


Spring 5-22-2015

An Exploratory Scenario for San Francisco to Become A Walking, Bicycling and Transit City

Chaowen Huang

Environmental Management, hcwstanley@gmail.com

Follow this and additional works at: <https://repository.usfca.edu/capstone>

 Part of the [Environmental Engineering Commons](#), [Environmental Studies Commons](#),
[Transportation Engineering Commons](#), and the [Urban Studies and Planning Commons](#)

Recommended Citation

Huang, Chaowen, "An Exploratory Scenario for San Francisco to Become A Walking, Bicycling and Transit City" (2015). *Master's Projects and Capstones*. 137.

<https://repository.usfca.edu/capstone/137>

This Project/Capstone is brought to you for free and open access by the Theses, Dissertations, Capstones and Projects at USF Scholarship: a digital repository @ Gleeson Library | Geschke Center. It has been accepted for inclusion in Master's Projects and Capstones by an authorized administrator of USF Scholarship: a digital repository @ Gleeson Library | Geschke Center. For more information, please contact repository@usfca.edu.

This Master's Project

**An Exploratory Scenario for
San Francisco to Become A Walking, Bicycling and Transit City**

by

Chaowen Huang

is submitted in partial fulfillment of the requirements
for the degree of:

**Master of Science
in
Environmental Management**

at the

University of San Francisco

Submitted:

Received:

.....
Chaowen Huang Date

.....
Christopher Ruehl, Ph.D. Date

Table of Contents

| | |
|--|----|
| Abstract | 3 |
| List of Tables | 4 |
| List of Figures | 5 |
| 1. Introduction | 6 |
| 1.1 Overview of the San Francisco’s Transportation Sector | 8 |
| 1.1.1 Overview of the City | 8 |
| 1.1.2 Transportation System Information | 8 |
| 1.2 San Francisco’s Transportation System Greenhouse Gas Emissions | 10 |
| 1.2.1 San Francisco’s GHG Inventory | 10 |
| 1.2.2 Contribution of Transportation Sector in GHG Inventory | 11 |
| 1.3 The Goal of Reducing Greenhouse Gas Emissions | 12 |
| 1.3.1 A Common Goal | 12 |
| 1.3.2 San Francisco’s Municipal Transportation Agency Goal | 12 |
| 1.3.3 Reduction Potential of Transportation Sector | 13 |
| 2. Strategies to Achieve the Goal | 14 |
| 2.1 Efficient Travel Demand Management | 15 |
| 2.1.1 Priority Transit | 15 |
| 2.1.2 Congestion and Parking Management | 16 |
| 2.1.3 Travel Choice and Information | 17 |
| 2.2 Rational Infrastructure Support | 18 |
| 2.2.1 Complete Street | 18 |
| 2.2.2 Transport Sharing | 19 |
| 2.2.3 Electric Vehicle | 20 |
| 3. The Blueprint of Walking, Bicycling and Transit City | 20 |
| 3.1 Non-private Vehicle Commuting | 20 |
| 3.1.1 GIS Data of Commuting by Public Transportation | 21 |
| 3.1.2 GIS Data of Commuting by Bicycle | 21 |
| 3.1.3 Analysis of Non-private Vehicle Commuting Status | 22 |

| | | |
|-----------|---|-----------|
| 3.2 | A City of Short Trip | 24 |
| 3.3 | The Attractive Bike | 25 |
| 3.4 | The Sustainable Scenario | 26 |
| 4. | Bike and Bus Rapid Transit (BBRT) | 27 |
| 4.1 | Status of San Francisco’s Bike Lane | 27 |
| 4.2 | Bike as True Public Transportation | 28 |
| 4.2.1 | Safety | 28 |
| 4.2.2 | Convenience | 31 |
| 4.2.3 | Speed | 32 |
| 4.3 | Integrated Bike and Bus System | 33 |
| 4.3.1 | Independent Bicycle Route | 33 |
| 4.3.2 | BRT | 34 |
| 4.3.3 | Experimental Conception of BBRT | 35 |
| 5. | Public Electric Vehicle Fleet | 38 |
| 5.1 | The City’s Electric Vehicle Fleet | 38 |
| 5.1.1 | Electric Vehicle | 38 |
| 5.1.2 | Integration of Electric Vehicle and Car-sharing | 39 |
| 5.1.3 | Public Electric Vehicle Sharing Program (PEVSP) | 41 |
| 5.2 | Power the City | 44 |
| 5.2.1 | Vehicle to Grid (V2G) | 44 |
| 5.2.2 | Renewable Energy Storage | 46 |
| 5.2.3 | Advanced Net Metering | 48 |
| 6. | Smart Transportation System | 49 |
| 6.1 | Real-time Transport Service Information System | 49 |
| 6.2 | Smart Parking | 51 |
| 6.3 | One-city Transit Passport | 52 |
| 7. | Conclusions | 53 |
| | Literature Cited | 55 |
| | Appendix | 60 |

Abstract

The effects of greenhouse gases (GHGs) on global warming and climate change have become increasingly evident, and the transportation sector is a dominant contributor to GHG emissions which responsible for 13% of the world's total GHG emissions and more than 21% of overall energy-related CO₂ emissions. Cities need sustainable transportation system that integrate new technologies and strategies to provide efficient and effective transit service while reducing its GHG emission and improving its livability. This paper explores a suitable and sustainable transportation scenario for San Francisco to achieve its 2035 goal which is to reduce 1,767,500 metric tons GHG emissions annually. There are three major initiatives in this "Walking, Bicycling and Transit City" scenario, which includes practical non-vehicle transit, large capacity low-carbon public transit, and green vehicle alternative to satisfy the city's need of mobility while minimizing the impact to the environment. The bike and bus rapid transit integrates the bicycle and bus transit systems to provide efficient and effective public transport service to the city. The public electric vehicle sharing program associated with vehicle to grid technology to replace existing internal combustion vehicles, reduce GHG emissions, lower congestion, as well as maintains people's need for special mobility. And the smart transportation system integrates new technologies to assist travelers to improve travel safety and travel efficiency.

List of Tables

| | |
|---|----|
| Table 1. San Francisco Population Information (2010) | 8 |
| Table 2. Vehicle Information | 9 |
| Table 3. Transportation Infrastructure | 10 |
| Table 4. San Francisco GHG Emissions, 2010 Inventory | 11 |
| Table 5. GHGs reduction potential (mT) in the transportation sector | 14 |
| Table 6. Trips in the city of San Francisco by mode in 2010 | 24 |
| Table 7. Percentage of all trips taken by bicycle in 2007 (population) | 25 |
| Table 8. Mode shift in the scenario | 27 |
| Table 9. Top 10 bicycle sharing programs in the world | 31 |
| Table 10. 2012 U.S. Car Rental Industry Inventory | 39 |
| Table 11. Factors affect users' attitudes about electric vehicle sharing programs | 43 |

List of Figures

| | |
|---|----|
| Figure 1. Private vehicles available by San Francisco household | 9 |
| Figure 2. San Francisco’s 2010 citywide GHG emissions by sector | 11 |
| Figure 3. GHG Emission Reduction Goals | 12 |
| Figure 4. Projected change in San Francisco transportation emissions, 2010-2035 | 13 |
| Figure 5. Transportation hierarchy | 15 |
| Figure 6. Distribution map of workers commuting by public transportation | 21 |
| Figure 7. Distribution map of workers commuting by bicycle | 22 |
| Figure 8. Commuting information: San Francisco vs. National Average | 23 |
| Figure 9. Commuting mode in San Francisco | 24 |
| Figure 10. The performance of different transportation modes in San Francisco | 26 |
| Figure 11. Green Lane Project Membership | 28 |
| Figure 12. The attitude of people for bicycling | 29 |
| Figure 13. Bike box, separate signal and sign in San Francisco | 30 |
| Figure 14. Predicted bicycle travel speed along different route types | 33 |
| Figure 15. Simulated BBRT Deployment map | 35 |
| Figure 16. Renderings of BBRT | 36 |
| Figure 17. U.S. Carsharing Market Trend | 40 |
| Figure 18. The concept of V2G | 45 |
| Figure 19. GHG Emission by Vehicle Type | 47 |
| Figure 20. One-city Transit Passport | 53 |

1. Introduction

City life not only gives people convenience, but also is the most efficient mode of human society. High concentration of resources is a characteristic of the city generally, and its transportation system specifically.

The effects of greenhouse gases (GHGs) on global warming and climate change have become increasingly evident (IPCC, 2013). The transportation sector is a dominant contributor to GHG emissions (Grazi & van den Bergh, 2008; OECD, 2009), responsible for about 13% of the world's total GHG emissions and more than 21% of overall energy-related CO₂ emissions in 2006 (IEA, 2006). With the growing population of the world, increasing production and expanding vehicle markets of the developing countries (for example, the annual vehicle sales in China increased from 15 million in 2010 to 19 million in 2013), both the emission and concentration of GHGs will continue to increase in the coming future.

The high-density population and employment of the urban area currently generate large number of trips and heavy traffic congestion, which result in substantial GHG emissions from the city's transportation sector. These travel issues from the transportation sector not only cause severe environmental problems, but also influence our society and economy (Cheng et al. 2013). However, rational urban planning, efficient travel demand management, and effective infrastructure support can help to reduce private vehicle dependency and shift trips to public transit and non-motorized alternatives (May & Roberts, 1995). In addition to the containment of GHG emissions, such strategies could have other co-benefits in the form of reduced health costs, improved travel efficiency and a reduction in energy dependency (Adler & Blue, 1998).

The current form of most cities' transportation system increases its air pollution and GHG emissions, as well as the avoidable loss of life and economic productivity due to accidents. Cities need sustainable transportation systems that integrate new technologies and strategies to provide efficient and effective transit service while reducing their GHG emission and improving their livability.

Therefore, this paper will explore a sustainable and suitable transportation scenario for San Francisco, which includes practical non-vehicle transit and large capacity low-carbon

public transit to satisfy the city's need of mobility while minimizing the impact to the environment. This "Walking, Bicycling and Transit City" scenario will help the city to achieve its 2035 goal which is to reduce 1,767,500 metric tons GHG emissions annually (50% below 1990 levels) by these three major initiatives: bike and bus rapid transit, a public electric vehicle sharing program, and a smart transportation system.

The bike and bus rapid transit initiative is an integration of the bicycle and bus transit systems to provide efficient and effective public transport service. It will help to make bikes become the true public transport for daily trips instead of a recreational sport. They will associate with buses running on renewable energy to become the major travel choice in San Francisco. The best way to encourage people to leave their car is to provide attractive alternatives. The bike and bus rapid transit initiative tries to use the perfect combination of long bus trips and short bicycle trips as an alternative to meet the most needs for mobility while benefiting the environment and human health.

The public electric vehicle sharing program is a way to replace existing internal combustion vehicles, reduce GHG emissions, and lower congestion, all while maintaining people's need for special mobility. The integration of vehicle to grid (V2G, a technology that aggregates batteries on vehicles into the grid as a resource of energy load, storage and generation) implementation will provide an attractive way to offset the GHG emissions from transportation sector.

The smart transportation system is a comprehensive utilization of new technologies. The system includes three strategies: real-time transport service information system, smart parking and one-city transit passport. It aims to assist travelers to improve travel safety and travel efficiency.

The transformation of San Francisco's streets is not about wider roads and more cars. It's about people, the built environment and nature. It's about the city adapting to more people, more trips and more opportunities in a sustainable way. The scenario described in this thesis may bring great change to the city as well as every single person who lives in the city, but it also create safe streets, a livable urban environment and thriving neighborhoods.

1.1 Overview of the San Francisco’s Transportation Sector

1.1.1 Overview of the City

With a land area of about 47.35 square miles on the northern end of the San Francisco Peninsula, San Francisco is the only city-county in California. The population of San Francisco is greater than 800,000 (Table 1), and it is one of the most densely city in the state of California with a density of about 17,200 people per square mile. San Francisco is after New York as the second most densely populated major city in the United States (US Census, 2011).

| | |
|--|----------|
| Area (Land in square miles) | 47.35 |
| Resident Population | 805,000 |
| Population Density (per square mile) | 17,200 |
| Number of Jobs (16 Years of Age or Over) | 437,000 |
| AM Vehicle Trips into SF | 522,000 |
| SF Residents Commuting Out of SF | 94,000 |
| Estimated Daytime SF Population | 1,200,00 |
| Occupied Housing Units | 324,588 |

Table 1. San Francisco Population Information (2010)
(Source: SFMTA, 2011)

1.1.2 Transportation System Information

In the past 10 years, more and more citizens have been taking public transit, carpooling, traveling by bike and using shared cars for their trips in San Francisco. This mode shift in San Francisco’s transportation system has helped control the growth in GHG emissions.

| | |
|--|---------|
| Total Households | 324,588 |
| Total Vehicles Available (estimated) | 350,000 |
| Registered Vehicles per Square Mile | 7,392 |
| Average Vehicles Available per Household | 1.07 |
| Registered Vehicles per Capita | 0.43 |

Table 2. Vehicle Information (Source: U.S. Census Bureau, 2009)

There were 324,588 households in San Francisco in 2009 (Table 2), and about 30% of households do not own a car (Fig. 1). However, despite congestion and the cost of owning a car, many people still choose private vehicle as the first choice for trips in the city. 90% of San Francisco’s residents live within two blocks of public transit service, but they continue to use cars for travel because of the convenience, safety, comfort and speed.

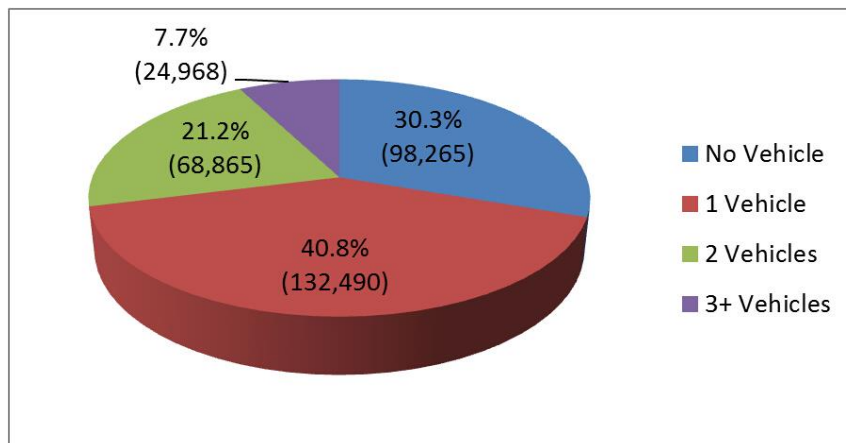


Figure 1. Private vehicles available by San Francisco household (Source: U.S. Census Bureau, 2009)

The transportation sector is a huge complicated system in San Francisco. It includes mass transit systems (San Francisco Municipal Railway (Muni), Bay Area Rapid Transit (BART), Caltrain, and ferries), paratransit, the street network for pedestrians, bicycles, private vehicles, commercial vehicles, taxis, and parking (Table 3).

| Type | Miles |
|--|-------|
| Streets | 946 |
| Streets in Parks | 65 |
| Bicycle Lanes and Paths | 53 |
| Dedicated Transit Lanes | 14.8 |
| Light Rail and Streetcar Right-of-Way | 71.5 |
| Cable Car Right-of-Way | 8.8 |
| Freeways (including ramps and exchanges) | 59 |
| BART Right-of-Way in SF | 7.2 |
| Caltrain Right-of-Way in SF | 6.5 |

Table 3. Transportation Infrastructure (Source: SFMTA, 2011)

1.2 San Francisco’s Transportation System Greenhouse Gas Emissions

1.2.1 San Francisco’s GHG Inventory

In 2010, San Francisco’s total greenhouse gas (GHG) emissions were about 5.3 million metric tons (Table 4). The buildings sector was the largest emissions source, contributing 52% of total GHG emission, with 24% coming from electricity use and 28% as natural gas use for heating and cooling. The transportation sector contributed about 40% of GHG emissions, almost 90% of which came from private vehicles. The waste sector (via methane production in landfills) contributed the remaining 5% of emissions. This inventory (San Francisco Department of Environment, 2013) has verified that the community of San Francisco successfully reduced its GHG emission by 14.5% between 1990 and 2010. San Francisco’s population grew 11% in the same time period with this encouraging reduction in GHG emissions. The reduction in citywide GHG emissions with equitable increase of population made San Francisco’ annual per capita emission from 9.0 mT in 1990 fall to 6.5 mT in 2010, in particular, a 28% decrease per capita.

| Source | CO ₂ e (tonnes) | Percentage (%) |
|-------------------------|----------------------------|----------------|
| Cars & Trucks | 2,118,863 | 40.0 |
| Commercial Electricity | 928,785 | 18.0 |
| Residential Natural Gas | 782,960 | 14.8 |
| Commercial Natural Gas | 609,521 | 11.0 |
| Waste | 244,625 | 5.0 |
| Residential Electricity | 335,195 | 6.0 |
| Municipal Electricity | 12,489 | 0.2 |
| Municipal Natural Gas | 119,860 | 2.0 |
| Rail (BART & Caltrain) | 68,046 | 1.0 |
| Ferry | 34,103 | 1.0 |
| Muni | 45,310 | 1.0 |
| TOTAL | 5,299,757 | 100.0 |

Table 4. San Francisco GHG Emissions, 2010 Inventory
(Source: San Francisco Department of the Environment, 2013)

1.2.2 Contribution of Transportation Sector in GHG Inventory

The Climate Action Strategy for San Francisco’s Transportation System indicated that transportation sector contributed about 37 percent of the GHG emissions (figure 2 shows that 32.5% from private vehicles, 3% from public transit, and 1.5% from municipal vehicles) to the city in 2010. In 1990, the San Francisco’s transportation sector produced about 2 million metric tons of greenhouse gases, and the city goal is to reduce those emissions by 50% by 2035 (SFMTA, 2011).

