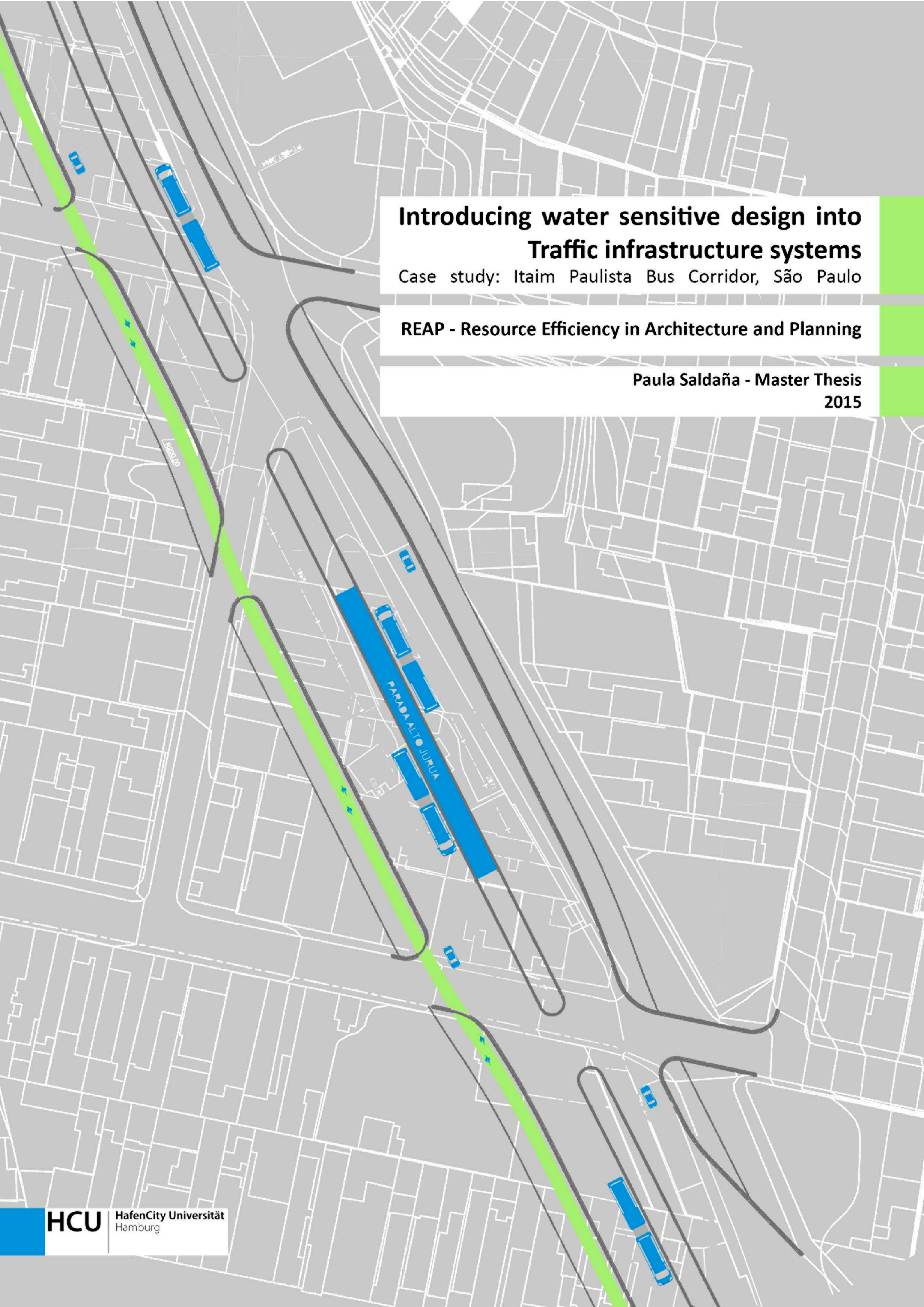

HCU HafenCity Universität Hamburg

Author:	Paula Saldaña Fernandez
Master Program:	Resource Efficiency in Architecture and Planning
Enrollment Nr.:	6016093
First advisor:	Prof. Dr.-Ing. Wolfgang Dickhaut (HafenCi-ty University Hamburg)
Second advisor:	Prof. Renato Anelli, Ph. D. (IAU-USP)
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Hamburg, 11 May, 2015

Campo Limpo-Reboucas Bus Corridor (SPTrans, 2013)

Abstract

In this thesis, I propose to broaden the scope of the design of road infrastructure systems to include adaptive and more efficient constructive methods. Water sensitive design and decentralized drainage systems can improve the performance of future transit projects that will be implemented until 2016 in the city of São Paulo within the framework of the newly approved Strategic Master Plan. The goal of this thesis is to establish that designing with water can reduce flood risks as well as induce to calmer, cleaner environments. A segment of the Itaim Paulista – São Mateus bus corridor (BRT system), located in the Eastern region of the city, was selected as study area to illustrate how green infrastructure could be adjusted to the existing project. The selected technologies presented here should add flexibility and resilience to the implementation of new bus corridors as well as contributing to the improvement of the quality of life for the residents and further development of the regional economy.

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List of acronyms

AEL	Área de Estruturação Local (Local Structuring Area)
AII	Área de Influencia Indireta (Indirect Influence Area)
AID	Área de Influencia Direta (Direct Influence Area)
ADA	Área Diretamente Afetada (Directly Affected Area)
APP	Área de Preservacao Permanente (Permanent Preservation Area)
APPa	Área de Protecao Paisagística (Landscape Protection Area)
CDU	Comissão de DesenvolvimentoUrbano (Urban Development Com mitee)
CET	Companhia de Engenharia e Tráfego (Traffic and Engineering Company)
CETESB	Companhia de Tecnologia de Saneamento Ambiental (Environmental Sanitation Technology Company)
CIRIA	Construction Industry Research and Information Association
DAEE	Departamento de Águas e Energia Elétrica (Department of Water and Electric Power)
DDOT	District Department of Transportation of District of Columbia, USA
EIA	Estudo de Impacto Ambiental (Environmental Impact Assess ment)
GSI	Green stormwater infrastructure
HIS	Habitação de Interesse Social (Social Interest Housing)
IAG	Instituto de Astronomia, Geofísica e Ciências Atmosféricas (Insti tute of Astronomy, Geophysics and Atmospheric Sciences)
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
LID	Low Impact Development
NTU	Associação Nacional das Empresas de Transportes Urbanos
PAC	Programa de Aceleração do Crescimento (Growth Acceleration Program)
PDE	Plano Diretor Estratégico (Master Plan)
PL	Projeto de Lei 688/13 (Bill 688/13, number of prea-pproved Mas ter Plan)

and abbreviations

PMSP	Prefeitura Municipal de São Paulo (Municipal Government of São Paulo)
PNMU	Política Nacional de Mobilidade Urbana (Urban Mobility National Policy)
RIMA	Relatório de Impacto Ambiental (Environmental Impact Report)
RMSP	Região Metropolitana de São Paulo (Metropolitan Region of São Paulo)
SEHAB	Secretaria Municipal de Habitação (Municipal Housing Secretariat)
SEMPLA	Secretaria Municipal de Planejamento, Orçamento e Gestão (Municipal Planning, Budget and Management Secretariat)
SIURB	Secretaria Municipal de Infraestrutura Urbana e Obras (Municipal Secretary of Infrastructure and Public works)
SMCS	Secretaria Municipal de Coordenação das Subprefeituras (Municipal Coordination of Subprefectures)
SMDU	Secretaria Municipal de Desenvolvimento Urbano (Municipal Urban Development Secretariat)
SMPED	Secretaria Municipal da Pessoa com Deficiência e Mobilidade Reduzida (Department of People with Disabilities and Reduced Mobility)
SMT	Secretaria Municipal de Transporte (Municipal Secretary of Transport)
SPObras	São Paulo Obras (São Paulo Works)
SPTrans	São Paulo Transportes S/A
SuDS	Sustainable Drainage Systems
SVMA	Secretaria Municipal do Verde e do Meio Ambiente (Municipal Secretariat of the Green and the Environment)
USP	Universidade de São Paulo (University of São Paulo)
IAU-USP	Instituto de Arquitetura e Urbanismo USP São Carlos (Institute of Architecture and Urbanismo in São Carlos)
FAU-USP	Faculdade de Arquitetura e Urbanismo USP (School of Architecture and Urbanism in São Paulo)

Glossary

Annual Rainfall
The average amount of rainfall over one year period for your location.

Catchment area
The area in which rain directly falls (i.e. a roof, a driveway, or a landscape). The area is the same regardless of slope; you can also think of the area as seen from a birds-eye view or as the horizontal surface space occupied.

Precipitation
Water released from clouds in the form of rain, freezing rain, sleet, snow, or hail.

Runoff Coefficient
The average percentage of rainfall that will runoff a particular surface (i.e. a metal roof has a runoff coefficient of 0.95 or 95% runoff). The runoff coefficient will vary depending on the composition of the surface and the rainfall intensity. The higher the rainfall intensity, the higher the runoff coefficient.

Infiltration
Is the passage of surface water into the soil. It is, therefore, a process that depends mainly the availability of water to seep, the nature of the soil, state of top-soil and the amounts of water and air initially present in into the soil.

Decentralized infiltration system
On-site installation for infiltration of wastewater runoff produced on a land.

Selective hygrophyte
Plant that has favorable water economy.

Selective xerophytie
Plant that is adapted to live in semi-arid and desert climates or in humid regions (saline water).

Mesophytic vegetation
Associated to the presence of water, typical of temperate and well drained areas.

Sources: *Dictionary of civil and construction engineering* (http://www.engenhariacivil.com/dicionario/) and *Elementos de Hidrologia Aplicada* (Rodrigues Barbosa Jr., Atenor (n.d.).

Parque Linear Agua Vermelha (SVMA, 2012)

1. Introduction

Cities are the main source of Green House Gas Emissions; they are centers of production and consumerism, demanding more energy consumption than rural areas. It is, therefore, in cities where adaptation to climate change measures must urgently be implemented. A city like São Paulo, with more than 22 million inhabitants (including the Metropolitan Region) has a huge effect beyond its geographical boundaries.

A large part of the environmental impact generated by cities in Brazil is directly related to their rapid, informal urbanization process. Despite many historical planning instruments created by the federal government throughout the last century (i.e. innovative master plans and pioneering public housing programs), population and industrial growth has always surpassed the infrastructure expansion needed to house the millions of rural and international workers who immigrated to the city looking for a better lively-hood at the beginning of the 20th century. The city grew organically, without comprehensive planning, in a car-centric manner, driven solely by economic expansion. Today, São Paulo has one of the worse transits in the world, with an average of 47 minutes spent by each citizen going to work every day (IBGE, 2012).

The Municipal Secretariat of Transport (SMT) in São Paulo has developed a series of interventions to better the mobility of the population and significantly improve public transport and traffic in the city (SPTrans, 2013). The most significant intervention is the implementation of Bus Rapid Transit (BRT) systems to connect previously neglected and excluded regions to the center of the city.

There is global tendency of adopting BRT systems as a sustainable solution for mobility in cities. Bus Rapid Transit was first implemented in Curitiba, Brazil in 1974 (ITDP, 2011), and since then it has become a widely used answer to the problem of traffic and pollution in cities like Ahmedabad, Bogotá or Mexico City.

The project “Terminals and Road Systems - Eastern Region 2” (Terminais e Sistemas Viários - Região Leste 2) is part of the Municipal Investment Program and Actions to Improve Public Collective Transport and Traffic (SPTrans, 2013). A section of this project has been selected as the region to be studied in this master thesis. More specifically, the study focuses on a 2 km- fragment of the Perimeter System Itaim Paulista- São Mateus Section III, where most of the expropriation of private housing and commerce will take place. A particularly complex segment, the Itaim Paulista- São Mateus bus corridor project provides a suit-able scenario where different technologies could be tested, implemented and monitored in order to replicate them throughout the city.

The purpose of this study, is to try to integrate water sensitive design (in the form of sustainable drainage systems and green infrastructure) as a plausible instrument for storm water management within conventionally planned transit projects. Currently, the aim of this kind of transportation (BRT) is to reduce CO2 emissions, reduce travel time and help to obtain a better quality of life for the citizens, but the required built infrastructure of the BRT system falls short to seriously address the impact of added paved areas into the built environment, producing considerable reduction of pervious surfaces and contributing to the heat island effect in cities. This situation provides experts a unique opportunity to introduce water sensitive design into transit systems as multi-level, multi-purpose, integrated interventions that link different stakeholders at the city planning stage and provide a comprehensive response to current city-living challenges, with visible positive improvements in the lifestyle of the inhabitants of the city.

This thesis is organized in five parts. The first two chapters analyze the local history and conditions, with special regard to the implementation of the new Master Plan for the city of São Paulo. The realization and passing of this legal instrument is paramount to the future development of the city in lieu of the very pressing challenges of overpopulation, water crisis and other climate related problems. Chapter two introduces the specific study area "as is", as it was presented and approved by the local authorities in 2013. In the same chapter, international best practice examples are analyzed and their results are considered as adaptable solutions for the site in question.

The third chapter presents the investigation of potential stormwater management technologies to be implemented along a 2 km-segment of Itaim Paulista – São Mateus bus corridor (study area). In the fourth chapter, virtual representations of the site with the previously studied technologies are presented as a design toolkit with guidelines for the implementation.

The fifth chapter exposes the conclusions and expectations about the future development of public infrastructure in cities at a time where physical and economic growth must include sustainability and adaptation to climate change at all levels of action.

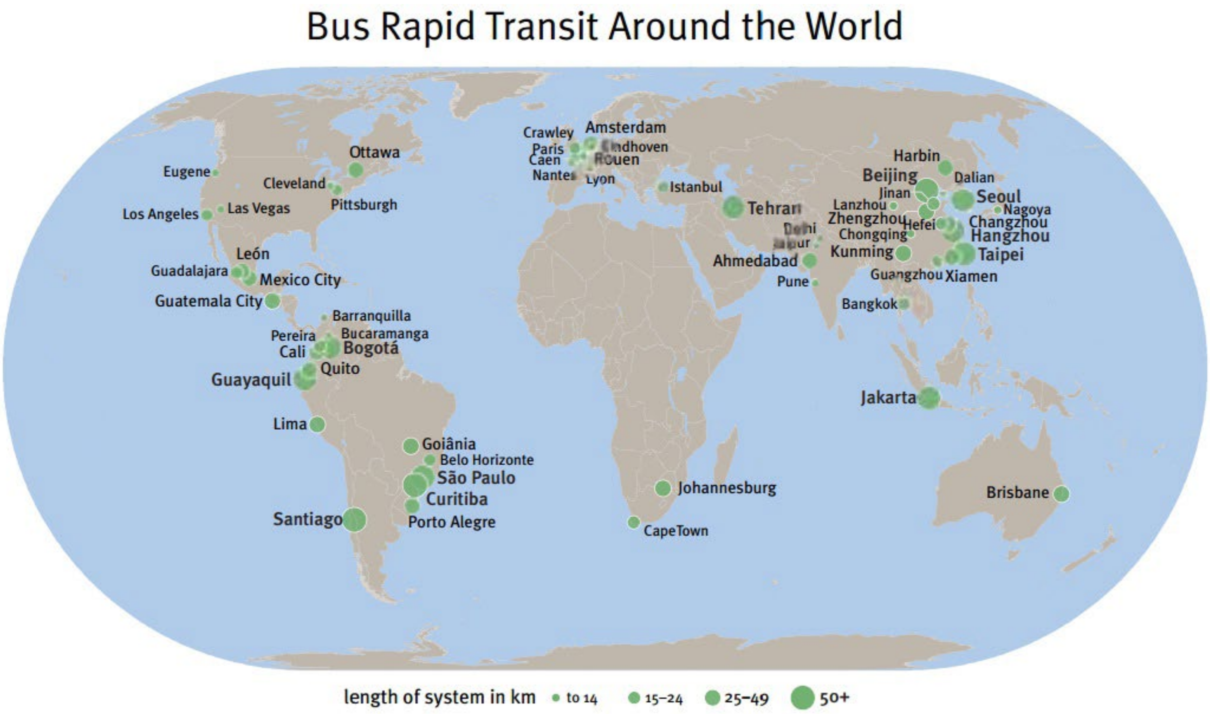


Figure 1:1 Bus Rapid Transit system around the world (ITDP, 2011).

1.1 Methodology

The quantitative part of the research of this thesis consisted on an extensive literature review on topics related to climate change, storm water management, urban mobility, city planning and best practice examples from different parts of the world. The research included interviews with experts in the fields of meteorology, hydrology and urban planning. Data was also obtained from public records from SPTrans, PMSP (Municipality of São Paulo), IBGE (Brazilian Institute of Geography and Statistics), and other local institutional sources such as SABESP (information about water consumption and sanitation) and SIURB (Municipal Secretary of Infrastructure and Public works).

The qualitative part of the research consisted on personal interviews and correspondence with local inhabitants, stakeholders of the project, and users of public transport during the field trip to São Paulo in October, 2014. The qualitative research also includes impressions collected from the students and faculty from the USP-São Carlos and HafenCity University in Hamburg, who took part on the Urban Studies Workshop in February, 2014.

In this study, the potential integration of flood control measures into road infrastructure systems was evaluated by using a dimensioning tool produced by the city of Bottrop in Germany. "Berechnung einer Regenwasserversickerungsanlage nach DWA-A 138 –Von der Mulde bis Sickerschacht" (Calculation of a Storm water management system according to German Law DWA-A-138 – from basin until infiltration shaft) is an Excel-file that calculates the dimensions of various storm water management devices such as: surface infiltration, basin infiltration, trench infiltration, pipe and trench infiltration, basin and trench infiltration and shaft infiltration. The first step was to obtain local rain data based on specific precipitation figures collected during long periods of time.

A major challenge was to find databases capable of providing specific information about rain events in São Paulo in the required format for the dimensioning tool created in Bottrop, Germany. Demographic and geographic information, for example, is obtained mainly through the IBGE and DataGEO data bases, which gather the most reliable data for all municipalities in the country with at least a ten year periodicity. Environmental information, in turn, is sectoral, depending on the natural element to be considered (water, air, soil, etc.). As the proposal here is to work with the issue of storm water management, I chose to use a database obtained from personal correspondence with Professor Plinio Tomaz, who has almost 50 years of experience as a hydraulic engineer, specialized in storm water management and sanitation in Guarulhos, São Paulo.

$$I = 4855{,}3 \times T ^{0{,}181} / (t + 15) ^{0{,}89}$$

T = years; t=minutes; I= L/s x ha

Equation 1:1 – Formula used by Paulo Sampaio Wilke to obtain the precipitation data from São Paulo in 1972 (Tomaz, 2015).

In order to obtain the necessary input data for the Bottrop tool, the project areas had to be calculated with the help of CAD programs (AutoCAD, ArchiCAD). The plans of the corridor intervention in the Eastern Region 2 were found in PDF format at the Municipality of São Paulo's website. The public files were then converted into CAD files and redrawn for better graphic understanding.

After the selected technologies were simulated using the Bottrop tool, the proposed solutions were drawn using CAD programs and plans were generated to compile a comprehensive design toolkit.

1.2 Context

The 'Vila' (village) of São Paulo was founded by Portuguese Jesuit priests in an already existing native Tupi village called: Piratininga. The Tupi had settled on the flat area between the Tamanduateí and Anhangabaú rivers (IBGE, 2014). For approximately 300 years, the Vila of São Paulo existed solely because of these two rivers, today they are forgotten, invisible (Ferraz et al, 2009).

Figure 1:2 Still image of video "Entre Rios" showing the location of the foundation of São Paulo (Ferraz et al, 2009).

Gradually, as the city grew exponentially fast, at the beginning of the 20th Century, the rivers became obstacles for the development of the city (and land speculation) so the practice of channeling and covering the watercourses had begun: The Tamanduateí was distanced from its former banks, giving space to urban reforms. In the 20s, the two rivers that divided the city were transformed into parks: Anhamgabaú Park, over the creek with his name, already channeled buried; and the Dom Pedro II Park on the banks of river Tamanduateí (Ferraz et al, 2009).

Prof. Alexandre Delijaicov (FAU-USP), when interviewed for the "Entre Rios" documentary about the development of the city in relationship to its watercourses, mentions that a crucial point in history was in 1922 when "the famous sanitary engineer Francisco Saturnino de Brito (who designed, for example the channels of Santos and was president of the Tiete River Improvement Commission) proposed the rescue of the urban river edge of the primordial public area for the future metropolis. Saturnino de Brito said that we should guarantee the integrity of the floodplain of Tiete River which had an average width of one kilometer to five hundred meters" (Ferraz et al, 2009). But the government at the time did not follow the visionary advice from Saturnino de Brito and in 1929 followed instead the car-centric master plan designed by Francisco Prestes Maia and Ulhoa Cintra: “Plano de Avenidas da Cidade de São Paulo” (Ferraz, 2009; IBGE, 2013). The plan marginalized (and buried) the existing watercourses and was justified as following the radial concentric model from cities in Europe such as Moscow, Paris, Vienna; but Prestes Maia failed to address that these cities did not obliterate their rivers, they were developed accommodating the rail, the waterway, and the motorcar. This political decision taken so long ago still affects the development of the city and is the origin of many of the physical problems experienced today (Ferraz et al, 2009).

Today, São Paulo has a new Master Plan and even if it still has strong “motorway urbanism” characteristics, the objectives are no longer to accommodate the car and its accompanying industries, the aim is to provide a more humane and fair city, with sustainability and resilience as one of its flags.

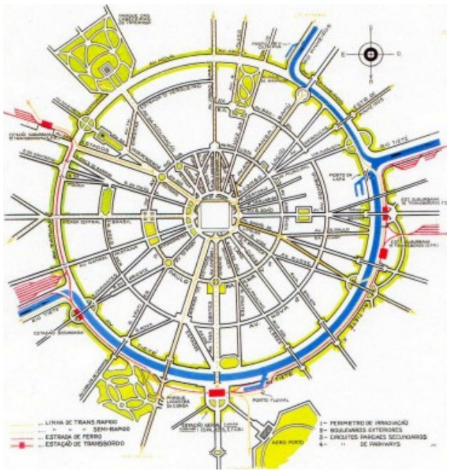


Figure 1:4 Theoretical scheme of the Plan of the Avenues of São Paulo (Maia, 1930; Biblioteca da FAU-USP, 2009).

Figure 1:3 Still images from video documentary “Entre Rios” showing the canalization of the Tamanduateí River in 1912 and its current condition near the Municipal Market in São Paulo (Ferraz et al, 2009).

1.2.1 The new Master Plan for São Paulo: a more humane scale

On July 30, 2014 Mayor Fernando Haddad signed the new law 16.050 / 2014 approving the Master Plan for the city of São Paulo PL 688/13 (Plano Diretor Estratégico Projeto de Lei 688/13). Law 16.050 / 2014 provides a set of principles and rules to guide the use and growth of the city for the next 16 years (PMSP, 2014). The main objective of the Master Plan (PDE) is to humanize and balance the development of the city in order to reduce socio-territorial inequalities. Housing, environment and public transport are some of the main topics addressed in this plan.

The new Master Plan for the city of São Paulo aims to accomplish a more sustainable development of the city. Through a significant extension of the public transportation network, the authorities expect to reduce inequalities and promote a better interconnection between the periphery and the city center. Another main aspect of the new plan is the incrementation of the plot occupancy rate, seeking more density and preventing further urban sprawl in an already extended urban footprint (PMSP, 2014). According to the rapporteur of the Plan, councilman Nabil Bonduki, the impacts of this plans will only become visible by 2016 and 2017 (Lamas, 2014).

To ensure wide participation of society, mandatory in the City Statute, the Organic Law of the Municipality and in the Strategic Master Plan, the Urban Metropolitan and Environmental Policy Committee promoted 45 public hearings: four macro-regional, 31 regional in all boroughs, and ten thematic. The hearings were disclosed in broadcast television, radio, mainstream newspapers, neighborhood newspapers, posters in buses and subway trains, as well coverage of Chamber TV (TV Camara) and Radio Webcam. More than five thousand citizens participated in the process, of which 3,410 signed the attendance lists and 724 made comments through speeches (Camara Municipal de São Paulo, 2013).

Portuguese	English
Art. 2.º Os princípios que regem o Plano Diretor Estratégico são:	**Art. 2** The principles governing the Master Plan are:
I – Função Social da Cidade e da Propriedade Urbana;	I - Social function of the city and the Urban Property;
II – Equidade e Inclusão Social e Territorial;	II - Equity and Social and Territorial Inclusion;
III – Gestão Democrática;	III - Democratic management;
IV – Direito a Cidade;	IV - Right to the City;
V – Direito ao Meio Ambiente Ecologicamente Equilibrado.	V - Right to an Ecologically Balanced Environment.

