

A SROI FRAMEWORK FOR THE LOS ANGELES METROPOLITAN TRANSPORTATION AUTHORITY AND BEYOND

PREPARED FOR THE LOS ANGELES METROPOLITAN TRANSPORTATION
AUTHORITY BY THE LA METRO CAPSTONE TEAM AT COLUMBIA
UNIVERSITY'S MASTER'S OF SUSTAINABILITY MANAGEMENT PROGRAM



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EXECUTIVE SUMMARY

This report provides an in depth look at the construction of a Sustainable Return on Investment model (SROI) for the Los Angeles Metropolitan Transportation Authority (LA Metro). The subject of this report, the SROI model, serves as a complimentary tool intended to elevate the value capture of commonly used financial decision-making frameworks such as Net Present Value, Return on Investment, and Money on Equity Return, in order to incorporate the often overlooked, yet important benefits to society and the environment a project may generate. In capturing and monetizing these benefits to the greatest extent possible given the project's constraints, this model begins to express the additional value previously unrecognized by typical analysis. The utility of this model makes it an exciting tool that would be well suited in the impact and environmental, social and governance (ESG) investing space.

The model transformed greatly over the 14 weeks, and as such, this report highlights the transition over three main phases: Phase 1: Initial Approach; Phase 2: Model Construction; Phase 3: Challenges. Each section provides insight into the extensive background research required to develop the aforementioned SROI model, and the accompanying appendix provides greater detail on some of the more granular analytic approaches taken. Section 2 features LA Metro's the findings of the model's case study, the evaluation of the Compressed Natural Gas (CNG) bus fleet which demonstrates the functionality and effectiveness of the model. Section 3 offers an in-depth look at the localized benefits that were not able to applied broadly throughout the model due to time constraints and informational limitations, in the form of an analysis of the Orange Rapid Transit Bus Line. This eludes to data gathering required for successful implementation of the model, as well the true value of this model.

LA METROPOLITAN TRANSPORTATION AUTHORITY

This report was designed for the Los Angeles Metropolitan Transportation Authority, hereon referred to as LA Metro. LA Metro's first transit line was serviced in 1990, and has since expanded to comprise 6 rail lines – 4 light rail and 2 heavy rail lines. Organized by color, this transportation network connects to alternative transit networks including 2 Metro Liner bus lines, and MetroLink, another commuter rail system servicing Southern California and spans a 1400 square mile radius. LA Metro services 140 million unique customers annually, with repetitive ridership making the usage much higher, and connects passengers to 88 cities comprised of 100 metro rail stations and nearly 1600 bus stops. LA Metro, as will be expanded upon in the benchmarking section, is a leader in sustainability and has had a robust sustainability program in place since 2009.

COLUMBIA UNIVERSITY'S MASTER OF SCIENCE IN SUSTAINABILITY MANAGEMENT DEGREE PROGRAM

The Columbia University's Master of Science in Sustainability Management Degree Program is a co-sponsored by the Earth Institute and the School of Professional Studies, offering an education in the systematic role of sustainability in any organization. It draws upon both qualitative and quantitative aspects of sustainability and environmental science, and incorporates sophisticated management and policy aspects. The program is intended for a new generation of professionals looking to explore critical interdisciplinary issues within the realm of sustainability.

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INTRODUCTION

This project involved the development of a unique sustainable return on investment (SROI) framework for the Los Angeles Metropolitan Transportation Authority. An SROI model is a decision-making framework that provides an estimation and/or assessment of the total value – inclusive of both the cash and non-cash benefits - that a project, program, or entity creates.¹ It builds upon traditional decision making frameworks by estimating and integrating, in dollar terms, the social and environmental value created, destroyed or displaced by a project, program, or organization to provide a more complete picture of the positive externalities created.² It is a powerful tool that can elevate traditional modelling by better reflecting the benefits to society and the environment created by a sustainability initiative. The customizable nature of the model makes this a retrospective tool that can be used to evaluate the impact of existing projects, or to directly compare between potential projects.

This project served as an opportunity for LA Metro to gain greater insight into the marginal benefit of their transit related initiatives. Though they are a public service and therefore less dependent on an attractive return on investment as a compelling aspect of project planning and decision-making, this tool possesses significant utility in creating a more compelling business case for sustainability.

The complexity of this project was mirrored by a dynamic development, refinement, and implementation process. Due to data limitations, and overall project capacity limitations, the project evolved through three main phases:

1. The initial approach;
2. SROI model construction;
3. And challenges.

For ease of understanding, the following report is broken up into these respective refinement phases.

¹ "Small Slices of a Bigger Pie: Attribution in SROI." *New Economics Foundation* (2011): 2. Web. 14 Sept. 2016.
https://issuu.com/neweconomicsfoundation/docs/small_slices_of_a_bigger_pie

² Ibid.

PHASE 1: INITIAL RESEARCH AND ANALYSIS

INITIAL APPROACH

In order to optimize the intended utility of the model, it was critical to understand what aspects of sustainability LA Metro found to be material, what areas they were tracking, and what indicators they had already implemented to guide this tracking. LA Metro publishes robust sustainability reports annually that in 2016, addressed the following key areas: greenhouse gas emissions and displacement, energy use, water use, waste and recycling, air pollutant emissions, and operating efficiency.³ As a first step to developing an SROI, these main indicators were used as the foundation of the model with the rationale that if these were the most important and material concerns, these categories should inform what information would be collected and evaluated within the model. Further research into the indicators and their respective sub-indicators was completed, ultimately yielding five main points of consideration for the SROI model:

1. Solid Waste and Recycling
2. Water Usage
3. Net Emissions from LA Metro Operations
4. Combined Total Energy Use
5. Passenger Ridership

Additional information gathered from LA Metro's publically available reports suggested the role of resilience was also an important consideration. Not only is resilience necessary for LA Metro to operate and perform long-term, but it also is pivotal for the preservation of the environment and protection of LA's population and social fabric. For these reasons, resiliency was also noted as a foundational model consideration, specifically evaluated through three resiliency indicators:

1. Technical Robustness
2. Technical Redundancy
3. Organizational Change Readiness

³ LA Metro Energy and Resource Report 2016, p. 3.

SOLID WASTE AND RECYCLING

Solid waste and recycling, measured as Total Solid Waste/Year (tons) or Total Recycled Solid Waste/Year (tons), is an important metric used by LA Metro. Such information can be useful in gauging financial, environmental and social impacts.

From a financial perspective, solid waste and recycling are an inherent part of LA Metro's operational costs. Reduced solid waste in turn reduces waste transportation and disposal costs, helping to reduce overall expenses and carve out a profit margin.

Solid waste and recycling is also inherently tied with environmental considerations, and a reduction of such can promote improved air quality and land use. An example of this correlation is landfill dependency. Reduced waste generation helps to reduce the inflow of waste material in landfills, a highly damaging waste sink. Landfills are a significant producer of methane emissions, a greenhouse gas (GHG) with a warming potential 28-36 times that of carbon dioxide,⁴ and as well are a significant source of toxic leachate runoff, which has been found to have damaging effects on ground water and human drinking water.⁵

Waste generation is also an important metric for evaluating citizen well-being. Fewer landfills create a better living environment for nearby communities and less pollution translates into overall better health.

⁴ "Understanding Global Warming Potentials." EPA. Environmental Protection Agency, 9 Apr. 2016. Web. 11 Nov. 2016.
<https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>

⁵ "Drinking Water Source Protection and Solid Waste Landfills." Rep. Ohio EPA, Dec. 2014. Web. Nov 2016.
<http://www.epa.state.oh.us/portals/28/documents/swap/SWAPandLandfills.pdf>

WATER USAGE

Los Angeles gets water from three sources: local groundwater, water imported through the State Water Project (SWP), and the Colorado River Aqueduct (CRA).⁶ LA Metro has recognized water usage as an environmental issue of paramount importance to Los Angeles, and to the State of California as a whole.

In an attempt to reduce water consumption at the operations level, LA Metro has utilized a series of water consumption metrics to determine areas for improved usage.⁷ In 2014, they used these metrics to explore water reduction opportunities and found the incorporation of water-reclamation strategies in their bus-washing operations to be an effective and scalable approach to water conservation.⁸ The success of this initiative has spurred LA Metro to look further into the use of reclaimed water as a method of reducing total usage of potable water, not only to reduce operational costs, but to also achieve compliance with Mayor Eric Garcetti's challenge to reduce potable water by 20% by 2014-2017.⁹

LA Metro is also proactively evaluating the use of metered water. One example of such considerations is the implementation of smart landscaping programs to replace existing facility landscaping. Smart landscaping utilizes vegetation requiring minimal water, drought resistant plants, and natural shading to generate low-maintenance, and harmonious landscaping. The benefits of smart landscaping will be further explored later in this report.

NET EMISSIONS FROM LA METRO'S OPERATIONS

The transportation sector contributes more than one-third of all GHG emissions in California,¹⁰ and as such, GHG emissions management is a key consideration of LA Metro. LA Metro has dedicated impressive resources to reducing the emissions associated with operating their transportation systems, and has established GHG emissions metrics to adequately measure and

⁶ LADWP. "Facts & Figures." LADWP>About Us>Water>Facts & Figures https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-factandfigures?_adf.ctrl-state=5avlyuyvl_4&_afLoop=395738708774768 (Last Accessed November, 25, 2016).

⁷ LA Metro Energy and Resource Report 2016, p. 28-31

⁸ Ibid.

⁹ City of Los Angeles. "Los Angeles Cuts Water Use by 13% in one year; exceeds Mayor Garcetti's Challenge." July 25, 2015. <http://mayorsfundla.org/wp-content/uploads/2015/09/Los-Angeles-Cuts-Water-Use-By-13-Percent.pdf>

¹⁰ "California Greenhouse Gas Emission Inventory – 2016 Edition." *California's Greenhouse Gas Emission Inventory*. N.p., 17 June 2016. 12 Nov. 2016. <<https://www.arb.ca.gov/cc/inventory/data/data.htm>>.

monitor the environmental impacts associated with these operations. The GHG emissions metrics LA Metro actively uses are: emissions per boarding; emissions per vehicle mile; and greenhouse gas displacement.¹¹ These metrics aim to reveal the physical magnitude of the system's total emissions, and help to identify current effectiveness and efficiency of the system in relationship with other modes of transportation.

Emissions per boarding is a way of capturing the efficiency of the system and can be used as an important guide when determining vehicle size needed, vehicle routes, and route headways. For example, a bus with no empty seats is maximized in terms of emissions per boarding, at which point the only way to further reduce environmental impacts would be to supply a lower-emissions vehicle, a larger yet similar emissions vehicle, or to reconfigure the route to reduce total emissions per route while maintaining full ridership. This information is very valuable.

Emissions per vehicle mile can be used to determine if a certain vehicle is appropriate for the route. This is important for internal evaluation because quantity of emissions vary between different modes of transport, including light rail, heavy rail and buses.

Emissions per revenue hour is another meaningful metric used, which compares the emissions generated per revenue hour versus the emissions associated with non-service operations. Non-service operations including maintenance, and help to identify the breakdown of emissions generation per component of LA Metro's holistic operations.

The combined use of such metrics have helped to generate a more informed and precise systems view of LA Metro's emissions generation. Equipped with such information, this has been used to justify the transition to zero-emissions buses, carpooling campaigns, and the design of walkable communities.

¹¹ LA Metro Energy and Resource Report 2016, p. 44-50.

COMBINED TOTAL ENERGY USE

LA Metro distinguishes energy use according to two main constraints: where the energy is employed and the type of energy used. Though total fuel use, rail propulsion power, and facility electric use are published as individual indicators, the combined expression of these as a single indicator was found to be a compelling informant for the proposed SROI framework.

A measure of the total energy consumption at the company level, rather than within individual work streams is relevant in assessing the overall energy efficiency of LA Metro. Identifying the overall energy footprint of LA Metro is an important first step to understanding where more granular energy efficiency measures can be implemented. Improved energy efficiency and reduced energy consumption are not only a cost savings measure, but they influence systems resilience by putting LA Metro in a more strategically optimal position to hedge oil price volatility.¹² Importantly, greater energy efficiency means lower emissions, which results in extensive environmental benefits and human health benefits.¹³

PASSENGER RIDERSHIP

A principal goal at LA Metro is to add and improve transportation amenities throughout the county with the intention of increasing ridership, while simultaneously reducing environmental impact. In order to address this, ridership must be thoughtfully tracked. There are two main indicators LA Metro uses to do so: Unlinked Passenger Trips (UPT) and Vehicle Miles Traveled per Capita (VMT).

UPT refers to ridership as a simple measure of total trips taken on the public system. This indicator is often displayed as UPT per capita where it is divided by the total population of LA County. VMT is based on the total estimated vehicle miles traveled by LA County residents based on statistical reports from the California Public Road Data divided by the Census Bureau population estimates of the LA County.¹⁴ This metric proved useful in determining if residents of

¹² Ebrahim, Zoheir, Oliver R. Inderwildi, and David A. King. "Macroeconomic Impacts of Oil Price Volatility: Mitigation and Resilience." *Frontiers in Energy* 8.1 (2014): 9-24. Springer. Web. Nov. 2016.

¹³ Regulatory Impact Analysis for the Clean Power Plan. *US EPA*. 23 Oct. 2015. 5 Nov. 2016. Pg. 166-221.

¹⁴ LA Metro Energy and Resource Report 2016, p. 46.

the region, as a result of better access to public transportation, traveled less in their personal vehicles, something that would have significant implications in the SROI modelling.

RESILIENCY

In determining which indicators could best measure resiliency, LA Metro's 2015 Sustainability Report and Resiliency framework was analyzed. Of all 62 indicators mentioned in the evaluated LA Metro reports, technical redundancy, technical robustness, and organizational change readiness were determined to be the most advantageous for the foundation of the SROI framework.

While robustness refers mostly to the actual ability of a system to withstand disturbances or crises,¹⁵ redundancy refers to the capacity to aid in the case of a disturbance or crises.¹⁶ As for readiness, this is a measure of how redundancy and robustness are managed and if they are efficient, effective, and prompt in case of a disaster or unforeseen event.¹⁷ Inherently, all of these indicators complement each other. These indicators provided important considerations for the model's construction, and future uses.