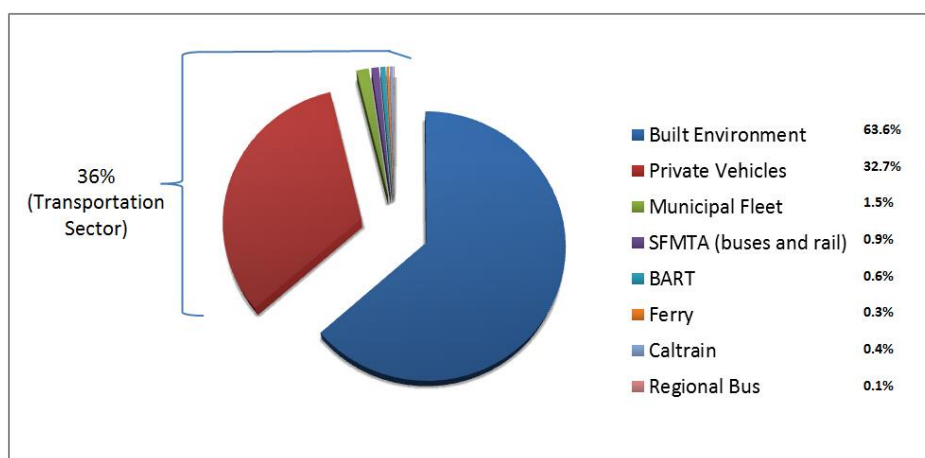


Figure 2. San Francisco’s 2010 citywide GHG emissions by sector
(Source: San Francisco County Transportation Authority, 2010)

1.3 The Goal of Reducing Greenhouse Gas Emissions

1.3.1 A Common Goal

Reducing greenhouse gas emissions is a common goal in the 21st century. There are many related goals set nationally, regionally and locally. The city of San Francisco has set the most aspiring goals (Fig. 3). These goals are well ahead of targets set by California’s Assembly Bill 32, the Global Warming Solutions Act, and the international Kyoto Protocol.

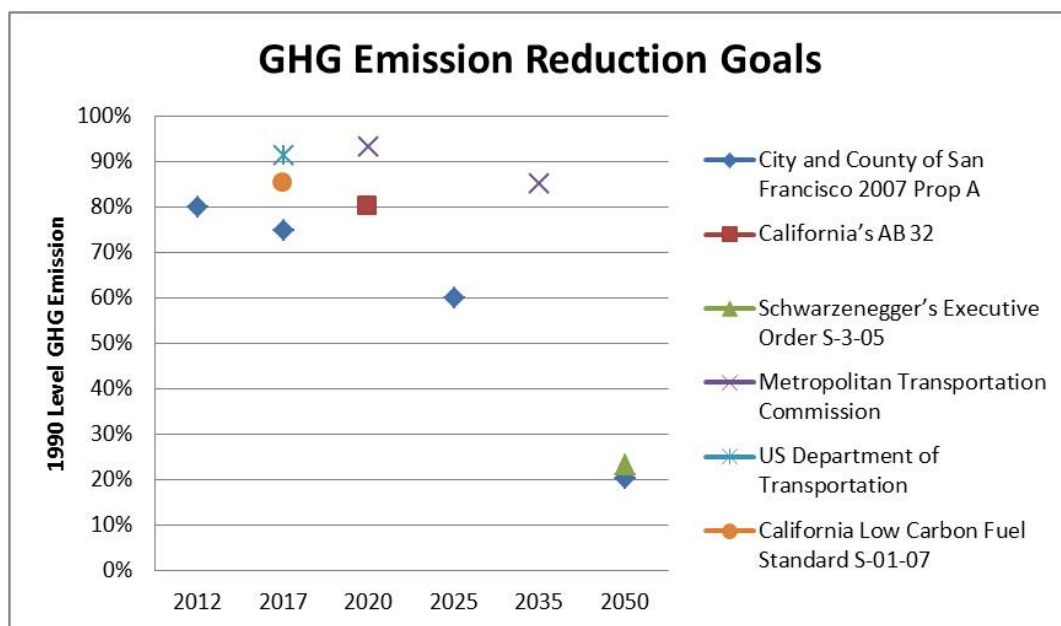


Figure 3. GHG Emission Reduction Goals (Source: SFMTA, 2011)

1.3.2 San Francisco’s Municipal Transportation Agency Goal

San Francisco’s Municipal Transportation Agency (SFMTA) has a specific goal for the transportation sector as part of the overall goal of the city. SFMTA predicts that the total amount of GHGs emitted in San Francisco will decline due to the implementation of the Climate Action Strategy and the reduction of vehicle emissions by 2035 (Fig. 4). Furthermore, SFMTA plans to increase transit’s share of the overall emissions by increasing transit ridership in the coming future. With the growing green transit and the advanced technologies, the emissions of the whole transportation sector will shrink further, and the share of different transportation modes will have significant changes (as shown in Fig. 4).

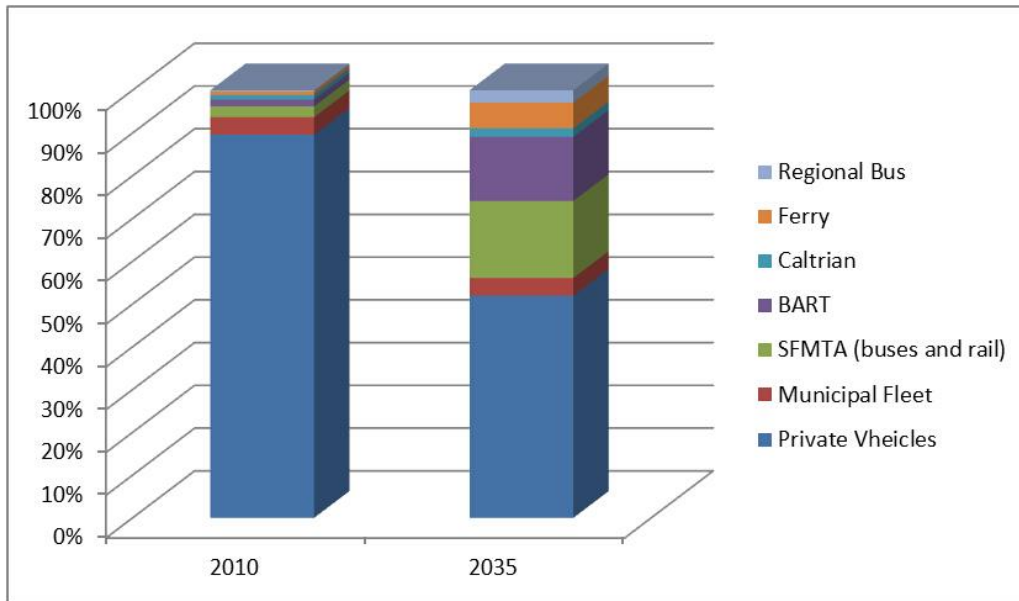


Figure 4. Projected change in San Francisco transportation emissions, 2010-2035
 (Source: San Francisco County Transportation Authority, 2010)

1.3.3 Reduction Potential of Transportation Sector

The emission reduction in the transportation sector will be the biggest challenge of the city’s overall reduction goal, but this also implies a great potential in terms of total GHG reductions. The challenge will be in reducing emissions from both improved vehicle travel status (such as an integration of energy efficient vehicles, low-carbon fuels, and electric vehicles) and travel mode shift (facilitated by improved public transit and travel demand management). This will require more and more San Franciscans to change their travel mode from driving alone to using transit, carpool, shared car, walking and bicycling. This will save money and reduce our carbon footprint, because the person who drives a vehicle will generate four times more GHG emissions per year than the one who relies on walking, bicycling, and public transit.

| Term | ①1990 | ②2010 | ③2035 Trend | ④2035 Trend with Low Carbon Fuel Standard | ⑤2035 Target | Reduction potential from CAS | Reduction potential to meet target |
|---------------------------|-----------|-----------|-------------|---|--------------|------------------------------|------------------------------------|
| Private Vehicles | 1,810,000 | 1,934,00 | 2,430,000 | 1,575,000 | 905,000 | ③-④ =925,000 | ③-⑤ =1,767,500 |
| Transit & Municipal Fleet | 215,000 | 221,400 | 350,000 | 280,000 | 107,500 | | |
| Transportation Sector | 2,025,000 | 2,155,400 | 2,780,000 | 1,855,000 | 1,012,500 | | |

Table 5. GHGs reduction potential (mT) in the transportation sector (Source: SFMTA, 2011)

Table 5 lists the emission reduction potential provided by SFMTA. If business as usual continues, the total GHG emission of transportation sector in 2035 will be 2,780,000 metric tons. The goal from San Francisco’s Climate Action Strategy with the implementing of California’s Low Carbon Fuel Standard is 1,855,000 metric tons GHG emission in 2035, which means the transportation sector has a 925,000 metric tons reduction potential according to this goal. The city’s 2035 target, which is 50% below 1990 level, indicates that the transportation sector has an even bigger reduction potential – 1,767,500 metric tons.

2. Strategies to Achieve the Goal

With their high density of population and concentrated resources, cities are the best place to address GHG emissions. Only 2% of the earth’s land area is cover by cities, but they consume 80% of the energy use and contribute 70% of the GHG emissions in the world (San Francisco Department of the Environment, 2013). Resource consumption and GHG emissions by cities will get even bigger in the coming future, as more and more people move into cities and more cities will be developed (U.S. Census, 2011). The 40 largest and most advanced cities—which represents 8% of the global population, about 540 million people, and more than 20% total gross domestic product of the world—together as a group “C40” announced at the Earth Summit held in Rio in June 2012 that the implementations of those reduction policies published by cities could help annual emissions to decrease one billion metric tons by 2030. City’s governments have the authority to operate and manage main

emission sources, thus they have the great potential to curb and reduce global emissions.

The growing city area and population increases travel distances and the number of trips, causing urban traffic congestion in most major cities in the world. Many other issues including intensified environmental contamination and, frequent traffic accidents, also increase dramatically due to severe traffic congestion (Sim et al., 2001). Therefore, cities need comprehensive strategies to address these transport problems and to achieve their GHG reduction goals. The integrated transport strategies from UK indicated that cities' transportation system could achieve better performance through the integration of management, infrastructure, and pricing measures to deal with complicated transport issues (May & Roberts, 1995).

2.1 Efficient Travel Demand Management

2.1.1 Priority Transit

The lack of planning result in sprawling urban is one of the major reasons for extensive use of private vehicles in the U.S. The Priority Transit strategy is to change this situation and actuate more trips make by public transit, bicycling and walking. Under this strategy, car trip is defined as a transport mode only for special purpose (Fig. 5). San Francisco has to provide more policies and infrastructures for bicyclist and pedestrian to support non-motorized transportation development in the city.

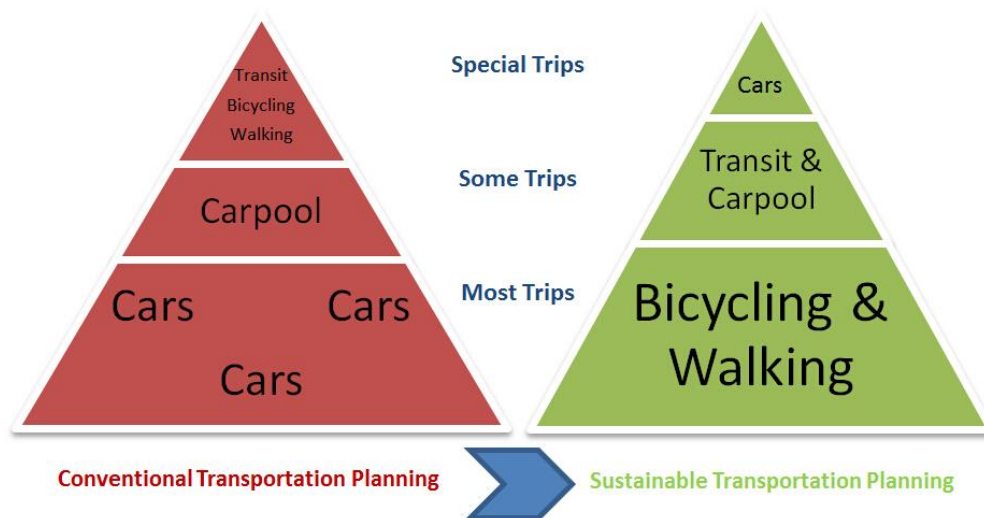


Figure 5. Transportation hierarchy

San Francisco ranked second in a nationwide study of accessibility to jobs by transit (University of Minnesota, 2014), and this one of the most advanced transit systems in the US has attracted more and more people to choose transit as their travel mode. However, the inefficient system and traffic congestion often makes it inconvenient, unreliable and uncomfortable for users. Dedicated transit lanes will be a good choice for San Francisco to improve the service quality and reliability, as well as more transit vehicles and rational transit routes to increase convenience and comfort for transit users. This is one of the most critical steps to meet the city's sustainability goals and reduce its carbon footprint.

2.1.2 Congestion and Parking Management

Good congestion and parking management facilitates drivers to get a parking space as fast as possible when they need to park their cars. This requires rational parking lots deployment, efficient information management and extensive education. According to a study of parking issue (Shoup, 2006), about 30% of the vehicles in the urban traffic flow are cruising for parking. The parking process is responsible for a substantial portion of urban congestion, travel delay, traffic conflicts and accidents. Advanced parking management can increase the accessibility from private vehicles to public transit and improve travel efficiency. Congestion pricing is a strategy to control traffic flow during peak hours and encourage people switch their travel mode from car trips to public transit and non-motorized alternatives.

Compared to policies that provide substantial incentives for driving and highway building, congestion and parking management is more focused on environmental and social aspects, so it is more likely to be sustained in the long term future. The implementation of congestion and parking management and road pricing will be critical GHG reduction tools for the entire transportation sector. These tools can reduce urban congestion, and make more efficient use of existing road capacity and parking facilities. In addition, the revenue can create funds to support public transit and develop bicycling and walking supported infrastructure. These sustainable public policies will encourage healthy travel and create livable urban environment.

Some major cities in the world, such as London, Singapore and Stockholm have achieved

great reduction in GHG emissions and traffic congestion while generating revenue from congestion pricing (SFMTA, 2011). In the U.S., San Francisco, Manhattan and Redwood City have tried to implement new parking policies to increase parking supply by using existing facilities efficiently, and avoid building new costly parking infrastructure in crowded urban area. However, this is just the beginning, it has a long way to go to integrate urban planning and transit development with congestion and parking management. Market-based mechanisms for travel demand management can help city to improve transportation system efficiency, reduce car trips and increase transit capacity. Transit reliability and accessibility users are significantly improved as well. Transportation system improvements with congestion and parking management will provide people more option for their trips.

2.1.3 Travel Choices and Information

The accessibility to precise travel information, including traffic status, travel options, and supported infrastructures can help travelers to make the best choice for their every trip. Travel choices and information is a strategy to provide incentives for people to make low carbon trips and reduce their personal carbon footprint. The most cost-effective strategy to reduce GHG emissions is to manage the demand of the transportation system. By providing useful travel choices and information, cities can reduce single-occupant car trip with very low direct costs. The top reason that people choose cars for travel is convenience (Transport for London, 2014). If we can make public transit as convenient as driving a car, or even better than driving, people will be willing to leave their cars and use public transit. In this reform, the first step and also the most important one is to provide plenty of travel choice and useful travel information to let people see that taking public transit is very easy and convenient.

It will be easier to select the best mode for each trip if people can access real-time and comprehensive travel information. This information helps them to adjust their journey plans accordingly and thus reduce the amount of time spent waiting, result in faster practical point-to-point journey times. There are no accurate figures available for the impact of real-time travel information on journey time, but the estimate range would be from a few million to tens of million dollars per year (KiM, 2009). Travel Choices is a strategy to create a connection between people and their destination through different travel options and precise

real-time traffic information. The advance in social media and technology bring us the possibility to coordinate trips with family, friends and anyone who has the same destination, result in less single-occupant car trips and low carbon travel behaviors.

Cities can provide broader education and outreach to citizens, who also can make more efficient use of existing resources. Communities and companies can set up programs to provide families and employers transit pass discounts and ride sharing. The development of smart mobile devices give Travel Choices and Information strategy the potential to make great GHG emissions reduction with a relative low public and private cost in the near term. Providing travel information to the organizations that generate demand for vehicle trips (such as school, shopping center and commercial center) through social media can help people reach these kind of destinations in more sustainable ways like bicycling, walking, transit, car sharing, or carpooling.

2.2 Rational Infrastructure Support

2.2.1 Complete Street

Most of the roads in the U.S. were designed to allow vehicles to move quickly and easily, as vehicle is the most popular transportation mode. It is a consensus around the world that streets need to be redesigned to address the needs for all users now (Daisa et al., 1998 & Dumbaugh, 2005).

A complete street should accommodate all people's needs and create livable urban environment for all users, including pedestrian, bicyclist, bus rider, motorist and even people with disabilities. The complete street strategy is aimed at providing roads that are safe and convenient, and creating the city's multimodal connective network instead of the past focus on road ways just for cars. More dedicated bike lanes, transit lanes and landscaping pedestrian sidewalks can develop the sustainable urban environment and create urban forest to facilitate the city's carbon sequestration.

A national survey published by the federal Bureau Transportation Statistics in 2002 indicated that roads with shoulders or sidewalks are available for about only 25% of all walking trips, and only about 5% of all bicycle trips take place on bike lanes. Most roads are not complete streets in the U.S., actually, there are too many incomplete streets. The 2003

National Transportation Availability and Use Survey showed that too few usable bike lanes and sidewalks is the top complaint among both disabled and able-bodied bicyclists and pedestrians in this country (McCann, 2005).

Complete Streets can be very cost effective strategy that begin with signage and paint, and then phased upgrades with more permanent infrastructures. It can create multiple benefits for the city (McCann, 2005): the comfortable landscapes and promotion of bicycling and walking can improve citizen's health; decrease air, water, and noise pollution since the reduction of vehicles and traffic congestion; reduce operational cost and increase transit reliability through integrated stations and dedicated lanes; and avoid substantial transportation-related costs to society.

Reserving more street space to pedestrians rather than cars will make a great contribution to increase the attractiveness of bicycling and walking. Along with the development of supported infrastructures, this strategy will promote bicycling ridership and the mode share in the entire transportation sector. Complete streets improve the urban environment, enhance transit services and pedestrian's safety can facilitate a lasting emissions reduction in the long term.