Figure 1:5 Excerpt from the Bill 688/13 (Camara Municipal de São Paulo, 2013).

Regarding the incorporation of more specific policies to protect the urban environment, the new Master Plan supports and promotes: "Incentives for the construction of sustainable buildings, soil permeability and the maintenance of open spaces and green areas and private property;" (PL 688/2013 Article XXV, part e, 2013).

The topic of mobility guides one of the main objectives of the Master Plan: there will be better and wider use of urban land along the main public transportation axes and terminals. The creation of Structuring Axes of Urban Transformation (Camara Municipal de São Paulo, 2013) facilitates the growth of density near major roads, bus corridors and stations. The Master Plan illustrates clearly where theses axes occur and what the area of influence from each means of transportation comprises (see image below).

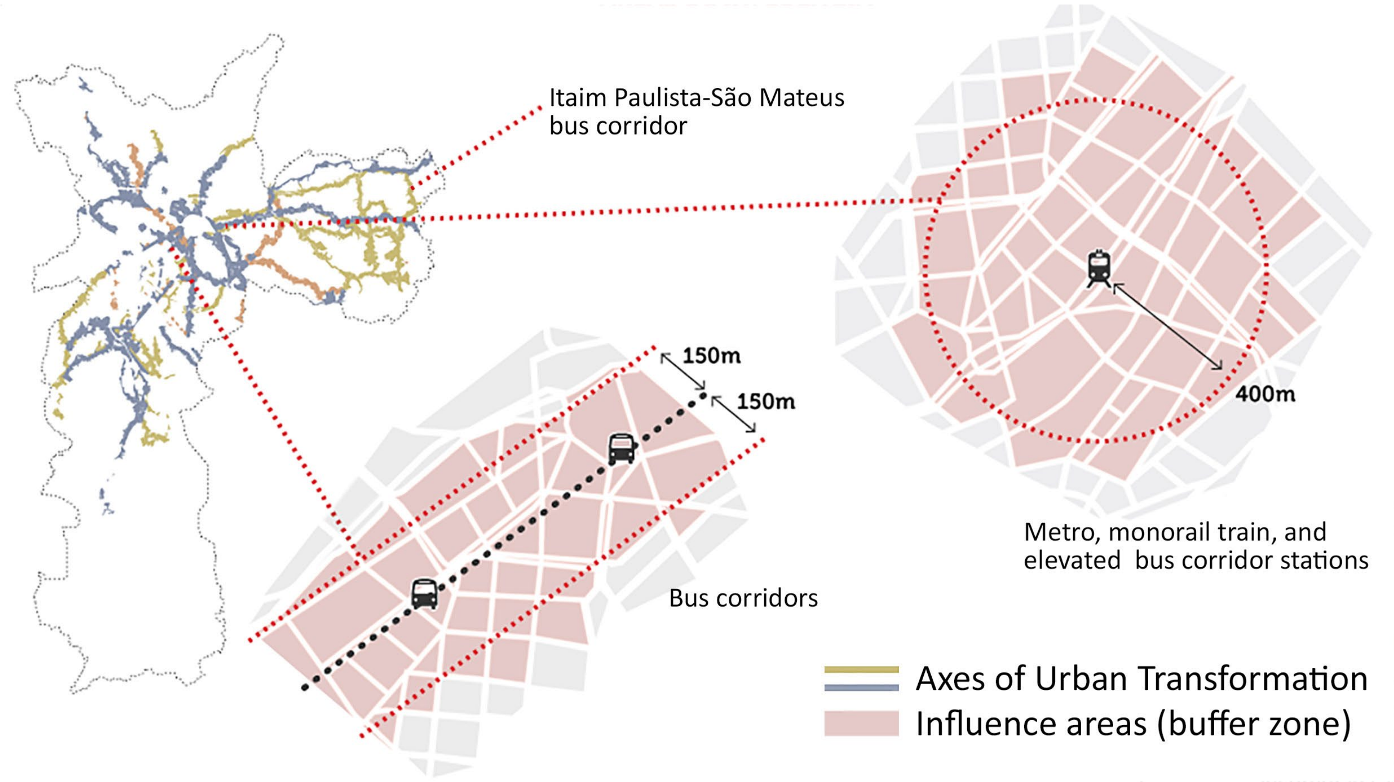


Figure 1:6 Structuring Axes of Urban Transformation with diagrams of the areas of influence of the public transportation network (Prefeitura de São Paulo, 2015; author, 2015).

Furthermore, the Municipal Government of São Paulo (PMSP) is preparing the Urban Mobility Municipal Plan - PlanMob / SP 2015, a mobility plan in which the main objective is to increase access to the city. In preparing the plan the City constituted in August 2014 one Inter-secretarial working group (GTI / PlanMob) with representatives of the Municipal Secretary of Urban Development (SMDU), Municipal Green and Environment - SVMA, Municipal Planning, Budget and Management - SEMPLA, Housing Secretariat - SEHAB, Municipal Department of People with Disabilities and Reduced Mobility - SMPED, Municipal Coordination of Sub prefectures -SMCS, beyond the Municipal Transportation Bureau - SMT, the São Paulo Transportation - SPTrans and Traffic Engineering Company - CET. According to the PNMU, "a municipal plan of urban mobility should act in two large sets of coordinated actions for a single purpose: to improve accessibility and urban mobility through the implementation of a mobility system with an integrated network of public transportation, composed of several complementary ways, non-motorized transport with emphasis on the bike, promote accessibility, cost savings for the user and social inclusion; to reduce the environmental impacts of urban mobility system, by reducing energy consumption, reducing emissions of local pollutants, improving air quality and the reduction of greenhouse gas emissions that cause global climate change" (Prefeitura de São Paulo, 2014).

Although the intention to mitigate climate related problems is mentioned in both the Master Plan and the previous Urban Mobility Plan, there is still not a realizable commitment to include effective adaptation to climate change actions to reduce human vulnerability. Specific flood prevention and adaptive measures are not included in the existing plans. There is always the intention and it is written in the law, but without specific, scientific guidelines the companies in charge of building the new road infrastructure can assume an environmentally friendly 'position by planting a few trees and leaving open spaces as public plazas without any further benefit.

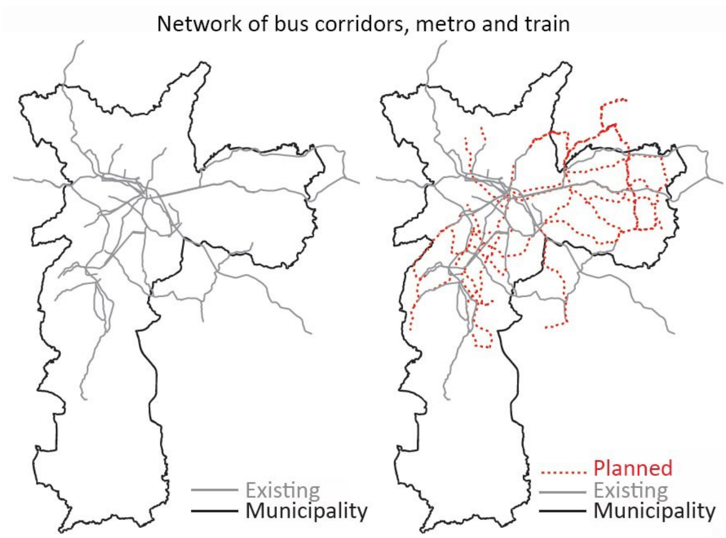


Figure 1:7 Proposed extension of public transit infrastructure in the new Master Plan (Prefeitura de São Paulo, 2015).

1.2.2 Urban Studies workshop: regional implementation of Master Plan (PL 688/13)

Estudos Urbanos SP, novas linhas de mobilidade (Urban Studies, new lines of mobility) was an expert workshop that took place on April, 2014 in the city of São Carlos (São Paulo State). It was an interdisciplinary meeting that invited the participants to study new visions about transportation, stormwater protection and urban development. The organizers of the event were Professor Renato Anelli from IAU USP in São Carlos, Professor Michael Koch from HafenCity University in Hamburg and the Municipality of São Paulo. Participants consisted of an international group of professionals and students from the fields of urban planning, architecture, landscape architecture, geography, civil engineering, environmental studies, the municipal government and residents from the study area.

Together with the Municipality of São Paulo, the two universities hosted the workshop. The project focused on Itaim Paulista, a district in the northeast of São Paulo, where structural interventions are planned in order to simultaneously improve issues at a social, economic and urban level.

In the context of the recent approval of the New Master Plan for São Paulo, one of the purposes of the workshop was to interpret and analyze the impact of a new bus corridor in the periphery of the city. During the ten days of the event, four interdisciplinary groups were formed with the intention to prepare urban study guidelines of integrated actions for the municipal government in the areas of urban development, environment, housing and transportation.

It was in the framework of this workshop that the idea for this thesis was generated. I met professors Anelli and Koch in Hamburg in June, 2014 and three months later was able to travel to São Paulo and start this investigation.

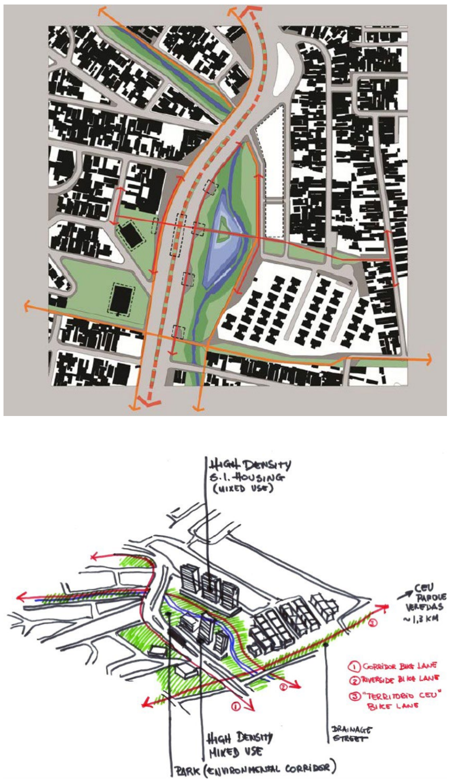


Figure 1:8 Concept analysis of Itaim Paulista - São Mateus bus corridor (Group Maurice-Estudos Urbanos, 2014).

1.2.3 Water scarcity in the Metropolis

The effects of a disordered and informal urbanization and an abusive hydrological system have raised the flood occurrences, erosion, sedimentation, water pollution and temperature in São Paulo, while the re-charge of the aquifers have decreased dramatically. The exceptional drought that affected Brazil's biggest (and wealthiest) city in 2014, raised the awareness and concern among the citizens about this dramatic situation. The threat of water shortages and no visible short-term solution to this problem has the population on edge. Marússia Whately, a water specialist at Instituto Socioambiental, says that "because of environmental degradation and political cowardice, millions of people in São Paulo are now wondering when the water will run out (Romero, 2015)". This quote reflects clearly the sentiment of the people interviewed for this thesis.

At a local level, the origin of the crisis involves a combination of factors, from the fast population growth, to a leaky system that spills about 30% of water before reaching the taps (SABESP, 2014). Pollution of the Tietê and Pinheiros rivers and the destruction of surrounding wetlands and forest also contribute to this worrying situation.

According to Antonio Nobre, one of Brazil's most respected Earth scientists and climatologists, drought is directly related to the extreme Amazon deforestation (Rocha, 2014). Nobre adds that: "If deforestation in the Amazon continues, São Paulo will probably dry up. If we don't act now, we're lost." Nobre produced a report in 2009 warning that if the massive volumes of vapor that usually travel from the Amazon to the south disappear, the RMSP will become a desert, he says that "the Amazon is a gigantic hydrological pump that brings the humidity of the Atlantic Ocean into the continent and guarantees the irrigation of the region (Rocha, 2014)."

As a short-term response to the biggest water crisis in the region to date, SABESP ordered periodical reductions of water pressure. Each district of São Paulo undergoes an average of 14 hours of daily reduction of water supply, depending on the topographic characteristics, size of population and type of pipes (Folha de São Paulo, 2015; SABESP, 2015). According to people interviewed during my field study visit in October, 2014, these measures are far from solving the threat of future water and energy shortages.

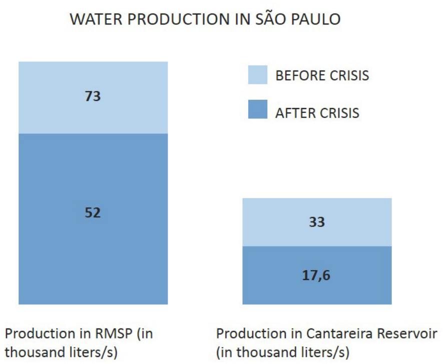


Figure 1:9 Water production in São Paulo (Veronezi/Folhapress, 2015; author, 2015).

Figure 1:10 P Levels in the Cantareira reservoir system remain dangerously low (BBC, 2014).

1.2.4 Itaim Paulista: a self-made district

São Paulo is often compared to New York City, with its “melting pot” characteristics and challenges. Each section and neighborhood usually has a predominant “nationality” among its inhabitants. With a population of 11 244 369 people, São Paulo is divided in 96 districts, of which Itaim Paulista is located on the Eastern extreme of the city (IBGE, 2010). Besides the earliest Portuguese colonizers, Itaim Paulista began to be populated by Japanese, Hungarians and Italians at the end of the 18th Century. Currently, the area has a predominant population of immigrants from Northeastern Brazil (one of the poorest regions of the country). In the 19th century, with the arrival of the Railway Estrada Ferro do Norte (Iron of the North Railway), formerly Central Brazil; the area began to gain urban characteristics with the construction of houses around the rails (Prefeitura de São Paulo, 2010).

The Eastern Region of São Paulo began its urbanization process by the settlement of popular plots with-out infrastructure, often irregularly

Figure 1:11 Conditions of sidewalks at plazas in Itaim Paulista (CLN, 2015).

obtained, and mostly built in a "self-construction" manner. It also grew demographically by the implementation of large social housing projects very much disconnected from the urban fabric. These publicly funded projects failed to address more basic sanitation and transportation deficiencies.

Today, the Sub-Municipality of Itaim Paulista has a population of 533 317 people. It comprises two districts: Vila Curucá and Itaim Paulista. According to the "Social Exclusion Map" of São Paulo, districts Vila Curucá and Itaim Paulista occupy ranks 7 and 10 respectively, meaning that these are some of the regions where more inequality and discrimination is evident in relationship to the rest of the city (Subprefeitura Itaim Paulista, 2008).

Figure 1:12 Location of Itaim Paulista district within the Municipality of São Paulo (IBGE, 2010; author, 2015).

The ZEIS – Zonas de Especial Interesse Social (Special Social Interest Zones)- are areas where predominantly new social housing must be recognized or created, whether in areas already occupied by slums, informal settlements popular - known as "regularization ZEIS" – either in empty areas, preferably inserted in regions with infrastructure (Camara Municipal de São Paulo, 2013). The Sistema Perimetral Itaim Paulista-São Mateus crosses through a type one ZEIS, which means that these areas are occupied by low-income population, where there is interest to regularize the situation of slums and irregular settlements and build public facilities (Canduzini, 2014). Before the approval of the New Strategic Master Plan, the maximum occupation rate of the plots was 0,5 (Subprefeitura Itaim Paulista, 2004). The current Master Plan stipulates an occupation rate of 1,0 which stimulates urban density and aims to stop the sprawl of the city (Prefeitura de São Paulo, 2014).

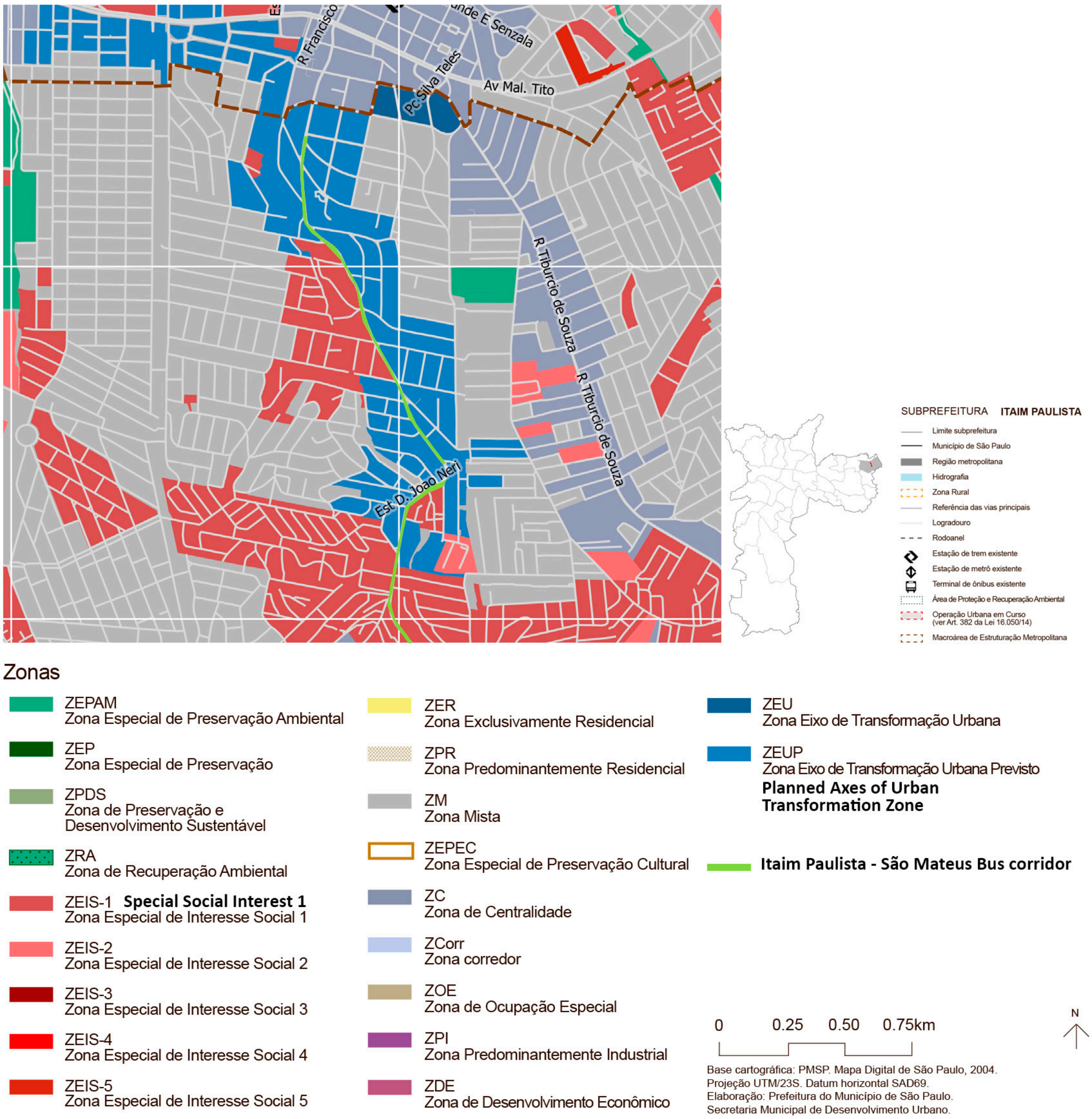
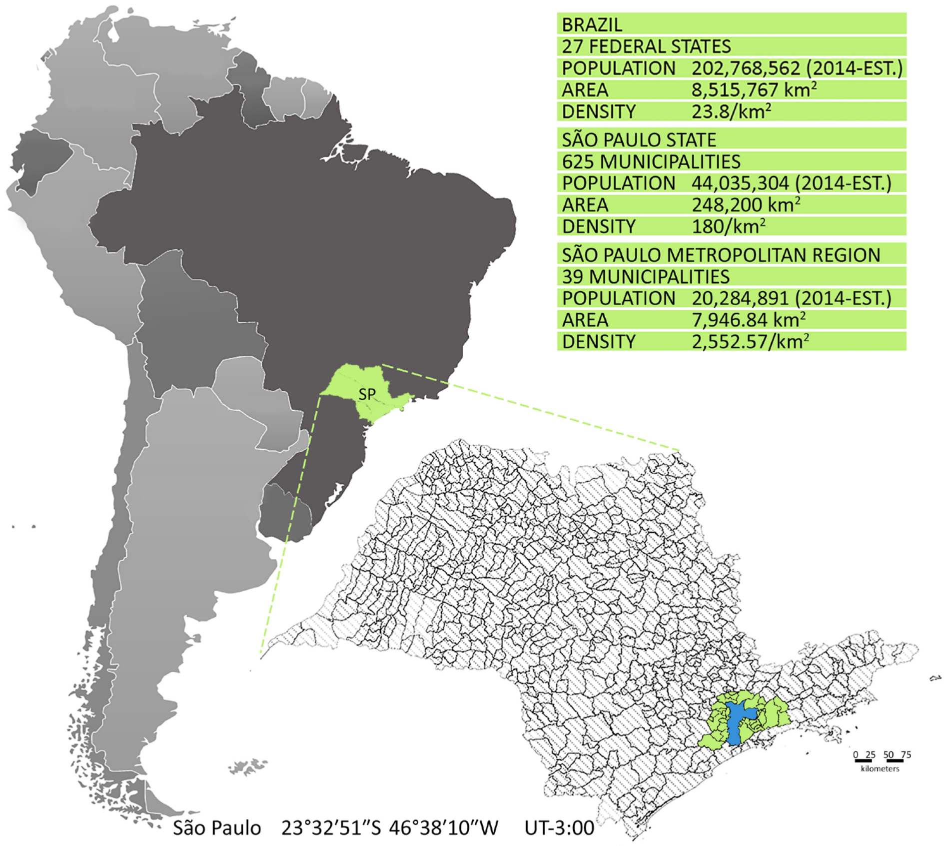


Figure 1:13 Zoning law along the Itaim Paulista – São Mateus bus corridor (Prefeitura Municipal de São Paulo, 2013; author, 2015).

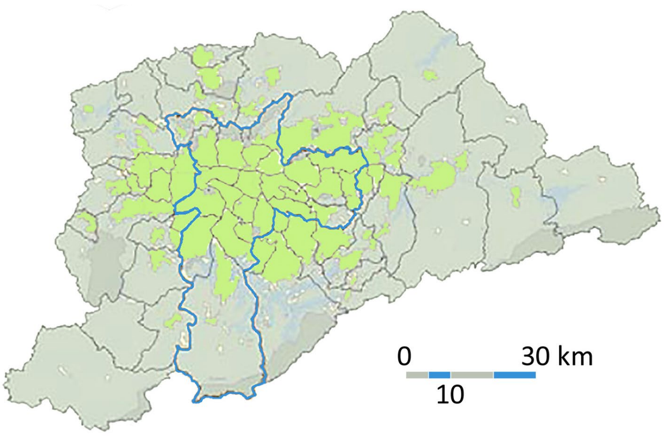
2. Analysis

São Paulo is located at an altitude of approximately 715 to 900 meters above sea level. The annual average temperature is around 20º C, and the annual precipitation is 1400–1500mm. There are rainy and dry seasons, and half the precipitation concentrates in the rainy season, normally from December to March (IBGE, 2014).



BRAZIL	
27 FEDERAL STATES	
POPULATION	202,768,562 (2014-EST.)
AREA	8,515,767 km²
DENSITY	23.8/km²
SÃO PAULO STATE	
625 MUNICIPALITIES	
POPULATION	44,035,304 (2014-EST.)
AREA	248,200 km²
DENSITY	180/km²
SÃO PAULO METROPOLITAN REGION	
39 MUNICIPALITIES	
POPULATION	20,284,891 (2014-EST.)
AREA	7,946.84 km²
DENSITY	2,552.57/km²

Figure 2:1 General information about Brazil, São Paulo State and Metropolitan Region of São Paulo (RMSP) (IBGE, 2013; author, 2015).



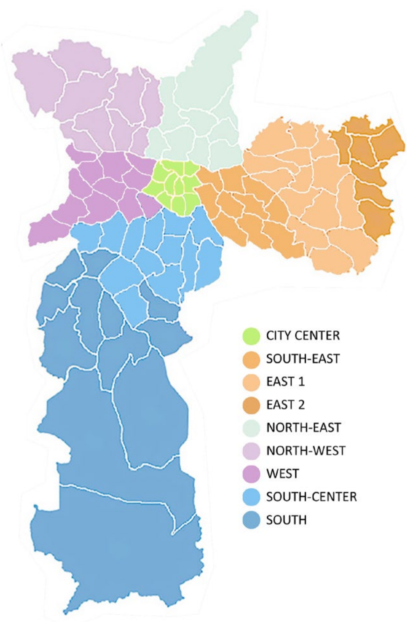


Figure 2:2 Map of the RMSP and the City of São Paulo with its regions and its 96 districts (IBGE, 2013; author, 2015).