BENCHMARKING COMPARABLE CITIES

The importance of benchmarking LA Metro was acknowledged in the early phases of the project, not only because the client had requested such analysis, but because it served as a valuable tool for understanding other city-level sustainability initiatives internationally. This helped to expand the scope of key performance metrics utilized in the sector and recognize patterns of utility.

¹⁵ Howell, Lee. *Resilience: What It Is and Why It's Needed*. Issue brief. PwC, 2013. Web. Oct. 2016. <
https://www.pwc.com/gx/en/governance-risk-compliance-consulting-services/resilience/publications/pdfs/issue3/what_it_is_and_why_its_needed.pdf>.

¹⁶ Ibid.

¹⁷ Ibid.

To develop a tool that would adequately benchmark transportation authorities against each other in a standardized fashion, a few considerations were taken into account to facilitate the screening of comparable cities. Looking exclusively for cities with an overall sustainability target, that show innovative potential, and possess urban sprawl conditions, ultimately eight cities were identified as being adequately comparable. These were as follows:

PHILADELPHIA

The Southeastern Pennsylvania Transportation Authority (SEPTA) is Philadelphia's public transportation authority. SEPTA is one of the leading transportation agencies that focuses on green infrastructure and storm water management;¹⁸ LA metro has shown interest in these types of projects.¹⁹ SEPTA also has a robust Sustainability Plan with goals, quantitative metrics and baselines, and at the city level, Philadelphia is on the list of top 50 cities with the highest urban sprawl index in the United States²⁰.

CHICAGO

The Chicago Transit Authority (CTA) is Chicago's public transportation authority, which includes bus and rapid transit. It has the second oldest subway line in the United States and it is the third largest rapid transit system by ridership.²¹ According to the list of top 50 cities with the highest urban sprawl index in the United States, it is ranked number 26 (Los Angeles is 21)²². CTA emphasizes sustainable transportation, clean vehicles, efficient facilities and resource recycling.²³

¹⁸ "Main Website". Southeastern Pennsylvania Transportation Authority. 23 Nov 2016. <http://www.septa.org>

¹⁹ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016. http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

²⁰ "Measuring Sprawl 2014." Smart Growth America. April 2014. 23 Nov 2016.

<https://www.smartgrowthamerica.org/app/legacy/documents/measuring-sprawl-2014.pdf>

²¹ "CTA Facts at a Glance." Chicago Transit Authority. 2016. 23 Nov 2016. <http://www.transitchicago.com/about/facts.aspx>

²² "Measuring Sprawl 2014." Smart Growth America. April 2014. 23 Nov 2016.

<https://www.smartgrowthamerica.org/app/legacy/documents/measuring-sprawl-2014.pdf>

²³ "CTA Green Initiatives." Chicago Transit Authority. 2016. 23 Nov 2016. <http://www.transitchicago.com/goinggreen/>

MUNICH

Munich is a world city with high innovative potential. In 2014 it was reported that Munich had a target of 100% clean electricity supply by 2025²⁴ and it has the highest share of bicycle transport.²⁵ Along with the Munich's sustainability goals and potential, like Los Angeles, it has high levels of congestion and the government has created policies to alleviate this problem.²⁶

VIENNA

Vienna has a metropolitan population of 2.5 million people and has a transit system that services about 1.3 million riders daily.²⁷ According to the International Association of Public Transport, Vienna is the best performing public transport system in the world.²⁸ Vienna has set a target to expand their electric vehicle (EV) charging network stations from 103 stations to 440 stations,²⁹ and to implement an electric vehicle car sharing program.³⁰

COPENHAGEN

The city of Copenhagen has a goal to be carbon neutral by 2025.³¹ In order to reach this goal they want to focus on 4 initiatives: energy consumption, energy production, green mobility and city administration initiatives.³² One initiative is to create more bike lanes and super cycle highways to increase the number of people biking to work or school.³³

²⁴ Frangoul, Anmar. "Munich: the 100% clean electricity city?" CNBC. 26 Sept 2014. 23 Nov 2016.

<http://www.cnn.com/2014/09/26/munich-the-100-clean-energy-city.html>

²⁵ "Radlhauptstadt München website." Landeshauptstadt München. 23 Nov 2016. <https://radlhauptstadt.muenchen.de>

²⁶ Wadlow, Tom. "Which European Cities suffer the worst traffic congestion?" Business Review Europe. 30 Nov 2016. 01 Dec 2016. <http://www.businessrevieweurope.eu/leadership/1175/Which-European-cities-suffer-the-worst-traffic-congestion>

²⁷ "4th Meeting of the European Higher Education Area Advisory Group on Diploma supplement revision 27 and 28 October 2016, Vienna, Austria." Österreichische Fachhochschul Konferenz. 27 Oct 2016. 23 Nov 2016.

http://media.ehea.info/file/20161027-28-Vienna/79/0/AG4-20161027-28-Practical_Information_Vienna_634790.pdf

²⁸ Sonuparlak, Itir. "Vienna, Austria Ranked as the Smartest City." The City Fix. 02 Feb 2012. 23 Nov 2016.

<http://thecityfix.com/blog/vienna-austria-ranked-as-the-smartest-city/>

²⁹ Cohen, Boyd. "The 10 smartest cities in Europe." Fast Coexist. 13 Jan 2014. 23 Nov 2016.

<http://www.fastcoexist.com/3024721/the-10-smartest-cities-in-europe>

³⁰ "Car2Go website." car2go Österreich GmbH. 2016. 23 Nov 2016. <https://www.car2go.com/AT/en/wien/>

³¹ "Copenhagen Climate Plan - The short version" City of Copenhagen. Aug 2009. 23 Nov 2016.

<https://www.energycommunity.org/documents/copenhagen.pdf>

³² Ibid.

³³ Ibid.

SAN FRANCISCO

San Francisco like Los Angeles is located in California and in some cases, may face the same political challenges and environmental vulnerabilities. According to the list of top 50 cities with the highest urban sprawl index in the United States San Francisco is ranked number 2 (Los Angeles is 21)³⁴.

PORTLAND

Portland is an environmentally friendly city that promotes the use of bikes and pedestrian zones. This is shown through its recent construction of the Tilikum Crossing, a bridge designed to only allow access to transit vehicles, cyclists, and pedestrians, but no cars.³⁵

NEW YORK

New York City's Metropolitan Transit Authority or MTA is the oldest and largest rapid transit system by ridership in the United States.³⁶ The agency also has an array of projects/initiatives that address environmental, social and governance issues. According to the list of top 50 cities with the highest urban sprawl index in the United States, New York is ranked number 1 (Los Angeles is 21)³⁷.

DEVELOPING THE BENCHMARKING TOOL

The Benchmarking tool is built upon many layers of data collection, exclusively from publically available data. As a preliminary step, material transportation sector issues were listed, collected heavily from the Sustainability Accounting Standards Board's (SASB) Transportation Sector

³⁴ "Measuring Sprawl 2014." Smart Growth America. April 2014. 23 Nov 2016.

<https://www.smartgrowthamerica.org/app/legacy/documents/measuring-sprawl-2014.pdf>

³⁵ "Tilikum Crossing: Bridge of the People." Portland Bureau of Transportation. 23 Nov 2016.

<https://www.portlandoregon.gov/transportation/68548>

³⁶ "Public Transportation for the New York Region." MTA. 23 Nov 2016. <http://web.mta.info/mta/network.htm>

³⁷ "Measuring Sprawl 2014." Smart Growth America. April 2014. 23 Nov 2016.

<https://www.smartgrowthamerica.org/app/legacy/documents/measuring-sprawl-2014.pdf>

Disclosure topics.³⁸ Additionally, client engagement had emphasized the interest in comparing across resiliency and green infrastructure categories, so these points of comparison were also incorporated into the tool as individual issues to be examined.

Using the previously identified material sector-specific issues, a more micro-level analysis was completed to better understand the integration of sustainability within the identified cities. There were three main points of interest:

1. Did the city implement an overarching sustainability approach? Was it an overall strategy or policy? Overarching quantitative and/or qualitative target(s)?
2. Do they have key performance indicators been identified?
3. Are considerations exclusively for the agency's direct operations or in its supply chain, individual measures, projects or initiatives?

Once this information was acquired, individual city-level projects and initiatives were categorized by the previously identified material issues. For each of these undertakings, the following information was gathered:

- Year of project/initiative;
- Objective(s) of the project;
- Specific target(s);
- Metrics used to measure progress;
- Total cost of project/initiative;
- Achieved targets;
- Any positive impacts (and/or) potential negative impacts

SCORING

Once equipped with information satiating all of these basic considerations and points of interest, scores were assigned to reflect the extent of these initiatives, and how they were integrated throughout multiple aspects of the transportation sector. The overarching approach to how the issues are managed (i.e. whether there is an overarching strategy in place, targets, as well as

³⁸ Sustainability Accounting Standards Board. Disclosure Topics: Transportation Sector. 2015. 23 Nov 2016.
http://www.sasb.org/wp-content/uploads/2015/10/Transportation_Issues_Table.pdf

metrics) are weighted 50% with second part, i.e. the individual measures would comprise of the other 50% of the overall score for that issue. While the overarching approach score could be determined based on the degree of fulfillment, individual projects were scored on a more qualitative and subjective basis. The array of projects per issue were scored based on comprehensiveness of the projects in addressing the issue, how long the projects had been underway or whether they were pilot attempts, and how rigorous they were overall.

Figure 1: Los Angeles, GHG Emissions

	Score	Weight	Total Score
Overarching approach	43.75 (out of 50)	50%	90.42 (out of 100)
Individual Projects/Initiatives	46.68 (out of 50)	50%	

Figure 1 shows an example of the tool's findings with an excerpt from the LA GHG emissions findings. An average of all the environmental issues was taken to calculate a total score for the environmental category. The same was done for the social and governance categories respectively. The maximum possible score for each category was 100; therefore, the maximum total score that a city could have earned is 300 (e.g. 100: environmental + 100: social + 100: governance). By summing up the scores of each category, the result produces a percentage out of 300 (the maximum score).

RESULTS

Overall, LA Metro scored 2nd out of 9 city transportation agencies in terms of their sustainability performance, with an overall score of 45.1 out of 100 (see Figure 1 above). New York City, who was deemed the leader among the considered cities, scored only 3.5 points better than LA Metro, with a final score of 48.8 out of 100. This discrepancy is likely attributed to improved governance and economic disclosure at New York MTA, for example the modernization of IT systems and cyber security, which LA did not discuss on its 2016 Energy and Resource Report. LA Metro did score highest across all cities for GHG Emissions reductions, as well as Waste Management & Recycling, Water Use, and Accessibility categories. Please see Appendices 1,2 and 3 for a comprehensive overview of the tool's findings.

Equipped with an understanding of LA’s existing sustainability measures on a relatively macro scale, complimenting these findings with the more localized context was an important next step in generating a more comprehensive basis of information needed to build the model.

LOS ANGELES: POLITICAL AND ECONOMIC CLIMATE

Understanding the political and economic context was incredibly important for the model’s development, as this added another layer of functionality to the model: tracking compliance with state and city-wide goals and policies. In Los Angeles alone, the city plans to: reduce water use by 19% aiming for 20% per capita by 2017; replace 95 miles of water pipe infrastructure; reduce annual sewer spills to fewer than 125; develop more rate tiers to encourage conservation.³⁹ The model not only provides a common place for data that is relevant to understanding current inputs and outputs that are subject to aggressive sustainability targets, but can also help to identify the compliance opportunities with the greatest return by having a comparability function built in.

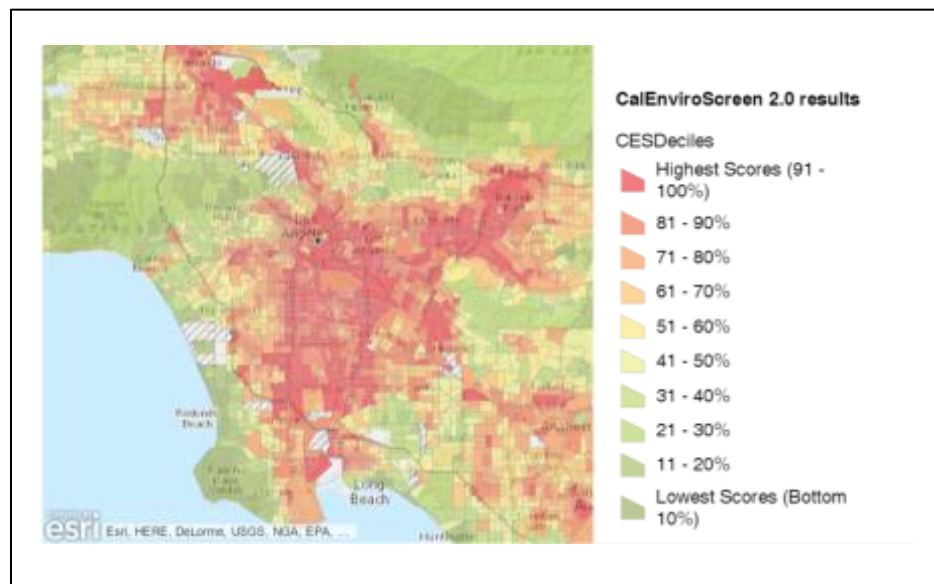
Another important benefit of the model was the identification of marginalized social benefit, which is achieved by understanding the preexisting social and economic conditions of the community where the sustainability initiative is occurring. More specifically, it is important to understand if the community that is investing in sustainability has a high percentage of people who are more vulnerable to pollution, such as young children and people with asthma, and negative socioeconomic factors, such as poverty, race and ethnicity, and education. Understanding these characteristics can help policymakers identify sustainability “hotspots” that will return the greatest marginal benefits to society as a result of investing in sustainability.

California has developed the CalEnviroScreen, a screening methodology that can be used to identify California communities that are disproportionately burdened by multiple sources of pollution. The tool uses environmental, health, and socioeconomic data to produce scores for every community in California. The final score attempts to capture the cumulative impacts of all the pollution in a determined region specific to the composition of the population that lives there. As a future development of the model, the localized demographics of vulnerable populations will be incorporated into the SROI model inputs, and will influence the ultimate

³⁹ “Sustainable City pLAn: The First Annual Report.” (2015):n. peg. The Mayor’s Office of Sustainability. Web.

return on the investment by adjusting the human health impacts of avoided emissions. Due to capacity limitations, this was not incorporated to the fullest extent, but represents a meaningful opportunity for further refinement.