Complete streets are not limited to a few dedicated lanes. Many cities have launched main roads reform to integrate bicycle plans, or develop special plans for non-motorized travel in specific areas. There were nearly 130 communities adopted Complete Streets policies and 488 Complete Streets policies are in place nationwide by 2012 (National Complete Streets Coalition, 2012). Nowadays, the adoption of complete street strategies has affected the urban built environment in a variety of implementations. This fundamentally new way of street design inspires planners, engineers and users to strive for developing cities with diversity.

2.2.2 *Transport Sharing*

Although San Francisco should and does strive to make it attractive for people to walk and bicycle, as well as convenient to take transit, there still some trips need to be made by vehicles. The rising trend in vehicle sharing is changing car ownership and the collaborative economy to expand the value of sharing services in the city. There were about 1,788,000

members sharing over 43,550 vehicles in 27 countries and 5 continents worldwide by 2012, and the number is still growing rapidly (Shaheen & Cohen, 2013). Transport sharing allows people to have on-demand mobility without undertaking the cost of owning, operating, and maintaining a vehicle (or a bike). Transport sharing strategy provides a variety of travel options to meet our growing needs in mobility. Furthermore, the vehicle sharing service can help reduce urban congestion and parking problems by decreasing total car ownership of the city.

2.2.3 Electric Vehicle

Electric vehicles use the energy stored in a battery to power the vehicle. Electric vehicles provide an efficient and clean alternative to the conventional vehicles with internal combustion engine. There are many pros and cons about electric vehicles. It is known that electric vehicles have faster acceleration but shorter distance range than conventional vehicles. They produce no local emissions and air pollutants, but require long charging times.

Electric vehicles are a direct solution for GHG emissions, because they reduce the use of carbon-based fuels from using electricity generated by renewable energy (details provide in chapter 5), and do not generate local emissions. Electric vehicles using renewable energy generate up to 70% less CO₂ than gasoline-powered vehicles equivalents (Papandreou, 2004). San Francisco has the plan to reduce fuel consumption by creating the largest per capita electric vehicle fleet in the country by 2035 (SFMTA, 2011). However, compare to many other cities in the U.S., many car owners in San Francisco don't have garages to set up a charging station for their electric vehicles. Therefore, the challenge for San Francisco is not only to increase the penetration of electric vehicle, but also has to provide infrastructure support for electric vehicle owners by establishing public charging station network all over the city.

3. The Blueprint of Walking, Bicycling and Transit City

3.1 Non-private Vehicle Commuting

The definition of non-private vehicle commuting in this chapter is a worker, age 16

years old and older, that commutes by those transportation modes without private vehicles, such as bicycling, walking, and public transit.

3.1.1 GIS Data of Commuting by Public Transportation

The San Francisco transit system is only responsible for about 2% of the city's GHG emissions during a general work day in 2010. In contrast, private vehicle contributed 33% of the total (SFMTA, 2011). Thus private vehicles generate 15 times more emission than transit vehicles. Only a few areas in San Francisco have high percentages of workers commuting by public transportation, such as the downtown core and Mission District (Fig. 6). The majority of the north, east, and southwest of the city have less than 30% workers using public transit for commuting.

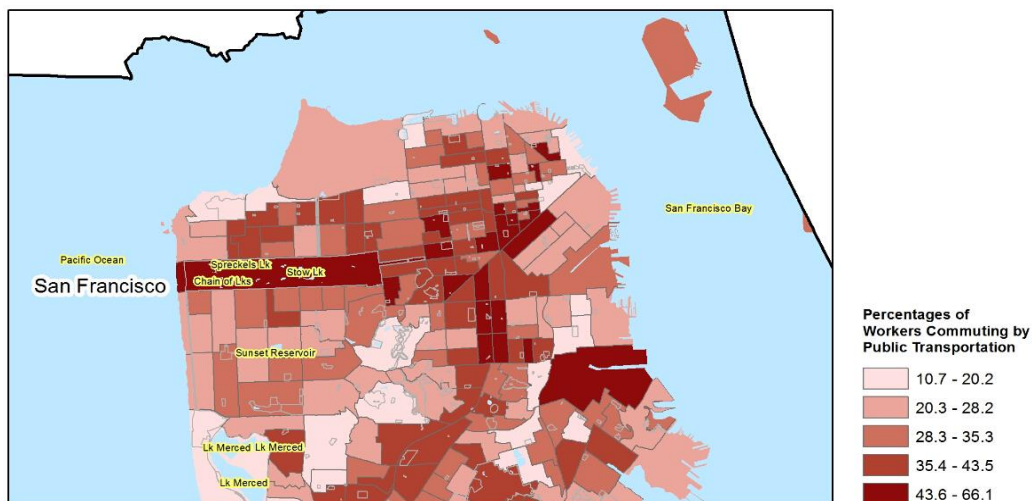


Figure 6. Distribution map of workers commuting by public transportation.
(Data from: 2006 American Community Survey)

3.1.2 GIS Data of Commuting by Bicycle

Bicycling is the least popular transportation mode in San Francisco. Only a tiny area in Mission District has more than 10 percent workers commuting by bicycle. More than a half of the city only has less than 1 percent workers using bicycle as commuting transportation (Fig. 7).

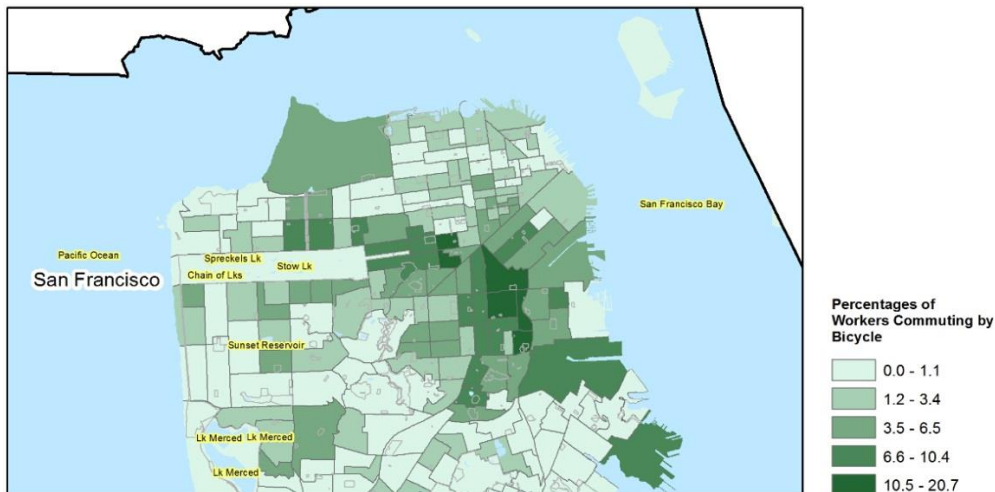


Figure 7. Distribution map of workers commuting by bicycle.
 (Data from: 2006 American Community Survey)

3.1.3 Analysis of Non-private Vehicle Commuting Status

The U.S. Census Bureau reported that there are about 265,000 workers commuting from another county into the San Francisco County every day. This number is among the highest in the nation, less than Manhattan (1.6 million) and Los Angeles County (471,000). There is 27.4% of workers commute outside the county where they live in the U.S (U.S. Census Bureau, 2013).

According to the American Community Survey 2006-2010 estimates, there are 265,164 workers work in San Francisco County but live outside the county, including 47,861 from Contra Costa County, 71,861 from Alameda County, and 75,047 from San Mateo County. At the same time, there are 102,709 San Francisco residents leave the county for work every work day. Among these workers, 19,087 commute to Santa Clara County 22,009 to Alameda County, and 43,423 going to San Mateo County.

From the public transit commute map (Fig. 6) we can see that more workers prefer public transportation as the commute mode in the commercial area, the percentage is around 50% -- more than any other area. The commonalities of those areas (Commercial area & Mission District) that have more workers commuting by public transit are:

- Optimal transit services and diversified transit options.
- Convenient transit routes and intensive bus trips.
- BART.

- Congested surface traffic.
- Lack of parking.

In contrast, the distribution of bicycle commuting is different from public transportation. The areas have high percentages of commuting by bicycle are quite dispersed, and some have overlap with public transit. A reasonable explanation of this situation is that those areas have suitable circumstance for bicycling. For example, they have dedicated bike lanes and slow traffic.

These two distribution maps demonstrate that public transit and bicycling are not the major mode for commuting. There is no doubt that driving to work is still the most popular option. However, compare to the national average (Fig. 8) San Francisco has a high percentage in using public transportation and bicycle as commuting tools.

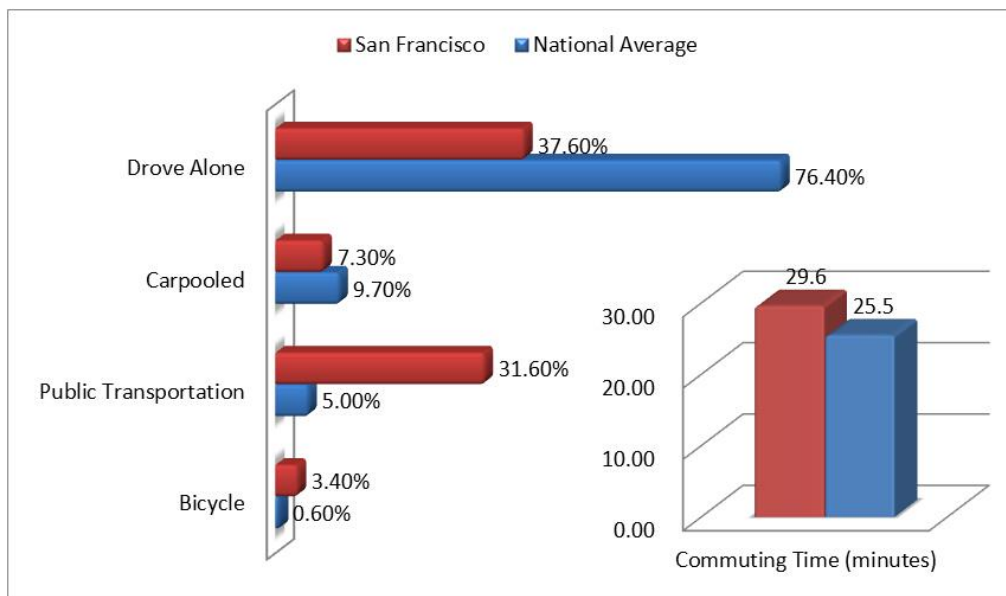


Figure 8. Commuting information: San Francisco vs. National Average
(Data from: U.S. Census. (2011))

In the long term, if San Francisco wants to become a sustainable city, it has to reverse the current situation of travel mode dominated by private vehicles. The city has to provide more infrastructures and policies support for public transit, bicyclist and pedestrian, especially in the residential area and the remote area. The best way to encourage people to leave their car is to create attractive alternatives.

3.2 A City of Short Trip

San Francisco’s 7 miles long and 7 miles wide geography and compact urban environment, together with priority transit policy give it great potential to achieve a walking, bicycling and transit city. On the way to this ideal sustainable city, the city has to provide more walkable landscaping sidewalk, create bicycle-friendly circumstance, and well implement the transit-oriented development (TOD) strategy.

| Mode | Car | Transit | Bicycle | Walk |
|----------------|-----|---------|---------|------|
| Length (miles) | 2.8 | 3.4 | 2.3 | 0.9 |
| Percentage (%) | 60% | 17% | 3% | 20% |

Table 6. Trips in the city of San Francisco by mode in 2010

(Source: San Francisco County Transportation Authority, 2010)

From the data of the National Household Travel Survey, the average distance of a typical trip in the U.S. is around 10 miles. However, most of trips within San Francisco are less than this national average number. More specifically, as table 6 shows that the average transit trip is the longest at 3.4 miles, and the average car trip is only 2.8 miles long, just a little bit longer than the average 2.3 miles bicycle trip. Above table indicate that San Francisco is a city of short trip, through the weight calculation, the average trip length is only about 2.5 miles.

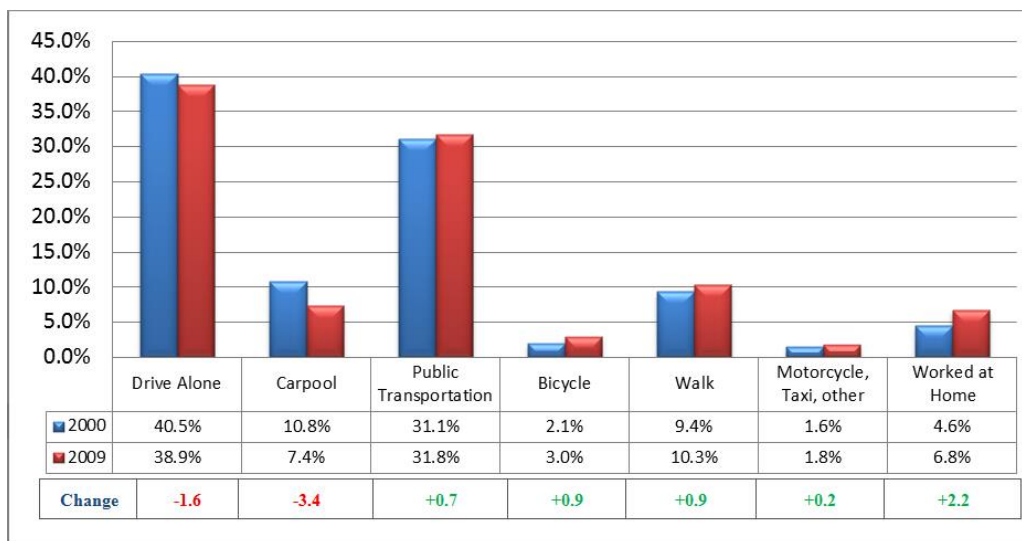


Figure 9. Commuting mode in San Francisco (Data from: U.S. Census, 2000 & 2010)

Compare the data from figure 9: during the decade of 2000-2009, the mode share of public transit, bicycling and walking all slightly increase; in contrast, car trips showed a downward trend, for both drive alone and carpool trips. Most of the car trips in 2010 were concentrated in the downtown core, and the outer districts of Richmond, Sunset, and Bayshore. Mission District had the least dependent on car trips, and the majority trips are taken by public transit.

3.3 The Attractive Bike

It will be a big challenge for San Francisco’s transit system to meet the traffic needs, with a projected growth of 250,000 new jobs and 150,000 new residents by 2035. It is necessary for the city to develop a well-functioning transit system with larger capacity. Furthermore, the city also needs great improvements in bicycle and pedestrian to balance the increasingly heavy traffic. Table 7 shows that San Francisco has a long way to go to develop the bicycle as a major travel mode and catch up with European cities.

| | | | |
|----------------------|------------|--------------------------------|------------|
| Netherlands | 27% | Amsterdam (743,000) | 37% |
| Denmark | 18% | Copenhagen (500,000) | 20% |
| Germany | 10% | Berlin (3,400,000) | 10% |
| Australia | 1% | Sydney (4,500,000) | 1% |
| United States | 1% | San Francisco (720,000) | 1% |

Table 7. Percentage of all trips taken by bicycle in 2007 (population)

(Source: Pucher & Buehler, 2007)

Driving alone is the most energy intensive travel mode, according to the life cycle cost analysis of average CO₂ emission per passenger mile, and bicycling is the most energy efficient mode (Chester et al., 2010). In Figure 10, the bubbles represent the CO₂ emission per passenger mile – bigger bubble means more emissions. Automobiles generate about 1 lb CO₂ per passenger mile, and are responsible for more than 80% of the entire transportation sector’s emissions. In contrast, public transit is very energy efficient in San Francisco,

because the city has about 30% workers commute by public transit, which is one of the nation’s highest public transportation usage, only ranked after New York City (US Census, 2011). The successful mode shift from automobile to walking, bicycling and transit will be a critical step for San Francisco to achieve a sustainable transportation system.

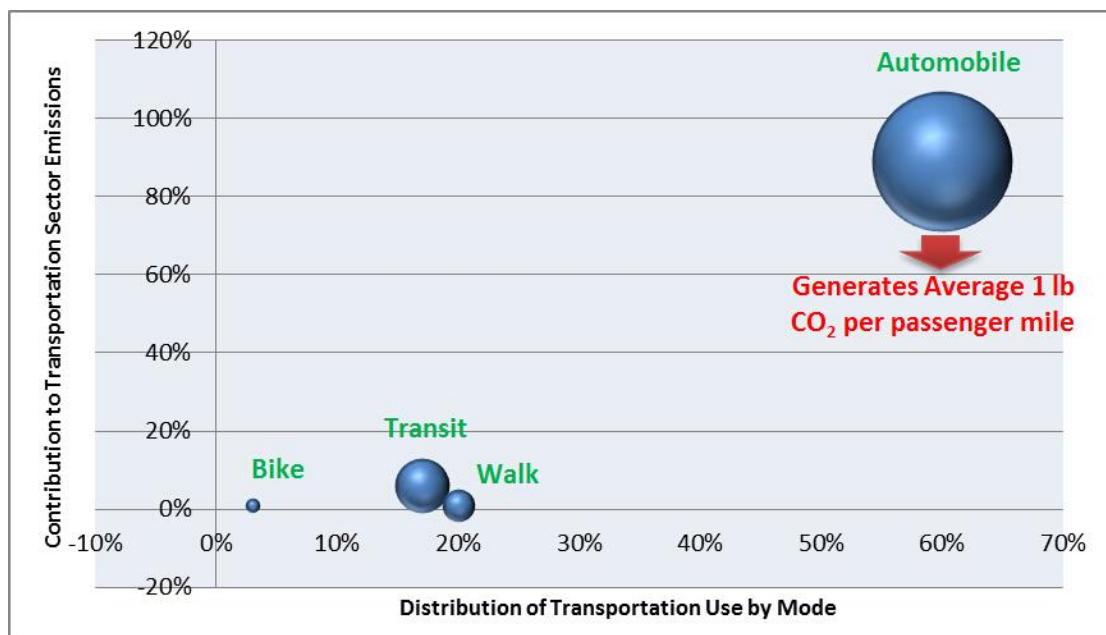


Figure 10. The performance of different transportation modes in San Francisco (Source: Chester et al., 2010)

3.4 The Sustainable Scenario

Currently, San Francisco’s transit system has no excess capacity during the peak hours, and most of trips are within bicycling and walking distance in the city. These facts imply that the city has great emissions reduction potential. The majority of car trips can be shifted to transit, walking and bicycle trips. Public electric vehicle sharing program can meet people’s needs for special mobility while reducing vehicle ownership and parking demand. Furthermore, there are no over long distances to cause the battery exhausted problem for electric vehicles due to the city’s compact urban environment.

| | Past | | Development as usual | The scenario | |
|-------------------|---------------------------|---|----------------------------|----------------------------|------------------|
| | Mode of transportation | Average trip length in San Francisco | Number of trips in 2010 | Number of trips in 2035 | Scenario goal |
| Automobile | 2.8 miles | 2,355,000 | 2,808,000 | 30% | 1,425,000 |
| Transit | 3.4 miles | 685,000 | 886,000 | 30% | 1,425,000 |
| Bicycle | 2.3 miles | 105,000 | 134,000 | 20% | 951,200 |
| Walk | 0.9 miles | 815,000 | 928,000 | 20% | 951,200 |
| Total | 2.55 miles | 3,970,000 | 4,756,000 | 100% | 4,756,000 |

Table 8. Mode shift in the scenario (Data from: San Francisco County Transportation Authority, 2010)

This walking, bicycling and transit city scenario aims to create a sustainable pattern for the city of San Francisco. Its goal is to reduce automobile trips from 60% in 2010 to 30% by 2035, shift the share to raise public transit trips to 30% and bicycle trips to 20% (Table 8). It will provide comprehensive transit service for low-income and transit dependent riders while maintaining different people’s mobility and reducing GHG emission. More sustainable travel options for people, and better access to healthy lifestyle in San Francisco. With complete street and safe traffic to build more connected neighborhoods. Improve economic and community development through the optimal transportation system. Constructing a more livable city for all, and incubate a more resilient city to adapt climate change.