2.1 Analysis of São Paulo

The city of São Paulo provides standardized guidelines for all types of infrastructure projects. In the case of urban drainage, Brazil adopts an absolute separator system, meaning that stormwater is separated from the wastewater sewage. The institutions responsible for the coordination of stormwater management measures are DAEE, SIURB, SABESP and CETESB (Canduzini, 2014). The association of environmental preservation with the development of public infrastructure is a new challenge for the municipality. The following is an image that summarizes the scope of work expected by the road engineers in terms of urban drainage. It is a conventional, grey scheme that has had very little improvement over the years.

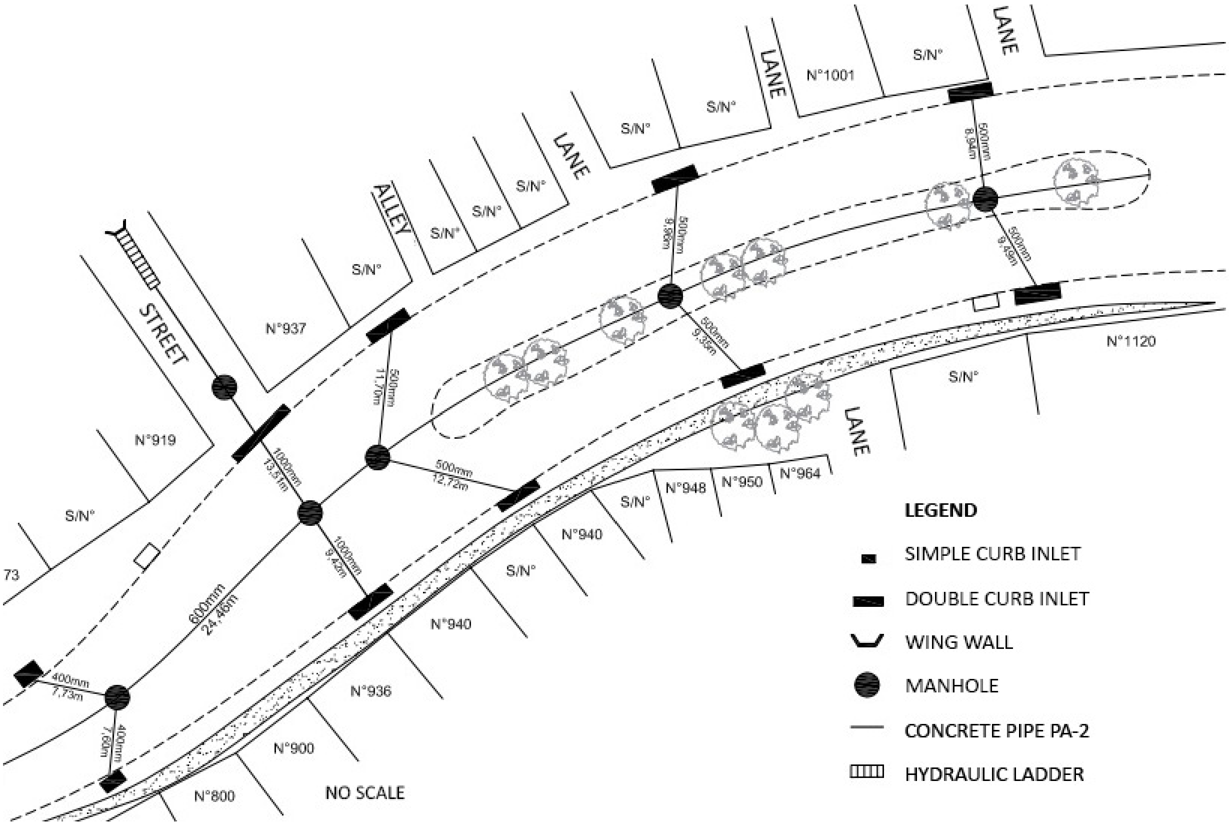


Figure 2:3 Typical urban drainage plan from the Urban Infrastructure Technical Detailing Manual in São Paulo (SPDR, 2011).

In the case of stormwater management in road infrastructures, conventional planning devices include:

Bocas de Lobo or Boca de Leao (curb opening inlets) which are collection boxes built in masonry. Their function is to receive the rainwater that runs through the gutters and direct it to the sewage system. In accordance with the specific need for drainage, the “bocas de lobo” may be simple, double or triple compartment and equipped with precast concrete or iron grids (Nakamura, 2011). Each municipality in the Estate of São Paulo has standardized measures but the dimensions of inlets and their type is determined by the flow of arrival defined by calculating rainfall in the region and return period of more intense rains. Besides curb inlets, the system consists on inspection shafts; connecting networks and branches, with pipes ranging from Ø 0.60 to Ø 1.50 meters for major networks and branches with Ø 0.50 or 0.60 m; man-holes; hydraulic ladders and wing walls (where necessary). The drainage project is developed on the basis of geometry and land registry survey of the environment of the site (SPDR, 2011).

The paradigm of urban drainage is starting to change in São Paulo and the new Master Plan gives room for more efficient and up to date implementations. At the same time, during the field trip in October, 2014, and through an ongoing monitoring of the public works in the city, there is evidence that authorities and some professionals still misunderstand the concept of “green infrastructure”. Such is the case of a recent report in the Globo newspaper stating that the Mayor of São Paulo has approved a pilot project to plant trees in the middle of the streets, making a small hole, directly in the asphalt (Globo, 2015). The pilot project is located in the Patrocinio Paulista Avenue in the Eastern region of São Paulo (Globo, 2015). Even if this program does not directly relate to urban drainage, it is a “make-up” solution where valuable re-sources are wasted and the proposed response to the deficit of trees in the city (which is the driving force of the initiative) can prove disastrous when the roots start to affect the sewer system usually buried under the asphalt.

Figure 2:4 Conventional urban drainage devices (Nakamura, 2011).

Figure 2:5 Trees planted directly in the asphalt (Fabio Arantes, 2015).

2.1.1 The site: Perimetral System Itaim Paulista – São Mateus, Section III

The Perimetral System Itaim Paulista – São Mateus, Section III is a segment of a bus corridor and terminals part of the project "Terminais e Sitemas Viários - Região Leste 2" (Terminals and Road Systems – Eastern Region 2) in São Paulo, Brazil. "The project aims to increase the attractiveness of public transport, through the reduction of travel time by optimizing the capacity and efficiency of public transport offer" (SISTRAN, 2013), as well as promote a better environmental quality and comfort for the inhabitants of the otherwise poorly connected Eastern region of São Paulo. The corridors of the Eastern Region 2 are divided in four sections with a total extension of 44.6 km (SISTRAN, 2013):

1. Perimetral System Bandeirantes – Salim Farah Malif – Section I (Southern region) with 15.9 km
2. Eastern Radial Corridor – Section III (Eastern Region) with 8.1 km
3. Perimetral System Itaim Paulista – São Mateus, Section II (Eastern Region) with 7.6 km
4. Perimetral System Itaim Paulista – São Mateus, Section III (Eastern Region) with 9.5 km

The present study is focused on the Perimetral System Itaim Paulista – São Mateus, Section III which ex-tends from Do Jaú Street, Iguatemi road, Da Passagem Funda and Saturnino Pereira Streets, Deputado Antônio Silva Cunha Bueno Viaduct, Roads Lajeado Velho and Dom João Neri until Marechal Tito Avenue (SISTRAN, 2013). The following image illustrates the AII (Indirectly Affected Area) of the implementation, it also shows the degrees of economic inequalities the farthest one moves from the center to the east of the city.

The new Master Plan for São Paulo identifies the corridors and terminals in Itaim Paulista as Structuring Axes of Urban Transformation (Eixos de Transformacao urbana), which means that in this region private owners and developers will be allowed to build more than elsewhere in the city, the areas of influence of the bus corridors are within a radius of approximately 150 m; there should be fewer cars on the road, public transport should be predominant and the construction of more garages should be restricted or minimized (Camara Municipal de São Paulo, 2013).

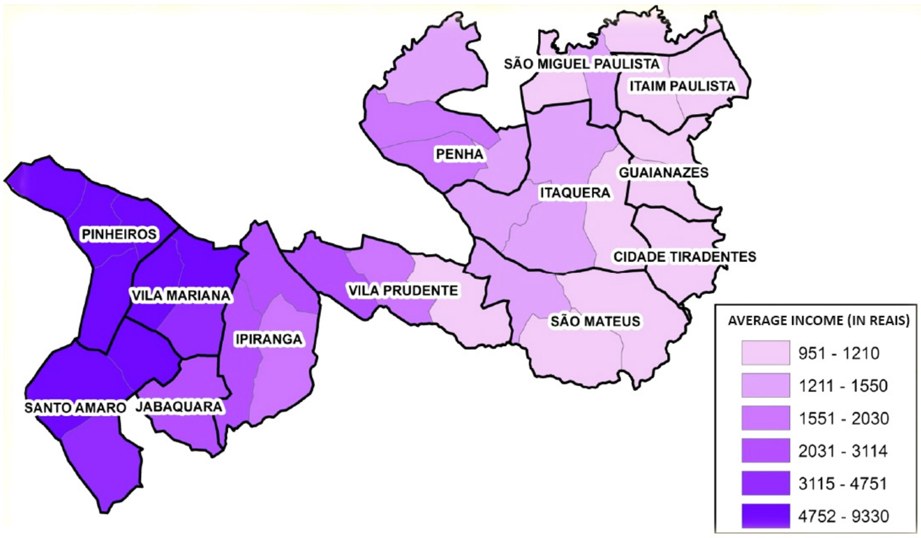


Figure 2:6 Social inequality in the AII districts. Note: 1000 BR$ = approx. € 290 (SISTRAN, 2013).

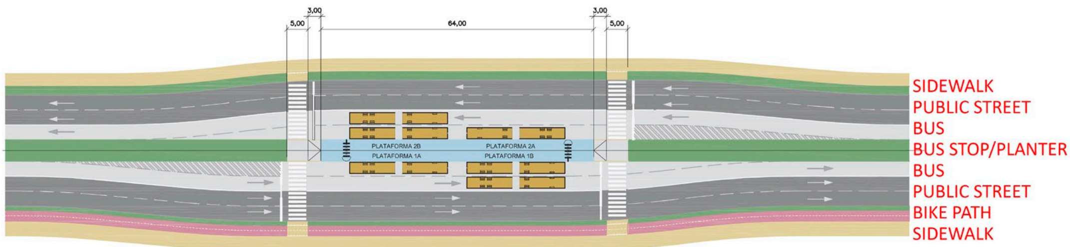


Figure 2:7 Proposed bus stop plan for a central platform scheme at Itaim Paulsta – São Mateus corridor (SISTRAN, 2013).

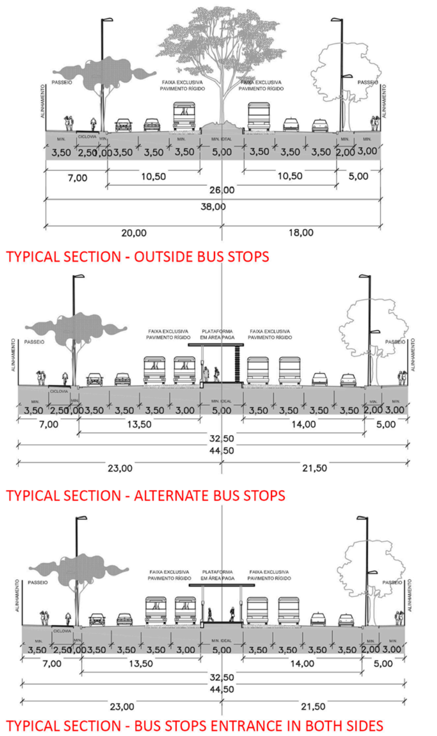


Figure 2:8 Typical sections of Itaim Paulista–São Mateus corridor (SISTRAN, 2013).

The budget given to the municipality by the federal government as part of the PAC 2 (Programa de Aceleração do Crescimento: Growth Acceleration Program for works for mobility, drainage and sanitation in the city) for the Perimetral System Itaim Paulista – São Mateus, Section III amounts to R$ 529 million (Brazilian Real), about 161,949,847.82 Euro (Prefeitura Municipal de São Paulo, 2013). We can then estimate a cost of about R$ 55684 or 17,034.89 Euro per kilometer. “In 2015 and 2016, São Paulo will turn into a construction site. The 165 kilometers of corridors will be running until March,” said the Mayor of the city, Fernando Haddad (O Estado de São Paulo, 2014). According to Haddad, the city has 37.5 km of corridors in the works. This year the city will begin to build 60.8 kilometers (O Estado de São Paulo, 2014).

There are many stakeholders involved in the project, including several Sub-Municipalities, the following table provides an overview of the responsibilities and functions of some of the main decision makers of this venture.

Table 2:1 Stakeholders of the Itaim Paulista – São Mateus corridor (SPTrans, 2013; and author, 2015).

Stakeholder	Activity/Role	Affiliation
SPTrans	Public transport operator of the city of São Paulo, responds to the SMT (Municipal Transport Secretary). In this project, SPTrans acts as the developer or "client".	Public
SISTRAN Engenharia Ltda. (Part of Consorcio Leste 2)	Multidisciplinary Engineering and Architecture Company specializing in infrastructure, construction, auto-motive, energy and environment projects, they are in charge of the project, the environmental assessment, the environmental impact report (RIMA) and the execution of the "Terminais e Sitemas Viários - Região Leste 2"	Private
DEPLAN	Departamento de Planejamento Ambiental (Department of Environmental Planning). Part of the SVMA, is responsible for the study, planning and implementation of the necessary actions to adapt the city to the new scenario of climate change. DEPLAN must outline a strategic action plan to the definition of policies, programs and projects lined in this new scenario of compulsory change, as well as implement new adaptation programs, assisting the bodies of the City Hall in the formulation of sectorial policies.	Public
DEPAVE	Departamento de Parques e Áreas Verdes (Department of Parks and Green Areas). It grants the Environmental Commitment Agreement (TCA)	Public
DEPRN	Departamento Estadual de Proteção dos Recursos Naturais (State Department of Natural Resources Protection). Grants the Environmental Recovery Commitment Agreement (TCRA)	Public
GEOMETRICA ENGENHARIA (Part of Consorcio Leste 2)	Engineering Company specializing in infrastructure projects, involved in the execution of the project.	Private

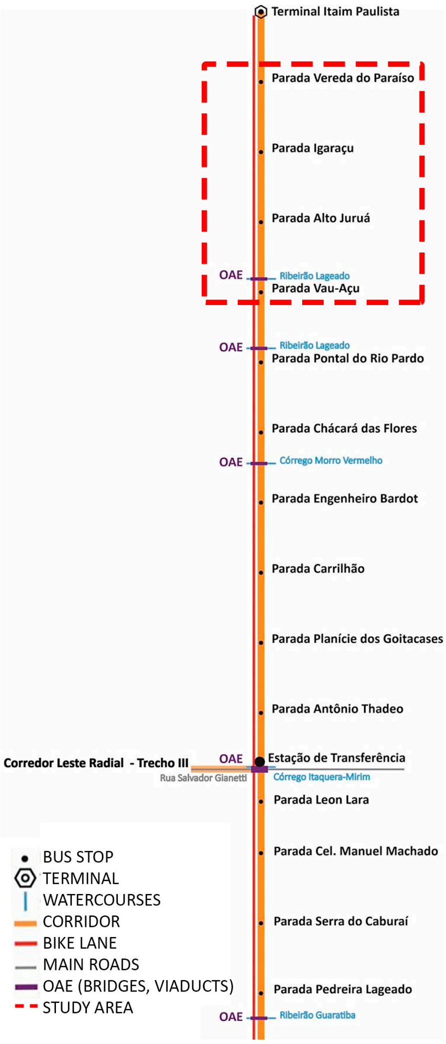


Figure 2:9 Two-kilometer study area from the Perimetral System Itaim Paulsta – São Mateus – Section III (SISTRAN, 2013).

At the beginning of implementation, additional specific environmental permits were obtained in order to continue the process of implementation (SPTrans, 2013):

- Tree management (cutting and / or transplantation);

- Significant vegetation management and / or immune to cut;

- Tree management or occupation of Permanent Protection Area (APP);

- Intervention in the Watershed Protected Area (APM).

For the execution of construction works of Terminals and Road Systems – Eastern Region 2, expropriation and intervention in public areas is required. Most of these expropriations will be carried out in the Perimetral System Itaim Paulista – São Mateus, Section III because at this section the roads are narrower and unable to support the implementation of new bus lanes and the existing traffic flow.

The expropriated areas (Fig. 2.10) along the Lajeado Stream give the opportunity for new open green spaces that provide both leisure and entertainment areas as well as natural flood prevention possibilities.

The main goal of the re-planting and landscaping program for the Itaim

Paulista – São Mateus corridor is to enhance the environmental quality of the ADA (directly affected area) by the management of existing isolated arboreal specimens, as well as their immediate surroundings. Another objective is to improve the functional effects of the green areas along the implementation and provide connections to compensatory plantations with significant open, park areas around. According to the professionals involved in the design of the project, to maintain the existing tree density of the area as a minimum, the intention is plant ad-di-tional appropriate species, increase the maintenance of green areas and provide connectivity between parkways and green areas (SISTRAN, 2013).

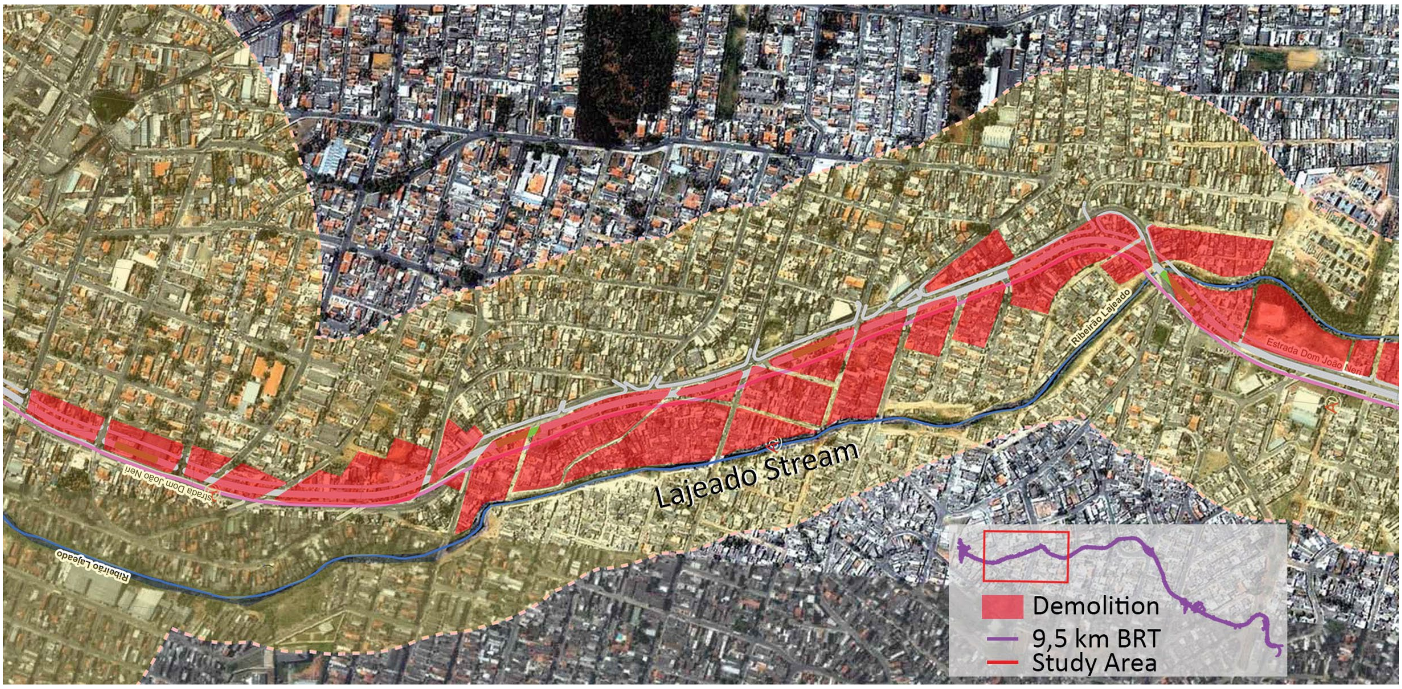


Figure 2:10 Study area within the buffer zone showing the scope of the future expropriation and demolition works (Google Earth, 2014; SPTrans, 2013; and author, 2015).

Figure 2:11 Plan showing the overlapping of proposed Itaim Paulista –São Mateus bus corridor with existing conditions (SPTrans, 2013; author, 2015).

2.1.2 Existing BRT corridors

The current urban mobility legislature (Federal law 12.587 - 2012 and Municipal Law 16.050 – 2014) has the implementation of exclusive lanes for buses (bus corridors) as one of the main objectives for the sus-tain-able development of São Paulo (SPTrans, 2013). The corridors are exclusive lanes for large buses and are designed to better distribute the vehicles on the roads, reducing traffic and travel times.

Table 2:2 Existing BRT systems in São Paulo (SPTrans, 2013; and author, 2015).

	Bus corridor	Year	Length
	Paes de Barros	1980	3,9 km
	Santo Amaro - 9 de Julho - Centro	1987	12,7 km
	Inajar - Rio Branco - Centro	1991	13,6 km
	Itapecerica - João Dias - Centro	2000	6,2 km
	Pituba - Lapa - Centro	2003	15,2 km
	Jd. Angela- Guarapiranga- Santo Amaro	2004	7,5 km
	Ver. Jose Diniz - Ibirapuera- Sta. Cruz	2004	10,3 km
	Campo Limpo - Reboucas - Centro	2004	13,8 km
	Parelheiros - Rio Bonito - Santo Amaro	2004	24,3 km
	Expresso Tiradentes	2007	10,8 km
			108,3 km

In a public audience carried out in October, 2013, SPObras presented the many benefits of the construc-tion of the new bus corridors in the Eastern Region 1 and 2 of São Paulo. Along with the positive general impacts of the implementations, it was mentioned that in terms flood prevention, the following measures are going to be employed (SPObras, 2013):

The Emergency Management Center (CGE) will conduct regular data survey and monitor the AID.

New green and permeable areas will be created

Environmental Compensation Program

Tree Planting and landscaping Program

Figure 2:12 Bus corridor at Av. Rio Branco (SPTrans, 2013).

Figure 2:13 M'boi Mirim corridor at Av. Vitor Manzini with new stops (SPObras, 2015).

Figure 2:14 Completed works at Av. Marques de São Vicente, part of the Inajar de Souza Bus Rapid Transit system in São Paulo (SPObras, June, 2014).

The following sections give an overview of some of the existing and future corridors (segments of corri-dors are still under construction). All of the studied and visited corridors follow conventional constructive methods with stormwater directly discharged into the central drainage system. The main contribution of the bus corridors in terms of stormwater management, according to the field study, is that parts of the sidewalks and middle section of the street were left as "green space", where urban trees and lawn can be planted encouraging natural runoff infiltration. But the infiltration capacity of the soils throughout the city varies drastically and a more scientific approach should be carried out determining how the new "green space" should be constructed.

2.1.2.1 Inajar de Souza Bus Corridor

The Corridor Inaja de Souza has an extension of 14,6 km and an area of 382000 m2 of flexible asphaltic concrete, plus 129000 m2 of rigid concrete pavement. It is currently under construction with an estimated completion date for August, 15, 2015 (SPObras, 2014).

Although it is an exclusive bus corridor system, it does not have terminals with "pre-paid ticket" facilities, but it is still an improvement from the conventional bus system, with more security and less waiting time for its users. In terms of the road adaptation, this corridor does not constitute large amounts of new paved area, due to its construction over an existing roadway with appropriate dimensions to adapt the requirements for larger buses.