Figure 2: CalEnviroScreen Map of Los Angeles and Surrounding Counties



The results of the CalEnviroScreen scoring methodology highlight the importance of broadening the definition of “sustainability” and examining the impacts of a sustainable investment within the context of the region. Los Angeles is one of the richest counties in the state, and therefore has the financial resources to invest in projects that help alleviate some of the burden the population faces.⁴⁰

⁴⁰ California Environmental Protection Agency. *Environmental Justice Program*. 2016: <http://www.calepa.ca.gov/EnvJustice/>

PHASE 2: SROI MODEL CONSTRUCTION

In order to build out a model that incorporated both the hard benefits, as in those denominated by dollar values, and the soft benefits, those that are more project specific and may not be as easily quantified, the model was built out to possess two distinct sections. LA Metro's CNG bus fleet served as a case study for the model.

In regards to the findings the model actually produces, this comes down to a net present value figure, an internal rate of return, and a money on equity return based upon the following 4 categories:

- Fuel use
- Electricity use
- Waste generation
- Water consumption

In addition to having these hard figures, there is also a survey component within the model that asks the user to indicate all of the applicable attributes of the project from a list of 24. This ranges from the implementation of smart landscaping, to permeable pavement to reduced diesel vehicles used, and are associated with the list of soft benefits associated with each feature. A barrier to having such benefits quantified is a lack of in-depth project information which is required to actually generate monetized benefits from these attributes, these feature benefits were expressed as mostly soft benefits.

STAKEHOLDER ENGAGEMENT

In building this model, it was important to engage with other stakeholders in the space to better refine the model's utility, to ensure the model design was user friendly and did not present an educational barrier for its functionality, and provided information that would be beneficial and unique.

The following stakeholders were engaged over the duration of the project:

- Andreas Georgoulas, Director at Zofnass Institute for Sustainable Development, Lecturer at Harvard Graduate School of Design, Research Director
- Doug Sereno, Director of Project Management at Port of Long Beach, Head of the Technical Subcommittee for the American Society of Civil Engineers LA Chapter Sustainability Committee
- Dominique Haregreaves, Executive Director of Green Building Council – LA Chapter
- Thomas Small, Culver City Councilmember
- Michael Sanio, Director of Sustainability/International Alliances at the American Society of Civil Engineers
- Jamesine Rogers Gibson, Western states senior climate analyst for the Climate & Energy program at the Union of Concerned Scientists
- Bryn Lindblad, Associate Director of Climate Resolve

HARD METRICS

The model is centralized around 4 main considerations, the management of which have useful and important financial implications. In addition, basic model assumptions were taken into account based on various sources, economic factors, and limitations.

BASIC MODEL ASSUMPTIONS

As a case study, the model was run with the scope limited to all buses operated by LA Metro since their complete conversion over to compressed natural gas (CNG) in 2010 (operating year zero).⁴¹ A project lifetime of 14-years was assumed based on the California Environmental Protection Agency Air Resources Board's Total Cost of Ownership assessment.⁴² A 4.5% discount rate was used based on projected interest rate payments for 2016 and beyond on senior lien

⁴¹ Metro Retires Last Diesel Bus, Becomes World's First Major Transit agency to Operate Only Clean Fuel Buses. *Los Angeles County Metropolitan Transportation Authority*. 12 Jan. 2011. 25 Nov. 2016.

⁴² Total Cost of Ownership to Advance Clean Transit. *California Environmental Protection Agency Air Resources Board*. 4 Oct. 2016. 25 Nov. 2016.

bonds for bus capital requirements.⁴³ The historical 10-year inflation rate for the United States is 1.86% while the 20-year rate is 2.19%, therefore an inflation rate of 2% was assumed.⁴⁴

FUEL USE

Mass transportation systems rely on electricity, natural gas, and liquid fuels to service the communities in which they operate. At LA Metro, fuel consumption for cross-organizational operations represents 84% of their total energy consumption⁴⁵ despite only representing 45% of their total annual energy costs.⁴⁶ This is largely attributed to the high number of buses operating on Compressed Natural Gas (CNG), which on a per gallon of gasoline equivalent (GGE) basis is approximately 75% cheaper than diesel or gasoline, Metro's next most significant fuel types. As direct and indirect bus fleets account for approximately 74% of annual boardings, and LA Metro has managed to transition to a 100% CNG-powered direct bus fleet, this has generated substantial savings for LA Metro.⁴⁷ These efforts and others like them have been carefully accounted for in the fuel consumption/cost forecast component of the SROI model.

In general, mass transportation systems are seen as a benefit to communities for providing a centralized mode of safe, reliable and affordable transportation options. The type of fuel used to service transit operations is a meaningful distinction as this has cost variance and significant emissions implications, and thus environmental and societal consequences as well. In order to most accurately quantify fuel-related benefits, the model breaks down fuel type into the following:

- Diesel
- Low Sulfur Diesel
- California Gasoline
- Gasoline (assumed for the other 49 states)
- Compressed Natural Gas

⁴³ "2014 Short Range Transportation Plan Technical Report." Los Angeles County Metropolitan Transportation Authority. 2014. 17 Nov. 2016.

⁴⁴ Historical Inflation Rates: 1914-2016. *US Inflation Calculator*. Oct. 2016. 25 Nov. 2016.
<http://www.usinflationcalculator.com/inflation/historical-inflation-rates/>

⁴⁵ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016.
http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

⁴⁶ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016.
http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

⁴⁷ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016.
http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

- Liquefied Natural Gas
- Biodiesel
- Electricity
- Ethanol

With a discount rate of 4.5%, the net present value of Metro’s direct CNG fleet fuel consumption is approximately -\$783 million. On a \$ per GGE basis, this amounts to approximately \$0.64 per GGE.

The fuel consumption/cost forecast model used to calculate NPV is based primarily on the U.S. Energy Information Administration’s (EIA) Annual Energy Outlook 2016 report.⁴⁸ Annual forecasts of average prices to all users for natural gas, motor gasoline, and distillate fuel oil were multiplied by proprietary annual fuel consumption estimates to calculate annual fuel costs for Metro’s direct and indirect fleets. While direct and indirect annual fuel consumption were both calculated for the purpose of utilization, only direct fuel consumption was used as the scope of the analysis was limited to LA Metro’s direct bus fleet.

Key assumptions underlying the model’s annual fuel consumption forecast include the following:

- Direct Revenue Fleet
 - 2016 direct revenue fleet fuel consumption will decrease by the same percentage that it decreased from 2014 to 2015
 - 2017 – 2020 direct revenue fleet fuel consumption will decrease until 2020, based on the assumption that oil price recovery will not be sufficient to increase bus ridership until 2021, with each year's respective declining rate reduced by 0.1%
 - 2020 – 2040 direct revenue fleet fuel consumption will increase annually at a rate of 2.0%
- Direct Non-Revenue Fleet
 - Nonrevenue diesel fuel consumption decreases annually until 2024 when diesel fuel represents only 3% of overall direct non-revenue fleet fuel consumption

⁴⁸ USA. U.S. Energy Information Administration (EIA). Office of Energy Analysis. Annual Energy Outlook 2016 (AEO2016). U.S. Energy Information Administration (EIA), Aug. 2016. Web. 27 Nov. 2016.

- 2016 fuel consumption assumes a declination rate of 12.5%, a 2.5% reduction from that which was observed from 2014 to 2015 of 15%⁴⁹
- 2017 – 2020 declination rates are reduced by 0.5% annually, based on a 2016 base year
- 2021 – 2024 diesel fuel consumption volumes were estimated by:
 - applying the 2017-2020 CAGR of gasoline's proportion of overall nonrevenue fleet fuel consumption to forecast the growth in gasoline relative to diesel
 - calculating diesel fuel volumes as 1 - (Gas/total fuel)
- 2025 – 2040 overall direct nonrevenue fleet total fuel consumption grows at a rate of 2.0% annually
- Indirect Revenue Fleet
 - Total indirect fuel consumption decreases until 2020, with each year's respective rate of declination reduced by 0.1% per year
 - 2020 – 2040 fuel consumption is projected to grow at 2% annually

It is critical to note how much fuel is being consumed as this denotes a significant amount of LA Metro's expenses, and is important in generated the final return values.

EMISSIONS AVOIDED

It is well known that ancillary human health benefits are associated with lower ambient concentrations of criteria air pollutants.⁵⁰ This model monetizes air quality co-benefits associated with reduced exposure to ambient fine particulate matter (PM_{2.5}) and ozone by reducing emissions of precursor pollutants, such as nitrogen oxides (NO_x), sulfur dioxide (SO₂) and directly emitted PM_{2.5}. The Regulatory Impact Analysis (RIA) of the Clean Power Plan (CPP) conducted by the Environmental Protection agency (EPA) contains dollar per ton emissions avoidance values associated directly with NO_x, PM_{2.5}, and SO₂. The RIA quantifies these dollar per ton avoidance values within a range, low to high, as the study references values from two epidemiology studies that value premature mortality from PM_{2.5} and ozone differently – Krewski et al. (2009) and Lepeule et al (2012).⁵¹ These ranges for 2020 can be seen below in Figure 3.

⁴⁹ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016.

⁵⁰ Regulatory Impact Analysis for the Clean Power Plan. *US EPA*. 23 Oct. 2015. 5 Nov. 2016. Pg. 166.

⁵¹ Ibid 188.

Figure 3: 2020 Regional Benefits Per Ton for Emissions Reduction (in 2011\$)⁵²

Pollutant	Discount Rate	Regional		
		East	West	California
SO ₂	3%	\$33,000 to \$75,000	\$6,200 to \$14,000	\$95,000 to \$210,000
	7%	\$30,000 to \$68,000	\$5,600 to \$13,000	\$85,000 to \$190,000
Directly emitted PM _{2.5} (EC+OC)	3%	\$140,000 to \$320,000	\$27,000 to \$60,000	\$370,000 to \$830,000
	7%	\$130,000 to \$290,000	\$24,000 to \$54,000	\$330,000 to \$740,000
Directly emitted PM _{2.5} (crustal)	3%	\$23,000 to \$52,000	\$11,000 to \$25,000	\$73,000 to \$160,000
	7%	\$21,000 to \$47,000	\$9,900 to \$22,000	\$66,000 to \$150,000
NO _x (as PM _{2.5})	3%	\$3,100 to \$7,000	\$0,670 to \$1,500	\$22,000 to \$49,000
	7%	\$2,800 to \$6,300	\$0,610 to \$1,400	\$19,000 to \$44,000
NO _x (as Ozone)	N/A	\$6,500 to \$28,000	\$2,000 to \$8,900	\$14,000 to \$59,000

The RIA provides regional emissions benefits, as shown above, for 2020, 2025, and 2030. Values were extrapolated for year between 2020 – 2024 and 2026 – 2030, as well as between 2016 – 2020. For all years before 2016, 2016 values were assumed, as emissions benefits would otherwise extrapolate to zero which is not a realistic assumption.

Additionally, a social cost of carbon dioxide (SC-CO₂) was used to monetize climate benefits associated with a reduction in greenhouse gas emissions. These values were also obtained from the RIA, and contain a range of values per year. This is due to the RIA sourcing three separate climate models that value the SC-CO₂ differently, the DICE, PAGE, and FUND models.⁵³ These values can be seen below in Figure 4. Values for the SC-CO₂ were extrapolated for years not shown below.

⁵² Regulatory Impact Analysis for the Clean Power Plan. US EPA. 23 Oct. 2015. 5 Nov. 2016. Pg. 188.

⁵³ Regulatory Impact Analysis for the Clean Power Plan. US EPA. 23 Oct. 2015. 5 Nov. 2016. Pg. 37.

Figure 4. SC-CO₂, 2015-2015 (in 2011\$ per ton)⁵⁴

Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% (95th percentile)
2015	\$11	\$35	\$54	\$100
2020	\$12	\$40	\$60	\$120
2025	\$13	\$44	\$65	\$130
2030	\$15	\$48	\$70	\$150
2035	\$17	\$53	\$75	\$160
2040	\$20	\$58	\$81	\$180
2045	\$22	\$62	\$86	\$190
2050	\$25	\$66	\$91	\$200

Total emissions generated for each fuel are broken down into specific emissions – carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄), carbon dioxide equivalent (CO₂e), sulfur dioxide (SO₂), nitrous oxides (NO_x), and particulate matter (PM_{2.5}). The SC-CO₂ is applied to CO₂e instead of CO₂ to completely capture the global warming potential of all emissions. Specific emission quantities for various fuel types were obtained from the 2016 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model produced by Argonne National Labs – an annually produced model from a government funded research lab.⁵⁵

These quantified values were applied to emissions generated from LA Metro’s CNG bus fleet to determine the cost to society associated with increased health impacts and greenhouse gas emissions. Total emissions avoided were also calculated based on passenger vehicle use avoidance as a result of LA Metro’s bus fleet services. Using an average passenger vehicle occupancy factor of 1.15⁵⁶, total annual bus ridership from 2010 – 2015, an average passenger miles traveled of 4.2⁵⁷, and average vehicle miles per gallon (mpg) efficiency of 22.1mpg in 2011 and 25.1mpg in 2016⁵⁸, these components were extrapolated out for future values in order to obtain an annual avoided passenger vehicle fuel use figure. Specific values from the GREET

⁵⁴ Ibid 173.

⁵⁵ GREET Model. *Energy Systems*. Argonne National Laboratory. 2016. Nov. 2016. <https://greet.es.anl.gov/>

⁵⁶ Life-Cycle Benefit-Cost Analysis Economic Parameters 2012. *California Department of Transportation*. 2012. 25 Nov. 2016.

⁵⁷ Metro’s 2016 Energy and Resources Report. *Los Angeles County Metropolitan Transportation Authority*. 2016. 15 Nov. 2016. Pg. 50.

⁵⁸ Sales-weighted fuel-economy rating of purchased new vehicles from October 2007 through November 2016. *University of Michigan Transportation Research Institute*. Nov. 2016. 25 Nov. 2016. http://www.umich.edu/~umtristwt/EDI_sales-weighted-mpg.html

model were then used to determine quantities of CO₂, N₂O, CH₄, CO₂e, SO₂, NO_x, and PM_{2.5} generated.