4. Bike and Bus Rapid Transit (BBRT)

4.1 Status of San Francisco’s Bike Lanes

In the current development of bicycle traffic, San Francisco cannot compare with Amsterdam or Copenhagen, but it has done quite well relative to other American cities. San Francisco is one of the initial seven members of the Green Lane Project in the U.S. (Fig. 11). Green lanes are next-generation bike lanes being built across the country. They are dedicated and appealing spaces for bicyclists that are protected from vehicles and independent from

pedestrian sidewalks. Most of them are printed green to attract attention.

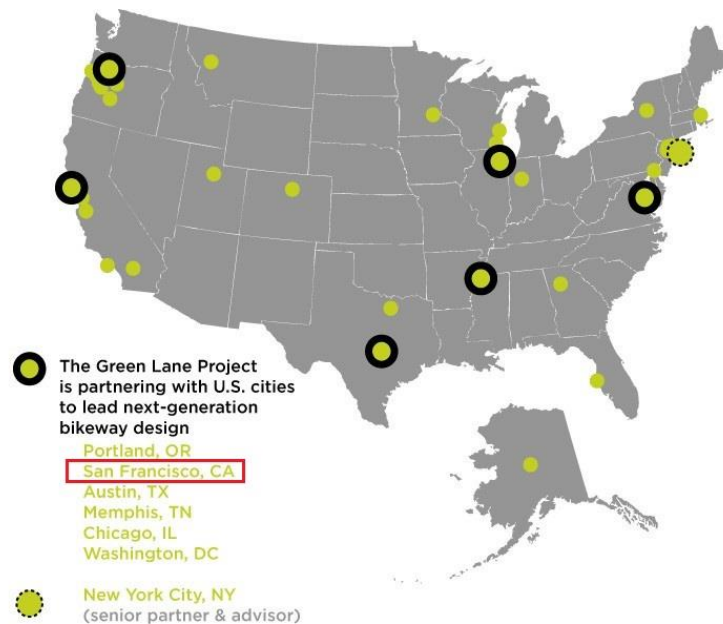


Figure 11. Green Lane Project Membership. (Source: <http://greenlaneproject.org>)

San Francisco is quickly catching up after last few years' development since 2007. By 2014, it has a total of 14 protected green lanes. Most of them are in the downtown core and Mission District. However, these are not enough for a city that has more than 0.8 million residents. To change people's travel behavior, it is critical to establish a complete network in the entire city with this kind of green lanes and change the future urban planning.

4.2 Bike as True Public Transportation

Currently, about 50% of all trips in this country are within 3 miles, a bikeable distance, but, only about 1% of all U.S. trips are made by bicycle. There are 60% of all Americans say that they are interested in taking more trips by bicycle (Portland Bureau of Transportation, 2010). Therefore, it is necessary to figure out what are the main concerns of bicyclists, or in other words, what factors influence the way people choose to ride.

4.2.1 Safety

For transportation, the most important thing must be safety. In fact, only less than 8% of all travelers are satisfied with the existing system of on-street bike lanes and like bicycle trips in the U.S. More than 90% of all travelers are not going to ride a bike (as Fig. 12 shows).

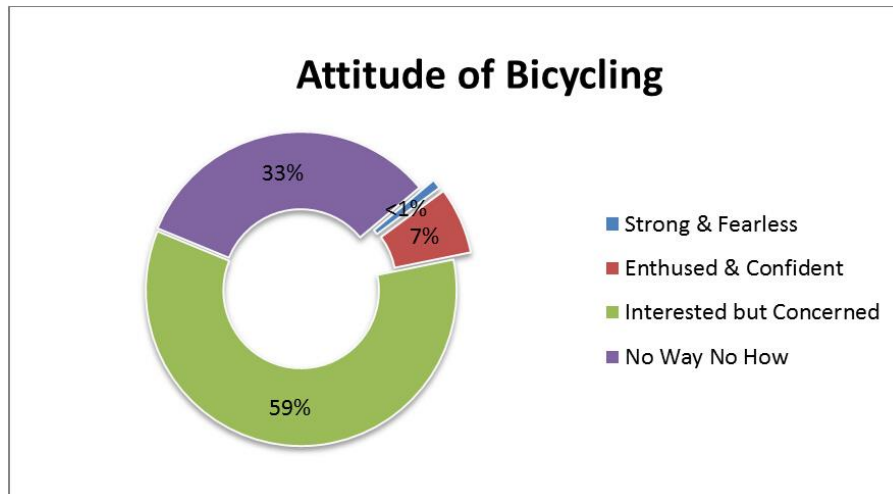


Figure 12. The attitude of people for bicycling. (Source: Portland Bureau of Transportation, 2010)

With respect to bicycle facilities, users prefer to pay the highest price for designated bike lane, followed by the no parking street and off-road bike lane (Tilahun et al. 2007). These results make it very clear that people are willing to make bicycling a practical and comfortable way for short trips. It is a signal that we can change how people travel by changing how the streets work. Providing safe and attractive bike lanes for bicyclist is the number one way we can encourage more people to get around by bike.

A protected bike lane is a dedicated bike lane with advanced protection for bicyclists. It uses additional physical separation—such as parked cars, curbs or plastic posts—to separate bikes and motor vehicle traffic (Professional Safety, 2013). This kind of advanced bike lanes have been implemented in Europe for a long time, and some cities in the U.S. try to adopt them in their transportation system recently. According to a study published in American Journal of Public Health (Teschke et al., 2012), bike lanes can cut injury risk in half, and dedicated bike lanes can make a 90% reduction from the risk of injury.

A buffered bike lane is another advanced bike lane that has a five-foot-wide striped buffer zone between bike lanes and moving vehicles. A survey shows that bicyclist feels safer and more confident to ride a bike on a buffered bike lane rather than on an unbuffered lane or share road (Transportation Alternatives Magazine, 2007). The buffered bike lane on the big avenue is more attractive to bicyclists than the general unbuffered bike lane and shared road design. Dedicated bike lane encourages bicycling, but those strong designed advanced bike

lanes like protected bike lanes and buffered bike lanes make urban streets more appealing to bicyclists and can attract even more bicyclists.

In addition to the safety on street, the safety at the intersection is also a critical problem, most of the accidents between motor vehicles and bikes happened at intersections. A bike box is a design that has improved intersection safety in parts of Northern Europe for over 20 years. It can help motorists and bicyclists identify potential conflicts, and prevent conflicts between bikes and vehicles.

A bike box is designed to extend across all lanes of traffic to help bicyclists turn across intersections, or to guide bicyclists as they switch from one side of the road to another. It can have a number of varied implementations. Bike boxes can assist bicyclists as they pass straight through the intersection with printed color zones to increase contrast and highlight the existence of bicyclists to motorists, thus reducing potential collisions between bikes and vehicles (Dill et al. 2012). The common practice in the Netherlands often provides a separate signal for bicyclist to give them a short head start. This is rare in the United States, but can be found in San Francisco (Fig. 13). In addition, a bike box places bicycles in front of vehicle traffic that will impede vehicles from making right turns at red signals. Therefore, the bike box usually paired with “no right-turn on red” signs.

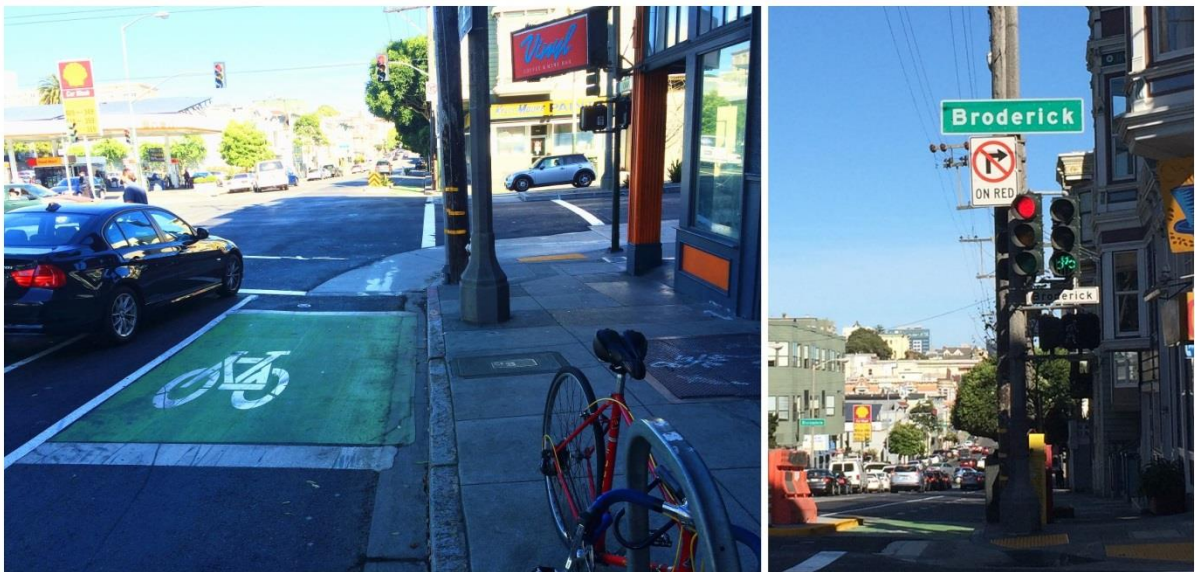


Figure 13. Bike box (left, Oak Street), separate signal and sign (right, Oak Street cross Broderick Street) in San Francisco.

4.2.2 Convenience

The second concern that prevents people from riding a bike is convenience. There isn't always a place to park a bike. People can't bring their bikes into most offices, restaurants, or supermarkets. The critical problem is: for some people who want to use bicycles for long trips, they have no way to bring their bikes into the bus or train, only limited space for a bus or train to carry bikes. Bikes are good for short trips, as buses are for long trips, and thus the convenience of transformation between these two kinds of transportations will influence people's choices.

Bike sharing program should be a good solution to improve the convenience of bicycle trips. The earliest well-known experimental community bicycle program was started in Amsterdam in 1965 (Furness, 2010), and Copenhagen was the first large city to start a bike share program at about twenty years ago. Cities like Amsterdam and Copenhagen have utilized bike sharing programs successfully for years and San Francisco just in its infancy. Nowadays, there are more than 500 cities in 49 countries launch bicycle sharing programs, with a total fleet of over 500,000 bicycles. China has 20 of the 25 largest most bicycle sharing programs in the world (Earth Policy Institute, 2013), and Paris hosts one of the world's largest public bicycle sharing programs (Table 9).

| City | Launched | Stations | Bikes | Price |
|-----------------------|----------|----------|--------|--|
| Hangzhou, China | 2008 | 2,965 | 69,750 | \$32.61 deposit + time charge |
| Paris, France | 2007 | 1,751 | 23,900 | \$38.52/year, \$2.26/day |
| Wuhan, China | 2009 | 1,318 | 90,000 | Free |
| Changwon, South Korea | 2010 | 230 | 4,600 | \$8/year, \$1/day |
| Lyon, France | 2005 | 345 | 4,000 | \$33.20/year, \$1.99/day |
| Barcelona, Spain | 2007 | 420 | 6,000 | \$61.93 per year |
| Montreal, Canada | 2009 | 450 | 5,120 | \$81.02/year, \$6.87/day |
| Tel Aviv, Israel | 2011 | 171 | 2,000 | \$77.27/year, \$4.69/day |
| Brussels, Belgium | 2009 | 305 | 3,700 | \$42.65/year, \$2.13/day |
| Warsaw, Poland | 2012 | 125 | 2,500 | \$3.13 initial fee + extra time after 20 minutes |

Table 9. Top 10 bicycle sharing programs in the world. (Source: USA Today, 2013)

Paris first launched its Vélib' (public bicycle program) in July 2007. The grand scale of the system bring the world a whole new picture about bike sharing. Vélib' is composed by 20,000 public bikes at 1,450 stations, connected with the city's public transit system (Reclaim, 2008). Users can buy an annual, monthly, weekly or day-long membership at a pretty low nominal fee, and use the membership card to rent a bike from one of the stations. The local people can also tie the card into their monthly Metrocard. About the rate, the first thirty minutes for free, and with accumulative fees thereafter to attract people use these shared bikes for short trips. During the implementation of Vélib', there were 5,000 on-street parking spaces replaced by Vélib' stations to make room for bikes near transit stations and cultural destinations.

The first year of Vélib' had carried about 26 million bike trips with an average trip distance of about 3 miles. There are 10% from former car trips within the roughly 65 million miles of new bike trips. This massive shift of transportation modes indicate the potential of single-occupancy car trips reduction by improving bike trips and bike sharing program. Vélib' has also release the stress of public transit during peak hours. The most inspiring thing is the Vélib' generated 2% of new trips that are not converted from other modes, thus it shows that a good transportation system can help the city to thrive.

4.2.3 Speed

Compared to the motor vehicle, the bicycle's speed is much slower. However, since bicycles are usually used for short trip (3 miles or less), speed isn't a problem. The main issue is the fluency of bicycle trip. Most of the unbuffered bike lanes and share roads are often blocked by cars, pedestrians and intersections. The person who is riding on this kind of bike lane has to be very careful and prepare for a sudden stop or detour.

GPS data was used to predict bicycle travel speed along different route types (El-Geneidy et al., 2007). The study divided the urban routes for cyclists into three types: regular streets, which cyclists would have the highest level of interaction with traffic and must travel in mixed traffic; on-street striped bike lanes, which have lower levels of interaction between cyclists and traffic; and dedicated bike lanes, which cyclists have minimal interaction with traffic. The result showed that cyclists tend to travel along various types of routes at different

speeds, and the average speed range is between 9.71 mph and 10.8 mph. Predicted travel speeds on dedicated bike lanes are higher than those on striped bike lanes and regular streets (Fig. 14). An unexpected fact is, even on-street striped bike lanes can improve the safety of cyclists, but they don't have positive effect on speed.

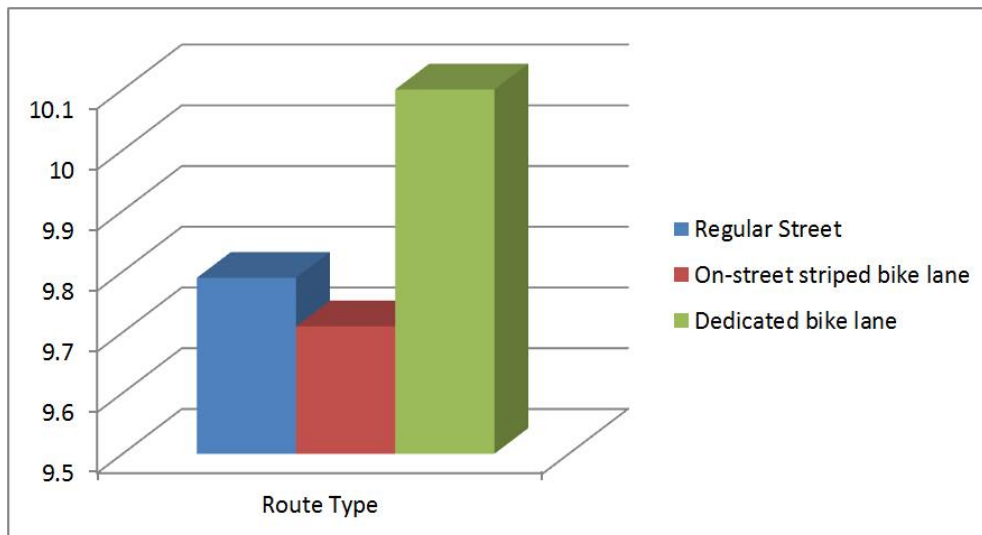


Figure 14. Predicted bicycle travel speed along different route types, mph.

(Source: El-Geneidy et al., 2007)

Additionally, the shortage of dedicated bike lanes would be a barrier for the development of bicycling. In San Francisco, there are only 14 streets have green bike lanes, and almost all of them are less than 1 miles (Green Lane Project, 2015). This means if bicyclists want to go to a destination safely, they have to spend much more time to detour to those streets that have green bike lanes, and cannot take the shortest route.