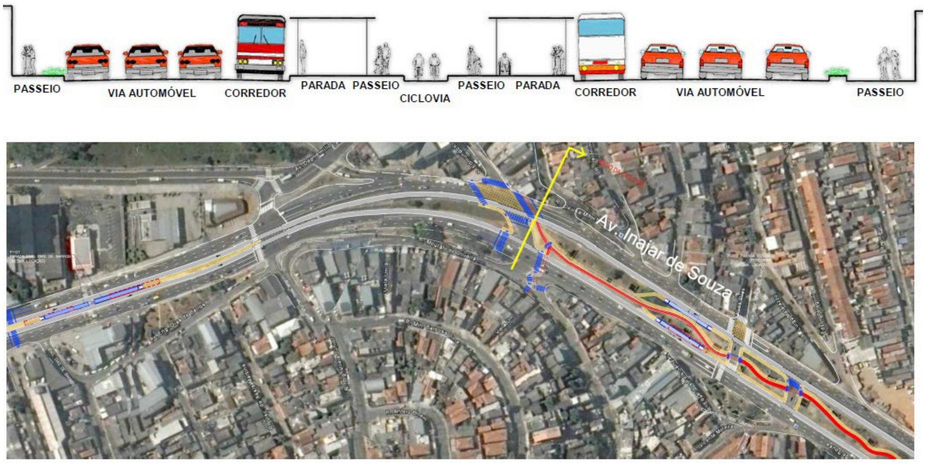


Figure 2:15 Typical Section, segment of Av. Inajar de Souza Bus Rapid Transit system in São Paulo (SPObras, 2014).

As seen in the previous section and plan, the corridor has sectors with exclusive bike paths in the middle of the bus roads, providing a speedier and more secure mobility for its users (SPObras, 2014).

2.1.2.2 Santo Amaro Bus Corridor

The Santo Amaro Binary Corridor, located in the Southern region of the city, has an extension of 8,5 km and is a retrofitting project. It is currently under construction with an estimated completion date for March, 2016 (SPObras, 2014). Bus stops are located on the left and right of the corridor, with payment inside the bus.

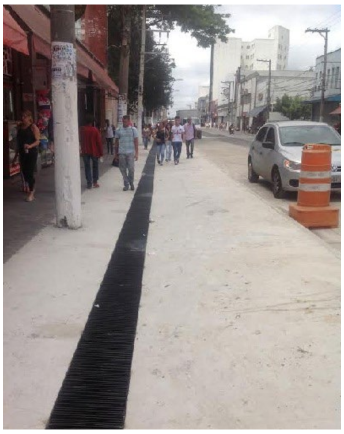


Figure 2:16 Sidewalk under construction (left) and another segment completed in Santo Amaro Corridor (SPObras, 2014).

The left image shows the sidewalk at Av. Adolfo Pinheiros, near 13 de Maio Street (SPObras, 2014). The sidewalk was enlarged and has to be set up to standard (textured floor cover and signalization). At anoth-er segment of the Santa Amaro Corridor, triple sluice gates (boca-de leão) were installed to improve drainage in the area. This was implemented taking into account the request and suggestions of local mer-chants (figure 2.17).

Figure 2:17 Conventional drainage ("boca de leão") in Santo Amaro Corridor (SPObras, 2014).

2.1.3 Linear Parks

The Strategic Master Plan introduces the Environmental Recovery Program for Water Courses and Bot-toms of Valleys, in order to consider Hydrological Networks as structuring elements of the urbanization. The Linear Parks, with the recovery of the valley bottoms, are the main line of action of this program, re-storing the environmental logic of the watershed (Prefeitura de São Paulo; Fungaro; Moreti, 2012).

According to Councilman Nabil Bonduki, the new Master Plan also proposes the creation of the Municipal Fund for Parks, intended solely for the purchase of areas and enable the implementation of parks in the city. The goal is to raise funds both from municipality and the private sector and citizens, in a kind of col-lective funding. The fund will have specific accounts for each park and for every cent donated to the Mu-nicipality, it will allocate the same value out of the Municipal Fund for the Environment (Fema) (Bonduki, 2014). In other words, in addition to the funds allocated for road infrastructure, there is an incentive and an opportunity to combine projects and efforts.

2.1.3.1 Parelheiros Linear Park

Figure 2:18 Parelheiros Linear Park (SPTrans, 2014)

The implementation of the Parelheiros Linear Park resulted in the licensing process of the Rio Bonito Cor-ridor as a compensation project. It was built during the 2004-2009 administration. The park was planned in the Regional Master Plan of the Parelheiros Sub-Prefeitura (local municipality) and its main objective was the recovery of the valley bottom through the restoration of the vegetation and the creation of leisure areas (Prefeitura Municipal de São Paulo, 2014).

Located in the Amazonas Park District, Parelheiros Linear Park was implemented along the Parelheiros Stream, it has two sources of drinking water, 1,500 trees, space for hiking, soccer field, playground and a square (SVMA, 2010). The area is cut by a watercourse tributary to the Kaolin Stream. The land use is pre-dominantly residential with a total area of 30,000 m². The park has an area of 16,032 m² and is divided in two sections: section 1- with 5608 m² with sports and leisure facilities-, and section 2 -without additional equipment - with an area of

10,424.40 m². The existing vegetation consisted mainly in grasses, reeds and marsh lily, closer to the stream, with a few native trees (Prefeitura Municipal de São Paulo, 2014).

Besides the preserved and newly planted vegetation, the stormwater management at Parelheiros Linear Park is provided with conventional drainage and materials. The storm water that is not infiltrated naturally is collected by gutters and discharged into conventional sewage system. There is still an opportunity for improvement by introducing decentralized storm water management devices like trenches and bio-swales.

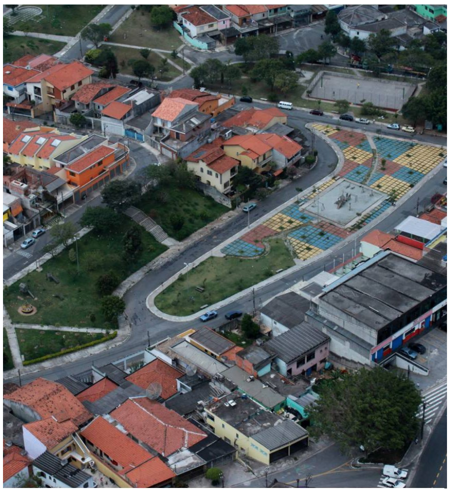


Figure 2:20 Aerial view of Ipiranguinha Linear Park (Prefeitura de São Paulo, 2014)

2.1.3.2 Ipiranguinha Linear Park

Implemented in 2007, in partnership between the Sub municipality of Vila Prudente/Sapopemba and the SVMA, the park was created to improve conservation areas of the Ipiranguinha Stream, tributary of the Aricanduva River, and to contribute to the urban drainage in the region (SMSP, 2014). The park has a total area of 24,905 m2 which includes playgrounds, walkways, lawns, sparse trees and resting areas (SMVA, 2010).

Another positive aspect of the Ipiranguinha Linear Park was the conscientious planting of an orchard with local species of fruits (avocado, jambeiro, pitangueira, etc.). This was initiated by the local inhabitants and taken over by the park's administration providing additional amenities to the local population and attract-ing local fauna.

Figure 2:19 Leisure infrastructure at Ipiranguinha Linear Park (Guia dos Pargues/SVMA, 2010)

2.1.3.3 Itaim Linear Park

In 2006, the Sub municipality of Itaim Paulista designed a re-urbanization project along the banks of the Itaim stream with the help of other public institutions such as SMSP, SEHAB, SVMA, and SABESP. Around 275 precarius homes were removed (the inhabitants were later relocated in social housing projects) from the banks of the Itaim stream and a unique agreement was signed between the inhabitants of the region and the Sub municipality promising that the newly recuperated stream bank would not be re-occupied. The investment had a total budget of R$ 20 million Brazilian reais (approx. € 5,8 million Euros), which in-cluded the relocalization of the inhabitants and the up-grading of the remaining informal settlements along the banks of the stream (Subprefeitura Itaim Paulista; Ramos, 2007).

The Linear Park Itaim is 3,5 km long and was created to ensure permanent preservation of the banks of the Itaim Stream as public areas (SVMA, 2012). The implementation of the park aimed to improve the urban drainage. The project was also part of the response to the extreme flood events of December 22, 2005, when just along the Itaim Stream, more than 600 families had to be evacuated (Ramos, 2007).

Figure 2:21 Conditions before linear park was implemented along and Itaim stream and destruction after en extreme flood event in December, 2005 (Central Leste Noticias, 2007).

This situation generated enough political pressure to seek for rapid solutions to the threat of future dev-astating floods. This gave the opportunity for the already designed project “Fluir” (Flow), developed by architect Rosane S. Keppke and engineer Aguinaldo Prieto from the Sub municipality of Itaim Paulista, to receive the support and the funds for its execution. “Fluir” was a proposal from the Strategic Master Plan developed by the Sub municipality of Itaim Paulista, which incorporated the demands of the civil society that participated in more than 25 public audiences and workshops. The civil society expressed that floods and lack of mobility are the worse barriers for the development of Itaim Paulista (Ramos, 2008).

Figure 2:22 Initial works of expropriation and cleaning of the Itaim stream in 2006 (Central Leste Noticias, 2007).

Figure 2:23 SABESP decontaminating the stream and correcting the banks with gabions (Central Leste Noticias, 2007).

“Fluir” has inspired the rest of the population in the municipality to accept and see value of the recupera-tion and preservation of the streams, as one local person said: “we cannot get rid of the water, we have to learn how to live with it”.

Figure 2:24 3D Model showing the planned park infrastructure (SPIT, 2005; Central Leste Noticias, 2007).

2.2 Analysis of international examples

There are several built and unbuilt best-practice examples that are combining a multidisciplinary, multi-layered approach to urban development in response to climate related problems. Transit infrastructure is a major topic to be addressed and improved in most developing cities where the rapid growth of the population outruns the capacity of the municipalities to provide proper services to the population. The previous section shows that there are already some improvements in the different ways of defining and allowing more sustainable growth actions. The following is a compilation of best-practice examples of water sensitive design and flood risk management activities drawn from: Mexico City (Mexico), Stock-holm (Sweden), and Portland (USA).

Figure 2:25 Location of best practice examples and study area.

These examples have been chosen based on some similarities in the scales of the city (Mexico City), cli-mate related problems (Portland), as well as the likelihood of adapting innovative proposals into the Pau-lista context (Stockholm).

Table 2:3 Overview of study regions (World Development Indicators, 2014; author, 2015)

City	Population City	Population Metropolitan Region	Area City (km²)	Area Metro (km²)	Elevation (masl)	Annual Precipitation (mm)	GDP per capita (Country-USD)
São Paulo	11895893	20284891	1522	7934	760	1454	5730.2
Mexico City	8851080	21178959	1485	7954	2240	770	8532.3
Portland	609456	2314554	376	17310[1]	15	914	45038.2
Stockholm	911989	2198044	188	6519	29	539	45260.1

[1] The Portland Metropolitan Region spans over two states: Oregon and Washington

2.2.1 Mexico City: Green infrastructure and ecological corridors

The Green Infrastructure and Ecologic Corridors in Pedregales project proposes clear and punctual solu-tions that can be implemented in densely urbanized areas of the southern region of Mexico City. Histo-ri-cally, a region with outstanding natural drainage qualities, Pedregal is today a densely populated colonia (neighborhood) facing serious climate related problems (Camarena, Herrera, Lot, & Suárez, 2011). Be-cause of the city's conventional urban growth (grey infrastructure), Mexico faces today problems with floods, heat island effects and a chronic deficiency of green, open, public spaces (i.e. there are very few parks and sports facilities for the majority of the population). All these problems are the result of exces-sive impervious paving over the natural infiltration areas and diverting of the original watercourses, prac-tice that begun since colonial times.

The project Green Infrastructure and Ecologic Corridors in Pedregales resulted in a book, with the same name, published by the UNAM (Na-tioanl Autonomous University of Mexico). The book is a compilation of research done by of professionals from the architecture, landscape ar-chitecture and biology departments at the UNAM-Universidad Nacio-nal Autónoma de México (National Autonomous University of Mexico) with the aim of providing guidelines to adapt conventional infrastruc-ture and provide pervious and plant-ed surfaces for the improvement of public space as well as restoring the original ecosystem (Camarena, et al, 2011).

The researchers defined conventional infrastructure as "grey", with impervious surfaces, heavy pave-ment, flood-prone zone, and dependent on a central drainage system. A “green” infrastructure, on the other hand, includes pervious surfaces, green areas, infiltration zones and groundwater (aquifer) re-charge (Camarena, et al, 2011).

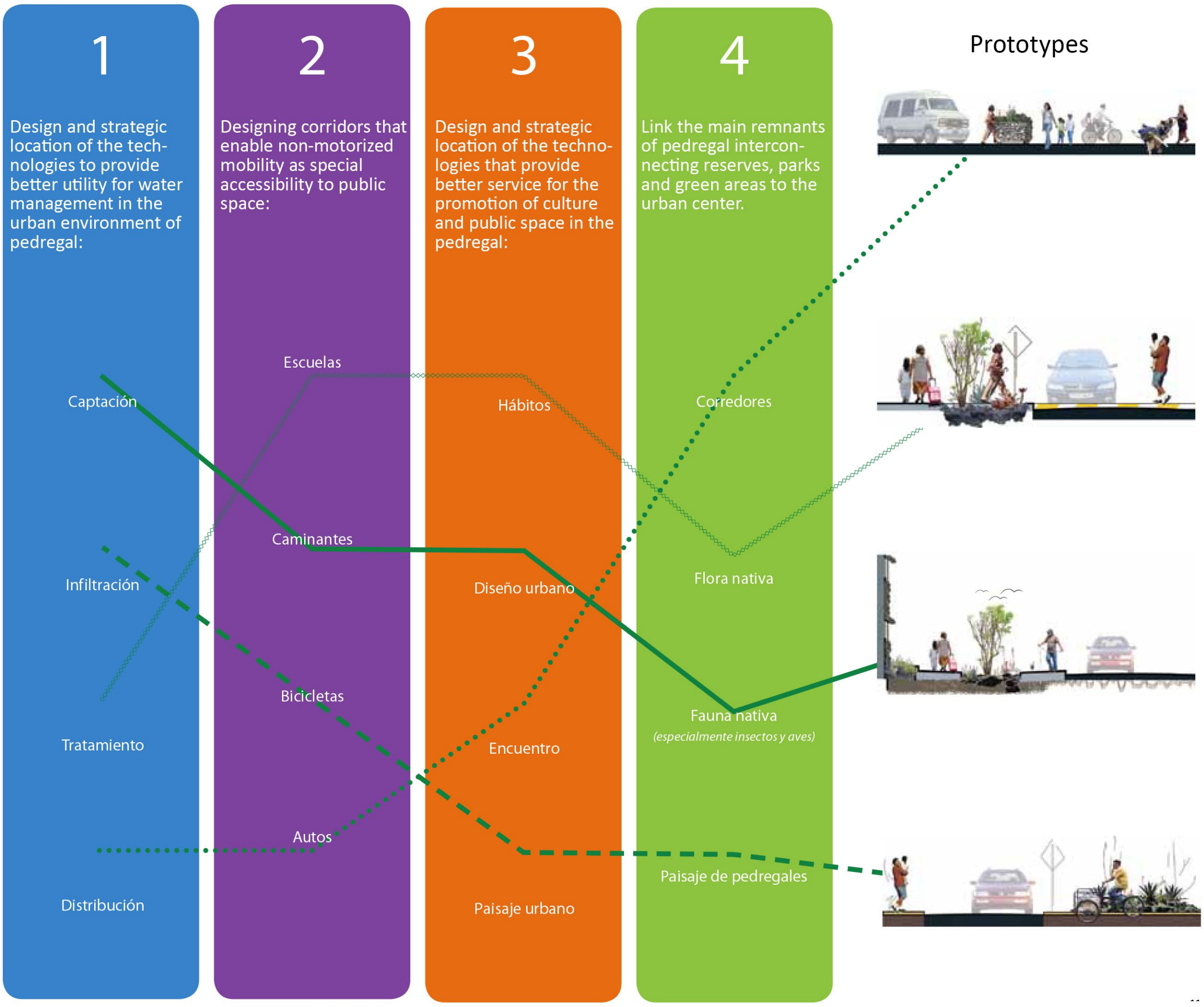


Figure 2:26 Thematic axes: (1) water, (2) non-motorized mobility, (3) public space, and (4) biodiversity (Camarena et al, 2011).

Through an extensive analysis of the region the researchers identified four points to be dealt with and improve: water, non-motorized mobil-ity, public space, and biodiversity. The book and the design toolkit that evolved from this research is divided into these four thematic axes (see figure 2:27).

The Green Infrastructure and Ecologic Corridors in Pedregales project is a relevant example for this study because both Mexico City and São Pau-lo face similar challenges due to bureaucracy and budget limita-tions,

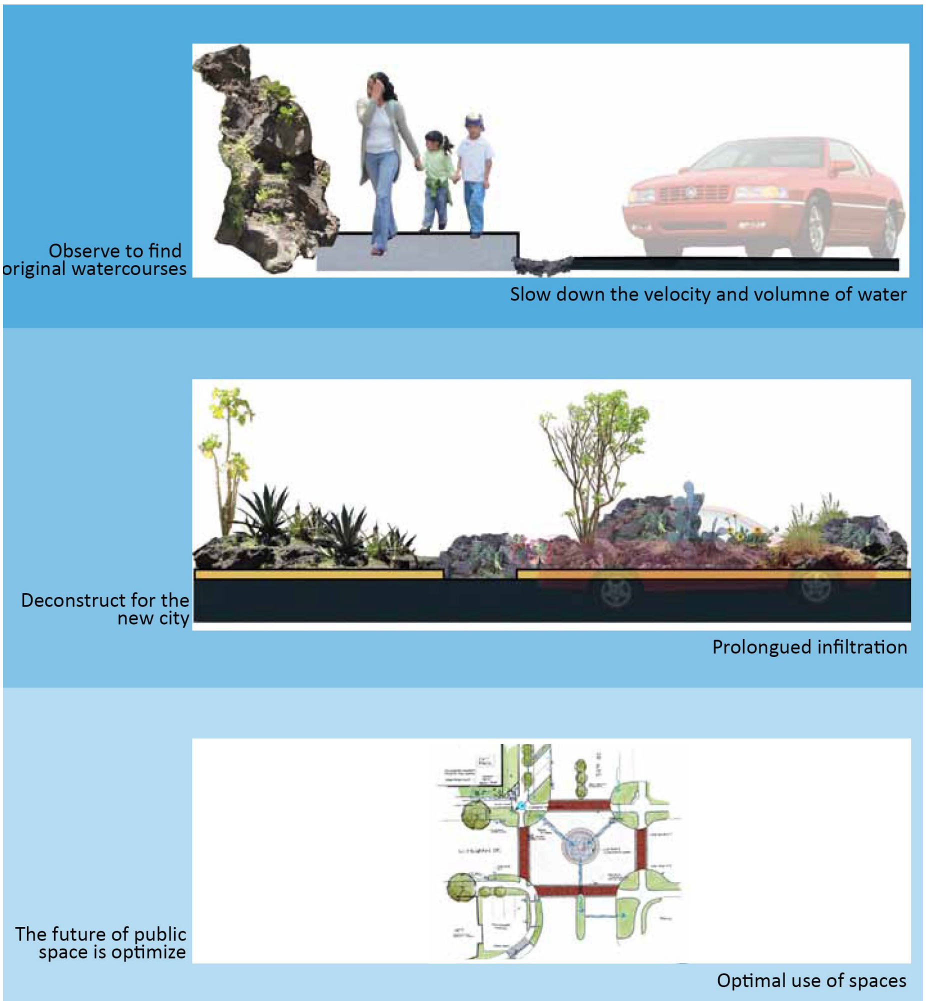


Figure 2:27 Prototypes for stormwater management measures in Mexico City (Camarena et al, 2011).

making it essential to create clear, easy to follow tools to convince authorities and the civil society in general of the importance of water sensitive design for our cities today.

Ficha técnica No. 1

THEME: INFILTRATION

MODEL: SLOW VELOCITY AND VOLUMEN OF WATER

Observar para encontrar los cauces originales

USE
- Median
- Av. Aztecas
- Mani Street, Chicoasén
- Wide streets and median
- Pedregal promenade

CAPACITY AND DIMENSIONS

Volume in m³	Variable	
Length x Width in m	Variable	0.25 – 3
Height in m	Floor level	

Vista General

FEATURES:
- Driving the water to the point of infiltration
- Apparent rocky ground
- Native vegetation
- Openings for crosswalks
- Fitting opening to allow free movement of water

Corte esquemático

BENEFITS
SAVE ENERGY CONSUMPTION
FLOOD FREE
LOW MAINTENANCE
SAVINGS IN IRRIGATION
GREAT APPEARANCE

COST
LOW HIGH

Posibles dimensiones

Figure 2:28 Example of technical sheets for the construction of prototypes (Camarena et al, 2011).

2.2.2 Stockholm: the solution

In 2009, the Traffic Department of Stockholm, Sweden, published the handbook: Planting Beds in the City of Stockholm with the purpose to inform authorities and contractors about the conditions of urban trees (Embren, 2009).The Stockholm system for planting urban trees consists of: “plant beds built with granite stone where storm water is infiltrated” and pollutants are filtered (Embren, 2009). Over more than 10 years of experimentation and perfection of the “Stockholm System,” for planting urban trees, under the supervision of the Traffic Department, the outcome is a city with healthy and resistant trees. The image below explains the basic components of the system.

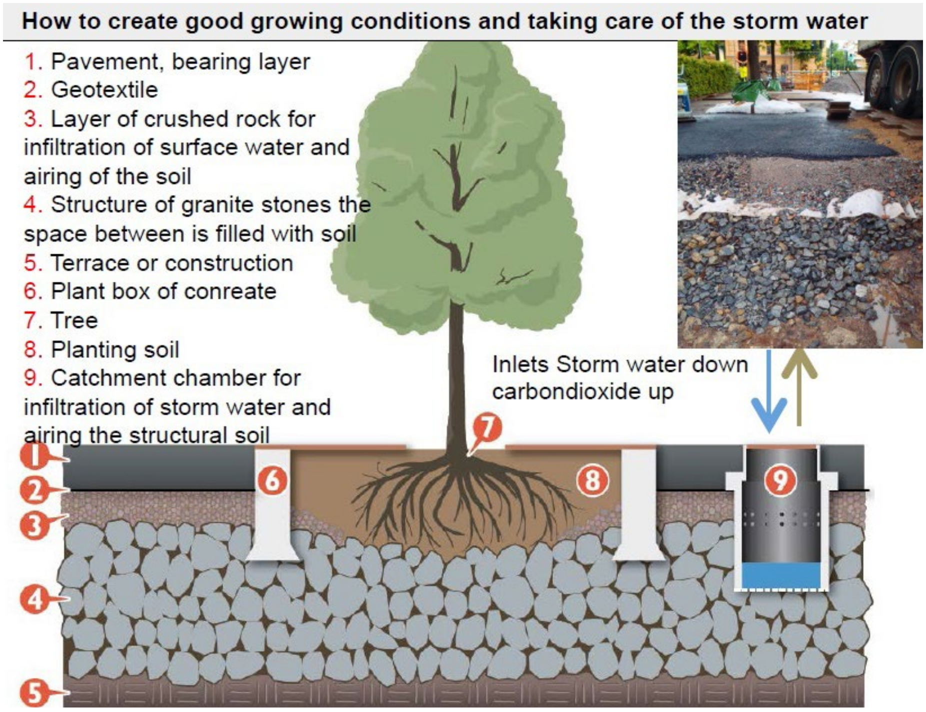


Figure 2:29 Diagram of the “Stockholm System” (Embren, 2013).

Recently, the Traffic Department used recycled concrete with the structural soil for the planting beds (Embren, 2013). This seems particularly appropriate for the situation in Itaim Paulista, where demolition of several concrete streets and houses will give room to the new bus corridor. The image below shows the new bed with the mix of recycled concrete and planting soil.

Figure 2:30 Planting beds utilizing recycled concrete instead of granite stones (Embren, 2013).

Overall, this is an optimal example to adopt in São Paulo because it combines stormwater management with a stable and healthy environment for the trees. Because this system has not been used in São Paulo it would be important to create a few testing beds in order to observe the amount of water that is taken in and see if the trees survive with that amount of water infiltrated; according to the they do very well in Stockholm, but the climatic conditions and the species are very different from the ones in São Paulo. The tests should also ascertain how long it will take for the rain water to disappear from the infiltration bed. Only after such tests have been conducted locally, we will be able to assess the actual reduction of stormwater using a “Stockholm System” in a sub-tropical region.

Figure 2:31 Testing planting beds in Stockholm (Embren, 2013).

2.2.3 Portland: Grey to Green

In 2008, the Environmental Services of the City of Portland in Oregon, USA, created the Green to Gray initiative in order to promote green infrastructure projects and programs to develop more natural storm-water runoff control, restore native plants, protect sensitive natural areas, and restore Portland's streams. Grey to Green encouraged the construction of facilities such as "green streets, Ecoroof, and rain gardens that capture and manage stormwater with vegetation and soils" (City of Portland, 2013).

Grey to Green was a public and private initiative that took place until 2013, with some of its individual pro-grams still undergoing. The following table gives an overview of the scope and results obtained by the City of Portland in five years.