EMISSIONS IMPORTANCE FACTOR

As discussed previously, monetized benefits associated with air pollutants and greenhouse gases are expressed within specific ranges in the model. To address this, the model prompts the user to weight emissions reduction, in relation to alleviating health impacts and mitigating climate change, on a scale of 1-10 with 1 weighted the least (lowest \$/ton value) and 10 weighted the most (highest \$/ton value). This was intended to have the capacity to tailor emissions reduction importance in a specific project to the needs of the relevant stakeholders. The future goal of this aspect of the model is to refine these ranges of \$/ton values with future case studies to reduce the range and eventually quantify an exact \$/ton value.

With an emissions importance factor of 1, an assumed lifetime of 14-years, and a start date of 2010, the net present value of emissions avoidance from removing passenger vehicles from roadways in LA as a result of LA Metro's bus services, was calculated at over \$2.8 billion. This is including the emissions from LA Metro's CNG buses.

ELECTRICITY

According to the U.S. Energy Information Administration (EIA), the average price of electricity for the transportation sector in California between August 2015 and August 2016 was \$0.0923/kwh.⁵⁹ Kilowatt hours of electricity saved from investments in energy efficiency were valued at this price within the SROI model.

In addition to the monetary savings from reduced electricity consumption, numerous studies have been done to try and quantify societal costs from electricity generation. In 2002, a survey of the existing literature surrounding research on valuing the environmental impacts of

⁵⁹ U.S. Energy Administration. *Electric Power Monthly: Average Price of Electricity to Ultimate Consumers by End-Use Sector*. U.S. Department of Energy. October 25, 2016: www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

electricity generation was published in The Journal of Energy Literature. Two researchers reviewed over 40 papers written on this topic and determined the following range of additional costs to society from electricity generation from each fuel type:

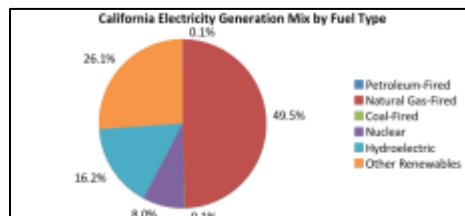
Figure 5. Price per Kilowatt Hour by Fuel Type⁶⁰

(US Cents/kWh)	Coal	Oil	Gas	Nuclear	Hydro	Wind	Solar	Biomass
Min	0.004	0.03	0.003	0.0003	0	0	0	0
Max	67.72	39.93	13.22	64.45	26.26	0.88	2.20	22.09
Difference	16930%	1331%	441%	214833%	—	—	—	—
Mean	14.01	12.32	4.61	7.12	3.36	0.31	0.84	4.95
Median	6.38	9.11	2.62	0.81	0.32	0.32	0.76	2.68
Std. Dev.	15.99	12.45	4.58	16.96	7.59	0.24	0.74	5.57
N	36	20	31	21	16	18	11	22

While these ranges of values hold tremendous weight, they were not incorporated into the electricity analysis of the model due to the project's time limitations.

The model assumes the following breakdown of electricity generation by fuel type for California using the most recently available data from the EIA:⁶¹

Figure 6. California Fuel Mix



⁶⁰ Sundqvist, T. and P. Soderholm, *Valuing the Environmental Impacts of Electricity Generation: A Critical Survey*, The Journal of Energy Literature, VIII (2):3-41. March 2003.
pure.iiasa.ac.at/6784/1/RR-03-05.pdf

⁶¹ U.S. Energy Administration. *California: State Profile and Energy Estimates*. U.S. Department of Energy. August 2016:
www.eia.gov/state/?sid=CA#tabs-4

Using the assumptions from the literature review, the model was able to calculate a weighted minimum and maximum cost of externalities from electricity generation specific to California. The weighted average cost to society of externalities from electricity generation is presented as a range of possible savings and is specific to LA Metro and other efficiency projects in California.

Figure 7. Weighted Average Cost of Fuel's Societal Externalities

	Coal	Oil	Gas	Nuclear	Hydro/Other Renewables	WAC (US Cents/kWh)
Min	0.004	0.03	0.003	0.0003	0.0	0.0015
Max	67.72	39.93	13.22	64.45	51.43	33.55
Weight	0.10%	0.10%	49.50%	8.00%	42.20%	--

WASTE

Waste Management has many impactful financial, environmental and social externalities associated with it, and thus is a major responsibility for LA Metro. LA Metro's waste management program focuses on two main categories, which can be broadly broken down into solid and liquid waste: total solid waste output including both recycled waste and solid output waste, and liquid waste, which comprises used oil waste, and both hazardous and total anti-freeze waste.⁶² Waste management efforts include initiatives such as the Pallet Return Program, landfill diversion, waste audits, and others.⁶³

SOLID WASTE

Electricity generated from fossil fuels and nuclear reactors creates a significant amount of solid waste.

Typically, coal plants can generate more than 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber each year.⁶⁴ Waste ponds typically house this waste, though an

⁶² Los Angeles County Metropolitan Transportation Authority, *Metro's 2016 Energy and Resource Report*, http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf.

⁶³ "Sustainability Reports." Environmental Compliance & Sustainability Department.

<https://www.metro.net/projects/ecsd/sustainability-reports/>

⁶⁴ "Environmental Impacts of Coal Power: Wastes Generated." *Union of Concerned Scientists*. Union of Concerned Scientists, n.d. Web 17 Nov. 2016. < <http://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/waste#.WE5BuqIrLwc>>.

estimated 42% of waste ponds are unlined. Without lining, waste is free to percolate through ground soil into the water table, and in local water supplies.⁶⁵ Waste can often contain toxic substances such as arsenic, mercury, chromium, and cadmium, all of which cause significant damage to human health and, specifically the nervous system.⁶⁶

Most of the adverse impacts of burning natural gas are associated with hydraulic fracturing and the natural gas extraction process. Although these activities have significant environmental impacts that should not be ignored, these impacts fall outside the scope of this model.

Though electricity generation from nuclear reactors generates a very small amount of solid waste,⁶⁷ material that is generated is highly radioactive and can cause serious health defects to humans who come in contact with even the smallest amounts of radiation.⁶⁸ The World Nuclear Association estimates that globally, nuclear generation facilities produce approximately 481,306 tons of low- and intermediate-level radioactive waste, and an estimated 12,000 tons of high-level waste.⁶⁹ When stored properly, nuclear waste poses no immediate threat to the environment and the surrounding communities however, there are very serious risk should the storage containers fail. Additionally, radioactive material remains in the environment until it has been reduced down to safe levels, which can take decades, as persistent side effect still plaguing the Chernobyl area in Ukraine after their nuclear accident in 1986.⁷⁰ These risks are serious and need to be weighed against the benefits of nuclear energy.

LIQUID WASTE

As mentioned, liquid waste is inclusive of both hazardous and non-hazardous waste. Hazardous liquid waste is mainly generated by LA Metro's bus maintenance divisions and repair centers from equipment such as chassis jets, steam bays, and fuel station trenches and clarifiers.⁷¹ Oil waste is a specific kind of hazardous waste, which is any petroleum-based or synthetic oil that has become unsuitable for its original purpose due to the presence of impurities or loss of

⁶⁵ Ibid.

⁶⁶ Ibid.

⁶⁷ "Radioactive Waste Management." *World Nuclear Association*. October, 2016, www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx

⁶⁸ "Radiation Health Effects." *EPA*. Environmental Protection Agency, July 2016. Web. 12 Nov. 2016. <https://www.epa.gov/radiation/radiation-health-effects>.

⁶⁹ "Radioactive Waste Management." *World Nuclear Association*. October, 2016, www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx

⁷⁰ "Chernobyl Accident 1986". *World Nuclear Association*. <http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx>

⁷¹ Los Angeles County Metropolitan Transportation Authority, *Metro's 2016 Energy and Resource Report*, http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

original properties.⁷² Alternatively, non-hazardous liquid waste is inclusive of storm sewer, catch basins, sanitary sewer clean-out residues, grease trap clean-out residues, industrial waste water, uncontaminated precipitation removed from secondary containment structures, wash water and some off specification commercial chemical products.⁷³ The last category is represented by anti-freeze waste, which is any liquid mixture that is mainly used for heat transfer or dehydration fluid in LA Metro’s bus maintenance facilities.⁷⁴

The aforementioned categories, or indicators of different types of waste that the company produces by running its operations are quantified by using the following metrics:

Figure 8. Waste Indications and their Metrics

Indicator	Metric
Total solid waste output	Tons/year
Used oil waste	Thousands of gallons / year
Total liquid waste	Thousands of gallons/ year
Total anti-freeze waste	Thousands of gallons/year/division

The total LA Metro’s waste cost was defined in the model by summing the costs of all five different categories of waste as this accurately accounts for the costs of the company’s waste management activities. LA Metro reports from 2010 to 2016 and data from Los Angeles County’s disposal fees for each kind of waste for the past 8 years were used to inform waste management activity costs.

The following assumptions were made to calculate costs:

- A no-fee service contract initiated in 2006 eliminated the cost of used oil waste disposal
- Since September 2011, used oil disposal became a revenue generating service and thus LA Metro will continue to receive 10 cents for each gallon of used oil it recycles
- The disposal fee used for total solid waste output is equal to the median price of all disposal companies operating in LA County

⁷² Ruhlin, Doug. “Used Oil vs. Waste Oil – What’s the Difference?!” *RMA: Environmental and Sustainability Consulting*. RMA, n.d. Web. 12 Nov. 2016. <http://www.rmagreen.com/rma-blog/bid/53516/Used-Oil-vs-Waste-Oil>

⁷³ Los Angeles County Metropolitan Transportation Authority, *Metro’s 2016 Energy and Resource Report*, http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

⁷⁴ “Metro’s 2016 Energy and Resource Report.” Los Angeles County Metropolitan Transportation Authority. http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

- A new contract was enacted on July 1, 2011 to eliminate the disposal fees for anti-freeze. Thus, no disposal fees were incurred in 2012.⁷⁵

Due to capacity limitations, a more specific approach to valuing waste management benefits was not incorporated within the SROI model, however this represents a promising future aspect of the model, and will be explored in the future models section of this report.

LIQUID WASTE FROM ENERGY GENERATION

Electricity generation requires a significant amount of water for cooling, and this generates important unintended consequences.

Coal plants are notorious consumers of water, requiring between 70 to 180 billion gallons of water to cycle through the power plant for cooling purposes.⁷⁶ For plants with minimal pollution control and once-through cooling, systems consume an estimated 300 gallons/MWh, however, this can be up to 714 gallons/MWh for plants with advanced pollution control system and wet cooling towers.⁷⁷ Once the water has completed its cycle, it is reintroduced back into the lake, river or ocean, however because it is circulating through a hot system, the water that is released is above typical surface water systems.⁷⁸ This creates ‘thermal pollution’ which can decrease fertility and increase heart rates in fish.⁷⁹

Hydraulic fracturing, the leading method for natural gas extraction in the US, is built upon a highly water-intensive removal process which consequently produces billions of gallons of wastewater.⁸⁰ The mixing of this water with other chemicals contaminates it, preventing its return to the environment.⁸¹

⁷⁵ “Metro’s 2016 Energy and Resource Report.” *Los Angeles County Metropolitan Transportation Authority*.

http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

⁷⁶ “Environmental impacts of coal power: Wastes Generated.” *Union of Concerned Scientists*, www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/waste#.WCCkD_krLmY

⁷⁷ “Water Use and Nuclear Power Plants.” *Nuclear Energy Institute*. November 2013, www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Water-Use-and-Nuclear-Power-Plants

⁷⁸ “Environmental impacts of coal power: Wastes Generated.” *Union of Concerned Scientists*, www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/waste#.WCCkD_krLmY

⁷⁹ “Environmental impacts of coal power: Wastes Generated.” *Union of Concerned Scientists*, www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/waste#.WCCkD_krLmY

⁸⁰ “Environmental Impacts of Natural Gas.” *Union of Concerned Scientists*, www.ucsusa.org/clean_energy/our-energy-choices/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas.html#.WCCqnvkrLmY

⁸¹ “Environmental Impacts of Natural Gas.” *Union of Concerned Scientists*, www.ucsusa.org/clean_energy/our-energy-choices/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas.html#.WCCqnvkrLmY

Nuclear is fundamentally dependent on internal cooling, a system that consumes an estimated 400 gallons/MWh with once-through cooling, and 720 gallons/MWh with wet cooling towers.⁸² This trumps the above-mentioned sources of electricity. Although nuclear doesn't consume high volumes of freshwater, it is cycled through the plant and returned back to the ecosystem at a higher temperature, which also creates thermal pollution.⁸³

Despite these externalities, the wastewater from energy generation is does not fall within the scope of this model. The integration of broader waste implications, such as looking at waste generated per energy source is a future consideration of the model.

WATER

The Los Angeles Department of Water and Power (LADWP) is the major provider of Metro's water consumption, sourcing the majority of their water from Sierra Nevada and Bay Area aqueducts (see Appendix 4 for all of LA County's water sources).⁸⁴ In 2015, LA Metro spent approximately \$6.76 per thousand gallons of LADWP as seen in Figure 9, which totaled over \$1.8 million. Such an expenditure was a departure from pre-2014 consumption expenses, as a result of alternate bus washing schedules that were implemented in 2014, generating a reduction in water consumption by 27%.

Going forward, the cost of water will still be a point of concern given the expected water price increases (please see Figure 9 and Appendix 6).⁸⁵ Exacerbating this, the service range for Metro is growing along with absolute consumption. This will further incentivize water conservation and efficiency measures in the near future.