Safety, convenience and speed are major concerns to hinder people to choose bicycle as the first choice for their trips. The best way to encourage people to ride a bike is to create safe, convenient and fluent bicycling environment for them.

4.3 Integration of Bike and Bus System

4.3.1 Independent Bicycle Route

Independent bicycle routes are the first and most important element of BBRT. The independent bicycle route is marked with signage and symbols, as well as painted stripes. It

will facilitate free flowing bicycling through both commercial and residential area streets with buffer zone and physical separation to protect bicyclists. These independent bicycle routes will serve to further expand bicycling ridership by improving safety (bicyclists can enjoy their trips in independent area with slow traffic) and inviting new riders (these bicycle routes can serve as confidence infrastructure to show a convenient and fluent network for new bicyclists). New protected bike lanes in five American cities (Austin, TX; Chicago, IL; Portland, OR; San Francisco, CA; and Washington, D.C.) have a measured increase in ridership range from 21% to 171%, and drew about 10% of new riders from other modes (Monsere et al., 2014). Independent bicycle routes provide standard that all levels of bicyclists can safely travel in the city without conflicts and collisions to motor vehicles and pedestrians. The systematic transformation of conventional streets into independent bicycle routes will improve safety and quality of trips for bicyclists and non-bicyclists alike.

4.3.2 BRT

Bus rapid transit (BRT) is a cost-effective and flexible alternative solution to railway transit; it is a high-quality bus based transit system that provides quick, comfortable, and convenient urban mobility (Rodríguez & Targa, 2004). The latest completed BRT systems in the United States were constructed at the cost range of between \$11 Million and \$58 Million USD per kilometer, about one-half lower than light rail transit, and can transport 4,000 to 40,000 passengers per day (Committee for Perth, 2014). BRT not only requires lower costs than railway transit, but also can well-serve dispersed travel needs by providing free transfer services (Al-Dubikhi & Mees, 2010). BRT is defined as a variety of bus-based applications including interconnected improvements in technology, operations, equipment and facilities to improve the level of service of bus-based mass transit system (Estupin~a~n & Rodríguez, 2008). The BRT system usually has enclosed platforms, dedicated travel lanes, pre-board fare collectors, limited stops, and specific branding of the route and buses.

BRT is not so common in the U.S. — there were only five BRT routes in the country by 2013. They are the Emerald Xpress in Eugene, Oregon; Cleveland's Health- Line; Pittsburgh's Martin Luther King Jr. Fast Busway; the Los Angeles Orange Line; and the Las Vegas Strip Downtown Express. (Davis, 2013). San Francisco should seriously consider this

kind of transit system for its future transit development. For example, develop pilot BRT routes connect Richmond, Sunset, and Mission District to the downtown core.

4.3.3 Experimental Conception of BBRT

The Bike and Bus Rapid Transit (BBRT) in this scenario is an integration of bicycle and bus transit system to provide efficient and effective public transport. It implements the complete street concept to respect and reserve all users' rights to use the road. Constructing a sustainable urban transportation system with the priority of pedestrians and non-motorized vehicles, follow by public transit, and car traffic only for special purposes.



Figure 15. Simulated BBRT Deployment map.

BBRT try to develop bicycle to be a real public transport mode to share the stress of conventional public transit, as a supplement of bus in dispersed short trips (Fig. 15). The perfect combination of long bus trips and short bicycle trips can meet the most needs for mobility while benefit to the environment and brings us a healthy lifestyle. The characteristic of BBRT is to use dedicated bus lanes to separate bicycles and motor vehicles traffic. This special design that protects bicyclists and pedestrians will increase people's confidence and attract more people to leave their cars.

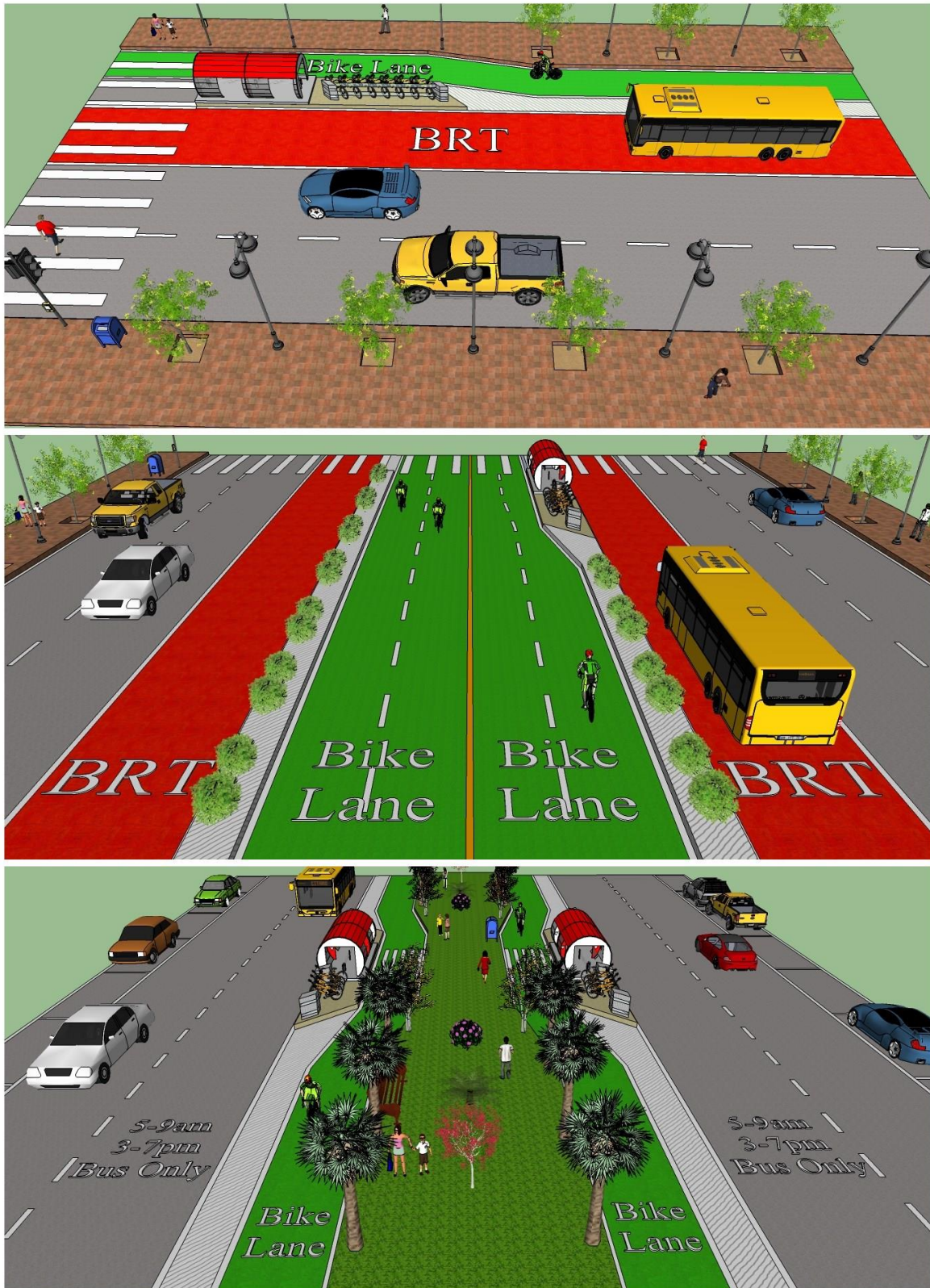


Figure 16. Renderings of BBRT (One-way, Commercial Area, Residential Area)

BBRT system, as Figure 16 shows, there are three different schemes based on different conditions and demands of various area in the city: one way scheme, commercial area

scheme, and residential area scheme. This BBRT will include efficient coordination, integrated smart card fare payment, convenient interchanges, appealing dedicated lanes, and multifunctional stations. It helps to cut down GHG emissions and address urban congestion by reducing car ownership while maintain people's mobility. This public transport system not only delivers the value for money, but also the value for environment and our health.

The concept of BBRT includes the following elements:

- 1) Multifunctional station: Combine public bicycle station and bus station to facilitate interchanges. Users can easily transfer between bus and bike which depend on their demands.
- 2) Independent bike lane and bus lane: Deploy bus lane between vehicle lane and bike lane to separate motor vehicles and bicycles, therefore create slow traffic zone for bicyclists. Buffer zone and physical separation between bike lane and bus lane can further increase bicyclists' feeling of safety.
- 3) No-traffic sidewalk: Without bike or bus station on the sidewalk, pedestrians can have a quiet and safe environment, and a wider sidewalk.
- 4) No on-street parking (commercial area scheme): Free up more road space and reorganize parking status to address urban congestion.
- 5) Greater proportion of road area: Reserve more road area for BBRT to increase the carrying capacity of the public transport, improve the fluency of public transport, and imply people to leave their cars.
- 6) Integrated smart card fare payment: Link the bike and bus together with the smart card, facilitate interchanges and easy to switch between long trip and short trip.
- 7) Flexible distribution of bike stations (especially in residential area scheme): Use the public bicycle system as the extension of bus system to reduce the inefficient distribution of bus, and encourage people to use bike to transfer to bus.
- 8) Central landscaping sidewalk (residential area scheme): Provide more public space for the communities while increasing urban forest and improving living environment.
- 9) Separation of people and vehicles (especially in residential area scheme): Attract more people to participate in outdoor activities to improve public health and enhance the connection of neighborhoods.

10) Appealing urban environment: Local economy will thrive under the appealing environment and increasing foot traffic.

5. Public Electric Vehicle Fleet

The second initiative of this scenario is to establish a Public Electric Vehicle Sharing Program (PEVSP) and an integration of Vehicle to Grid (V2G). BBRT aims to change San Francisco's travel pattern from driving to walking, bicycling and transit. However, there are still about 350,000 private vehicles in the city. Even if their use changes, they are still a huge potential emission source. PEVSP is a way to replace these existing internal combustion vehicles to reduce GHG emissions and congestion while retaining people's need for special mobility. The implementation of V2G is an advanced expansion of PEVSP, as well as an attractive way to offset the GHG emissions from transportation sector.

5.1 The City's Electric Vehicle Fleet

5.1.1 *Electric Vehicle*

Concerns about energy independence and climate change issues are growing rapidly all over the world. Energy independence is already a big political issue in the USA. About two-thirds of the nation's oil consumption is imported, including almost all the fuel used for transportation purposes (Guille & Gross, 2009). This strong energy dependence on foreign sources and the rising environmental and social awareness motivate many new transportation technologies. All those technologies aim to produce more fuel-efficient vehicles or use alternative energy to reduce the need for oil. The electric vehicle is one of the most attractive technologies that can directly address these issues. Several studies have shown that electric vehicles can reduce local air pollution and traffic noise (Brady and O'Mahony, 2011; Hawkins et al., 2013), and can cut back GHG emissions from transportation sector (Brouwer et al., 2013).

San Francisco should consider electric vehicles as a serious alternative to conventional internal combustion vehicles. Electric vehicles have no local greenhouse gas emission, no

need for oil, and are very quiet. However, they currently cannot compete with internal combustion vehicles because of the high cost and the lack of infrastructure support. For example, the initial price of a Nissan Leaf is about 40 percent higher than a same level gasoline vehicle: even with the \$7500 federal tax credit and \$2500 California state clean vehicle rebate the price still 30 percent higher (Lavelle, 2012). With the high efficiency, as well as lower fuel and maintenance costs, the \$6,655 initial price premium will be paid back in six years. Therefore, this scenario needs governments and private companies to provide more incentives and infrastructures to further boost this electrification trend.

5.1.2 *Integration of Electric Vehicle and Car-sharing*

The increase of private vehicles raises congestion and environmental problems, as well as accident costs in urban traffic (Button, 1994). Therefore, car-sharing has developed as a new transit trend in many European cities (Steininger & Zettl, 1996). The shift in trip structure and distance has highlighted the benefits of car-sharing in terms of social considerations, economical considerations and environmental considerations. These benefits include reducing parking demand, saving the costs from vehicle purchase and maintenance, and reducing environmental impacts (Efthymiou et al., 2013).

| Company | Cars service in U.S. | Revenue |
|----------------------------|----------------------|----------|
| Enterprise Holdings | 941,064 | \$11,500 |
| Hertz | 366,000 | \$4,600 |
| Avis Budget Group | 300,000 | \$4,510 |
| Dollar Thrifty AG | 122,000 | \$1,563 |
| Zipcar | 8,800 | \$205 |

Table 10. 2012 U.S. Car Rental Industry Inventory. (Source: Shaheen & Cohen, 2013)

Carsharing is a rising transportation industry in which users access a fleet of shared vehicles for short-term use (Kent & Dowling, 2013). Car rental is a large and mature industry

in the US (Table 10), and thus carsharing – a new model of car rental – has great potential. Carsharing market has been growing rapidly in the US during 2002 to 2012 (Fig. 17), the membership rose from 12,098 to 806,332, and the number of shared vehicles grew more than twenty times from 455 to 12,634.

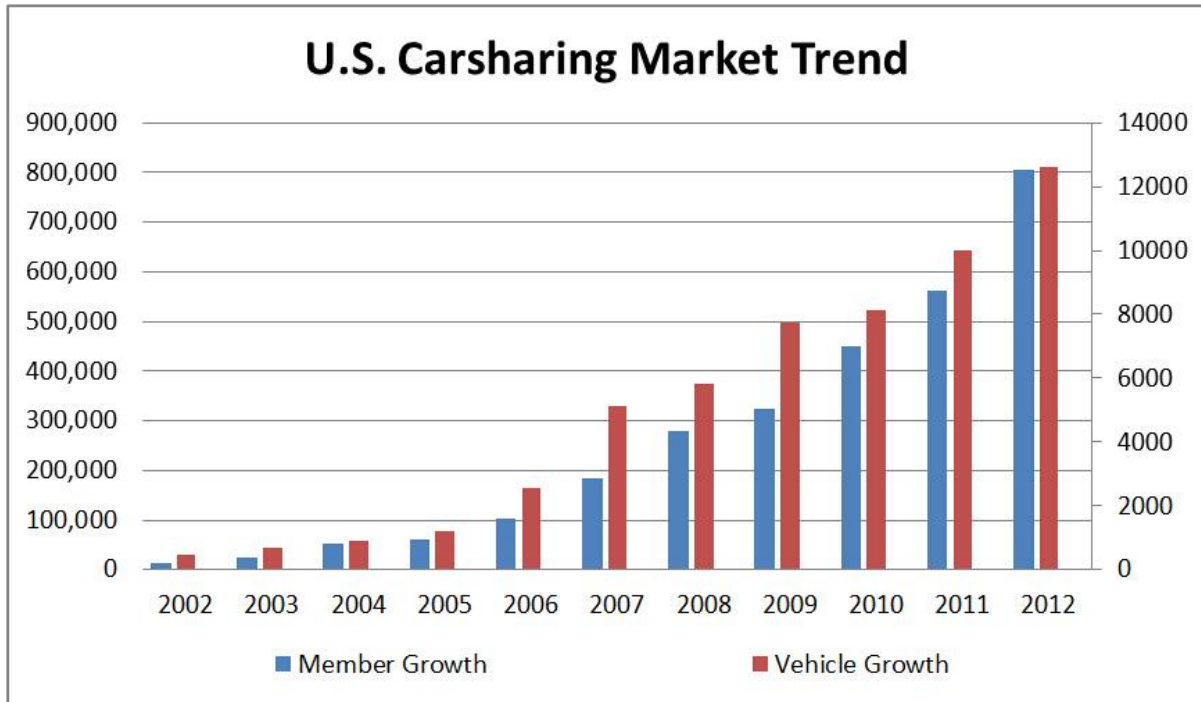


Figure 17. U.S. Carsharing Market Trend. (Source: Shaheen & Cohen, 2013)

Carsharing can be classified into three types: neighborhood carsharing, station carsharing and multimodal (Barth & Shaheen, 2002). A well-developed carsharing system can encourage people to leave their private vehicles by providing convenient access to a vehicle only when needed while giving benefits from reducing cost of owning a private vehicle (Martin & Shaheen, 2011a). Carsharing is a big concept that includes many business and management models (Shaheen & Cohen, 2012). It can be one-way, peer-to-peer, or integrate into an existing public transport system. Car-sharing organizations can be non-profit organizations, for-profit companies, or community cooperations (Hampshire and Gaites, 2011).

Many city governments have realized the benefits of both electric vehicles and car-sharing, and are trying to integrate these two new industries in numerous ways by providing financial supports (Bakker and Trip, 2013). Many major cities in Europe have

implemented electric vehicles sharing programs, such as Paris, Berlin and Hamburg (IEA, 2012).

Electric vehicle sharing system can directly reduce traffic congestion and the frequency of car use, address parking problem by mitigate car ownership of citizens, and take actions on climate change (Dowling & Kent, 2015). In addition, it can educate the public about the new technology and benefits of electric vehicle by provide opportunity for people to drive an electric vehicle.

5.1.3 Public Electric Vehicle Sharing Program (PEVSP)

The ownership and use of a vehicle can change people's travel choices (Musti & Kockelman, 2011). The Public Electric Vehicle Sharing Program (PEVSP) will provide electric vehicles at different locations through the whole city to facilitate instant trips and flexible trips for users. These electric vehicles can be rented for a short time period or just for one-way trips. Furthermore, these electric vehicles are instant access and no need for reservation. The PEVSP can help people to enjoy those environmental and physical benefits from electric vehicles while avoiding the high cost of owning an electric vehicle.

PEVSP will establish a public multimodal electric vehicles sharing system for sustainable urban environments. Stations are allocated at many locations all over the city, especially near conventional public transit stations. There are two main reasons that the program should be develop as a public system instead of a private system. First, this system aims to be a public service like subway and bus service that provided by the city. People who live in this city will recognize that it is no need to own a vehicle, all the demands of mobility will be met by public transit, even some special trips need vehicles can also be achieve by PEVSP – a public service as well. Second, the public service attribute of PEVSP will make stations have priority to build near public transit stations, facilitate users access and transfer to public transit.