Table 2:4 Grey to Green Accomplishments (City of Portland, 2014; author, 2015)

Actions	Programs & Partners	Results	Characteristics
Planting Yard and Street Trees	Urban Canopy Program - Friends of Trees - Private Contractors	32200 new street and yard trees	Innovative planting models to get more trees planted in low-canopy. Community volunteers contributed almost $2 million dollars worth of hours
Constructing Green Streets	Tabor to the River Program – SE Clay Green Street – Green Street Stewards Program (on going)	867 new green street planters	Environmental Services continues to monitor performance and improve designs to reduce maintenance costs
Controlling Invasive Plants	Parks & Recreations' Protect the Best Program – Early Detection, Rapid Response Program	7400 acres (2994,67 ha) treated for invasive plants	Besides preventing degradation of natural parks, the invasive species program supported Youth Conservation Crew, giving job opportunities to 14-18 year-old people to help clear ivy from parks.
Replacing culverts (channels)	Army Corps of Engineers - Metro, Portland Parks & Recreation - Reed College - East Multnomah Soil & Water Conservation District - NOAA	13 culverts have been removed and replaced. 9 culverts that block fish passage and create water quality problems in Crystal Springs Creek will be removed or replaced by 2015.	The project includes restoration of ponds and facilities in parks to manage stormwater runoff from area streets.
Building Ecoroofs	Ecoroof Incentive program – Green Roof info Think-tank (GRiT)	Since 2008: 191 ecoroofs covering 11 acres of rooftop (= 8 football fields) By 2015: 398 ecoroofs (ongoing)	The ecoroofs manage millions of gallons of stormwater before reaching the sewer system. More development projects are pairing ecoroofs with photovoltaic panels or adding habitat features to maximize use of rooftops.
Acquiring and Protecting Open Spaces	Environmental Services – Volunteers	406 acres of natural areas were purchased to protect natural stormwater management functions and clean water sources.	Land management and revegetation on the acquired River View Natural Area is helping the native forest come back to life, and community volunteers are helping restore the forest so it can sustain visitors in the future.
Natural Area Revegetation	Watershed Revegetation Program - Public and private property owners	4100 acres of native vegetation restored.	The program includes 500.000 new native tree and shrub seedlings planted.

Figure 2:32 Stormwater planter design in the streets of Portland, Oregon, USA (City of Portland, 2014).

Figure 2:33 Stormwater planter with inlet from Capitol Highway and 34th Street in Portland, Oregon (City of Portland, 2014).

The Green Street's program in particular is a good example of stormwater runoff management in a more natural manner, allowing water to soak back into the ground and recharge the groundwater (City of Portland, 2013). According to the city officials, this program is more cost-effective than piping stormwater to a treatment plant. Another positive aspect of this program is the embellishment of the city, creating a more pleasant, calm environment for the people (City of Portland, 2013).

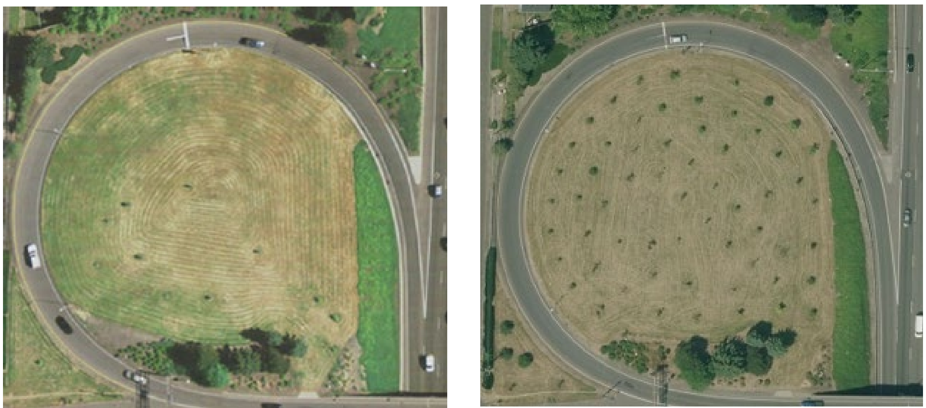


Figure 2:34 Growing the urban forest in underused open-spaces: Before and after image of a highway exchange that grows from a few trees to more than 50 (City of Portland, 2014).

One of the main aspects of the Grey to Green initiative is its educational and participatory approach. Port-land inserted several “best practice” examples throughout the city and promoted their benefits in a strong free media campaign. For example, Portland’s Bureau of Environmental Services published a series of videos to teach private owners how to build their own stormwater management facility step by step. The following images are stills from one of these educational videos available online as an open-source tool (https://www.youtube.com/watch?v=hXjq9ZDA1_g) (City of Portland, 2012).

The City of São Paulo could take the example of Grey to Green and develop a “How to…” and pilot pro-grams where communities could help to implement and maintain green infrastructure in their neighbor-hoods under the supervision and support from experts from the municipality.

Figure 2:35 Still images of step-by-step video "How to Build a Raingarden" (City of Portland, 2012).

3.

Planning (phase 1)

In order to unify the concepts observed in the previous chapter, the 2 km-study area of the Itaim Paulista - São Mateus corridor serves as a real platform to showcase a comprehensive list of tech-nologies that can improve the management of stormwater and recharge the ground-water. There is al-ready a predisposition and intention on behalf of the municipal government to move from heavy conven-tional and central-ized infrastructure into more local and adaptive measures to improve urban drainage in São Paulo. The implementation of the linear parks (Parelheiros Linear Park, etc.) is a clear example of this tendency, its main purpose being the recovery of ancient flood plains.

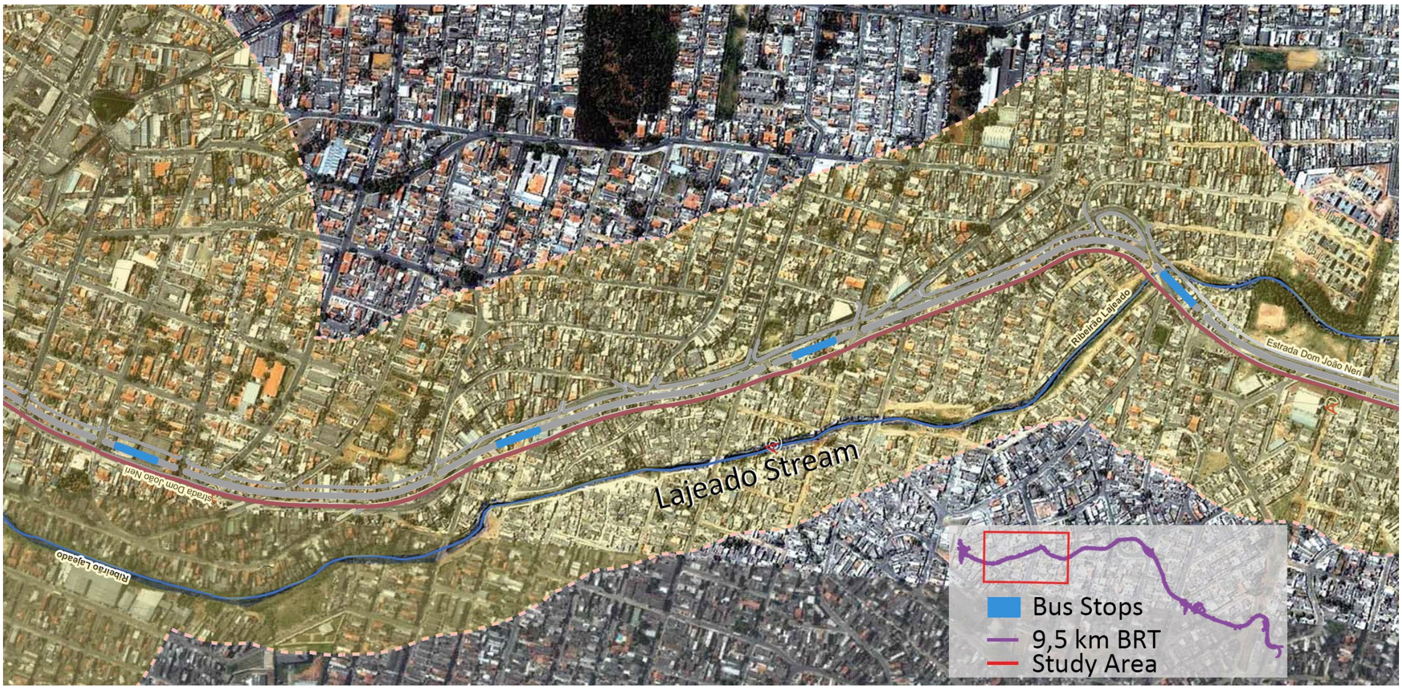


Figure 3:1 Two kilometer study area with 150 m buffer zone (Google Earth, 2014; SPTrans, 2013; and author, 2015).

The urban water cycle is under increasing social, environmental and economic pressure. The challenges of managing the water cycle are demonstrated by the extreme droughts experienced last year (2014) in São Paulo and the severe floods that occurred in February 2015. Al-ternative approaches need to be explored and the conventional urban development is no longer sustainable nor affordable. To extend the ef-ficien-cy of drainage in public spaces such as parks, streets, avenues, gardens and squares, the authorities and contractor companies should include sustainable drainage systems and green infrastructure in all of the interventions in the city, new and old.

Sustainable Drainage Systems (SuDS) are very different from conven-tional urban drainage methods used in most cities in Brazil.

Component	Description	Example
Filter strips	These are wide, gently sloping areas of grass or other dense vegetation that treat runoff from adjacent impermeable areas.	
Swales	Swales are broad, shallow channels covered by grass or other suitable vegetation. They are designed to convey and/or store runoff, and can infiltrate the water into the ground (if ground conditions allow).	
Infiltration basins	Infiltration basins are depressions in the surface that are designed to store runoff and infiltrate the water to the ground. They may also be landscaped to provide aesthetic and amenity value.	
Wet ponds	Wet ponds are basins that have a permanent pool of water for water quality treatment. They provide temporary storage for additional storm runoff above the permanent water level. Wet ponds may provide amenity and wildlife benefits.	
Pervious surfaces	Pervious surfaces allow rainwater to infiltrate through the surface into an underlying storage layer, where water is stored before infiltration to the ground, reuse, or release to surface water.	
Constructed wetlands	Constructed wetlands are ponds with shallow areas and wetland vegetation to improve pollutant removal and enhance wildlife habitat.	
Filter drains and perforated pipes	Filter drains are trenches that are filled with permeable material. Surface water from the edge of paved areas flows into the trenches, is filtered and conveyed to other parts of the site. A slotted or perforated pipe may be built into the base of the trench to collect and convey the water.	

Table 3:1 Sustainable drainage systems that may be applied along the Itaim Paulista –São Mateus corridor (Woods-Ballard et al, 2007; author, 2015)

The basic principle of SuDS is to mimic nature and manage rainfall locally, reducing the discharge into sewer systems. SuDS help to attenuate the runoff; allow water to soak into the ground and replenish the groundwater; and filter out pollutants (Woods-Ballard et al, 2007).

Understanding the role of the interventions listed in the previous table and taking into consideration the local conditions, can lead to a substantial reduction of runoff can be achieved. The storage of stormwater in detention and retention basins, storm drainage trenches, swales, stormgardens and constructed pervious surfaces can mitigate floods in the ADA (Directly Affected Area) of the project. The table below illustrates the relationship between cost (German values) and different characteristics of stormwater facilities.

Before determining which technology or strategy is best suited for the site, an analysis of the 2 km-study area was conducted with the help of geographical information systems (Open GIS, Google Earth, Google Maps, Streetview and the local database DataGEO) and CAD files. Specific areas and dimensions of the implementation were then calculated and categorized according to the material on the surface. The 2 km segment of the corridor was divided into 6 sections or regions in order to work at a more precise scale. Each section was analyzed individually and the areas were inserted into the tool: "Calculation of a Storm-water management structure according to German Law DWA-A-138", developed by the City of Bottrop, Germany.

Table 3:2 possible applications of infiltration systems (DWA-A138, 2006; Sicker mbH, 2013)

Surface availability (Low → High)	Infiltration	Storage	Discharge	Cost (Germany)
Low	Surface			2,5-5 €/m²
	Swale	Swale		3,5-12 €/m²
	Swale and Trench	Swale and Trench		25 €/m²
	Pipe- and Trench infiltration	Pipe- and Trench infiltration	Pipe- and Trench infiltration	100-135 €/m³
	Basin	Basin		12 €/m²
High	Drop Shaft	Drop Shaft		1000 €/unit

Capability to infiltrate in the ground: High ← → Low

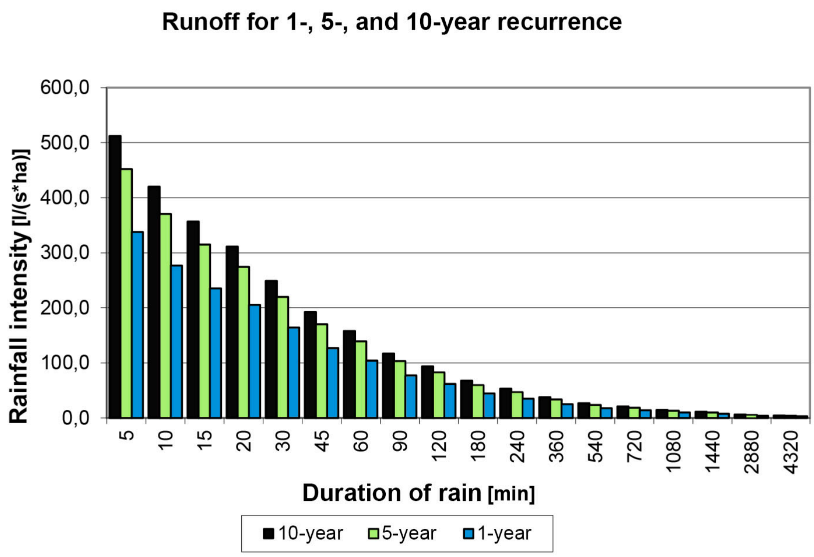
To find the appropriate device to control the generation of runoff and reduction of overall volume of small and large rain events was one of the aims of this study. The Bottrop dimensioning tool suggests the ideal dimensions of infiltration facilities, according to the local rain data, the type of soil (permeability co-efficient) and the surface of the materials chosen in the project (runoff coefficient).

In the case of São Paulo, the rain data introduced in the following table and chart was obtained from Engineer Plinio Tamaz, expert in hydraulic engineering from Guarulhos, São Paulo. Prof. Tamaz calculated the rainfall intensity with data recorded since 1934, utilizing the formula: I= 4855,3 x T ^0,181/ (t + 15) ^0,89 (in which T= years; t=minutes; I= l/s * ha).

Table 3:3 Rain data for São Paulo inserted in the dimensioning tool developed by the City of Bottrop (Bottrop, 2011; author, 2015)

Raindata for São Paulo:

D (Duration) [min]	$r_{D(n)}$ 1 [l/(s*ha)]	$r_{D(n)}$ 0,2 [l/(s*ha)]	$r_{D(n)}$ 0,1 [l/(s*ha)]
5	337,5	451,7	512,0
10	276,7	370,3	419,8
15	235,3	314,8	356,9
20	205,1	274,5	311,2
30	164,0	219,5	248,8
45	127,0	169,9	192,6
60	104,1	139,3	157,9
90	77,2	103,2	117,0
120	61,7	82,6	93,6
180	44,5	59,5	67,5
240	35,0	46,9	53,1
360	24,9	33,3	37,7
540	17,5	23,5	26,6
720	13,7	18,3	20,7
1080	9,6	12,8	14,5
1440	7,4	9,9	11,3
2880	4,0	5,4	6,1
4320	2,8	3,8	4,3



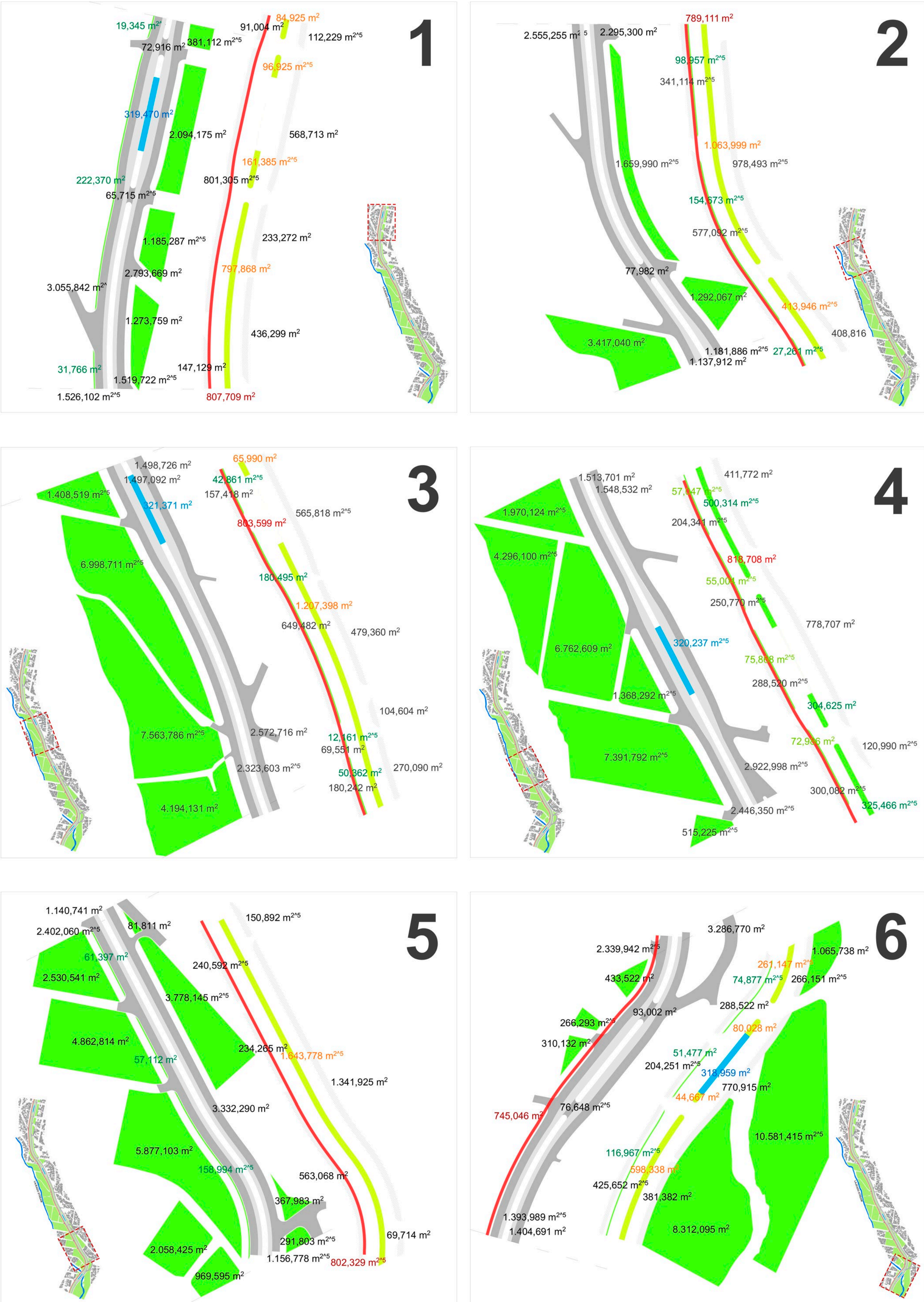


Figure 3:2 Areas separated according surface materials in the 6 sections that comprise the 2km-study area (Author, 2015).

An essential factor to determine appropriate runoff control devices is the type of soil of the site. In Itaim Paulista, along the Lajeado Stream, there is a mix combination of soil, with a predominant silty sandstone, which allows for a moderate percolation into the ground.

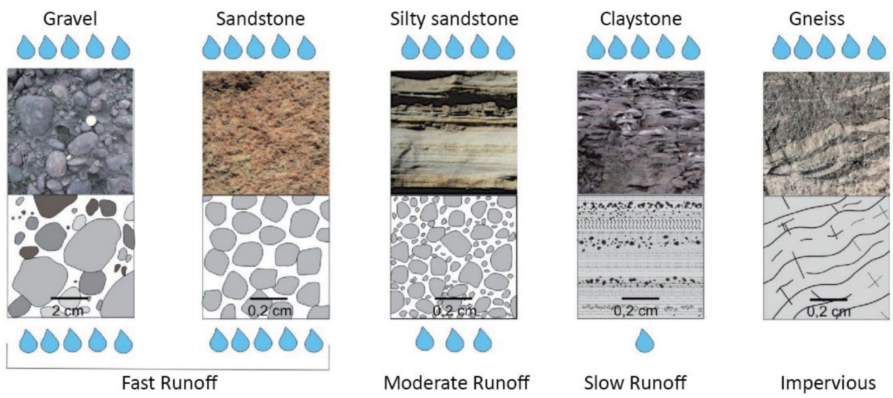


Figure 3:3 Infiltration capacity of different types of soils from the book: “The Groundwaters of the State of São Paulo” (Iritani & Ezaqui, 2009).

Table 3:4 Relationship between soil, infiltration capacity, and preferable infiltration device (Siecker mbH, 2013)

Type of Soil	Kf-Value (m/s) Runoff coefficient	Infiltration Capacity	Preferred type of Infiltration
Medium sand	10^{-4}	very good	SI, BI, TI, SH
Fine sand, silty sand	10^{-5}	Good	SI, BI, TI, SH
Boulder clay, silt	10^{-6}	moderately	BTI, BTS
Silt, clayey silt	10^{-7}	poorly	BTS

SI: Surface infiltration; BI: Basin infiltration; TI: Trench infiltration; SH: Shaft infiltration; BTI: Basin + trench; BTS: Basin + trench system (combined with derated drainage)

Closer to the Lajeado Stream there is a predominantly clayish soil type, deeming natural surface infiltration insufficient as single runoff management device at these specific points. Designers should observe carefully the critical sections of the site after the rain in order to correctly assess more specific behavior of the soil.

3.1 Green infrastructure

Green Infrastructure and Low Impact Development are sustainable, attractive, and cost effective tools for urban planning (Wansley, 2011):

- Green Infrastructure (GI): "An interconnected network of undisturbed natural areas and open space that helps preserve the values and functions of our watersheds and provides a wide array of benefits to both people and wildlife" (Benedict & McMahon, 2006).

- Low Impact Development (LID): "a comprehensive land planning and engineering design ap-proach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds" (Low Impact Development Center Inc., 2011).

According to the U. S. Dept. of Planning & Development (DPD) and the Seattle Public Utilities (SPU), "Green stormwater infrastructure (GSI) means a drainage control facility that uses infiltration, evapotran-spiration, or stormwater reuse." Examples of green stormwater infrastructure include bioretention facili-ties (rain gardens, natural landscaping, street trees, and curb extensions), permeable pavements, and green roofs. These strategies use natural processes to reduce development impacts. This section high-lights three practices appropriate for use in the public space.

3.1.1 Permeable Pavement

Permeable paving systems provide a hard surface, while allowing water to flow through to the underlying soils instead of into the storm sewer (ICPI, 2008). It is a LID system in which the space used for the prac-tice can also be used for sidewalks, roads, and parking spaces. The Itaim Paulista – São Mateus corridor is an ideal site for utilizing this type of floor covering.

There are three types of permeable paving: porous asphalt, permeable interlocking concrete pavement and grass pavers (Massachusetts Low Impact Development Toolkit, 2010).

According to the ABCP (Brazilian Association of Portland Cement), some of the advantages of permeable pavements include (Marchioni et al, 2011):

- Maintain the usable area of the land
- Reduce by up to 100% flash floods
- Reduce erosion
- Improve water quality
- Reduce spending on drainage features such as the "big pools" (piscinões).

According to the Precast Concrete Paving and Kerb Association in En-gland (Interpave), "Concrete block permeable paving (CBPP) is the most versatile SuDS technique, with important attenuation and pollution source control characteristics" (Interpave, 2008). Interpave identifies three different CBPP systems with the possibility of: (a) full infiltration, (b) partial infiltration, and (c) no infiltration.


(a) Permeable Asphalt


(b) Permeable Concrete


(c) Interlocking concrete pavers.


(d) Open-celled Paving grid with vegeta-tion.

Figure 3:4 Permeable pavement suggest-ed in the Pedestrian Design Guidelines for New Delhi, India (UTTIPEC, DDA, 2009).