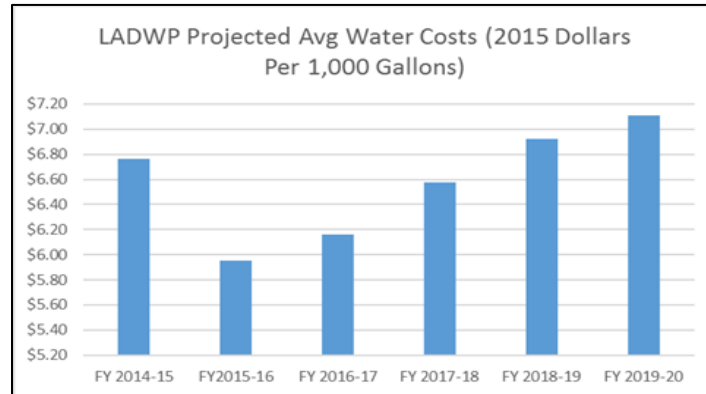
⁸² "Water Use and Nuclear Power Plants." *Nuclear Energy Institute*. November 2013, www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Water-Use-and-Nuclear-Power-Plants

⁸³ "Environmental impacts of coal power: Wastes Generated." *Union of Concerned Scientists*, www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/waste#.WCCkD_krLmY

⁸⁴ "Facts & Figures." LADWP. https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-factandfigures?_adf.ctrl-state=5avlyuyvl_4&_afLoop=395738708774768

⁸⁵ Ibid.

Figure 9. LA Department of Water and Power Projected Costs



LA Metro is pursuing several measures to advance water savings. Such measures represent financial, environmental, and social savings, and therefore are points of interest within the SROI model. Many water savings benefits are realized within the project specific soft benefits section of the model such as in: addition of green space; smart landscaping; rainwater capture; use of permeable temporary pavement; paved surface reduction; water recycling; wastewater infrastructure displacement.

In traditional ROI models the financial savings of water conservation and efficiency measures for water consumed are a function of the volume of water saved in a given year multiplied by the cost of water that year. While seemingly straightforward, there are a few caveats to this approach. Firstly, LA Metro only recorded usage from their major supplier, LADWP, between 2008 and 2011, and only began including other water sources to their total beginning in 2012 (see Figure 8). Second, LA Metro has been expanding services for the past several years and has measures projected for upcoming years. These factors considered, measuring absolute consumption may miss relative savings as consumption is rising with an expanding transit service area rather than because of less efficient equipment and services. When exploring savings opportunities, it is important to look at the components that are influencing overall consumption.

Figure 10. LA Metro Annual Water Consumption (million gallons)⁸⁶

	2008	2009	2010	2011	2012	2013	2014	2015
LA Metro LADWP-only:	250	227	236	238	300	<350	250	N/A
Total Water suppliers ⁸⁷	N/A	N/A	N/A	N/A	360	407	298	265

SOFT METRICS

As mentioned, the mode has an input section that describes project features, and the user is to select all of the 24 different attributes that apply. Based on these responses, feature specific soft benefits are provided. The 24 project features are as follows.

REDUCED NUMBER OF VEHICLES USING DIESEL

- Reduced Diesel Particulate Matter (PM)
 - Diesel PM includes known carcinogens, such as benzene and formaldehyde, and more than 50% of these particles are classified as ‘ultrafine’, which are particularly dangerous because they have a heightened penetrability in the lungs because of their size.⁸⁸ In particular, people that live or work near heavily traveled roadways, ports, rail yards, bus yards, or trucking distribution centers experience high exposure to these particles which makes them more vulnerable to health adversities like lung cancer.⁸⁹ A study of U.S. workers in the trucking industry found the longer an employee was working in the industry, the higher their risk for lung cancer was.⁹⁰ This same relationship was seen among railroad workers, whom showed a 40% increased risk of lung cancer.⁹¹ Diesel PM can lead to increased hospital visits and admissions due to worsening asthma, emphysema-

⁸⁶Each year’s consumption taken from the successive year’s Metro Energy and Resource Report.

⁸⁷Includes: Pasadena Water and Power (PWP), California Water Services, Park Water Company, Golden State Water Company.

⁸⁸United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

⁸⁹ Ibid.

⁹⁰ Ibid.

⁹¹ Ibid.

related symptoms and increase blood pressure, and can promote other potential triggers of heart attack and stroke.⁹² Studies of both men and women demonstrate cardiovascular effects of diesel PM exposure, including coronary vasoconstriction and premature death from cardiovascular disease.⁹³

INCREASED NUMBER OF VEHICLES OPERATING ON COMPRESSED NATURAL GAS / LIQUEFIED NATURAL GAS

- Reduced Diesel Particulate Matter (PM)
 - Diesel PM includes known carcinogens, such as benzene and formaldehyde, and more than 50% of these particles are classified as ‘ultrafine’, which are particularly dangerous because they have a heightened penetrability in the lungs because of their size.⁹⁴ In particular, people that live or work near heavily traveled roadways, ports, rail yards, bus yards, or trucking distribution centers experience high exposure to these particles which makes them more vulnerable to health adversities like lung cancer.⁹⁵ A study of U.S. workers in the trucking industry found the longer an employee was working in the industry, the higher their risk for lung cancer was.⁹⁶ This same relationship was seen among railroad workers, whom showed a 40% increased risk of lung cancer.⁹⁷ Diesel PM can lead to increased hospital visits and admissions due to worsening asthma, emphysema-related symptoms and increase blood pressure, and can promote other potential triggers of heart attack and stroke.⁹⁸ Studies of both men and women demonstrate cardiovascular effects of diesel PM exposure, including coronary vasoconstriction and premature death from cardiovascular disease.⁹⁹
- Reduced Carbon Dioxide Emissions
 - Reduced CO₂ emissions decreases the amount of greenhouse gases emitted into the atmosphere. The increased concentration of anthropogenically produced

⁹² Ibid.

⁹³ Ibid.

⁹⁴United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

⁹⁵ Ibid.

⁹⁶ Ibid.

⁹⁷ Ibid.

⁹⁸ Ibid.

⁹⁹ Ibid.

greenhouse gases in the atmosphere has been accepted among international scientists to be a highly contributing to the global warming trend experienced.¹⁰⁰

- Reduced Volatile Organic Compound (VOC) Emissions
 - Increased concentrations of VOCs increase the level of ground ozone, a photochemical oxidant and precursor for smog.¹⁰¹ Consequences of smog include lung irritation, inflammation and exacerbation of existing chronic conditions, which can be seen at even low exposures.¹⁰² Smog ultimately increases the amount of medical attention required per capita.
- Reduced Nitrous Oxide (NO_x) Emissions
 - Aquatic environments are particularly sensitive to nitrogen, a key nutrient for plant growth.¹⁰³ The incorporation of exaggerated amounts of nitrogen from acidic rainfall in an aquatic system can impede the ecosystem balance, functionality, and cause eutrophication.^{104,105}
 - Nitrogen oxide emissions contribute to the greenhouse effect. Nitrous oxides have a warming potential 265–298 times stronger than CO₂, and are thus a strong contributing pollutant to the global warming trend experienced around the world.¹⁰⁶
- Reduced Sulfur Oxide (SO_x) Emissions
 - SO_x are a family of toxic pollutants that easily transition between different compounds.¹⁰⁷ SO₂ easily dissolves in water to form sulfurous acid.¹⁰⁸ Though innately toxic, SO₃ is moisture-loving compound and readily forms acid rain with the combination of atmospheric moisture.¹⁰⁹ The precipitation of this compound, and the addition of sulfurous acid into water systems can alter the pH of aquatic

¹⁰⁰ *Global Climate Change: Facts, Causes*: National Aeronautics and Space Administration, December 8, 2016.

<http://climate.nasa.gov/causes/>. Accessed November 2016.

¹⁰¹ "What is CNG?" *CNG Now!*, 2016. Nov. 2016. <http://www.cngnow.com/what-is-cng/clean/Pages/information.aspx>.

¹⁰² *Ibid.*

¹⁰³ United States, Environmental Protection Agency, Clean Air Technology Center. *Nitrogen Oxides (NO_x), Why and How They Are Controlled*. November 1999.

¹⁰⁴ United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹⁰⁵ *Ibid.*

¹⁰⁶ "Understanding Global Warming Potentials." EPA. Environmental Protection Agency, 9 Apr. 2016. Web. 11 Nov. 2016. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>

¹⁰⁷ Government of Canada. Environment and Climate Change Canada. *Sulphur Oxides – SO_x*. 7 Jul. 2013. Nov. 2016. <https://www.ec.gc.ca/air/default.asp?lang=En&n=BBB2123F-1>. Accessed November 2016.

United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹⁰⁸ *Ibid.*

¹⁰⁹ *Ibid.*

environments, another sensitive aspect of aquatic ecosystem health.¹¹⁰ The ease in which SO_x can combine with other gases and particles in the atmosphere makes the range of harmful impacts quite broad.¹¹¹

INCREASED THE NUMBER OF VEHICLES OPERATING ON CLEAN FUEL

- Reduced Ground Ozone
 - Ground ozone creates a photochemical oxidant and precursor for smog, the consequences of which includes lung irritation, inflammation and exacerbation of existing chronic conditions, and can be seen at even low exposures.¹¹² Smog ultimately increases the amount of medical attention required per capita.
- Less Ambient Ozone
 - Ambient ozone is attributed to premature mortality.¹¹³
- Reduced Particulate Matter (PM)
 - Less ozone reduces the number of hospital visits experienced per capita. Rates of asthma hospitalization for children have been found to increase during warm seasonal episodes of high ozone concentration.¹¹⁴ Additionally, a relationship between ozone and both cardiovascular and respiratory emergency room visits during spring and summer months when ambient ozone concentrations are highest has been found.¹¹⁵
- Reduced Fine Particulate Matter (PM_{2.5})
 - Exposure to PM_{2.5} causes numerous adverse health effects, including heart and lung disease, increased hospital admissions for respiratory and cardiovascular diseases, premature death after long-term exposure, and decreased lung function and pulmonary inflammation due to short term exposures.¹¹⁶ A relationship between increased PM_{2.5} concentrations and an increased risk of stroke has also been shown, and it has been found that PM_{2.5} contributes to substantial mortality across California.¹¹⁷

¹¹⁰ "Sulphur Oxides – SO_x." *Government of Canada*. Environment and Climate Change Canada. 7 Jul, 2013.

<https://www.ec.gc.ca/air/default.asp?lang=En&n=BBB2123F-1>. Accessed November 2016.

¹¹¹ Ibid.

¹¹² United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹¹³ Ibid.

¹¹⁴ Ibid.

¹¹⁵ Ibid.

¹¹⁶ Ibid.

¹¹⁷ Ibid.

INCREASED NUMBER OF VEHICLES OPERATING ON ELECTRICITY

- Zero Particulate Matter (PM) Emissions
 - Less ozone reduces the number of hospital visits experienced per capita. Rates of asthma hospitalization for children have been found to increase during warm seasonal episodes of high ozone concentration.¹¹⁸ Additionally, a relationship between ozone and both cardiovascular and respiratory emergency room visits during spring and summer months when ambient ozone concentrations are highest has been found.¹¹⁹
 - Reductions in PM 2.5 cause reduced hospital visits. This is because PM2.5 causes numerous adverse health effects, including heart and lung disease; increased hospital admissions for respiratory and cardiovascular diseases; premature death after long-term exposure; decreased lung function and pulmonary inflammation due to short-term exposures.¹²⁰ Association between increased PM2.5 concentrations and an increased risk of stroke have been observed, and PM2.5 has been found to contribute to substantial mortality across California.
- Reduced Carbon Dioxide Emissions
 - Reduced CO₂ emissions decreases the amount of greenhouse gases emitted into the atmosphere. The increased concentration anthropogenically produced greenhouse gases in the atmosphere has been accepted among international scientists to be a highly contributing to the global warming trend experienced.¹²¹
- Reduced Nitrous Oxide (NO_x) Emissions
 - Aquatic environments are particularly sensitive to nitrogen, a key nutrient for plant growth.¹²² The incorporation of exaggerated amounts of nitrogen from acidic rainfall in an aquatic system can impede the ecosystem balance, functionality, and cause eutrophication.¹²³
 - Nitrogen oxide emissions contribute to the greenhouse effect. Nitrous oxides have a warming potential 265–298 times stronger than CO₂, and are thus a strong contributing pollutant to the global warming trend experienced around the world.¹²⁴

¹¹⁸ Ibid.

¹¹⁹ Ibid.

¹²⁰ Ibid.

¹²¹ Ibid.

¹²² United States, Environmental Protection Agency, Clean Air Technology Center. *Nitrogen Oxides (NO_x), Why and How They Are Controlled*. November 1999.

¹²³ Ibid.

¹²⁴ "Understanding Global Warming Potentials." EPA. Environmental Protection Agency, 9 Apr. 2016. Web. 11 Nov. 2016. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>

- Reduced Sulfur Oxide (SO_x) Emissions
 - SO_x are a family of toxic pollutants, which easily transition between different compounds.¹²⁵ SO₂ easily dissolves in water to form sulfurous acid.¹²⁶ Though innately toxic, SO₃ is moisture-loving compound and readily forms acid rain with the combination of atmospheric moisture.¹²⁷ The precipitation of this compound, and the addition of sulfurous acid into water systems can alter the pH of aquatic environments, another sensitive aspect of aquatic ecosystem health.¹²⁸ The ease in which SO_x can combine with other gases and particles in the atmosphere makes the range of harmful impacts quite broad.¹²⁹

SMART LANDSCAPING

- Reduced Fertilizers and Pesticides
 - Less fertilizers and pesticides are needed in smart landscaping due to natural erosional buffers and nutrient mechanisms.¹³⁰ This reduces groundwater contamination potential and a reduced risk of drinking water contamination and eutrophication.¹³¹
 - Reduced risk of elevated levels of nitrates in drinking water have been linked to methemoglobinemia (blue baby syndrome), and may be associated with birth defects and miscarriages.¹³² Reduced fertilizers and pesticides also reduce the risk of perchlorate exposure, of which 20% is through drinking water.¹³³ If exposure occurs while pregnant, thyroid hormone levels in newborns can be altered which may disrupt normal development.¹³⁴ Additionally, a study of bladder cancer in the U.S. touched on the potential role of low-level pesticide contamination in drinking water in these elevated levels of bladder cancer.¹³⁵

¹²⁵ Government of Canada. Environment and Climate Change Canada. *Sulphur Oxides – SO_x*. 7 Jul. 2013. Nov. 2016. <https://www.ec.gc.ca/air/default.asp?lang=En&n=BBB2123F-1>. Accessed November 2016.

¹²⁶ Ibid.

¹²⁷ Ibid.

¹²⁸ Ibid.

¹²⁹ Ibid.

¹³⁰ United States. Environmental Protection Agency, WaterSense. *Water-Smart Landscapes: Start with WaterSense*. July 2013. https://www3.epa.gov/watersense/docs/water-efficient_landscaping_508.pdf. Accessed November 2016.