From a study of the electric vehicle sharing programs in the city of Seoul (Kim & Park, 2015), this kind of program can reduce people's dependents of private vehicle while maintaining the diversity of mobility for different people and different occasions. People in Seoul can spend about 7.0 USD to travel 13km (the average trip distance of a Seoul citizen)

within an hour with shared electric vehicles provided by those programs. The same distance trip may cost the taxi fare of 10.0 USD and the public transit fare of 1.1 USD. In this scenario, PEVSP vehicles can be rented for a short time period (no more than one day) to make trips between different stations or just for one-way trips. Electric vehicle sharing programs will provide people an alternative form of mobility instead of conventional private vehicle (IEA, 2012). People can commute in the city by traditional public transit, then transfer to a PEVSP vehicle to reach a non-public-transport destination. By the end of day, the user returns the vehicle to any PEVSP station. The user is free of any parking or waiting issues. The electric vehicle provided by PEVSP should be safe, comfortable, reliable and smart. These vehicles have to ensure the accessibility for everyone, even have special design for people have mobility problem, such as elderly and disabled people. These vehicles are connected to the city's transit network; they can communicate with each other, as well as public transportations and city infrastructure. The PEVSP vehicle integrates into the existing public transportation system, using a new rational and efficient service to fill the service gap of traditional public transport systems. For some special occasion, the program can provide chauffeur drive to serve as taxi. This is a way to reduce the share of private vehicles in transportation sector without compromise to people's mobility.

Instant trip and flexible trip are two main targets of PEVSP. In the regular car-sharing system, the user has to book a car online or over the phone, typically on an hourly basis. Shared cars usually occupy dedicated parking spots, an electronic key is used to access the car, and the car must be returned to that specific spot once the booking is complete. The PEVSP is based on an on-demand, no reservation system. Users can check out a PEVSP vehicle while they get in the station, without preparing and waiting. Instant access to a shared vehicle provides great convenience to user, just like using their private vehicles. This is a critical characteristic to make people leave their private vehicles and accept this new public transport. However, the program management must have the knowledge of the city's travel condition to satisfy user demand and maximize vehicle use in every station.

Flexible trip is the other target that PEVSP has to achieve. Users can rent an electric vehicle from PEVSP to travel the city as using their private vehicle. They can jump in the vehicle for one-way trip and drop it off at any station. They can also use the vehicle to travel

many locations, and finally return it by the end of the day. Users don't need any plan for their trips and no need for schedule, every trip through the PEVSP just like traveling in their own cars. All PEVSP stations are deployed near public transport stations at residential center or in the commercial areas so as to provide public transit users with better accessibility from and to the sharing stations, filling the gap between public transportation and private vehicle. All members can access the PEVSP at any time without a reservation.

The implementation of PEVSP has to solve two major problems: build up user groups and manage demands. To build up user group, it has to understand what factors affect users' attitudes. The study of Seoul's electric vehicle sharing programs (Kim & Park, 2015) indicated that there are four main factors: the condition of shared electric vehicles; the fee and payment; the use of electric vehicles; and economic and environmental perspective. They respectively account for 17.5%, 16.3%, 14.5%, and 12.0% of the users' attitude variance (Table 11). Since this program is associated with public transit, PEVSP not only has to address all these factors, but also should provide thoughtful public transportation access and support to facilitate users' travel and transfer.

| 17.5% | 16.3% | 14.5% | 12.0% |
|---|---|---|---|
| Shared Electric Vehicle: <ul style="list-style-type: none"> ● Comfort ● Speed ● Cleanness ● Noise | Fee & Payment: <ul style="list-style-type: none"> ● Membership fee ● Rental fee ● Payment system ● Booking system | The Use of Electric Vehicle: <ul style="list-style-type: none"> ● Simplicity of using the vehicle and charger ● Driving range ● Renting station availability | Economic and Environmental Perspective: <ul style="list-style-type: none"> ● Travel cost saving ● Reduce concerns ● Environmental concerns |

Table 11. Factors affect users' attitudes about electric vehicle sharing programs. (Source: Kim & Park, 2015)

PEVSP aims to deal with the unbalanced demand of mobility from different groups through different areas of the city. The biggest challenge is to manage and forecast demands of different time and different locations. It needs a complete user-based allocation system to prevent stations from accumulating too many vehicles, while others are short of supply. One solution from the Personal Intelligent City Accessible Vehicle project is to set up a system

supervisor to address some flexible users to return the vehicles to specific stations (Cepolina & Farina, 2012). In addition, the rational design of the fleet dimension and distribution is also critical. This needs to balance the fleet cost and waiting times. The development of PEVSP requires fully research of stations set up to provide suitable location for users to get and return the vehicles. The number of available vehicles and real time information about traffic conditions are also essential to the program management.

5.2 Power the City

5.2.1 *Vehicle to Grid (V2G)*

PEVSP is a good opportunity to integrate an electric vehicle fleet to the conventional electrical system because the large number of electric vehicles with batteries can be centralized and connected to the grid. The city's transportation sector with PEVSP has great potential to make contributions to the electric supply system as storage and even generation resources, so as to offset the negative impacts of GHG emissions.

Vehicle-to-grid (V2G) aggregates those vehicles with a battery (hybrid electric vehicles, battery electric vehicles, and plug-in hybrid electric vehicles) into the grid as a distributed resource of energy load, storage and generation. It has not only the ability to deliver power from vehicle to the grid, but also can better utilize fluctuating renewable energy sources (Lund & Kempton, 2008). V2G technology provides potential solutions to energy storage and stabilization. Its benefits include peak load shifting, smoothing variable generation from renewable energy, and providing distributed energy storage capacity (Peterson et al., 2010).

Electric vehicles have two fundamental characteristics: one is they are vehicles and other is they have batteries on board to receive, output and store electricity. Based on the physical and natural characteristics, the electric vehicle and the grid can have an advanced integration at the distribution voltage level. Electric vehicles which have batteries can be plugged into the grid to charge, getting the energy they need. When the electric vehicle fleet reaches a certain size, it will create a new load demand to the conventional electricity system. However, the stabilization of batteries can make electric vehicle much more than a simple load to the dynamic electricity system. As figure 18 shows, implementation of V2G makes an electric vehicle become an energy storage device as well as a generation resource for certain period of

time (Guille & Gross, 2009). The technology aggregates electric vehicles to function like a giant battery with an intelligent software interface feeding power from grid to car or car to grid on an as-needed basis. Electric vehicles will play an important role in improving the economical and environmental attributes, and reliability of electricity system operations by turning into active player in the new grid system under the V2G concept.

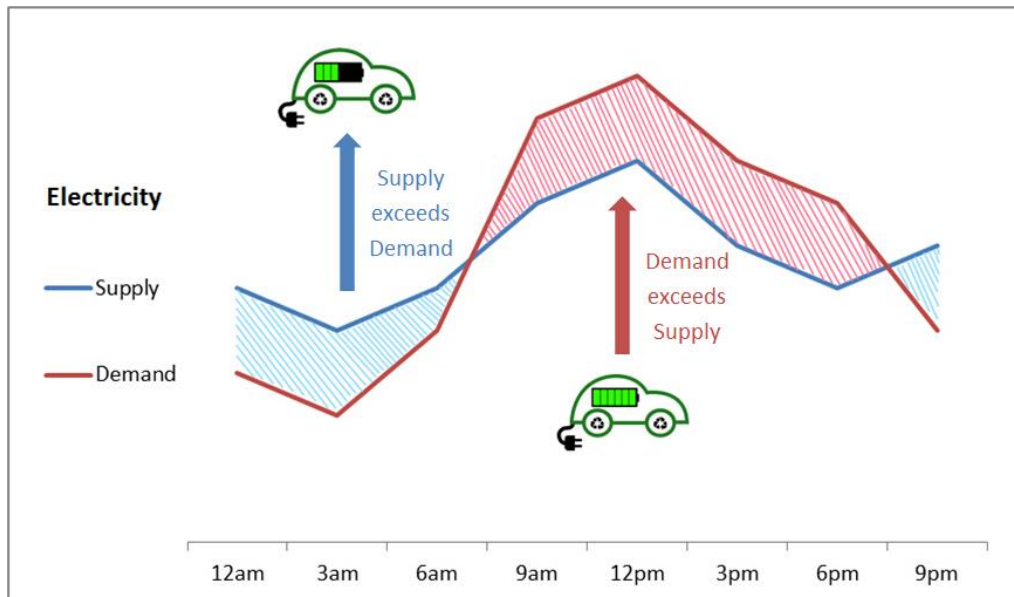


Figure 18. The concept of V2G.

As transport, electric vehicles are dispersed over an area at any point of time and not always stationary. The average round-trip commuting distance in the US is about 32 miles, and the average commuting time is about 52 min. Indeed, about 60% of the commuters in the US drive a distance under 50 miles (Sanna, 2005). Thereby, those electric vehicles used for commuting are idle for 22 hours a day on average. Only part of the energy is consumed by the commute (For example, the US Environmental Protection Agency official range for the Nissan 2013 model year Leaf is 75 mile.) and there is still some in the battery. Consequently, each electric vehicle becomes a potential source of both storage capacity and energy that the grid can control either as load or supply.

During the off-peak period at night, the electric vehicle in charging phase plays a role as a load. With the V2G system, aggregation of electric vehicles can consume the excess electricity to lower the need for down regulation service (such as for nuclear generators,

which have to maintain a continuous steady output even no demand, V2G can overcome the problems with the low loads at night by better utilizing base-loaded units) during those off-peak conditions (Blumsack et al., 2008). During the peak period in the day time, the electric vehicle parking in the parking lot can be peak shaving (a process from the electricity business that shift demand from peak times to times with lower demand) equipment. However, the energy from the battery of a single electric vehicle is a very small resource that can only have insignificant impact on the grid. Therefore, the V2G system has to aggregate large number of electric vehicles to overcome the small storage capacity limitation of a single battery. For example, the battery capacity of a Nissan Leaf is 24kWh and the average charging time is 6 hours, an aggregation of 12,500 Leafs represents a 50-MW load, the amount equal to the capacity of a typical wind power plant that will have an impact on the system during off-peak conditions. Likewise, it can have same impact during peak period.

5.2.2 Renewable Energy Storage

One of the great benefits from V2G implementation is that electric vehicles can be an important bridge to high penetration of renewable energy. Most potentially renewable energy resources are intermittent, such as wind and solar. The wind may not be blowing and the sun may not be shining when the power is needed. This is a natural characteristic, but it could be a big problem in an electricity system. Energy storage is the biggest challenge for the development of renewable energy, and a large electric vehicle fleet — a citywide PEVSP— could be a new form of electricity storage. As a matter of fact, electric vehicles would be true green transport only when the electricity is from carbon neutral generation – electricity generated by renewable energy sources. The GHG emissions of Electric vehicles using electricity from renewable energy are about 4 times less than conventional gasoline vehicles (Fig. 19). Therefore, the development of renewable energy storage with V2G technology is essential for the popularization of electric vehicle.

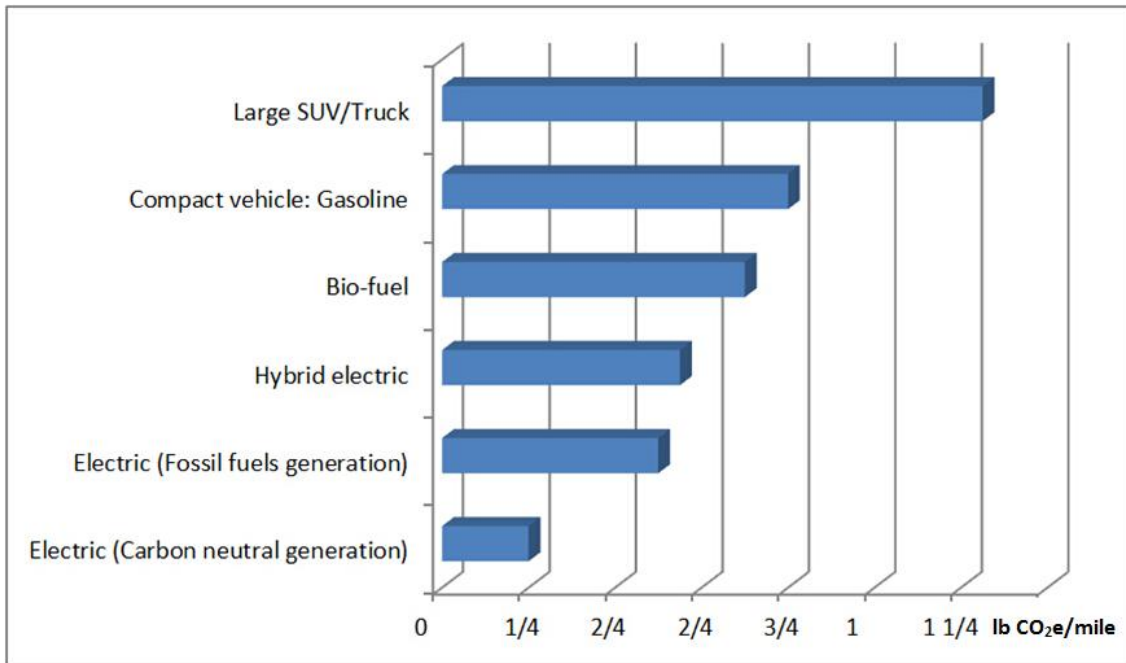


Figure 19. GHG Emission by Vehicle Type. (Source: Papandreou, 2004)

Wind power is currently the most mature and lowest-cost renewable energy source in the world. The total U.S. wind power is estimated to be larger than the nation's total electricity demand – around 3,000 Billion Kilowatt-hours (Grubb and Meyer, 1993). However, wind power is intermittent. In the global industry, wind could only provide about 30% of electricity generation without requiring storage (Kelly and Weinberg, 1993). In most cases, wind's time distribution and geographical distribution are hard for utilities to predict and control. Therefore, there is no doubt that the storage capacity from a sufficient scale electric vehicle fleet can greatly enhance the energy economy and raise the penetration of wind power. For example, 2,083 Nissan Leafs with average 24kWh battery storage capacity can store one hours of electricity generation from a typical 50MW wind power plant.

The other well-known renewable resource is photovoltaic; which requires much land but low maintenance. In some area with plenty of sunshine, such as California's Central Valley, the peak output of photovoltaic can match local peak electrical demand, even with air conditioning loads (Kempton & Letendre, 1997). Similar to wind power, solar energy has an uneven time and geographical distribution, plus the load peak is usually a few hours later than the solar radiation peak. Thus photovoltaic has great dependence on energy storage. The potential storage capacity from electric vehicle can improve the popularity of photovoltaic

and peak load management.

Therefore, the storage capacity of a large scale electric vehicle fleet through V2G aggregation could have great potential to improve the penetration of renewable energy in the whole electricity system. It can benefit peak shifting and increase the stabilization of intermittent renewable energy sources, as well as the development of renewable energy industry.

5.2.3 *Advanced Net Metering*

If electric vehicles reach 25% penetration in 13 US regions by 2020, the US will need 160 new power plants to meet the increase demand for charging those electric vehicles in the early evening. That is because at that time, around 5 p.m., electric demand is still near the peak load (Guille & Gross, 2009). However, if all electric vehicles owners change the charging times to low demand period, most existing power system can accommodate the load without requiring the installation of new power plants (Sanna, 2005). Furthermore, the electric vehicles aggregation through V2G can utilize base load units to help system to overcome the low load problems at night. The charging of electric vehicle fleet can help maintain a continuous steady output during the low demand periods. Electric vehicles in the V2G system with night charging will improve the efficiency of the electricity system, reduce GHG emissions, and increase the renewable energy penetration. A strategy to stimulate electric vehicles owners to charge the vehicles during low demand periods will determine the success of V2G system. Therefore, this scenario will integrate net metering strategy to the PEVSP to take full advantage of V2G.

For electric vehicles, the battery which connects to the grid can charge during low demand period and discharge when load peaks. The vehicles in V2G system have three common characteristics: the connection with electricity flow between the grid and batteries, communication with the grid operator, and real-time meters to measure the energy flow and monitor the batteries' capacity. The last characteristic is where net metering is implemented.

The net metering policy is a service to electricity consumers: electricity consumer generates electricity from an eligible individual on-site generating facility and delivers to the local electricity system can offset consumer's electricity consumption during the applicable

billing period. It aims to foster renewable energy with private investment. Electric vehicles in a V2G system can store excess supply as well as intermittent renewable energy, and deliver to the grid during peak period, so it's practically compliant with the net metering policy. If the city can implement this advanced net metering policy to those electric vehicles in V2G system, it will benefit both electric vehicle owners and the electricity system. The large number of unified specifications of electric vehicles from PEVSP associated with V2G technology under advanced net metering policy even can produce a new electric vehicle fleet – electric vehicles with removable and exchangeable batteries. Large number of removable and exchangeable batteries can be charged at off-peak periods to store renewable energy, and then deliver the energy to power electric vehicles during the peak hours. There is no more concern that the vehicles will run out of power due to long time uninterrupted service. The development of PEVSP with advanced net metering can not only improve the efficiency of the whole transportation sector, but also can power the city, benefit everyone in the San Francisco.

6. Smart Transportation System

This smart transportation system is a comprehensive utilization of new technologies composed of real-time transport service information system, smart parking and one-city transit passport. It aims to improve travel safety and travel efficiency. The information collected from the system can support transportation managers in making decision, facilitate rational utilization of resources, and provide inspiration for the future development. This smart transportation system helps travelers to reduce travel times, delay, and the stress of travel so that benefit the whole transportation sector to reduce energy consumption and emission (Adler & Blue, 1998).

6.1 Real-time Transport Service Information System

The real-time transport service information system is a strategy corresponding to the real-time traffic information system. In this scenario, travelers can get all the real-time information of bus, shared bike and electric vehicle, and the supported infrastructure. It can

support and assist travelers to choose the best mode of transportation and optimize the trip before travelling and adjust the trip on the route. It aims to improve travel safety and reduce travel time while facilitating healthy travel in the existing transportation system. Furthermore, the feedback from travelers can help transportation managers to improve the system, provide useful data to address congestions and optimize the deployment of transport network (Lee et al., 2010). This system will include three modules: a bus information module, a bike and electric vehicle information module, and an infrastructure information module.