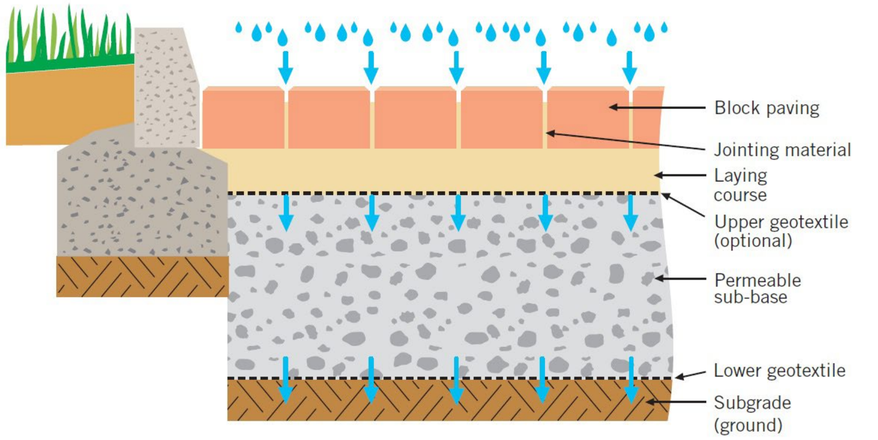


Figure 3:5 Full infiltration CBPP system (Interpave, 2008).

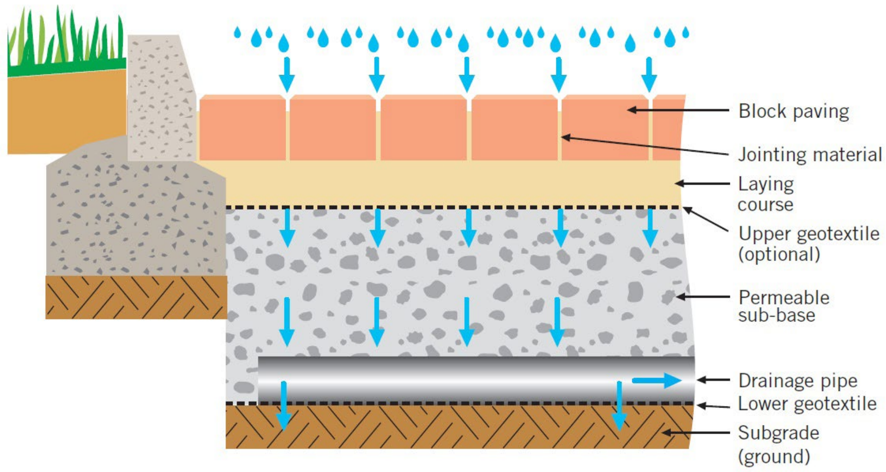


Figure 3:6 Partial infiltration CBPP system (Interpave, 2008).

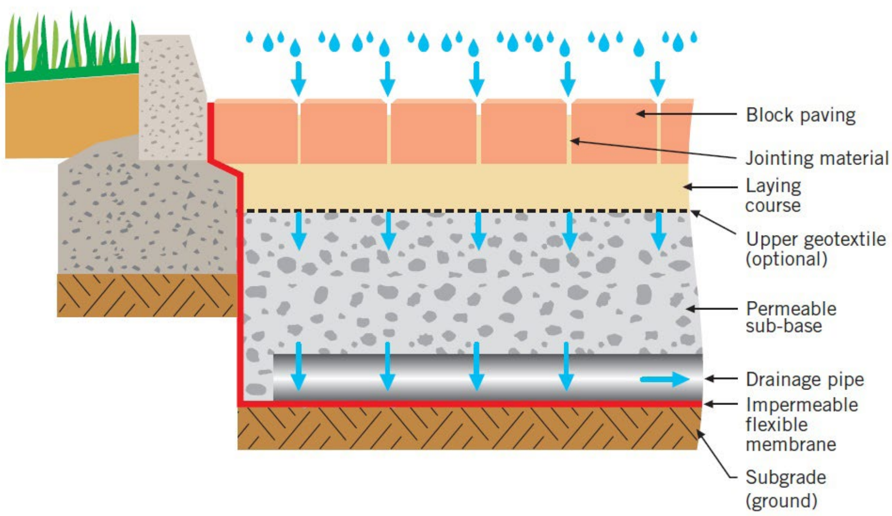


Figure 3:7 No infiltration CBPP system (Interpave, 2008).

In São Paulo, the SIURB (Municipal Urban Infrastructure Bureau) is testing two types of permeable pave-ments to be used in points of chronic flooding. The materials were developed by the FCTH (Hydraulics Technological Center Foundation) and have been evaluated at USP (SIURB; Rhino Pisos, 2013). The mate-rials being tested in a parking lot of the FCTH are porous asphalt and interlocked porous concrete. It was proven that both types of pavements have high permeability so the specific, local capacity of the soil to permeate water will determine if it is necessary to add infiltration trenches and basins to raise the infiltra-tion of rainwater into the ground (SIURB, 2013).

The two materials developed are: draining asphalt pavement and interlocked draining concrete, the latter composed of porous concrete blocks. Application of these solutions is similar to the asphalt concrete floor and interlocked, respectively, which are commonly used products (SIURB; Rhino Pisos, 2013).

According to SIURB, permeable pavements cost about 20% more than the floors used today but the high-er cost can be justified for the stormwater management possibilities of these types of surfaces. Permea-ble pavement's variety of applications give room for creativity in the design of streetscapes, the figure below is an example of an innovative implementation that enhances the aesthetical appeal of public spaces (Plataforma Arquitectura, 2014).

Figure 3:8 Outstanding design of public space using permeable pavement by Durán & Hermida Arquitectos Asociados (©Sebastián Cre-spo; Plataforma Arquitectura, 2014)

3.1.2 Bioretention

Bioretention uses the natural functions of plants and soils to remove pollutants from stormwater runoff. The strategy uses storage, sediment capture, and biological processes to clean the water. These mimic processes that occur in nature before water reaches waterways. Rain gardens are an important, cost ef-fective measure that can be implemented both in public and private areas in a combined effort to infil-trate stormwater onsite.

According to susDRAIN, a platform created by CIRIA to assist in SuDS projects, the plant selection for the raingardens will be influenced by the following (susDRAIN, 2013):

- Need for tolerance of wide fluctuations in soil moisture levels from inundation to long dry peri-ods, exacerbated by a highly permeable growing media.
- Provision of sufficient structure to assist pedestrian and driver differentiation between footpath, road and rain garden without blocking sight lines.
- Use of evergreen species to reduce leaf debris in the rain gardens and the associated mainte-nance.
- Aesthetics.

Figure 3:9 Diagrammatic section of a kerb-side rain garden system by HOK.

(An HOK Product Design creation, the FrenoTM rain garden system from www.hoklife.com/2010/11/10/hok-greenbuild-whats-your-net-postive-idea/)

3.1.3 Urban trees

According to the *Manual Técnico de Arborização Urbana* (Urban Afforestation Technical Manual), produced by the Municipal Secretariat of the Green and the Environment, urban trees play important roles for citizens and the environment, raising soil permeability and control the temperature and humidity (SVMA, 2015). Trees do not only provide a healthy physical environment, they are a powerful green infra-structure tool due to their ability to capture water on leaves, direct it to the ground on stems, absorb it through root systems, and transpire it as water vapor directly back into the atmosphere. In the particular case of the Itaim Paulista – São Mateus BRT system, tree planted on sidewalks can become both a filtering and caption device of rain water to be stored and used during the dry periods.

The landscaping approach of the existing project created by SISTRAN is to preserve –and transplant- as many native species of trees as possible. The present study aims to recognize which of these tree species are most appropriate for the purpose of encouraging stormwater infiltration and conservation of exceed-ing water into reservoirs under the sidewalks.

Table 3:5 Native species existing in Itaim Paulista to be transplanted outside the ADA (SPTrans, 2013; author, 2015)

Popular Name	Scientific name	Family
Amarelão	*Agonandra excelsa*	Opiliaceae
Chupa ferro	*Metrodorea nigra*	Rutaceae
Embiriçú	*Pseudobombax grandiflorum*	Malvaceae
Goiabeira	*Psidium guajava*	Myrtaceae
Ipê	*Tabebuia sp.*	Bignoniaceae
Ipê amarelo (yellow)	*Tabebuia chrysotricha*	Bignoniaceae
Ipê roxo (purple)	*Handroanthus impetiginosus*	Bignoniaceae
Laranjeira do mato	*Actinostemon sp.*	Euphorbiaceae
Mirindiba rosa	*Lafoensia glyptocarpa*	Lythraceae
Palmeira indaiá	*Atallea dubia*	Arecaceae
Pau Brasil	*Caesalpinia echinata*	Fabaceae
Pau d'arco	*Handroanthus vellosoi*	Bignoniaceae
Pau ferro	*Gaesalpinia ferrea*	Fabaceae
Pitangueira	*Eugenia uniflora*	Myrtaceae
Sibipiruna	*Caesalpinia pluviosa*	Fabaceae

Presently, many of the trees found in the sidewalks of several neighborhoods in São Paulo are exotic spe-cies, such as: Acácia-Negra (Acacia mearnsii), Alfeneiro (Ligustrum japonicum, Ligustrum lucidum, and Ligustrum vulgare), Eucalipto (Eucalyptus robusta), Falsa-seringueira (Ficus elastica), Figueira (Ficus ben-jamina), Leucena (Leucaena leucocephala), and Palmeira Seafórtia (Archontophoenix cunninghamiana) (SPTrans, 2013).

Following the Manual Técnico de Arborização Urbana (Urban Afforestation Technical Manual), the follow-ing native species have been selected for two types of planting conditions: in open soil areas (new green spaces where expropriation occurred) and in covered soil areas (in sidewalks and planters in the middle section of the streets).

Table 3:6 Selected native tree species for park and garden afforestation in São Paulo (SVMA, 2015; author, 2015).

Scientific name	Popular name	Height	Diameter of stem	Soil moisture condition	Observations
Andira fraxinifolia	Angelim-doce	6-12 m	30-40 cm	selective hygrophyte	Attracts fauna, medium size
Genipa americana	Jenipapo	8-14 m	40-60 cm	selective hygrophyte	Human consumption
Plinia edulis	Cambucá	5-10 m	30-40 cm	selective hygrophyte	Human consumption
Tapirira guianensis	Peito de pombo	8-14 m	40-60 cm	humid soils	Attracts fauna, medium size
Eugenia brasiliensis	Grumixama	8-12 m	25-40 cm	selective hygrophyte	Human consumption
Cariniana estrelensis	Jequitibá branco	35-45 m	90-120 cm	selective hygrophyte	Attracts fauna, large size
Campomanesia xanthocarpa	Guabiroba	10-20 m	30-50 cm	selective hygrophyte	Human consumption, large size
Euterpe edulis	Juçara	8-12 m	10-15 cm	Mesophytic or slightly hygrophytes	Human consumption, palm tree
Syagrus romanzoffiana	Jerivá	8-15 m	35-50 cm	selective hygrophytes	Human consumption, palm tree

Table 3:7 Selected native tree species for sidewalk afforestation in São Paulo (SVMA, 2015; author, 2015).

Scientific name	Popular name	Height	Diameter of stem	Soil moisture condition	Observations
Handroanthus chrysotrichus	Ipê-amarelo	4-10 m	30-40 cm	Well drained soils	Ornamental, medium size
Licaria tomentosa	Oiti	8-15 m	30-60 cm	selective hygrophyte	Attracts fauna, medium size
Sapindus saponaria	Sabão-de-soldado	5-9 m	30-40 cm	characteristic of floodplains	Attracts fauna, medium size
Pachira aquatica	Monguba	6-14 m	40-80 cm	selective hygrophyte	Attracts fauna, medium size
Dictyoloma vandellianum	Tingui Preto	4-7 m	20-30 cm	selective hygrophyte	Small size
Cordia superba	Babosa Branca	7-10 m	20-30 cm	selective hygrophyte	Attracts fauna, medium size

Landscape architect James Urban is one of the leading specialist and promoters of the planting of urban forest. He has written extensively about urban arboriculture and soils, including the preservation and installation of trees in the urban environment and the specification and installation of specialized planting soils for roof gardens, urban landscape plantings, and rain water management. A member of the Urban Tree Foundation, he has developed a series of guidelines and specifications as an open source data base for professionals and authorities involved in the field of urban planning (See appendix).The following ta-ble is a tool developed by Urban in order to determine the volume of soils for different sizes of trees.

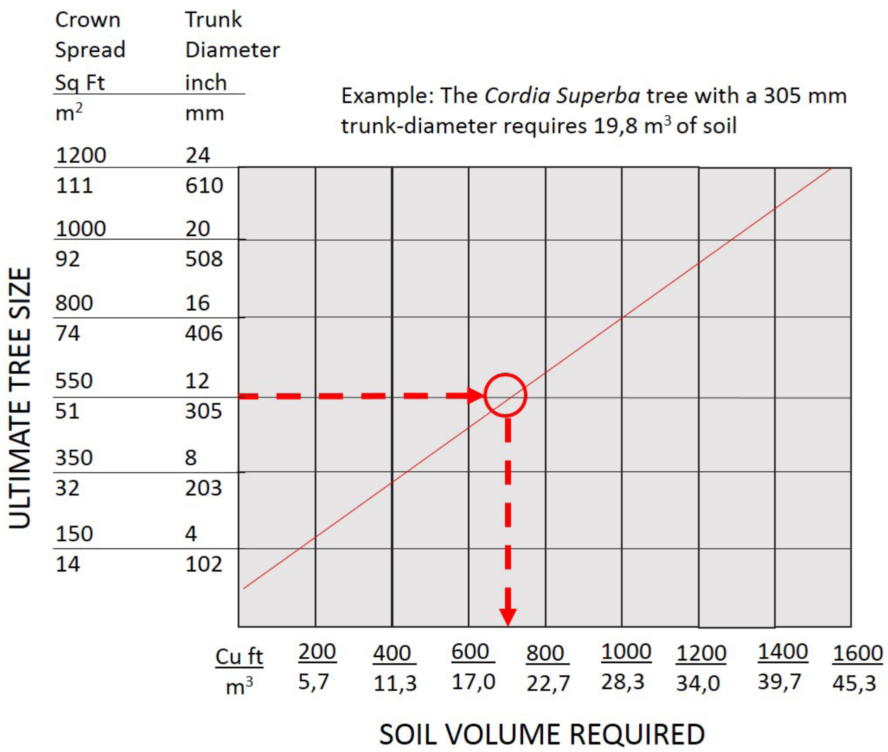
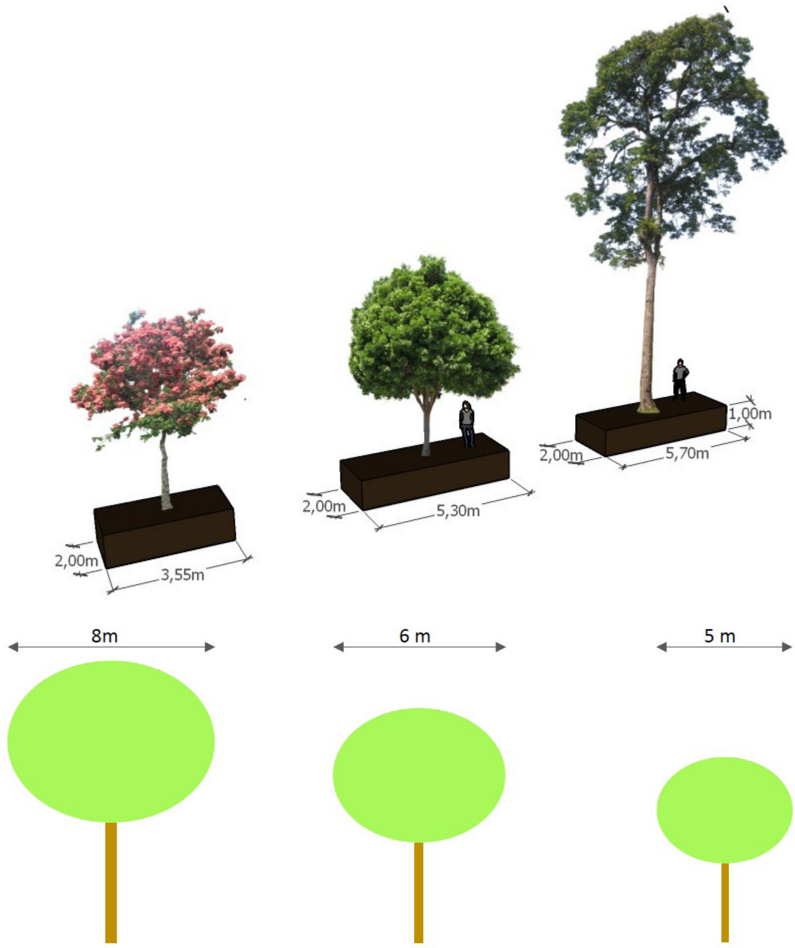


Figure 3:10 Soil volume and ultimate tree size relationships (Urban, 2007; author, 2015).

Taking into account the sizes of the selected trees for this project, the following diagram shows the calcu-lated soil requirements at each instance: planted in sidewalks or plazas, middle of the street planter and in the proposed park areas along the Lajeado Stream.



Tree (large size) in middle section
50,26 m^2 of crown spread =
11,3 m^3 of soil volume

Tree (medium size) in sidewalk
28,27 m^2 of crown spread =
10,59 m^3 of soil volume

Tree (small size) in sidewalk
19,63 m^2 of crown spread =
7,06 m^3 of soil volume

Figure 3:11 Soil volume requirements for selected tree sizes (author, 2015).

Width of sidewalks "P" (m)	Maximum height of species "h" (m)	Distance "d" of axis of trees to the curb in relationship to the radius "R" of the circumscribed circumference of the tree (m)	Size of trees under the electrical wiring
P < 1,50	-	-	-
1,50 ≤ P < 1,80	Small size h=5,00	d = (P - 1,20) / 2 (1)	Small size
1,80 ≤ P < 2,00	Small size h=5,00	d ≥ 0,30	Small size
2,00 ≤ P <2,40	Medium size h=8,00	d ≥ 0,30	Small size
2,40 ≤ P < 3,00	Medium and large size h=12,00	d > 0,30 and d = 1,5R	Small size (2)
P ≥ 3,00	Large size H > 12,00	d > 0,30 and d = 1,5R	(2) and (3)

Notes:
(1) The pit should have rectangular section of 2d x 0,60 m when there is no possibility for using floor plates or draining.
(2) Avoid interference with lighting cone.
(3) Where necessary, the large canopy trees should be conducted (early), through proper cultural treatment above the aerial wiring and street lighting.

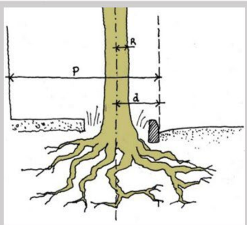


Figure 3:12 Guidelines for planting trees (SVMA, 2010; author, 2015).

3.2 Rainwater harvesting and groundwater recharge

92,508,450 liters of rainwater could be harvested in a year on roads and sidewalks in the study area of Itaim Paulista, taking in consideration a mean annual rainfall of 1500mm (Laudon, 2014). This volume could be translated into 10,278,717 toilet flushes or the washing of 977,526 cars (Laudon, 2014). There are two main benefits from harvesting rainwater: the reduction of runoff and the saving of drinking water for non-potable use.

Due to the "Water Crisis" suffered in São Paulo in 2014, a strong campaign for water savings and reutiliza-tion of rainwater is being carried out by the local government and SABESP. The campaign focuses mainly in the reduction of private consumption and slowing the water pressure periodically. Some private initia-tives include the purchase of water tanks to harvest water domestically, but the cost of installation often discourages a wider size of the population. A 300 liter bin will cost approximately 50 EUR, a 1000 l barrel 250 EUR.

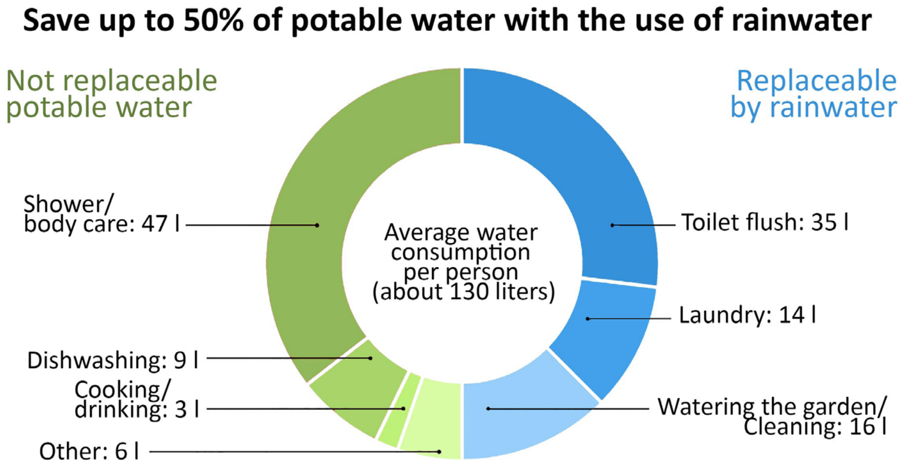


Figure 3:13 Water savings possibilities if a complete system of rainwater harvesting was installed in individual houses in Germany (Otto Graf GmbH, 2012).

The transformation of rain water into drinking water in urban areas is not recommended in São Paulo, to do so, the water must meet the Ordinance No. 518/04 of the Ministry of Health (Tamaz, 2007). In this case, it is recommended for the developers of the BRT projects to promote the use of the water collected both in the public and private domains for non-potable use, such as gardening and cleaning.

Figure 3:14 Rain barrel from the Graf Company with 1600 liter storage capacity (Otto Graf GmbH, 2012).

The reservoirs or tanks can be: buried, half-buried, supported or elevated (Graf, 2012). The material may be concrete, reinforced masonry, plastics such as polyethylene, PVC, fiberglass, and stainless steel. They should always be closed and not allow sunlight in. In the public domain, underground reservoirs tanks could be connected to other infiltration devices such as trenches, vegetated swales or tree pits. The wa-ter harvested could be pumped and directed to public taps along the corridor.

3.3 SuDS: Swale and Trench infiltration

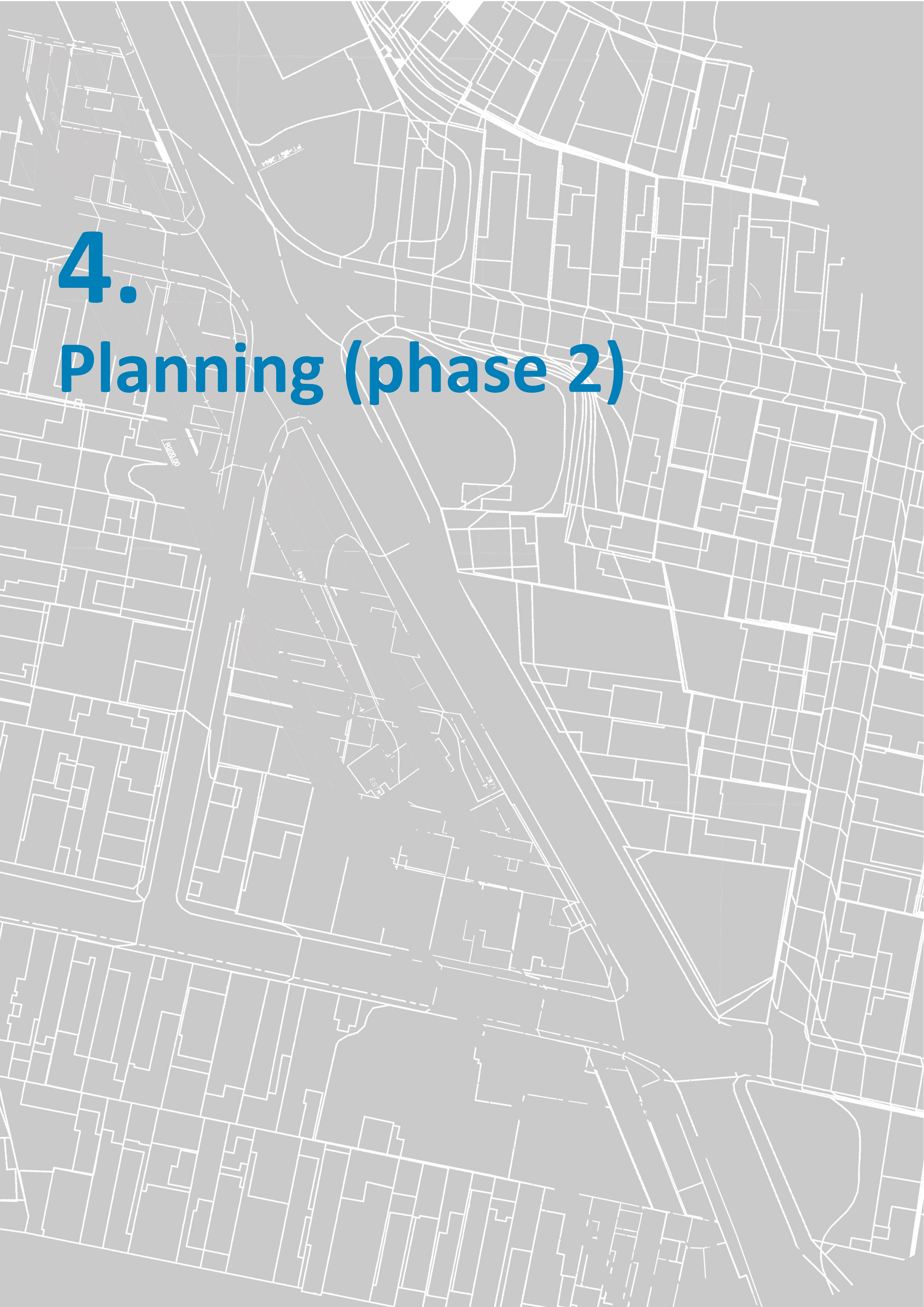
“A Vegetated Swale is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and/or grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. In steeper slope situ-ations, check dams may be used to further enhance attenuation and infiltration opportunities” (DEP, 2014).