¹³¹ Ibid.

¹³² United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹³³ Ibid.

¹³⁴ Ibid.

¹³⁵ Ibid.

- Reduced Water Usage
 - Reduced water spending due to reduced water use.
- Improved Conservation
 - Conservation of natural resources and preservation of habitat for plants and wildlife is facilitated by building on natural coupling of organisms and their varieties.¹³⁶
- Reduced Energy Expenditure
 - Decreased energy use because of lower water demand, and therefore the pumping and treatment that accompanies such demand.¹³⁷ This is important as water-related energy use in California consumes approximately 20% of the state's electricity, and 30% of the state's non-power plant natural gas.¹³⁸
- Improved Water Capture
 - Improved water capture reduces runoff of storm water and irrigation water that carries topsoils, fertilizers, and pesticides into lakes, rivers, and streams. This reduced runoff limits the pressure on the city's aging wastewater infrastructure and eliminates expansion and replacement costs.
 - Improved water capture reduces runoff, which poses a risk of contamination to neighboring water bodies, of ecosystem damage, of damage to social fabric and economic losses from reduces recreational utility of these water bodies.¹³⁹
- Cost Savings
 - Playing to the natural conditions and symbiosis of the flora and fauna, there are reduced landscaping labor and maintenance costs associated with smart landscaping.¹⁴⁰
- Improved Efficiency from Natural Co-benefits
 - Extended life for water resource infrastructure (e.g., reservoirs, treatment plants, groundwater aquifers) because of reduced water demand and surface runoff, which in turn, reduces the pressure on the city's aging wastewater infrastructure and eliminates expansion and replacement costs.

¹³⁶ United States. Environmental Protection Agency, WaterSense. *Water-Smart Landscapes: Start with WaterSense*. July 2013. https://www3.epa.gov/watersense/docs/water-efficient_landscaping_508.pdf. Accessed November 2016.

¹³⁷ Ibid.

¹³⁸ CA The Resources Agency Department of Water Resources. "Managing an Uncertain Future."

¹³⁹ October 2008 <http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf> (Last visited November 27, 2016).

¹⁴⁰ United States. Environmental Protection Agency, WaterSense. *Water-Smart Landscapes: Start with WaterSense*. July 2013. https://www3.epa.gov/watersense/docs/water-efficient_landscaping_508.pdf. Accessed November 2016.

MORE DIRECT TRANSIT PATHWAYS

- Reduced VMT
 - Increased public transit accessibility and efficiency dissuades drivers from using own vehicles for travel.
 - Increased public transit accessibility and efficiency dissuades drivers from using side streets to avoid traffic jams which poses a risk to the safety of cyclists and pedestrians in the immediate areas as vehicle speed is directly associated with risk of pedestrian fatality.

IMPROVED CONNECTIVITY REACHES RIDERS WITH PREVIOUSLY LIMITED TRANSIT OPTIONS

- Improved Access to Jobs
 - With a greater access comes a greater access to jobs, improved job competition, and an increased pool of skilled labor available for hire.¹⁴¹ This has been shown to increase economic stimulus improved salaries.¹⁴²

REDUCED VEHICLE MILES TRAVELED

- Reduced Exposure to Poor Air Quality from Vehicle Transit
 - Exposure to air pollutants from vehicle emissions has been linked to adverse birth outcomes, such as low birth weight and preterm births, and a recent study of children in Los Angeles found that children with the highest prenatal exposure to traffic- related pollution were up to 15% more likely to be diagnosed with autism than children of mothers in the lowest quartile of exposure.¹⁴³ Motor vehicle exhaust is also a major source of polycyclic aromatic hydrocarbons, which has been found to damage DNA has potential links to cancer generation.¹⁴⁴

¹⁴¹ Nelson, Arthur C., Anderson, Jeffery, Barthaolomew, Keith, Perlich, Pamela, Sanchez, Thomas W., Ewing Reid." *The Best Stimulus for the Money: Briefing Papers on the Economics of Transportation Spending*. Issue brief. Smart Growth America, Apr. 2009. Web. Nov. 2016. <https://www.smartgrowthamerica.org/app/legacy/documents/thebeststimulus.pdf>

¹⁴² Ibid.

¹⁴³ United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹⁴⁴ Ibid.

WASTE DIVERSION

- Reduced Use of Waste Storage Tanks
 - A reduced dependence on storage tanks reduces the risk of groundwater contamination and soil contamination from leakage. Common groundwater pollutants found at such tanks and other similar cleanup sites in California include gasoline and diesel fuels, chlorinated solvents, other VOCs such as benzene, toluene, and methyl tert-butyl ether, heavy metals such as lead, chromium and arsenic, polycyclic aromatic hydrocarbons, persistent organic pollutants like polychlorinated biphenyls, DDT and other insecticides, and perchlorate.¹⁴⁵ All of these compounds are highly toxic to humans in concentrated doses.¹⁴⁶

RECYCLING RECEPTACLES

- Improved Waste Diversion
 - Diversion from landfills reduces the risk of groundwater contamination and soil contamination from leakage. Common groundwater pollutants found at such tanks and other similar cleanup sites in California include gasoline and diesel fuels, chlorinated solvents, other VOCs such as benzene, toluene, and methyl tert-butyl ether, heavy metals such as lead, chromium and arsenic, polycyclic aromatic hydrocarbons, persistent organic pollutants like polychlorinated biphenyls, DDT and other insecticides, and perchlorate.¹⁴⁷ All of these compounds are highly toxic to humans in concentrated doses.¹⁴⁸
- Improved Profitability
 - Greater opportunity for increased profitability of public-private waste management partnerships by increasing the amount siphoned to processing and buy back.

¹⁴⁵ Ibid.

¹⁴⁶ Ibid.

¹⁴⁷ United States, Environmental Protection Agency. *Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Final Rule*. Federal Register, 2015. Vol. 80, No. 205.

¹⁴⁸ "The Priority List of Hazardous Substances That Will Be Candidates for Toxicological Profiles." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 12 Feb. 2016. Nov. 2016. <https://www.atsdr.cdc.gov/spl/>.

NEW CONSTRUCTION/O&M JOBS

- Job Creation from Operation and Maintenance of a Project
 - Job creation will increase income and thus purchasing power within communities, as well as increase economic growth due to increased income.¹⁴⁹

EXISTING INFRASTRUCTURE EFFICIENCY AND QUALITY IMPROVEMENTS

- Improved Land Efficiency
 - Reduced land repurposing and alteration which preserves the natural, or existing-use conditions of land; recycling and reuse of resources.

WALKING PATHS

- Improved Community Health
 - Walking paths encourage an active lifestyle, which is critical in combatting obesity-related illnesses; this ultimately impacts the number of hospital visits per capita.¹⁵⁰
- Improved Community Cohesion
 - Improved community cohesion is experience by increased common space for community engagement and interaction.¹⁵¹ These spaces also improve property value because of improved neighborhood connections, and is further amplified if these spaces are complemented by a green space.¹⁵² In some cases, this even increases economic development due to increased pedestrian traffic.¹⁵³

¹⁴⁹ Nelson, Arthur C., Anderson, Jeffery, Barthaolomew, Keith, Perllich, Pamela, Sanchez, Thomas W., Ewing Reid." *The Best Stimulus for the Money: Briefing Papers on the Economics of Transportation Spending*. Issue brief. Smart Growth America, Apr. 2009. Web. Nov. 2016. <https://www.smartgrowthamerica.org/app/legacy/documents/thebeststimulus.pdf>

¹⁵⁰ American Trails. *Economic Benefits of Trails*. <http://www.americantrails.org/resources/economics/economic-benefits-trails-macdonald.html>. Accessed November 2016.

¹⁵¹ Ibid.

¹⁵² Ibid.

¹⁵³ Ibid.

GREEN SPACE

- Improved Community Cohesion
 - Improved community cohesion is experience by increased common space for community engagement and interaction.¹⁵⁴ These spaces also improve property value because of improved neighborhood connections. In some cases, this even increases economic development due to increased pedestrian traffic.¹⁵⁵
- Psychological Benefits
 - Psychological benefits are attributed to reduced noise pollution that typically accompanies green spaces that spare the physical environment construction and motor vehicle noises.¹⁵⁶
- Reducing Urban Heat
 - Benefit of the cooling properties of green spaces through their shade, solar radiation deflection, and release of moisture in the air.¹⁵⁷
- Reduced Heat Island Effect
 - A reduction in paved areas results in lower heat absorption and thus helps to reduce the heat island effect. The EPA states “research shows that electricity demand for cooling increases 1.5–2.0% for every 1°F (0.6°C) increase in air temperatures, starting from 68 to 77°F (20 to 25°C), suggesting that 5–10% of community-wide demand for electricity is used to compensate for the heat island effect.”¹⁵⁸
- Carbon Sinks
 - Trees act as natural carbon sinks because they absorb more carbon than they release as carbon dioxide, and therefore assist in offsetting greenhouse gas emissions into the atmosphere.¹⁵⁹
- Reduced Storm Water Effects
 - The absorptive capacity of green spaces greatly exceeds that of paved areas, and thus reduce the amount of runoff and normalize water runoff rates.¹⁶⁰ Within

¹⁵⁴ Ibid.

¹⁵⁵ Ibid.

¹⁵⁶ Jabr, Ferris. “Why Your Brain Needs More Downtime.” *Scientific American*. Nature America, 15 Oct. 2013. Web. Oct. 2016. <https://www.scientificamerican.com/article/mental-downtime/>

¹⁵⁷ United States. Environmental Protection Agency. *Reduce Urban Heat Island Effect*. November 18, 2016.

<https://www.epa.gov/green-infrastructure/reduce-urban-heat-island-effect>. Accessed November 2016.

¹⁵⁸ USEPA (2011), Heat Island Effect, U.S. Environmental Protection Agency (www.epa.gov); atwww.epa.gov/heatisld. (Last Accessed November, 19, 2016).

¹⁵⁹ Fer. *Making the EU work for people and forests*. 2016. <http://www.fern.org/campaign/forests-and-climate/what-are-carbon-sinks>. Accessed November 2016.

storm water runoff, contaminants are often incorporated and can introduce impurities and pollution into other water bodies causing ecosystem damage, and reduced usability of water bodies.¹⁶¹ Depending on the functionality of the water body, this can impact the overall profitability of the resource. As well, the reduced runoff limits the pressure on the city's aging wastewater infrastructure and eliminates expansion and replacement costs.

CYCLING PATHS

- Improved Community Health
 - Cycling paths encourage an active lifestyle, which is critical in combatting obesity-related illnesses; this ultimately impacts the number of hospital visits per capita.¹⁶²

INCREASED ON-SITE BIKE STORAGE/ BIKE SHARING

- Improved Community Health
 - Increased on-site bike storage/bike sharing encourages an active lifestyle, which is critical in combatting obesity-related illnesses; this ultimately impacts the number of hospital visits per capita.¹⁶³

¹⁶⁰ Gittleman, Mara, Carson J. Q. Farmer, Peleg Kremer and Timon Mcpheason. "Estimating stormwater runoff for community gardens in New York City." *Urban Ecosystems* (2016): n.p., Web.

¹⁶¹ *National Service Center for Environmental Publications*. Rep. United States Environmental Protection Agency, 1999. Web. Oct. 2016.

<https://nepis.epa.gov/Exe/ZyNET.exe/9100PXC1.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1995+Thru+1999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C95thru99%5CTxt%5C00000029%5C9100PXC1.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL>

¹⁶² American Trails. *Economic Benefits of Trails*. <http://www.americantrails.org/resources/economics/economic-benefits-trails-macdonald.html>. Accessed November 2016.

¹⁶³ Ibid.

IMPROVED COMMUNITY LIGHTING

- Improved Community Safety and Lowers Crime Rates
 - Some studies have shown improved community lighting has reduced crime up to 7% because with improved visibility, potential offenders are more exposed and less likely to commit crimes.¹⁶⁴ Additionally, enhanced lighting can indicate greater community investment, pride, and cohesiveness, which has the potential to discourage crime.¹⁶⁵

RAINWATER RECAPTURE

- Cost Savings
 - Improved reuse efficiency lowers the expenditure of water purchasing, and generates cost savings. It also reduces energy use which is important considering water-related energy use in California consumes approximately 20% of the state's electricity, and 30% of the state's non-power plant natural gas.¹⁶⁶
- Improved Operational Independence
 - In the event of drought conditions, on-site water storage from recapture is important for resiliency and disaster preparedness.

PERMEABLE TEMPORARY PAVEMENTS

- Reduced Storm Water Runoff
 - Reduced storm water runoff allows for water percolation, which reduces outflow and normalizes water runoff rates.¹⁶⁷ Within storm water runoff, contaminants are often incorporated and can introduce impurities and pollution into other water bodies causing ecosystem damage, and reduced usability of water

¹⁶⁴ Moore, Eli, Prakash Swati, Garzon Catalina, Hernandez Cristina, McNeil Leonard, Perez Carla, Smith, Carla, Vanderwarker, Amy, Violich, Carmen. "MEASURING WHAT MATTERS: NEIGHBORHOOD RESEARCH FOR ECONOMIC AND ENVIRONMENTAL HEALTH AND JUSTICE IN RICHMOND, NORTH RICHMOND, AND SAN PABLO." PACIFIC INSTITUTE. THE PACIFIC INSTITUTE, MAY 2009. WEB. NOV. 2016. <http://pacinst.org/publication/measuring-what-matters/>

¹⁶⁵ Ibid.

¹⁶⁶ CA The Resources Agency Department of Water Resources. "Managing an Uncertain Future." October 2008 <http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf> (Last visited November 27, 2016).

¹⁶⁷ Metropolitan Area Planning Council. *Fact Sheet: Permeable Paving*. February 10, 2010. <http://www.mapc.org/resources/low-impact-dev-toolkit/permeable-paving>. Accessed November 2016.

bodies.¹⁶⁸ Depending on the functionality of the water body, this can impact the overall profitability of the resource. As well, the reduced runoff limits the pressure on the city's aging wastewater infrastructure and eliminates expansion and replacement costs.