The bus information module collects bus information and GPS information to provide the schedule, position and speed of each bus for travelers (Jiang et al., 2013). It is an advanced bus tracker that allows travelers get every detail on real-time map interface through data processing and prediction, such as departure time, arrival time, stop and return, and even the available capacity of each bus.

The bike and electric vehicle information module can provide bike/vehicle status monitoring, bike/vehicle positioning, available bike/vehicle of different location, battery status, and any other information about shared bike and electric vehicle of concern to travelers. Furthermore, the module can also be personalized for reservation, carpool mating, and parking solution.

The infrastructure information is a database of all transportation relative infrastructures. It will assist travelers to find out every station, charging station, transfer platform, fix station, and every supported infrastructure that travelers may need during their trips. It is a complement of the bus information module and bike and electric vehicle information module.

The system can analyze the temporal and spatial distribution of travelers flow and optimize the deployment of different transportation mode, in other to provide recommendations for different travelers of different trips. Travelers can receive this necessary information at home, in the office or en-route to determine their trips, route and mode choices (Jou et al., 2004). With this system to avoid traffic congestion and delay, find out shorter route, and choose the best transportation mode will directly save energy, reduce pollution, and make contribution to the GHG emission reduction goal.

6.2 Smart Parking

People have to spend 3.5 to 14 minutes in seeking available parking space each time they park, and cause 8% to 74% of traffic in congested downtown areas such as San Francisco, New York and London (Shoup, 2006).

The goal of smart parking is not to provide enough convenient parking spaces to encourage more driving. This scenario needs a strategy to entice people out of their cars, offer convenient access to public transit, and provide real-time parking spot availability information to drivers (Surpris et al., 2014) through rational parking deployment and technology assistance.

The progress of parking gives substantial additional emissions of GHGs and pollutants to the emissions from the traffic flow (Höglund, 2004). Smart parking system is to monitor parking spot availability, convey that information to drivers who are searching for spaces, and finally direct drivers to available parking spaces. As city grows faster and has higher density, the limited parking space and inefficient use of parking spaces leads to congestions due to the conflict of general drivers and parking seekers. It is important that parking seekers need more assistance of parking to reduce inefficiencies in finding spaces.

Sometimes people prefer driving their vehicles just because the inconvenience of feeder bus and fixed route bus services. Quick convenient access to parking spaces is critical to make public transportation competitive with private vehicle in the suburban areas. Smart parking uses advanced technologies to help drivers reserve, locate and pay for parking can reduce the restriction of limited parking at transit stations. The smart parking system can provide real-time information via smart meters and low-power sensors to drivers about the number of available parking spaces in parking lots, the schedule and status of buses, and traffic information of the route. A field operational test at the Rockridge Bay Area Rapid Transit (BART) District station in Oakland, California indicated that transit-based smart parking system can increase public transit in mode share; reduce commute time; decrease drive alone and the total vehicle miles of travel (Rodier & Shaheen, 2010). The purpose of smart parking is to make more efficient use of existing facilities, improve transit accessibility, and help expand the transit ridership.

6.3 One-city Transit passport

The one-city transit passport in this scenario is an electronic smart card as an alternative measure for people to access and pay for transport services, while record and manage their travel data. This smart card can be a conventional transit card, or an extended application on any mobile device, such as smart phone, smart watch, and tablet. It is an advanced Clipper card (a non-contact reloadable smart card used for electronic transit fare payment in the San Francisco Bay Area).

For the first function, this smart card can be used to access public transportation and pay for the service, like a Clipper card. This advanced Clipper card is not limited to a physical card, it can also presents as an application on smart phone with Quick Response Code (two-dimensional barcode). With this one-city transit passport, users can access to any public transport in the city, including BART, bus, Cal-train, and ferry. Furthermore, it can be used for the shared bike and electric vehicle, and parking as well. There is no gap between different modes of public transport. This is an important step to introduce the shared bike and electric vehicle to the citizens as a new green public transport.

The second function of this one-city transit passport is to create a personal travel account for every user. Unlike the Clipper card just passive recording travel data, this one-city transit passport will process and take advantage of the data. This account will have user's balance, travel record, and provide travel information. You can manage your balance at any time and meet your every trip demand through online operation on smart device. The accounts is bound with personal identity, you can rent a shared electric vehicle as easy as to take a bus without cumbersome procedures. The travel record on your account can help you recognize your travel behavior, thus you can plan and adjust your future trips. Those travel data coordinate with smart mobile device can facilitate a healthy lifestyle and reduce personal carbon footprint. With the cloud technology, system can integrate personal travel data and real-time travel information to provide better route plans for every user. It is a travel management terminal, not a simple transit card (Fig. 20). For example, when you plan to travel from A to B by bus and bike, your one-city transit passport account will provide you the route, fare cost, travel time, health data, personal carbon footprint, and even reserves a shared bike for you. Each change in your travel plan will have instant effect on your account

and display on your smart phone. It can offer specific travel plan base on user’s behavior and preference.

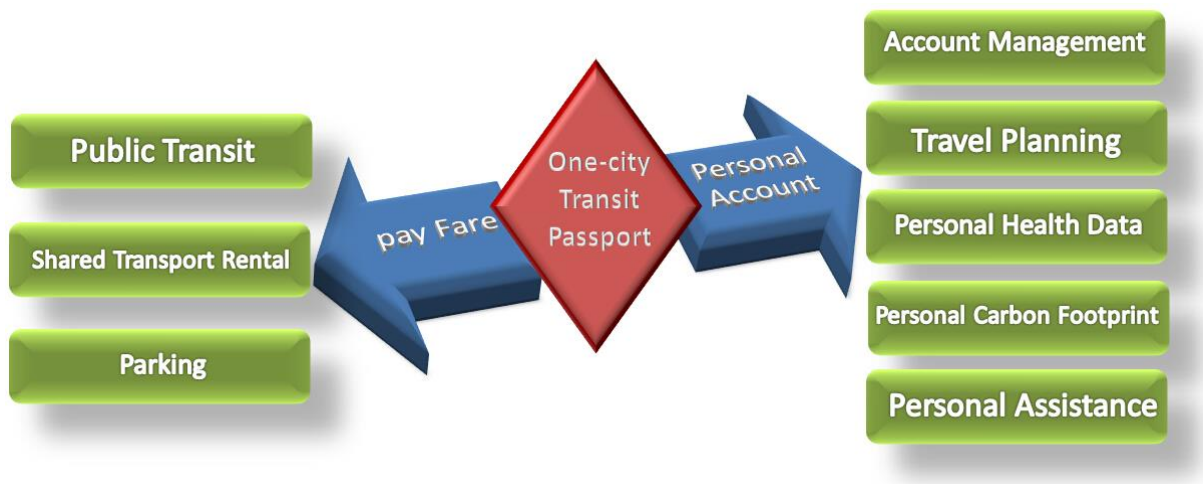


Figure 20. One-city Transit Passport.

This one-city transit passport can not only improve individual travel quality and efficiency, but also provide data to help transportation manager to understand user behavior (Pelletier et al., 2011), forecast demand of the whole transportation system, optimize resource allocation and better develop long-term network planning.

7. Conclusion

This paper analyzed San Francisco’s current transportation system, and explored a sustainable and suitable transportation scenario to help the city achieve its GHG emissions reduction goals. The walking, bicycling and transit city scenario is made up of three initiatives: bike and bus rapid transit, a public electric vehicle fleet, and smart transportation system.

Among these three initiatives, the public electric vehicle fleet is the most challenging one to implement. PEVSP will be a subversion of the whole transportation sector. It has to change the market which is dominated by internal combustion vehicles, change people’s travel behavior, and even change the operation pattern of the transportation system. It can cut 80 percent of the transportation sector’s GHG emissions from its major source – private vehicles.

However, Rome was not built in a day. This kind of city scale reform needs a lot of political and financial support, as well as considerable time to achieve. The application of electric vehicle aggregation through V2G is very attractive: the owner can make beneficial contribution to the grid by parking their cars there and connecting to the grid, and then their cars will become a load and storage/generation device. Nevertheless this will happen only when the electric vehicle becomes universal.

Even if all drivers switch to electric vehicles, the vehicle production, battery production and disposal, and infrastructure construction still results in GHG emissions before the first mile traveled. Therefore, strategies to develop public transit and reduce demand for private vehicle use are essential to the reduction of GHG emissions in the long-term. The bike and bus rapid transit will be the most practical and efficient initiative in this scenario. It is also a city scale reform, but it is more like an upgrade on the existing system. Conditions are ripe for its implementation. All it needs now is unified planning and orderly implementation.

The smart transportation system is like a software system upgrade. Many of its components are already in existence, but need to be integrated. This auxiliary means will play the biggest role only in the case of transportation infrastructure being good constructed. It will increase people's awareness of low carbon journey and change their travel habits in the long-term.

Literature Cited

- 2006 American Community Survey (ACS), 2009 Statistical Abstract, Table 1244
- 8th Avenue Bike Lane Study: Buffered Lanes Preferred. (2007). *Transportation Alternatives Magazine*, 13(3), 6.
- Adler, J. L. and Blue, V. J. 1998. Toward the Design of Intelligent Traveler Information Systems. *Transportation Research Part C*. 6: 157-172
- Al-Dubikhi, S., & Mees, P. (2010). Bus rapid transit in Ottawa, 1978 to 2008: Assessing the results. *TPR: Town Planning Review*, 81(4), 407-424. doi:10.3828/tpr.2010.9
- Amin, S.M., Wollenberg, B.F., 2005. Toward a smart grid: power delivery of the 21st century. *Power and Energy Magazine, IEEE* 3, 34–41.
- Bakker, S., Trip, J., 2013. Policy options to support the adoption of electric vehicles in the urban environment. *Transport. Res. Part D* 25, 18–23.
- Barth, M., Shaheen, S.A., 2002. Shared-use vehicle systems: framework for classifying carsharing, station cars, and combined approaches. *J. Transport. Res. Board* 1791, 105–112.
- Blumsack, S., Samaras, C., Hines, P., 2008. Long-term electric system investments to support plug-in hybrid electric vehicles. In: *Power and Energy Society General Meeting – Conversion and Delivery of Electrical Energy in the 21st Century*, pp. 1–6.
- Brady, J., O'Mahony, M., 2011. Travel to work in Dublin. The potential impacts of electric vehicles on climate change and urban air quality. *Transport. Res. Part D* 16 (2), 188–193.
- Brouwer, A.S., Kuramochi, T.K., van der Broek, M., Faaij, A., 2013. Fulfilling the electricity demand of electric vehicles in the long term future: an evaluation of centralized and decentralized power supply systems. *Appl. Energy* 107, 33–51.
- Button, K. (1994) Alternative approaches toward containing transport externalities: An international comparison. *Transportation Research* 28A, 289-305.
- Cepolina, E. M., & Farina, A. (2012). A new shared vehicle system for urban areas. *Transportation Research Part C: Emerging Technologies*, 21(1), 230-243. doi: 10.1016/j.trc.2011.10.005
- Chester M.V., Horvath A., Madanat S. (2010). Comparison of life cycle energy and emissions footprints of passenger transportation in metropolitan regions. *Atmospheric Environment*, 44 (8), pp. 1071-1079.
- Committee for Perth, 2014. Research report: Bus Rapid Transit and Light Rail Transit, An Overview of Costs and Benefits. November 2014.
- Daisa, James M., Kloster, Tom, & Ledbetter, Richard. (1998). Creating livable street design guidelines for Metro's 2040 Growth Concept and Regional Transportation Plan. Paper presented at the Proceedings of the Conference on Transportation, Land Use, and Air Quality.
- Davis, J. (2013). BRT: Transit Mode of Choice?. *Planning*, 79(5), 28-32.
- Dill, J., Monsere, C. M., & McNeil, N. (2012). Evaluation of bike boxes at signalized intersections.
- Dumbaugh, E. (2005). Safe streets, livable streets. *Journal of the American Planning Association*, 71(3), 283-298.

- E.A, Bueno, R., Cegan, J, and Munitz, C. (2011). Consumption-Based Emissions Inventory for San Francisco: Technical Report. Somerville, MA: Stockholm Environment Institute U.S. Center. sei-us.org
- Efthymiou, D., Antoniou, C., Waddell, P., 2013. Factors affecting the adoption of vehicle sharing systems by young drivers. *Transp. Policy* 29, 64–73.
- El-Geneidy, A.M., Krizek, K.J., Iacono, M.J. (2007) Predicting Bicycle Travel Speeds Along Different Facilities Using GPS Data: A Proof-of-Concept Model. Proceedings of the 86th Annual Meeting of the Transportation Research Board, Compendium of Papers. TRB, Washington, D.C., USA (CD-ROM)
- Estupiñán, N., & Rodríguez, D. A. (2008). The relationship between urban form and station boardings for Bogotá's BRT. *Transportation Research Part A: Policy & Practice*, 42(2), 296-306. doi:10.1016/j.tra.2007.10.006
- Furness, Zack (2010). *One Less Car: Bicycling and the Politics of Automobility*. Philadelphia: Temple University Press. pp. 55–59. ISBN 978-1-59213-613-1.
- Green lane project, 2015. <http://greenlaneproject.org>
- Grubb, M. J. and Meyer, N. 1. (1993) Wind energy: resources, systems and regional strategies. *Renewable Energy: Sources for Fuels and Electricity*, eds T. B. Johanson, H. Kelly, A. K. N. Reddy, R. H. Williams, and L. Burnham, pp. 157-212. Island Press, Washington, DC and Covello, CA.
- Guille, C., & Gross, G. (2009). A conceptual framework for the vehicle-to-grid (V2G) implementation. *Energy Policy*, 37(11), 4379-4390.
- Hawkins, T.R., Singh, B., Majeau-Bettez, G., Strømman, A.H., 2013. Comparative environmental life cycle assessment of conventional and electric vehicles. *J. Ind. Ecol.* 17 (1), 53–64.
- Höglund, P. G. (2004). Parking, energy consumption and air pollution. *Science of the Total Environment*, 334-335, 39-45. doi: 10.1016/j.scitotenv.2004.04.028
<http://mashable.com/2011/04/13/smart-Parking-Tech/>
- IEA (International Energy Agency). 2012. EV City Casebook. <<http://www.iea.org/publications/freepublications/publication/EVCityCasebook.pdf>>.
- IEA (International Energy Agency). 2012. EV City Casebook. <<http://www.iea.org/publications/freepublications/publication/EVCityCasebook.pdf>>.
- IPCC, 2013: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.
- Jiang, T., Wu, Z., Song, Y., Liu, X., Liu, H., & Zhang, H. (2013). Sustainable transport data collection and application: China Urban Transport Database. *Mathematical Problems in Engineering*, 2013. doi: 10.1155/2013/879752
- Jou, R. C., Lam, S. H., Weng, M. C., & Chen, C. C. (2004). Real time traffic information and its impacts on route switching behavior of expressway drivers. *Journal of Advanced Transportation*, 38(2), 187-223.
- Kelly, H. and Weinberg, C. (1993) Utility strategies for using renewables. *Renewable Energy*:

- Sources for Fuels and Electricity, eds T. B. Johanson, H. Kelly, A. K. N. Reddy, R. H. Williams, and L. Burnham, pp. IO1 I-1070. Island Press, Washington, DC.
- Kempton, W., & Letendre, S. E. (1997). Electric vehicles as a new power source for electric utilities. *Transportation Research Part D: Transport and Environment*, 2(3), 157-175.
- KiM Netherlands Institute for Transport Policy Analysis, 2009. Realtime public transport information and division of roles. Ministry of Infrastructure and the Environment. Nov, 2009
- Kim, D., Ko, J., & Park, Y. (2015). Factors affecting electric vehicle sharing program participants' attitudes about car ownership and program participation. *Transportation Research Part D: Transport and Environment*, 36, 96-106. doi: 10.1016/j.trd.2015.02.009
- Larsen, Janet. (2013). Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide, Plan B Updates. Earth Policy Institute.
- Lavelle, Marianne. (2012). How to Compare the Cost of Electric and Gas Cars. The great energy challenge, *National Geographic*, Oct 1, 2012
- Lee, W. H., Tseng, S. S., & Shieh, W. Y. (2010). Collaborative real-time traffic information generation and sharing framework for the intelligent transportation system. *Information Sciences*, 180(1), 62-70. doi: 10.1016/j.ins.2009.09.004
- Lund, H., & Kempton, W. (2008). Integration of renewable energy into the transport and electricity sectors through V2G. *Energy Policy*, 36(9), 3578-3587.
- Martin, E., Shaheen, S. 2011a. The impact of carsharing on household vehicle ownership. Access: The magazine of the University of California Transportation Center, vol. 38, pp. 22-27.
- May, A. D., & Roberts, M. (1995). The design of integrated transport strategies. *Transport Policy*, 2(2), 97-105.
- McCann, B. (2005). Complete the streets! *Planning*, 71(5), 18-23.
- Monsere, C., J. Dill, N. McNeil, K. Clifton, N. Foster, and T. Goddard. (2014). Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. National Institute for Transportation and Communities, Portland, OR.
- Morency, C., Trépanier, M., & Agard, B. (2007). Measuring transit use variability with smart-card data. *Transport Policy*, 14(3), 193-203. doi: 10.1016/j.tranpol.2007.01.001
- Moving the Goalposts How Bikes Become Public Transportation. (2008). *Reclaim*, 14(4), 10-13.
- National Complete Streets Coalition, 2012. The Best Complete Streets Policies of 2012. Smart Growth America.
- Papandreou, Timothy. (2004). Moving Toward Sustainable Mobility: Analyzing the Travel Patterns and Demographics of Flexcar Carshare Users in Los Angeles. [Master's Thesis]. University of California, Los Angeles, School of Public Affairs.
- Pelletier, M. P., Trépanier, M., & Morency, C. (2011). Smart card data use in public transit: A literature review. *Transportation Research Part C: Emerging Technologies*, 19(4), 557-568. doi: 10.1016/j.trc.2010.12.003
- Peterson, S. B., Whitacre, J. F., & Apt, J. (2010). The economics of using plug-in hybrid electric vehicle battery packs for grid storage. *Journal of Power Sources*, 195(8), 2377-2384.
- Portland Bureau of Transportation. 2010. Portland Bicycle Plan for 2030. City of Portland:

- Bureau of Transportation.
- Pucher, J. Buehler, R. (2007) At the Frontiers of Cycling: policy Innovations in the Netherlands, Denmark, and Germany. *World Transport Policy and Practice*, 13 (3), 8-56.
- Rodier, C. J., & Shaheen, S. A. (2010). Transit-based smart parking: An evaluation of the San Francisco Bay area field test. *Transportation Research Part C: Emerging Technologies*, 18(2), 225-233. doi: 10.1016/j.trc.2009.07.002
- Rodríguez, D.A., Targa, F., 2004. The value of accessibility to Bogota's bus rapid transit system. *Transport Reviews* 24 (5), 587–610.
- San Francisco County Transportation Authority. (2010) San Francisco County Transportation Authority SF-CHAMP Model [Software].
- San Francisco Department of the Environment. (2013). San Francisco Climate Action Strategy. San Francisco: Department of the Environment.
- San Francisco Municipal Transportation Agency. (2011). Climate Action Strategy for San Francisco's Transportation System, San Francisco: SFMTA.
- Sanna, L., 2005. Driving the solution, the plug-in hybrid vehicle. *EPRI Journal*, 8–17.
- Shaheen, Susan, and Adam Cohen (2013). "Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends." *Transportation Sustainability Research Center - University of California, Berkeley*.
- Shoup, D. C. (2006). Cruising for parking. *Transport Policy*, 13(6), 479-486. doi: 10.1016/j.tranpol.2006.05.005
- Sim, L. L., Malone-Lee, L. C., & Chin, K. H. L. (2001). Integrating land use and transport planning to reduce work-related travel: A case study of Tampines Regional Centre in Singapore. *Habitat International*, 25(3), 399-414.
- Surpris, G., Liu, D., & Vincenzi, D. (2014). How much can a smart parking system save you? *Ergonomics in Design*, 22(4), 15-20. doi: 10.1177/1064804614526202
- Teschke, K., Harris, M. A., Reynolds, C. C. O., Winters, M., Babul, S., Chipman, M., . . . Crompton, P. A. (2012). Route infrastructure and the risk of injuries to bicyclists: A case-crossover study. *American Journal of Public Health*, 102(12), 2336-2343. doi: 10.2105/AJPH.2012.300762
- Tilahun, N. Y., Levinson, D. M., & Krizek, K. J. (2007). Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey. *Transportation Research Part A: Policy & Practice*, 41(4), 287-301. doi:10.1016/j.tra.2006.09.007
- Transport for London, 2014. Why do people travel by car? Roads Task Force - Technical Note 15. Transport for London.
- U.S. Census Bureau. (2009). American Community Survey: S081 Commuting Characteristics by Sex. Economic Characteristics. Retrieved Oct. 14, 2010.
- U.S. Census Bureau. American Community Survey. 2013. <http://www.census.gov/newsroom/press-releases/2013/cb13-r22.html>
- U.S. Census. (2000). S0801 and PHC-T-40 Estimated Daytime Population and Employment Residence Ratios.
- U.S. Census. (2010). 2009 American Community Survey 1-year Estimates. <http://Fact-finder.census.gov>. Retrieved Sep. 30, 2010.
- U.S. Census. (2011). 2011 American Community Survey 1-year Estimates.
- University of Minnesota, 2014. "Access Across America: Transit 2014". Accessed April 30,

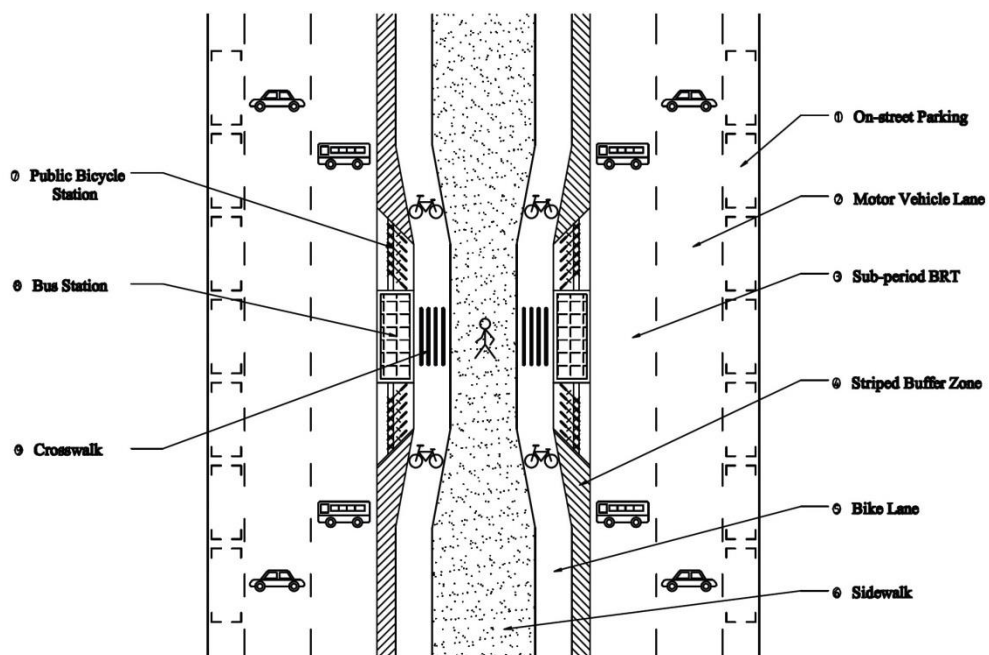
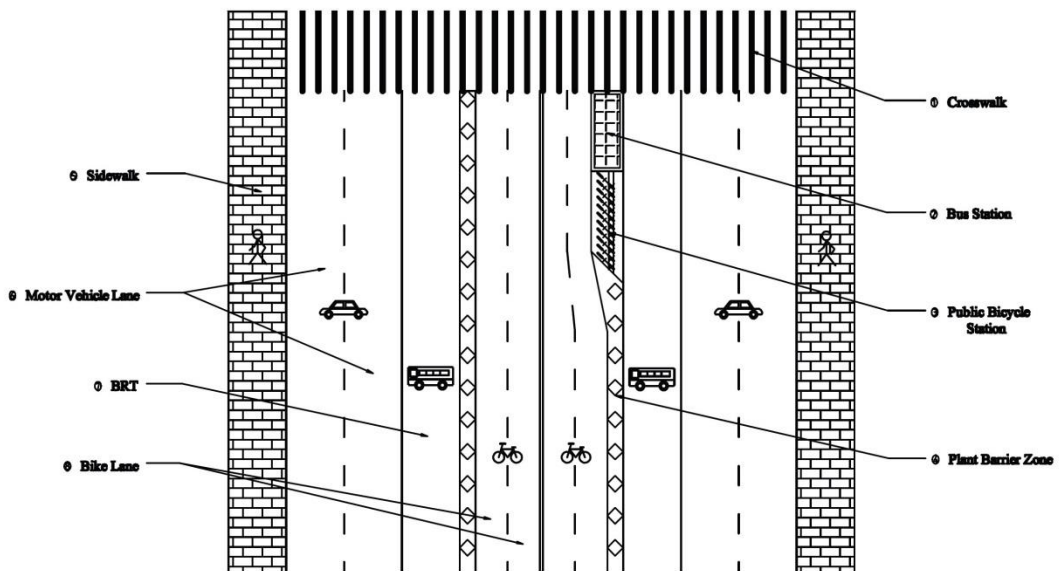
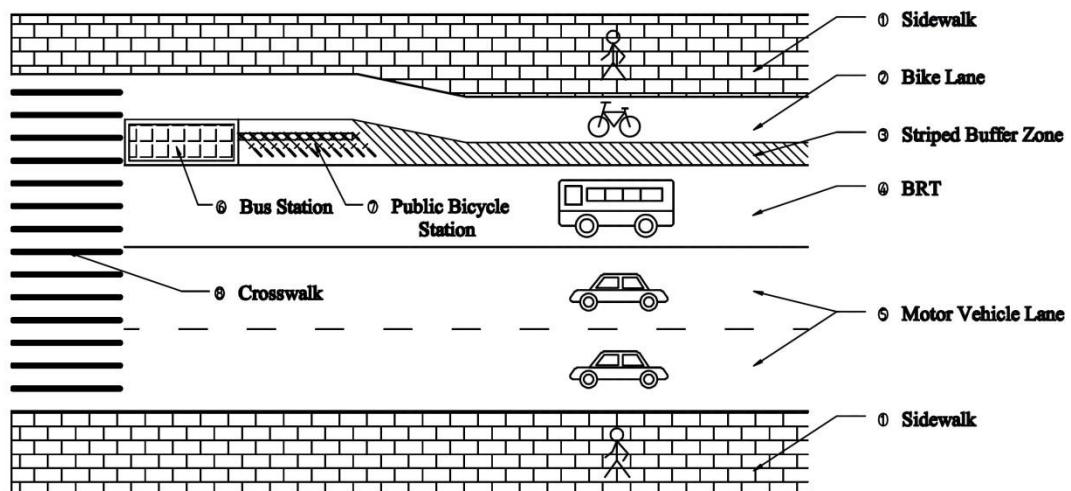
2015. <http://www.access.umn.edu/research/america/transit2014/index.html>
USA Today, 2013. Best bike-sharing cities in the world. Accessed May 2, 2015.
<http://www.usatoday.com/story/travel/destinations/2013/10/01/best-cities-bike-sharing/2896227/>

Appendix

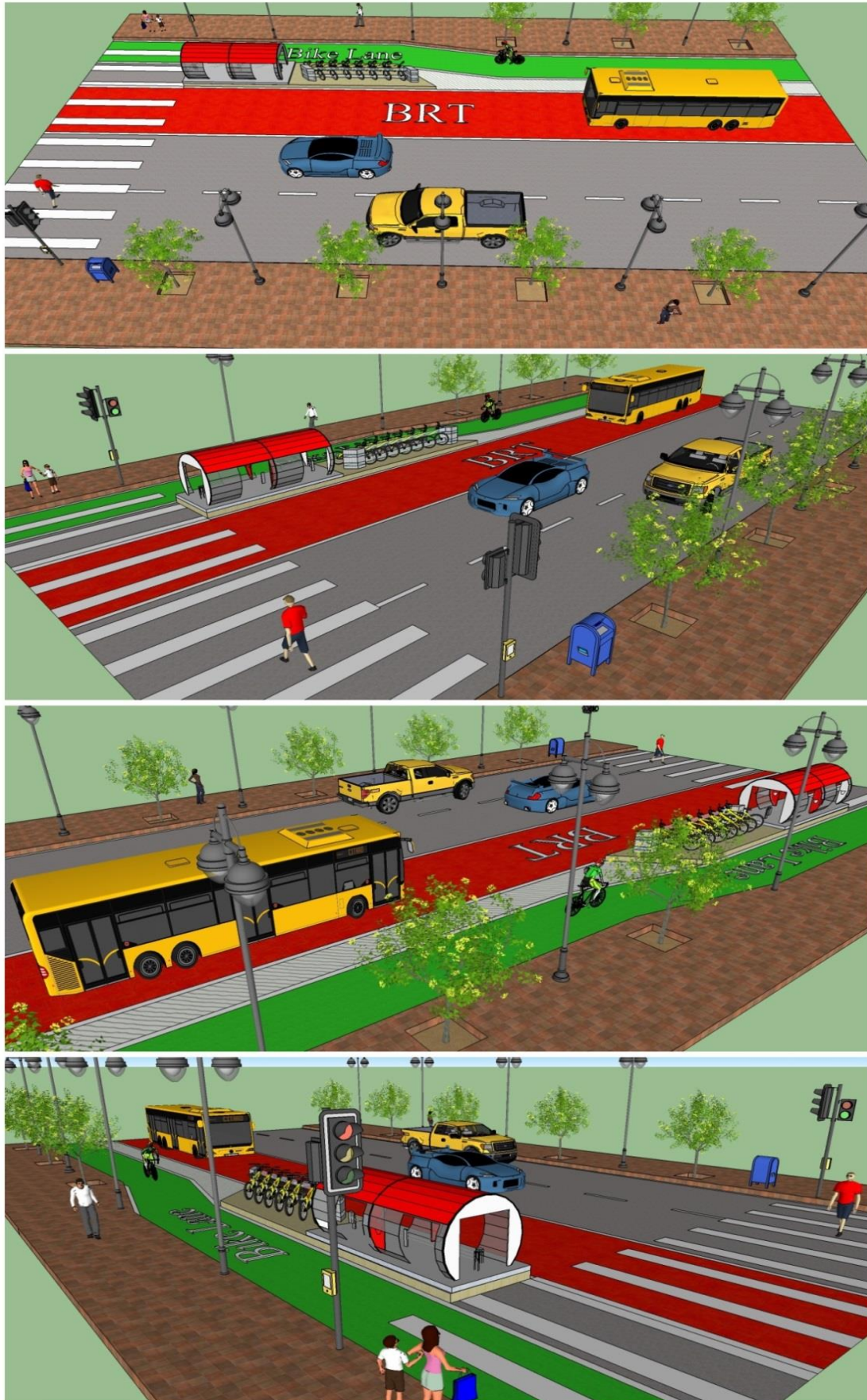
Appendix 1. GHG Emission Reduction Goals (Source: SFMTA, 2011)

| Term | 2012 | 2017 | 2020 | 2025 | 2035 | 2050 |
|--|-----------------------|------------------------------------|---------------------------------|-----------------------|----------------------------------|-----------------------|
| City and County of San Francisco 2007 Prop A | 20% below 1990 levels | 25% below 1990 levels | | 40% below 1990 levels | | 80% below 1990 levels |
| California's AB 32 | | | 20% below 1990 levels | | | |
| Schwarzenegger's Executive Order S-3-05 | | | | | | 80% below 1990 levels |
| Metropolitan Transportation Commission | | | 7% per capita below 2005 levels | | 15% per capita below 2005 levels | |
| US Department of Transportation | | 35 miles per gallon CAFE standards | | | | |
| California Low Carbon Fuel Standard S-01-07 | | 10% reduction in carbon intensity | | | | |

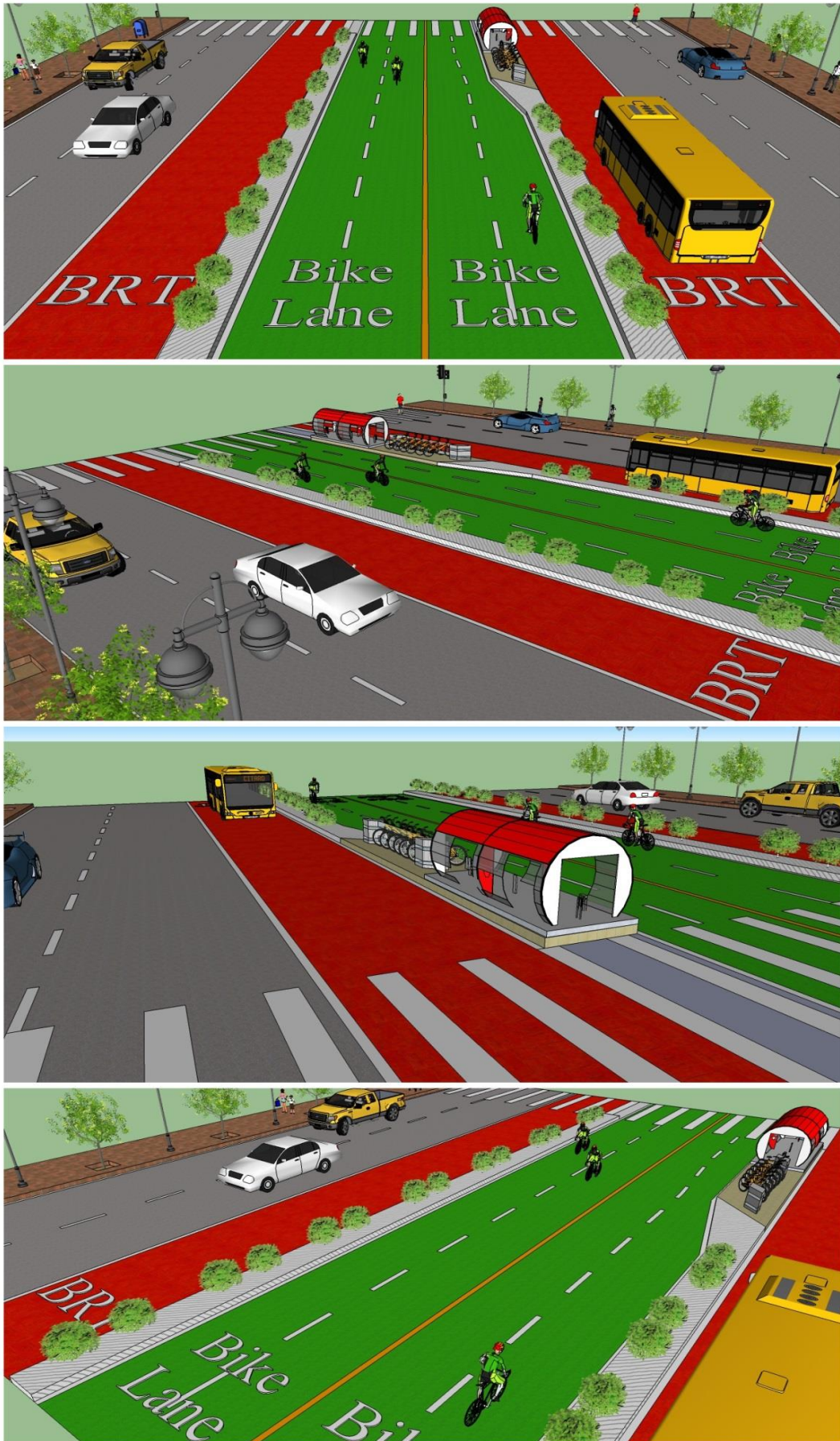
Appendix 2. BBRT Concept: One-way, Commercial Area, and Residential Area.



Appendix 3. BBRT Renderings – One-way



Appendix 4. BBRT Renderings – Commercial Area



Appendix 5. BBRT Renderings - Residential Area