The typical construction of the swale consists of vegetation over at least 60 cm of permeable soil. The swales can also contain an underlying 30 cm aggregate layer to enhance the reduction of the stormwater.

Figure 3:15 Hollow percolation (Ecobine, 2010).

A trench infiltration system retains the water on site, filters the water and reduces risk of floods in streams and rivers. A properly dimensioned trench can also help recharge the groundwater (Siecker mbH, 2013).

4. Planning (phase 2)



The choice of stormwater facilities is based on the context of the surrounding streetscape. Multi-purpose design of stormwater facilities will add aesthetic value to the region by providing visually appealing landscaping and enhanced community spaces on streets. The results obtained using the Bottrop tool provide the dimensioning of four devices suited to be implemented in the study area: swale infiltration, trench infiltration, swale + trench infiltration and pipe-trench infiltration. Surface infiltration is not recommended in the study area due to the poor infiltration capacity of the soil. Infiltration through a shaft is possible, but it was excluded because of its higher cost and lesser aesthetic features.

It is important to point out that these results are only informative, they do not replace the necessary expertise of a hydraulic engineer for dimensioning a stormwater infiltration facility. However, it is a starting point to begin to analyze the possibilities of the site. Each facility is calculated individually and the combination of technologies could result in smaller dimensions and lesser costs of implementation. In summary, the standard low impact development techniques to be used in the execution of the Itaim Paulista – São Mateus corridor shall be: permeable pavement, bioretention, trenches and swales.

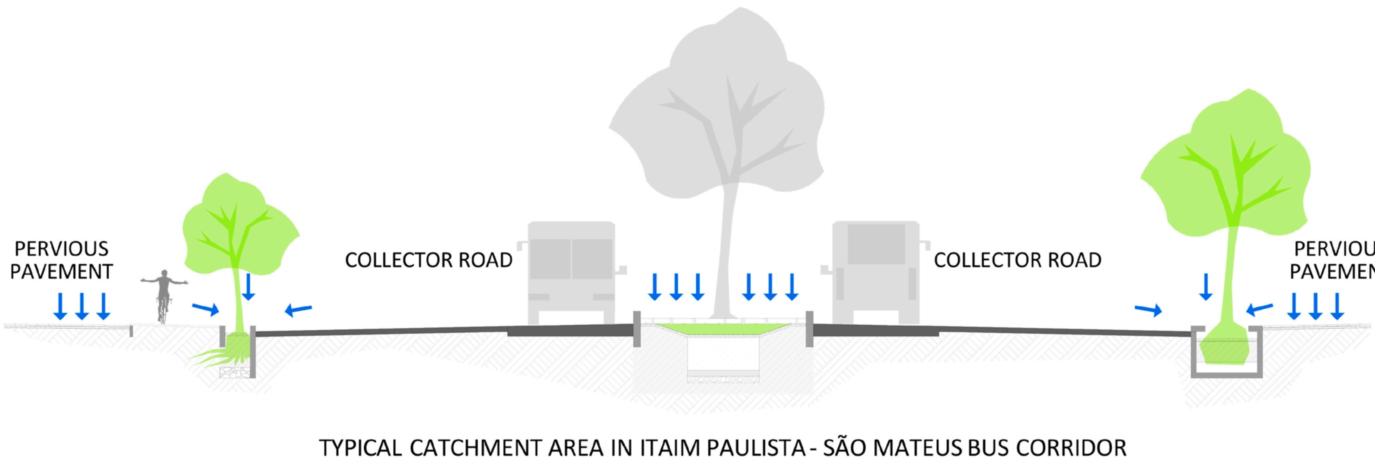


Figure 4:1 Rain water management concept (Author, 2015).

Table 4:1 Dimensions for each stormwater facility calculated with the Bottrop tool (Bottrop, 20; author, 2015).

TRENCH INFILTRATION	REQUIRED LENGHT OF TRENCH (m)	VOLUME OF TRENCH (m^3)	EFFECTIVE VOLUME OF TRENCH (m^3)	TRENCH WIDTH (m)	TRENCH HEIGHT (m)
SECTION 1	508,30	1016,70	355,80	2,00	1,00
SECTION 2	577,80	866,60	303,30	1,50	1,00
SECTION 3	568,10	1136,30	397,70	2,00	1,00
SECTION 4	600,10	1200,20	420,10	2,00	1,00
SECTION 5	568,10	1136,30	397,70	2,00	1,00
SECTION 6	596,30	1192,70	417,40	2,00	1,00
TOTAL	3418,70	6548,80	2292,00		

SWALE INFILTRATION	ESTIMATED AREA FOR SWALE (m^2)	VOLUME OF SWALE (m^3)	MAXIMUM HEIGHT OF RETENTION (m)	EMPTYING TIME for n=1 (hour)	EMPTYING TIME (hour)
SECTION 1	2000,00	362,63	0,18	0,60	1,01
SECTION 2	2100,00	295,24	0,14	0,46	0,78
SECTION 3	3000,00	358,94	0,12	0,39	0,66
SECTION 4	5000,00	313,79	0,06	0,18	0,35
SECTION 5	5000,00	288,44	0,06	0,16	0,32
SECTION 6	8000,00	246,96	0,03	0,08	0,17
TOTAL	25100,00	1866,00			

SWALE-TRENCH INFILTRATION	ACTUAL AREA OF SWALE (m^2)	VOLUME OF SWALE (m^3)	TRENCH LENGTH (m)	EMPTYING TIME (hour)	TRENCH WIDTH (m)	TRENCH HEIGHT (m)	MAX. H OF RETENTION (m)
SECTION 1	937,60	273,47	468,80	1,62	2,00	1,00	0,29
SECTION 2	796,67	238,57	531,11	1,66	1,50	1,00	0,30
SECTION 3	1386,79	247,72	693,40	0,99	2,00	1,00	0,18
SECTION 4	1413,86	269,52	706,93	1,06	2,00	1,00	0,19
SECTION 5	1518,22	229,36	759,11	0,84	2,00	1,00	0,15
SECTION 6	1542,74	246,96	771,37	0,89	2,00	1,00	0,16
TOTAL	7595,88	1505,60	3930,72				

PIPE-TRENCH INFILTRATION	REQUIRED LENGHT OF TRENCH (m)	VOLUME OF TRENCH (m^3)	EFFECTIVE VOLUME OF TRENCH (m^3)	PIPE DIAMETER (m)	TRENCH WIDTH (m)	TRENCH HEIGHT (m)
SECTION 1	503,10	1006,20	358,00	0,15	2,00	1,00
SECTION 2	439,30	878,70	312,60	0,15	2,00	1,00
SECTION 3	562,30	1124,60	400,10	0,15	2,00	1,00
SECTION 4	593,90	1187,80	422,60	0,15	2,00	1,00
SECTION 5	562,30	1124,60	400,10	0,15	2,00	1,00
SECTION 6	590,20	1180,40	419,90	0,15	2,00	1,00
TOTAL	3251,10	6502,30	2313,30			

4.1 Cross-sections: scenarios and possibilities

The following are drawings of green infrastructure and stormwater facilities inserted in the study area of the Itaim Paulista – São Mateus bus corridor.

Figure 4:2 Plan with proposed interventions along Itaim Paulista –São Mateus bus corridor (Author, 2015).

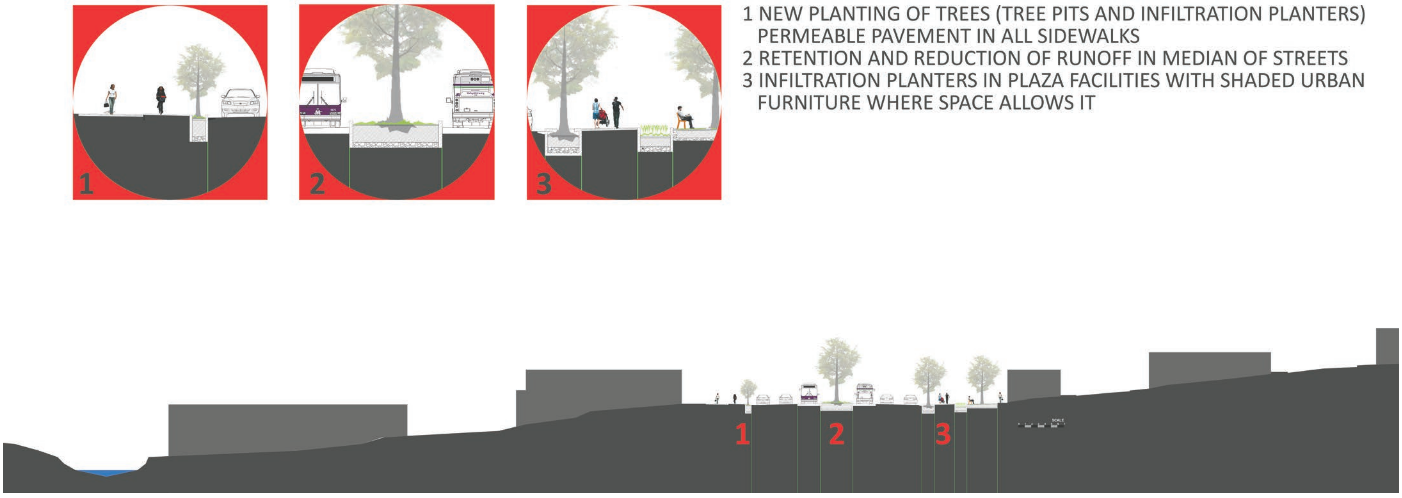


Figure 4:3 Cross-section A-A (Author, 2015).

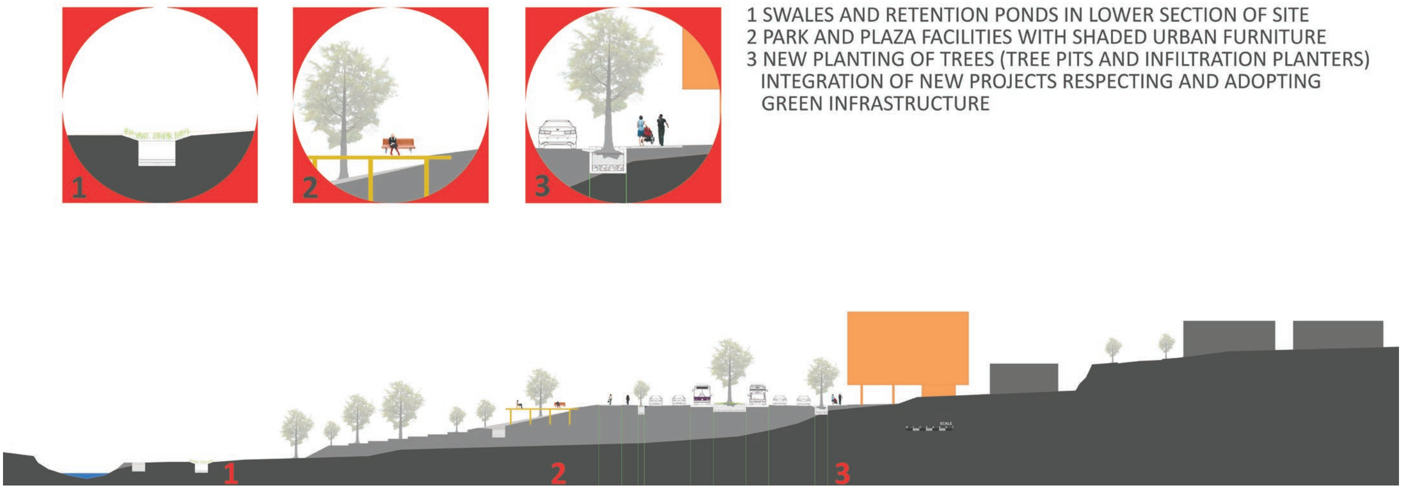


Figure 4:4 Cross-section B-B (Author, 2015).

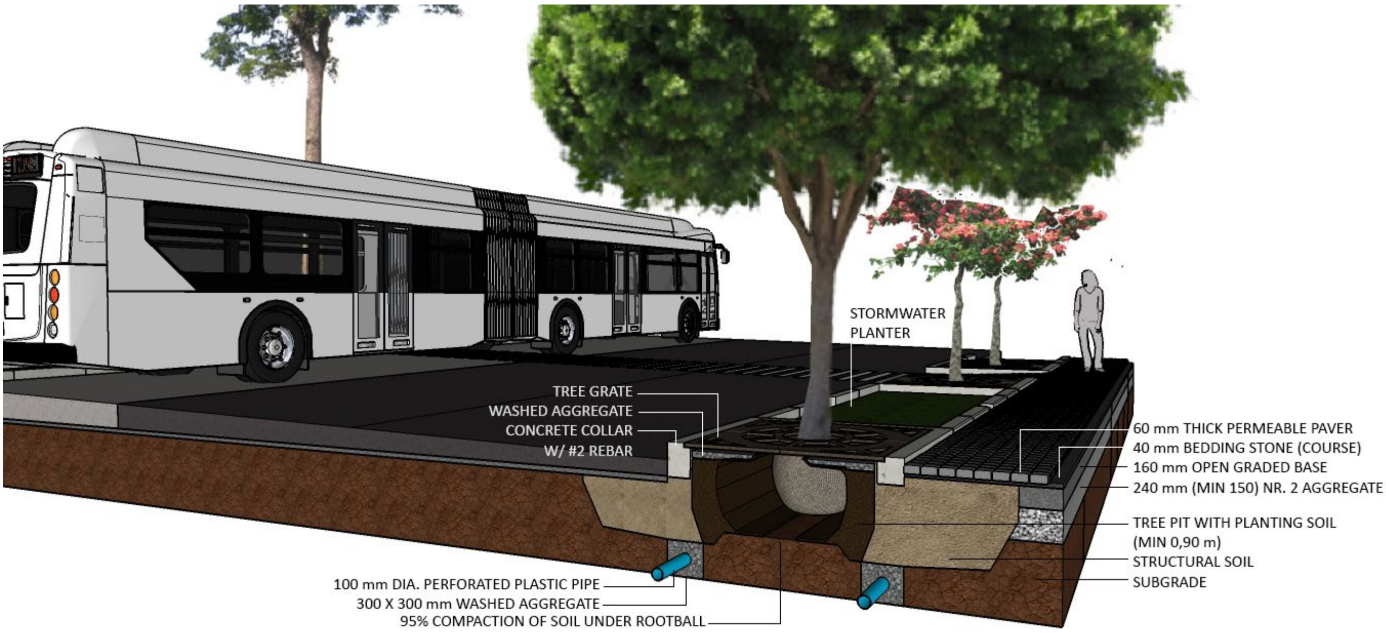


Figure 4:5 Tree pit and permeable paver detail for Itaim Paulista – São Mateus bus corridor (Author, 2015).

4.2 Beyond the corridor: Design Toolkit

The following pages contain a few examples of technical sheets with technologies to help reduce the incidence of flood-related disasters and preserve water. A similar "Design Toolkit" could be presented to Sub-municipalities to start the discussion about the benefits of water sensitive design of cities.

planting trees in streetscapes

BENEFITS

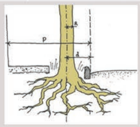
Reduces the risk of flooding, the presence of particles and carbon dioxide in the air, heat island effect associated with increased urbanization, the load on sewage and treatment plants, and thus pollution in lakes and seas.(1)

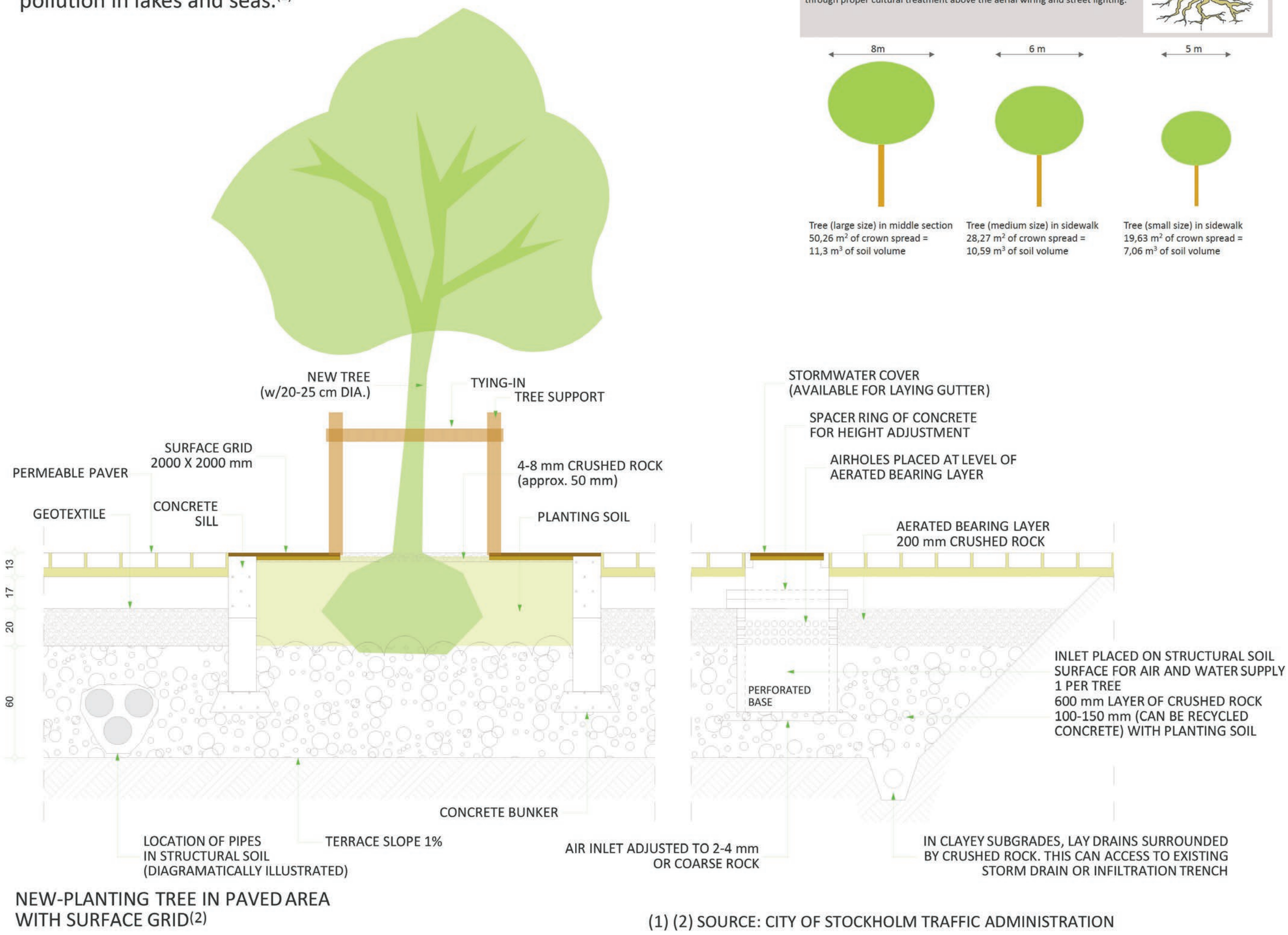
COST

MEDIUM/HIGH

Width of sidewalks "P" (m)	Maximum height of species "h" (m)	Distance "d" of axis of trees to the curb in relationship to the radius "R" of the circumscribed circumference of the tree (m)	Size of trees under the electrical wiring
P < 1,50	-	-	-
1,50 ≤ P < 1,80	Small size h=5,00	d = (P - 1,20) / 2 (1)	Small size
1,80 ≤ P < 2,00	Small size h=5,00	d ≥ 0,30	Small size
2,00 ≤ P <2,40	Medium size h=8,00	d ≥ 0,30	Small size
2,40 ≤ P < 3,00	Medium and large size h=12,00	d > 0,30 and d = 1,5R	Small size (2)
P ≥ 3,00	Large size H > 12,00	d > 0,30 and d = 1,5R	(2) and (3)

Notes:
(1) The pit should have rectangular section of 2d x 0,60 m when there is no possibility for using floor plates or draining.
(2) Avoid interference with lighting cone.
(3) Where necessary, the large canopy trees should be conducted (early), through proper cultural treatment above the aerial wiring and street lighting.





NEW-PLANTING TREE IN PAVED AREA WITH SURFACE GRID(2)

(1) (2) SOURCE: CITY OF STOCKHOLM TRAFFIC ADMINISTRATION

TECHNICAL SHEET 1

Figure 4:6 Guidelines for the planting of urban trees (Author, 2015).