- Groundwater recharge
 - The permeability of such pavement allows for water to percolate through the pavement and ground soil to reach the water table.¹⁶⁹ This is necessary for groundwater and aquifer recharge, which is a critical aspect for water sustainability and resiliency.
- Filtration
 - Permeable pavements act like a filter, which excludes certain pollutants from entering the water table and contaminating groundwater.¹⁷⁰

REDUCED AMOUNT OF SURFACE PAVED

- Reduced Storm Water Runoff
 - Reduced storm water runoff allows for water percolation, which reduces outflow and normalizes water runoff rates.¹⁷¹ Within storm water runoff, contaminants are often incorporated and can introduce impurities and pollution into other water bodies causing ecosystem damage, and reduced usability of water bodies.¹⁷² Depending on the functionality of the water body, this can impact the overall profitability of the resource. As well, the reduced runoff limits the pressure on the city's aging wastewater infrastructure and eliminates expansion and replacement costs.
- Reduced Storm Water Runoff
 - Reduced paved surface encourages greater water to percolate through the pavement and ground soil to reach the water table.¹⁷³ This is necessary for groundwater and aquifer recharge, which is a critical aspect for water sustainability and resiliency. As well, the reduced runoff limits the pressure on the

¹⁶⁸ Ibid.

¹⁶⁹ Ibid

¹⁷⁰ Ibid

¹⁷¹ Metropolitan Area Planning Council. *Fact Sheet: Permeable Paving*. February 10, 2010. <http://www.mapc.org/resources/low-impact-dev-toolkit/permeable-paving>. Accessed November 2016.

¹⁷² Ibid.

¹⁷³ Ibid.

city's aging wastewater infrastructure and eliminates expansion and replacement costs.

- Reduced Heat Island Effect
 - A reduction in paved areas results in lower heat absorption and thus helps to reduce the heat island effect. The EPA states “research shows that electricity demand for cooling increases 1.5–2.0% for every 1°F (0.6°C) increase in air temperatures, starting from 68 to 77°F (20 to 25°C), suggesting that 5–10% of community-wide demand for electricity is used to compensate for the heat island effect.”¹⁷⁴

INCLUSION OF RECYCLED WATER IN OPERATIONS

- Cost Savings
 - Improved reuse efficiency lowers the expenditure of water purchasing, and thus generates cost savings.
- Prioritization of Potable Water
 - Reducing the demand for potable water for operations that do not require such high quality water allow for potable water to be diverted to more important uses.
- Reduced Wastewater Discharge
 - By recycling water, less treated water is discharge back into the environment, which reduces the need for chemical fertilizer as recycled water retains nutrients, and replenishes groundwater.
- Reduced Wastewater Discharge
 - All wastewater that enters a municipal water system has to be treated to a minimal level or purity before being reintroduced to the water cycle. By reusing water within operations, this reduced the treatment burden and the stress on such infrastructure.

¹⁷⁴USEPA (2011), Heat Island Effect, U.S. Environmental Protection Agency (www.epa.gov); at www.epa.gov/heatisld. (Last Accessed November, 19, 2016).

ADDED ENERGY TO THE GRID THROUGH SOLAR PANELS

- Energy Production
 - Installing solar panels allows for independent generation of energy which also helps to energize the grid, diversify the larger energy mix, and shift energy dependence away from non-renewables.

ACHIEVED ENERGY INDEPENDENCE THROUGH INDEPENDENT ENERGY SOURCES

- Cost Savings
 - Cost savings are generated through reduced energy expenditure due to reliance on internal energy sources to meet energy needs.

CASE STUDY: LA CNG BUS FLEET

As previously mentioned, the scope of this project included LA Metro's entire CNG bus fleet. Using the assumptions and hard metrics outlined in the preceding sections, an IRR of 35% with a MoER of 3.71x was found for the expected scenario. In addition, worse and best case scenarios were run to test the upper and lower bounds of the model. The best case was run at a lifetime of 17-years, discount factor of 3%, and emissions importance factor of 10, while the worst case was run at a lifetime of 10-years, discount factor of 7%, and emissions importance factor of 1. It's Important to note that even under worse case conditions the model returned an IRR of 26%. These results can be seen below in Figure 11.

Figure 11: SROI Findings for worse, expected, and best case scenarios

	Worse Case	Expected Case	Best Case
Lifetime (years)	10	14	17
Discount Factor	7%	4.5%	3%
Emissions Importance (1-10)	1	5	10
NPV	\$453,599,121	\$3,938,042,351	\$9,339,154,028
IRR	26%	35%	42%
MoER	2.92x	3.71x	4.36x

It should be noted that the emissions importance factor is heavily important in the outcome of the model. Therefore, it is understood limitations exist with a user preference determining a significant portion of the model. However, even under worse case conditions there is still tremendous value created – a net present value of over \$450 million. With continued refinement through further case study applications, the range incorporated into the emissions importance factor can be further honed.

PHASE 3: CHALLENGES

Oriented with a thorough understanding of LA Metro’s sustainability considerations and material issues, as well as an understanding of the importance of the localized context needed to create a thoughtful and robust sustainable return on investment figure, the project initially attempted to use the Orange Bus Rapid Transit Line as a case study for the SROI model. With a targeted route, the localized implications of the project could be incorporated into the model’s findings, and could reflect the marginalized benefits of the Orange Line.

Due to the informational constraints, time limitations, and capacity restraints, the Orange Line case study could not be incorporated into the SROI model. However, it still serves as an example of the monetization capacity of the project at hand.

ORANGE LINE BUS RAPID TRANSIT SYSTEM

The Metro Orange Line Bus Rapid Transit (BRT) service began operations in October 2005 as one of the first full-service BRT lines in the U.S. and the first exclusive busway in LA.¹⁷⁵ It was the culmination of more than 20 years of planning for rapid transit in the San Fernando Valley as a

¹⁷⁵ "Metro Orange Line B R T Project Evaluation, Columbia Demonstration ..." 2016. Accessed 28 Nov. 2016
<https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

solution for rapidly increasing travel demand and congestion. This strategy sought to provide premium, high-capacity rapid transit at a lower cost than light rail or subway lines.

The capital cost of the Orange Line was \$324 million in 2004 dollars, or \$23.1 million per mile.¹⁷⁶ The majority of the project costs were funded by state and local funds, while the recreational paths were paid for using federal funds.¹⁷⁷ Over the years, the line has become one of the nation's most successful BRT lines, accommodating over 74 million boardings in the last decade.¹⁷⁸ The 14.5-mile long Orange Line has 14 stations and runs through the San Fernando Valley to the Red Line subway in North Hollywood (please see Fig. 12).¹⁷⁹ The Orange Line uses a fleet of 60-foot articulated buses that run on compressed natural gas (CNG) and runs almost entirely along a two-lane, dedicated busway.

During the initial construction phase of the Orange Line, extensive native drought-tolerant landscaping along the corridors, and a bicycle and pedestrian path parallel to the busway, was initiated. The line is designed to emulate a light rail line in urban design-with canopied platforms, real time information, bicycle parking and automated fare collection machines- and the ability to bypass congestion delays.¹⁸⁰

Figure 12. Metro Orange Line Map



¹⁷⁶ "Metro Orange Line BRT Project Evaluation, Columbia Demonstration ..." 2016. 28 Nov. 2016
<https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

¹⁷⁷ "Metro Orange Line BRT Project Evaluation, Columbia Demonstration ..." 2016. 28 Nov. 2016
<https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

¹⁷⁸ "Metro Orange Line." 2015. Accessed 28 Nov. 2016 <<https://www.metro.net/projects/orangeline/>>

¹⁷⁹ "Metro Orange Line BRT Project Evaluation, Columbia Demonstration ..." 2016. Accessed 28 Nov. 2016
<https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

¹⁸⁰ "Metro Orange Line BRT Project Evaluation, Columbia Demonstration ..." 2016. 28 Nov. 2016
<https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

Using the Orange Line as a sample for evaluating localized benefits, analysis was completed which identified several project specific areas of benefit: water savings; job and opportunity creation; increase in property value; improved quality of life in terms of improved safety and connectivity; opportunity cost of time savings; and reduction in vehicular accidents. Please see Appendix 5 for a detailed explanation of the valuation of each metric.

WATER

La Metro is pursuing several measures to advance water savings. Specific to the Orange Line, the corridor along the traveled-way has installed a native and drought tolerant landscaping called xeriscape vegetation which has reduced Metro's irrigation needs.¹⁸¹ The Orange Line's North Hollywood Station is also one of the first to experiment with permeable temporary pavement that limits the amount of rainwater run-off.¹⁸² Additionally, in 2015 portions of the Orange Line began installation of recycled water lines and in 2016 this reclamation and reuse was explored as a separate purple-pipe recycled water line.¹⁸³

The water savings of the Orange Line represent a large portion of LA Metro's total water consumption, 28% in 2015, or 74.2 million gallons. While reduction of water use will directly lower costs, SROI savings will benefit the total LA metropolitan region. Calculations for LA Metro Orange Line serve as analysis that can be applied to determine benefits over the greater LA area.

JOB CREATION/ OPPORTUNITIES

One way to define growth stimulation is through job creation. In this case, to define the Orange Line's contribution to financial growth of the surrounding neighborhoods of Orange Line, the number of new jobs created from the Orange Line were assessed. This indicator was assessed by looking at the number of square footage added post-development of the Orange Line which was then quantified by determining the labor was needed for these developments (commercial and

¹⁸¹Chester, Mikhail. "Methodology for the Environmental Life-cycle Assessment of Los Angeles Metro's Orange Bus Rapid Transit and Gold Light Rail Transit Lines." Center for Earth Systems Engineering and Management, Arizona State University. July 2012: p.12.

¹⁸²LA Metro Energy and Resource Report 2016, p. 31.

¹⁸³ibid., p. 29.

residential looked at separately). More specifically, the total number of direct and indirect jobs created as a result of the Orange Line construction were identified. Direct jobs are relevant to the employees hired by the Orange Line and indirect jobs are those which stem from the employment and business revenues motivated by the construction of the Orange Line. The case study conducted by EconWorks looked at direct and indirect jobs created until 2012, and was used as a starting point for such calculations.¹⁸⁴

REAL ESTATE VALUE

There is an important link between public transit and economic development. Based on recent studies, cities with well-developed public transit systems attract business and commerce.¹⁸⁵ This trend was again validated in recent elections where many cities approved bond or sales tax measures to invest further in public transit systems. One of the most important impacts is how a new transit system changes travel, residential and business location decisions, and subsequently property values of nearby areas. Many economic studies based on empirical studies suggest that the arrival of public transit can change the amenities associated with a given set of neighborhoods.¹⁸⁶ Namely, residents who use the public transit system may enjoy reduced time traveling to work, shopping, and entertainment opportunities while businesses near a transit station can face lower costs and increased foot traffic. Thus, it is often assumed that properties located near a station enjoy a premium over those farther from public transit. Some property owners may suffer a penalty from the nuisance effects of a rail system, but the net impact on the relevant residential property market should be positive.¹⁸⁷

REDUCED CRIME

One way to measure quality of life is through safety. In this case, safety numbers related to the mass public transportation system of LA Metro were assessed. Being the newest line along with the gold line, the Orange Line has better security measures when compared to older lines, such

¹⁸⁴ "Project: Orange Line BRT - View Case Study | AASHTO." 2016. Accessed on 27 Nov. 2016

<https://planningtools.transportation.org/290/view-case-study.html?case_id=153>

¹⁸⁵ Nelson, Arthur C., Anderson, Jeffery, Barthaolomew, Keith, Perlich, Pamela, Sanchez, Thomas W., Ewing Reid." *The Best Stimulus for the Money: Briefing Papers on the Economics of Transportation Spending*. Issue brief. Smart Growth America, Apr. 2009. Web. Nov. 2016. <https://www.smartgrowthamerica.org/app/legacy/documents/thebeststimulus.pdf>

¹⁸⁶ Brown, AE. "Rubber Tires for Residents: Bus Rapid Transit and Changing ... - TRID." 2016.

<<https://trid.trb.org/view.aspx?id=1393978>>

¹⁸⁷ Cervero, R. "LA-value added3 - National Association of Realtors." 2002.

<[http://rodomino.realtor.org/smart_growth.nsf/docfiles/losangeles.pdf/\\$FILE/losangeles.pdf](http://rodomino.realtor.org/smart_growth.nsf/docfiles/losangeles.pdf/$FILE/losangeles.pdf)>

as additional cameras, more lighting, and open spaces. These measures help to reduce the number of crimes that take place in the public transportation system. To determine the societal economic benefits of having less public transportation related crimes the number of crimes taking place in the Orange Line area when compared to other LA Metro lines and buses was evaluated. The number of crimes, including vandalism, taking place in each line, increased the cost of per crime to the city.

For future financial benefits, LA Metro can determine the cost per crime to their organization specifically and multiply it by the number of crimes taking place in each line. This will provide an avoided cost for the orange line attributable to being safer than other lines—which could help justifies the investment on safety measures.

Overall crime shows to be very low on the Metro system, with most crimes involving theft. The Blue Line and Green Line have the highest crime rates — the Blue Line has 14.3 per million riders and the Green Line has 19.7 per million riders.

Figure 13 shows the number of crimes that took place in each LA Metro line during the first two quarters of 2011 as reported in the crime database maintained by Los Angeles Times using data from the LAPD and Sheriff's department. Part 1 crimes include homicide, rape/attempted rape, assault, robbery, burglary, grand theft and petty theft. Part 2 crimes include battery, lesser sex offenses, carrying illegal weapons and some types of narcotics crimes.