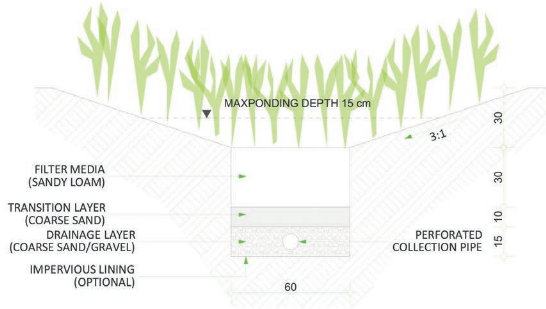
vegetated swales

BENEFITS

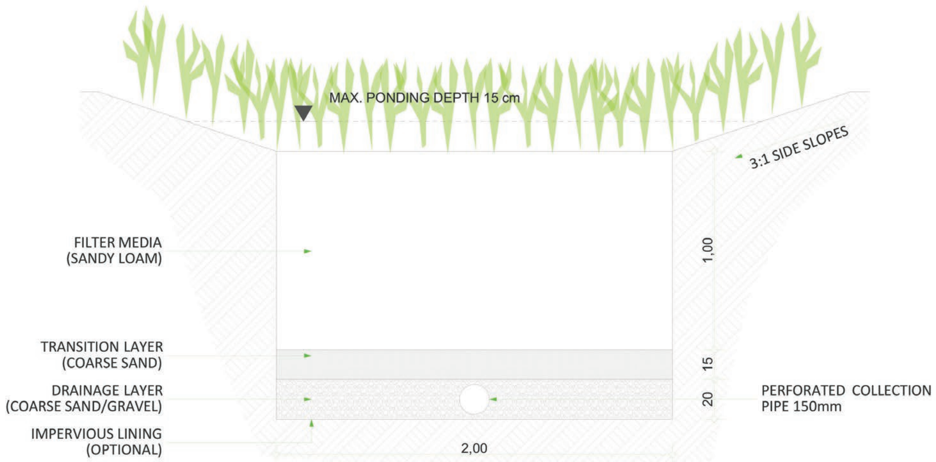
Provide an environmentally superior alternative to conventional curb and gutter conveyance systems,
Enhance the aesthetic value of the site by selecting appropriate native vegetation.[1]

COST

MEDIUM/LOW



VEGETATED SWALE
(MIN. DIMENSIONS)



VEGETATED SWALE
(MAX. DIMENSIONS)

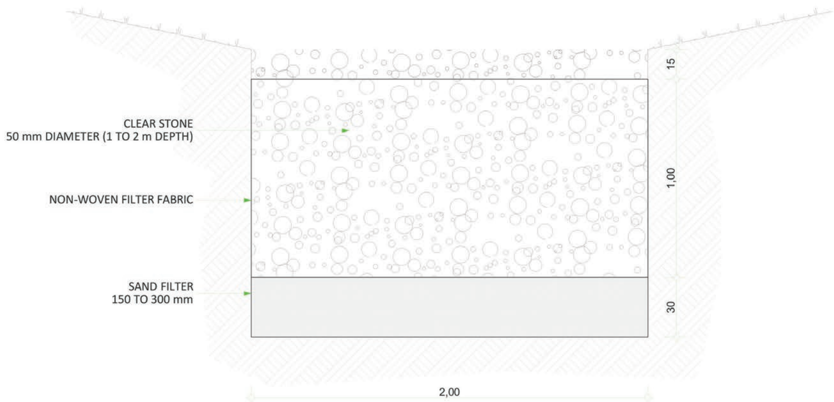
(1) (2) (3) STORMWATER BEST MANAGEMENT PRACTICES MANUAL, US DEP, 2014

TECHNICAL SHEET 2

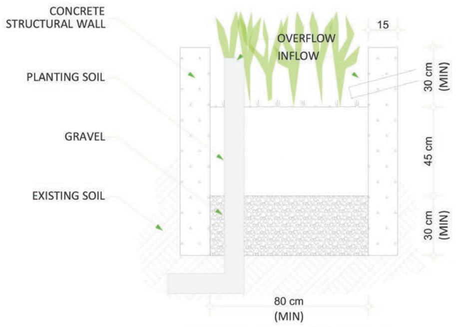
Figure 4:7 Guidelines for designing vegetated swales (Author, 2015).

infiltration trench and infiltration planter

TRENCH INFILTRATION	INFILTRATION PLANTERS	COST
Reduce significantly both runoff rates and volumes. Provides a significant reduction in the pollutant load discharged to receiving body. Easily incorporated into site landscaping. Fit well beside roads.(1)	Reduce runoff rates and volumes Adds aesthetic value to the streets. Reduces the discharged of pollutants into the sewarge system. Can be integrated along side-walks without taking a lot of space from pedestrians.	MEDIUM/LOW



INFILTRATION TRENCH
(DIMENSIONS ESTIMATED WITH BOTTROP TOOL)



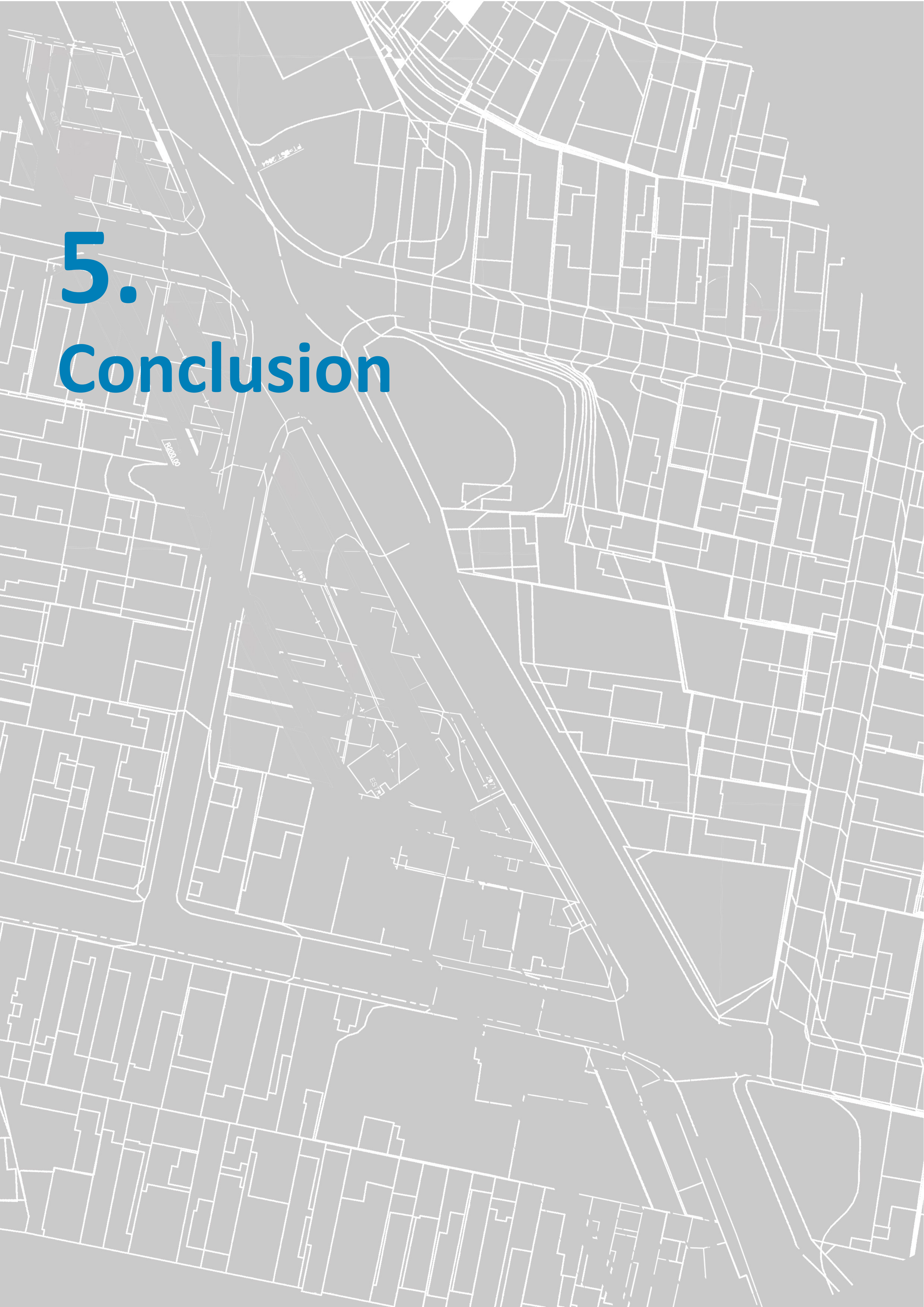
INFILTRATION PLANTER

(1) SuDS Manual-CIRIA, 2007
(2) STORMWATER BEST MANAGEMENT PRACTICES MANUAL, US DEP, 2014
(3) CITY OF PORTLAND, 2013

TECHNICAL SHEET 3

Figure 4:8 Guidelines for designing infiltration trenches and infiltration planters (Author, 2015).

5. Conclusion



5.1 Achieved results

The technology innovations applied in the 2km section of the Itaim Paulista-São Mateus bus corridor can be replicated either directly or with modifications in other sections of the project and throughout the city. By starting with one section of the system, the local government can start a monitoring and testing program based on the observation during extreme periods –rainy and dry seasons. Monitoring is important not only to validate the prevention measures, the technologies can always be improved and adapted to specific site conditions.

The results obtained with the dimensioning tool provide the maximum reduction of runoff per facility for each section. The combination of these stormwater management practices with the addition of green infrastructure programs would result in an all-encompassing planning strategy that the authorities ought to consider viable and necessary to accompany the implementation of the bus corridors.

Figure 4:9 Ideal landscape solution for river and stream banks, design by Gustafson Gunthrie NIchol (www.ggnltd.com).

5.2 Future development

"We need to build differently based on what we already know, we need to demand that our planners, our architects and even our developers take into account the emotional effect of the things they build. If they do, then we can have cities that are healthier, more resilient, happier, wealthier… we can have cities that draw us together rather than push us apart, we can have cities that brings out the best in us, and that is one way to get a happier city..." Charles Montgomery (Happy City, 2013)

The importance of designing people friendly, happy environments results on safer environments. Charles Montgomery proposes a design of cities for emotional life, the "roads, our neighborhoods are emotional infrastructure" (Montgomery, 2013), the planning of such infrastructures must include a sociological and psychological input from professionals to assist the technicians in the construction of such public conditions.

The following table is a checklist with tasks that institutions and decision makers should perform in order to prevent water-related contingencies.

Table 5:1 Enabling environment for adaptation to flood risk (Wilby and Keenan, 2012).

Information	National data platforms • Baseline data: climate and socio-economic indicators • Topographic surveys (floodplains, coast) • Scenarios of long-term drivers of flood risk (climatic and non-climatic) Monitoring and surveillance networks Maps of risk and vulnerability (by gender, social group, etc.) Educational programs to raise awareness of risks and responses Research programs
Institutions	Bridging agencies • Trans boundary cooperation (riparian districts and municipalities) • Cross-sectorial planning and cooperation • Information exchange between scientists and stakeholders Legal structures • Building codes, updating design standards, planning rules • Periodic review and adaptive management • Budgets, responsibilities, accountabilities • Public participation, transparency • Economic analysis of adaptation benefits • Insurance (household to sovereign level)
Preparedness	Public and household contingency planning (pre-, during, post- event) Multi-actor and agency coordination • Assigned roles, responsibilities, resources (standing orders) • Agreed jurisdictions (regional, national, international) • Role-play exercises

The higher occupancy rate proposed in the new Strategic Master Plan promotes the construction of new developments and governmental housing projects (HIS), raising the value of the property. The upgrading of the public infrastructure and improvement of transport services can have both positive and negative connotations for Itaim Paulista. Some of the current inhabitants may be driven away by the rise of rent prices and gentrification can occur changing completely the face of this traditional district of national immigrants. The transfer of people to other regions does not eliminate the social problems nor lowers the exclusion of large parts of the population. There should be an institutional effort to preserve the inhabitants in the region, starting with the residents that must be evicted due to the improvement protection of the river basins. Monetary compensation is guaranteed as their properties must be demolished to give room to the new bus corridor, but their relocation within the district is not secured. The road infrastructure plan should contain alternatives for the location of *new* homes for *old* residents.

The new Master Plan for São Paulo and its process of implementation encouraged the inclusion of a larger scope of decision makers, opening on-line and physical platforms for public participation. But at the level of execution and construction a lot of the positive inputs and goals of the Master Plan are often forgotten or reduced due to budgetary restrictions and dubious political agendas. A clear relationship between flood adaptation measures and monetary savings must be drawn and assimilated by the stakeholders. Water sensitive design of infrastructure is no longer a plus or an extra feature, it should become a requirement. Integrated water sensitive design saves money and improves the lifestyle of the population.

Image: São Paulo from a helicopter (Ana Paula Hirama, 2011)

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Appendix A

CALCULATIONS USING BOTTROP TOOL

INPUT OF AREAS PER SECTION, PER SURFACE MATERIAL

Description of area	A_E [m²]	Ψ_m [-]	A_u [m²]
	18.760		**10.204**
Asphalt (Cars)	5.850	0,90	5.265
Rigid concrete (Bus)	3.046	0,90	2.741
Sidewalk	2.390	0,50	1.195
Bike path	808	0,10	81
Bus Stop (flat roof)	320	0,90	288
Green area (park)	4.934	0,10	493
Green area (middle of street)	1.139	0,10	114
Green area (sidewalk)	273	0,10	27

Description of area	A_E [m²]	Ψ_m [-]	A_u [m²]
	17.393		**8.911**
Asphalt (Cars)	4.851	0,90	4.366
Rigid concrete (Bus)	2.320	0,90	2.088
Sidewalk	2.306	0,50	1.153
Bike path	789	0,75	592
Green area (park)	5.369	0,10	537
Green area (middle of street)	1.478	0,10	148
Green area (sidewalk)	281	0,10	28

Description of area	A_E [m²]	Ψ_m [-]	A_u [m²]
	33.217		**11.404**
Asphalt (Cars)	4.896	0,90	4.407
Rigid concrete (Bus)	2.996	0,90	2.696
Sidewalk	2.477	0,50	1.238
Bike path	804	0,75	603
Bus stop	320	0,90	288
Green area (middle of street)	1.273	0,10	127
Green area (sidewalk)	286	0,10	29
Green area (park 1)	6.999	0,10	700
Green area (Park 2)	7.564	0,10	756

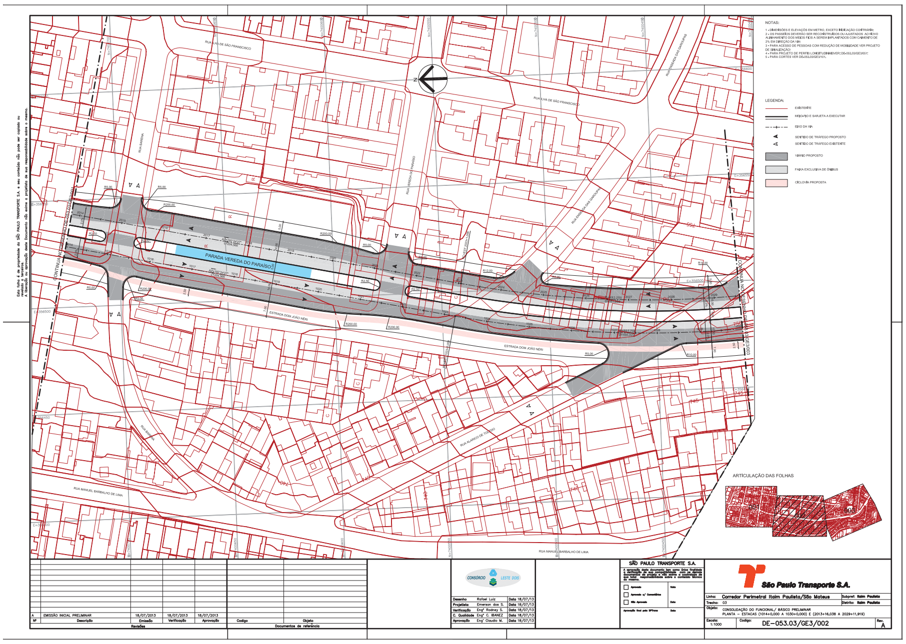
Description of area	A_E [m²] 35.632	Ψ_m [-]	A_u [m²] 12.046
Asphalt (Cars)	5.369	0,90	4.832
Rigid concrete (Bus)	3.062	0,90	2.756
Sidewalk	2.355	0,50	1.178
Bike path	830	0,75	622
Bus stop	320	0,90	288
Green area (middle of street)	1.130	0,10	113
Green area (sidewalk)	261	0,10	26
Green area (park 1)	7.392	0,10	739
Green area (Park 2)	8.150	0,10	815
Green area (Park 3)	6.763	0,10	676

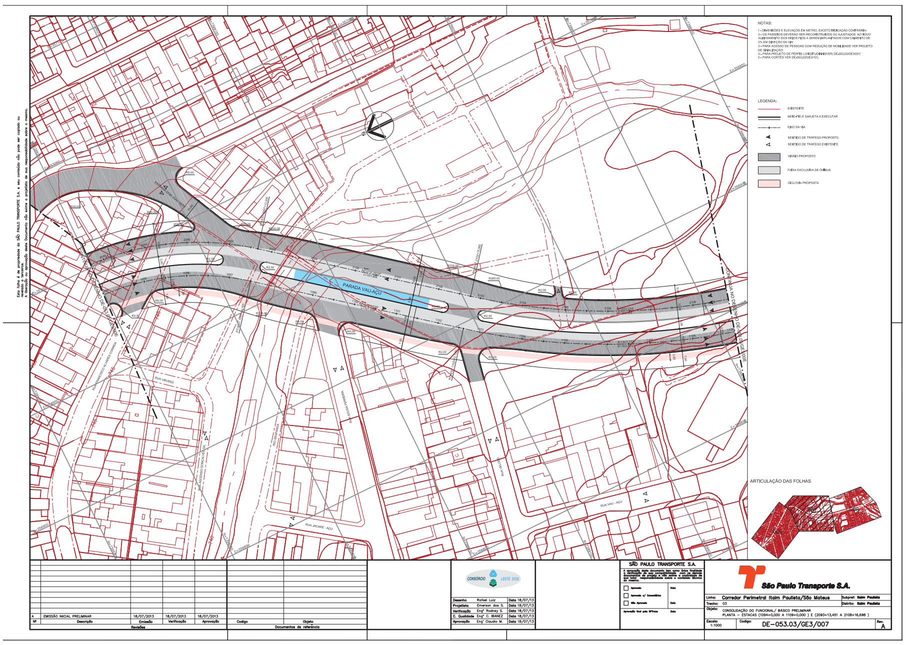
Description of area	A_E [m²] 34.174	Ψ_m [-]	A_u [m²] 11.405
Asphalt (Cars)	5.734	0,90	5.161
Rigid concrete (Bus)	2.298	0,90	2.068
Sidewalk	2.600	0,50	1.300
Bike path	802	0,75	602
Green area (middle of street)	1.644	0,10	164
Green area (sidewalk)	278	0,10	28
Green area (Park 1)	3.778	0,10	378
Green area (Park 2)	2.531	0,10	253
Green area (Park 2)	4.863	0,10	486
Green area (Park 3)	5.877	0,10	588
Green area (Park 4)	3.770	0,10	377

Description of area	A_E [m²] 34.194	Ψ_m [-]	A_u [m²] 11.970
Asphalt (Cars)	5.796	0,90	5.217
Rigid concrete (Bus)	2.799	0,90	2.519
Sidewalk	2.337	0,50	1.168
Bike path	745	0,75	559
Bus stop	320	0,90	288
Green area (sidewalk)	244	0,10	24
Green area (Park 1)	8.312	0,10	831
Green area (Park 2)	2.076	0,10	208
Green area (Park 2)	5.581	0,10	558
Green area (Park 3)	5.000	0,10	500
Green area (Middle)	984	0,10	98

Appendix B

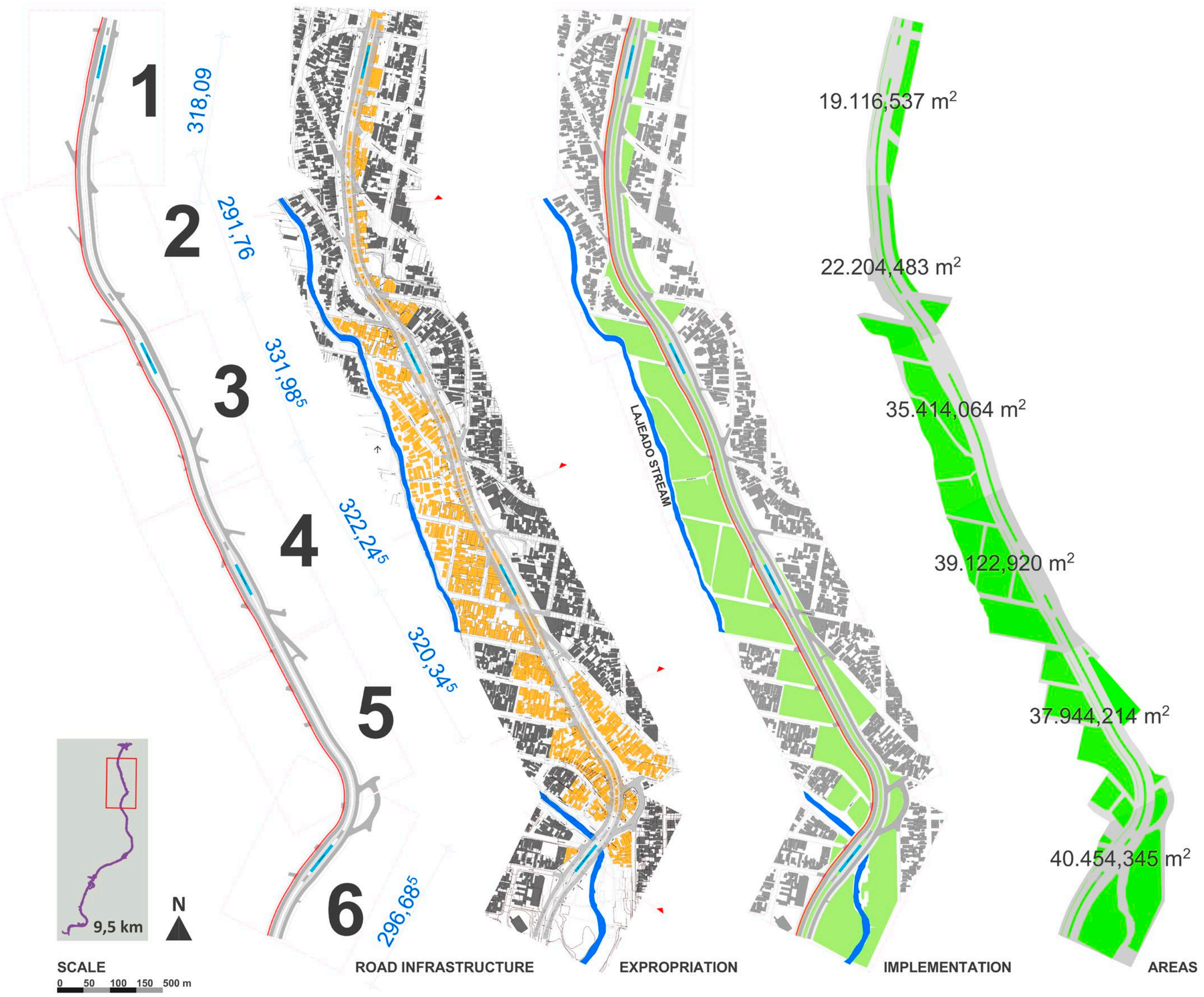
SAMPLE OF PLANS DEVELOPED BY SISTRAN ENGENHARIA
Source: SPTRANS

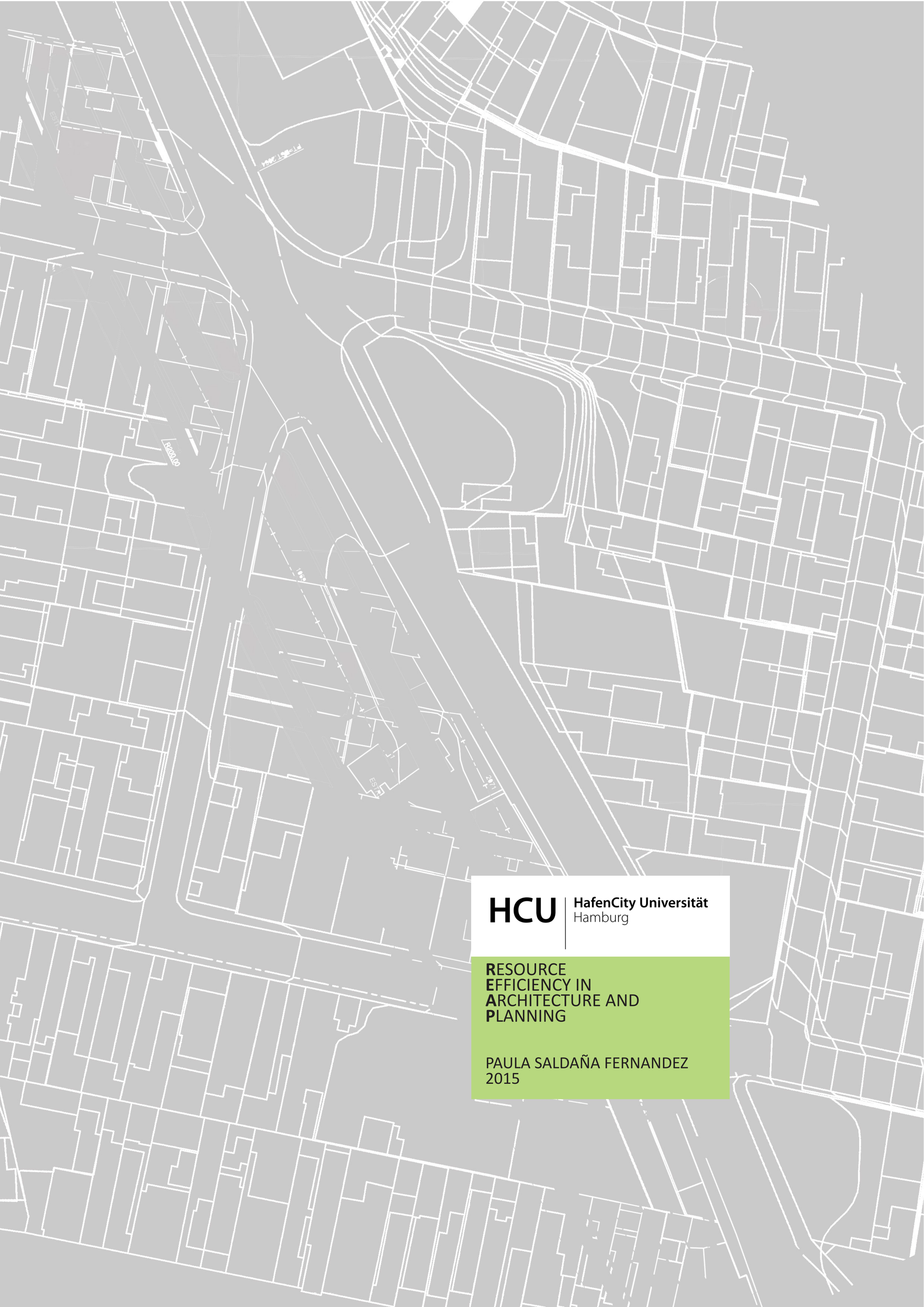




Appendix C

ANALYSIS OF THE STUDY AREA





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RESOURCE
EFFICIENCY IN
ARCHITECTURE AND
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2015