Figure 13. LA Metro Crime Summary July 2011

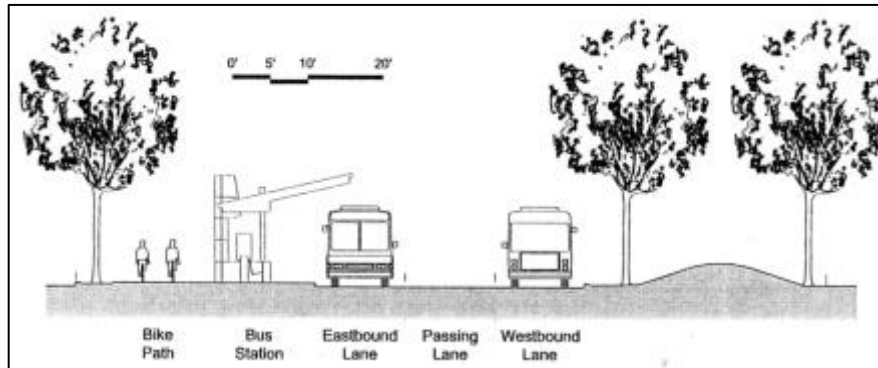
TRANSIT SERVICES SUMMARY JULY 2011						
	Blue Line	Green Line	Red Line	Gold Line	Orange Line	Bus
REPORTED CRIMES						
PART 1 CRIMES	28	27	13	2	2	38
PART 2 CRIMES	38	7	23	9	8	40
TOTAL (Except Vandalism)	66	34	36	11	11	78
REPORTED VANDALISM	21	5	3	2	3	19
ARRESTS						
TOTAL	349	149	178	82	83	194
CALLS FOR SERVICE						
TOTAL	386	128	247	77	52	851
CITATIONS						
FARE RELATED CITATIONS	2,087	655	1,801	880	647	9
OTHER CITATIONS	89	8	68	19	3	1
TRAFFIC CITATIONS	982	231	231	487	1,131	1,263
TOTAL CITATIONS ISSUED	3,068	895	2,106	1,806	1,581	1,273
FARE ENFORCEMENT						
RODERSHIP	2,428,171	1,165,062	4,529,229	1,110,868	891,179	27,914,188
FARE CHECKS	298,466	109,534	577,648	175,979	84,121	21,271
% OF PASSENGERS INSPECTED	12.26	19.56	12.34	15.79	16.92	6.88
BOARDING	7,614	1,896	11,267	3,596	3,496	6,916
RIDES	N/A	N/A	224	224	278	2,781
FARE WARNING	1,379	836	1,999	666	187	177

QUALITY OF LIFE: SAFETY AND CONNECTIVITY

One way to measure improved community mobility and access is to look into the contribution of the Orange Line to active transportation, which includes, in this case, biking and walking. This is achieved by LA Metro contributing to added bike lanes and pedestrian ways.

The Orange line also includes dedicated bike paths and greenery on one or both sides of the traveled way. The Class 1 bike paths are often separated from the road by roughly 20 to 60 feet of landscaping. Bike path construction energy and environmental effects are not allocated to the Orange line. The paths and greenery provide visual, aesthetic, community enhancement, and natural barriers. Primarily bicyclists, pedestrians, and the surrounding homes realize the benefits of these qualities. It is acknowledged by CESEM that the bike paths would not exist without the Orange line.

Figure 14. Orange Line Section at Topham Street



OPPORTUNITY COST OF TIME SAVINGS

One large social benefit of the Orange Line extension project is the overall net time savings for passenger travel. This is largely attributed to the Orange Line offering an alternative to those who would otherwise travel to their destination via individual vehicle or carpool travel. This time savings is valued by the passengers as a normal good as it can supplement either work or leisure time budgets. For the purpose of this study, the opportunity cost of time savings was calculated as an average hourly wage for LA County workers, where the main assumptions are that arriving to a destination sooner allows for more time to earn a wage. This methodology does not fully capture the time valuation for leisure ridership and it also makes the assumption that riders on the Orange Line have an equivalent average wage as LA County's average hourly wage.

The total net time savings for the Orange Line Extension is calculated by comparing the projected increase in Unlinked Passenger Trips (UPT) inclusive of the average travel times, with the total Vehicle Miles Traveled (VMT) and associated travel time, to determine the net annual difference in travel time. A main assumption for this segment of the analysis exists in the state of substitution between VMT and UPT, where it is assumed that a transit trip and vehicle trip achieve equivalent distances, when in actuality one mode of transportation may be more direct than the other.

The Federal Transit Administration's (FTA) total projected increase in UPT is approximately 9,000 trips by 2030¹⁸⁸. The FTA's research has further concluded that a time efficiency of 12 minutes per trip is achieved for travel into the San Fernando Valley via the Orange Line service (average of 43 minutes per trip) rather than driving (average of 55 minutes per trip). By extrapolating both UPT and projected time savings, it can be determined that a total of more than 660,000 hours would be saved each year from the 22% reduction in travel time. This figure, when multiplied by the average hourly wage as calculated for May 2015 by the Bureau of Labor Statistics¹⁸⁹ of \$59.81, yields a total annual opportunity cost of time savings of \$39.6M. While this valuation of opportunity cost of time savings may vary depending on how the input assumptions change over time, further provisions can be made to address time valuation concerns.

Arguably, there are other related factors that are not included in this figure that may also be currently unaccounted for. One such benefit is travel time reliability, which is not considered in the hard metric valuation model, can potentially be of higher value than passenger time savings¹⁹⁰. Travel time reliability represents the value that passengers have for a higher confidence in arrival time, where even if it were to take on average longer to travel on the bus than in a car, a passenger may prefer to take the mode that provides the most certainty in arrival time. For other analyses this particular soft metric factor may need to be quantified. For instance, if the Orange Line were to enhance to a light-rail service, which could subsequently provide greater arrival time confidence, this would be an important component of the SROI model.

VEHICULAR ACCIDENT AVOIDANCE

Another social benefit realized by the Orange Line extension project is the reduction in automobile accidents and related injuries and deaths as the service will act as a substitute for those who currently resort to driving.

¹⁸⁸ DOT - Federal Transit Administration. "Metro Orange Line BRT Project Evaluation." *FTA Research* (n.d.): n. pag. 5 Oct. 2011. Web. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf

¹⁸⁹ "Occupational Employment and Wages in Los Angeles-Long Beach-Glendale - May 2015: Western Information Office: U.S. Bureau of Labor Statistics." *U.S. Bureau of Labor Statistics*. U.S. Bureau of Labor Statistics, 26 July 2016. Web. 22 Nov. 2016. http://www.bls.gov/regions/west/news-release/occupationalemploymentandwages_losangeles.htm

¹⁹⁰ Tseng, Yin-Yen, Piet Rietveld, and Erik. "A Meta-analysis of Valuation of Travel Time Reliability." *Department of Spatial Economics, Vrije Universiteit Amsterdam* (n.d.): n. pag. 2004. Web. 22 Nov. 2016. http://www.cvs-congres.nl/cvspdfdocs/cvs05_105.pdf

In order to calculate the total benefit, it is first essential to understand the estimated reduction in Vehicle Miles Traveled (VMT) associated with the increased service on the Orange Line. Projections can then be made to support the number of avoided vehicular deaths based on current statistics. The model includes a calculation for the anticipated dollar value for deaths avoided and is calculated as follows.

The total number of deaths avoided due to a reduction in VMT is first based upon an assumption of how many vehicle trips are offset by the provided service. Based on a customer survey as reported in the FTA research paper for the Orange Line, 64% of riders would drive alone while the other 36% of riders would carpool if they were to have to drive instead of utilize the transit service¹⁹¹. This means that corresponding to an increase in ridership projection of 9,000 daily passengers, there would be a total of 7,380 reduced vehicle trips taken out of substitution. Based on research from Travel Behavior¹⁹² the average vehicle trip taken in LA County is approximately 8.1 miles in length. This projects that there are 21.8 million vehicle miles avoided each year due to this increased service. Furthermore, based on vehicular-related deaths occurring in California in 2014, there is an estimated 0.92 deaths per 100 million vehicle miles driven¹⁹³. By extrapolating these existing trends, it can be determined that an estimated 0.2 deaths per year will be avoided with a daily increased ridership of 9,000 UPT. Based on research, the statistical value of a human life, as calculated in terms of a 'working value' is \$3.4 million dollars¹⁹⁴. The total annual savings due to avoided deaths associated with a reduction in VMT is equal to \$676,000.

Notably, this figure is based on a wide breadth of research and assumptions, each of which can vary based on time and other influences. The calculation also does not include the values associated with non-fatal injuries, property damages, and avoided increases in insurance premiums. Each of these soft metrics can be further refined as appropriate and included in the model accordingly.

¹⁹¹ DOT - Federal Transit Administration. "Metro Orange Line BRT Project Evaluation." *FTA Research* (n.d.): Oct. 2011. Web. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf

¹⁹² McGuckin, Nancy. "TRAVEL IN LA COUNTY." *TRAVEL IN LA COUNTY* (n.d.): n. pag. *Saferoutescalifornia*. www.travelbehavior.us, 2009. Web. 22 Nov. 2016. https://saferoutescalifornia.files.wordpress.com/2012/08/travel-in-la-county_nhts2009.pdf

¹⁹³ General Statistics. "Fatality Facts. Insurance Institute for Highway Safety, n.d. Web. 22 Nov. 2016.

<http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/state-by-state-overview>

¹⁹⁴ Valuing Accidents - Transportation Benefit-Cost Analysis. "Transportation Benefit-Cost Analysis. N.p., n.d. Web. 22 Nov. 2016. <http://bca.transportationeconomics.org/benefits/safety/valuing-accidents>

FUTURE APPLICATIONS

It is with great hopes this model be used as a complimentary tool to basic financial analysis as it is able to better measure the true value created for society and the environment: value that is important to public entities such as LA Metro, and to society. Future applications of the model include the mainstream integration of this tool in decision-making scenarios. Suggested applications are as a supplementary tool to reflect the marginal societal benefits a project may generate to gain project funding, to help with constituent outreach, enhance ridership through campaigns targeting specific project benefits, or as an additional resource to help determine which project or initiative will generate the greatest impact for the lowest cost.

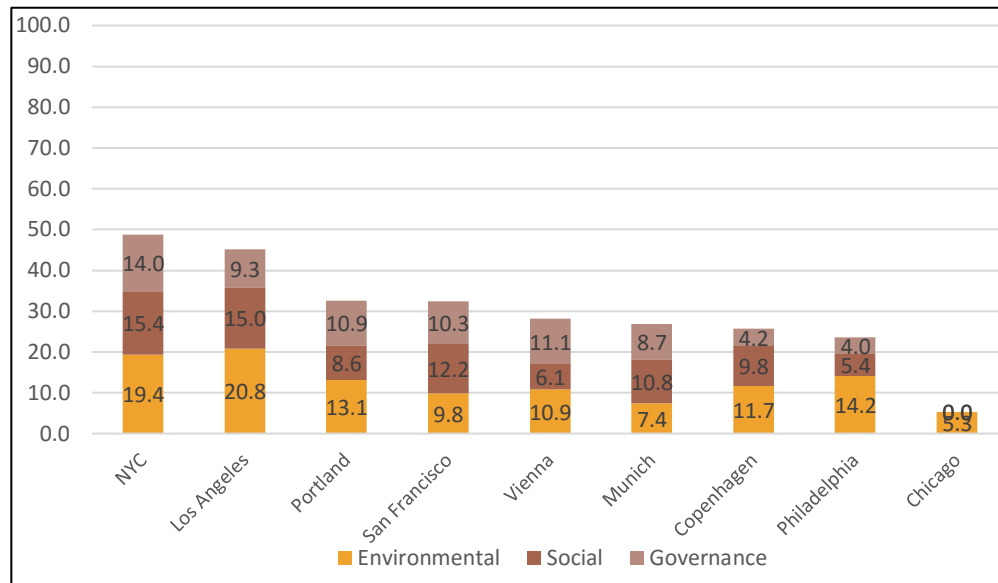
Due to project constraints, it is recommended internal efforts be allocated to help identify the localized benefits of a project in order to generate a more holistic and realistic social and environmental benefit representation. It is suggested the work done for the Orange Line be used as a foundation for micro-level valuation.

CONCLUSION

Due to the capacity and granular data limitations, the model was unable to incorporate a comprehensive monetization of all of the soft benefits, or highly detailed savings that would be accrued from very specific waste management strategy, for example. Despite this, the model does a very detailed and thoughtful analysis of many benefits often overlooked with traditional financial valuation measures, and generates a higher return than what would typically be realized using typical approaches. Though subject to some degree of subjectivity, the SROI model created provides a unique platform to convey the positive externalities and meaningful benefits of sustainability.

APPENDICES

APPENDIX 1: BREAKDOWN OF SCORES ALONG CATEGORIES (ENVIRONMENTAL, SOCIAL AND GOVERNANCE)



City	Environmental	Social	Governance	Total
NYC	19.4	15.4	14.0	48.8
Los Angeles	20.8	15.0	9.3	45.1
Portland	13.1	8.6	10.9	32.6
San Francisco	9.8	12.2	10.3	32.3
Vienna	10.9	6.1	11.1	28.2
Munich	7.4	10.8	8.7	26.8
Copenhagen	11.7	9.8	4.2	25.7
Philadelphia	14.2	5.4	4.0	23.5
Chicago	5.3	0.0	0.0	5.3

APPENDIX 2: BREAK DOWN OF INDIVIDUAL ISSUE SCORES PER CITY

<i>Individual Issue Scores are out of 100</i>									
	Chicago	Copenhagen	Los Angeles	Munich	New York	Philadelphia	Portland	San Francisco	Vienna
Energy Management	26.25	48.75	85.00	71.90	74.72	87.50	75.00	48.75	86.39
GHG Emissions	16.25	59.25	90.42	33.80	65.00	67.50	65.50	76.25	37.50
Green Infrastructure / Land Use	16.25	45.42	45.83	0.00	67.50	21.25	33.25	12.92	40.00
Resiliency	0.00	43.75	41.25	0.00	53.75	0.00	15.00	0.00	25.00
Waste Management and Recycling	26.25	42.50	86.39	48.80	38.75	58.75	53.33	42.50	0.00
Wastewater Management	0.00	0.00	12.50	0.00	50.00	0.00	32.92	0.00	0.00
Water Use	26.25	5.00	75.50	0.00	57.50	62.50	0.00	26.25	40.00
Accidents & Safety Measures	0.00	50.00	48.75	25.00	62.00	0.00	0.00	38.75	48.75
Employee Working Conditions	0.00	40.00	52.50	51.80	52.50	0.00	32.50	58.75	25.00
Human Health	0.00	0.00	49.17	0.00	0.00	65.00	0.00	0.00	0.00
Public Safety	0.00	27.50	30.00	52.50	70.00	0.00	70.25	48.75	0.00
Accessibility	0.00	50.83	81.25	55.40	52.50	13.75	68.39	58.75	77.50
Cyber Security	0.00	0.00	0.00	0.00	39.17	0.00	0.00	0.00	6.25
Modernizing IT Systems	0.00	0.00	0.00	49.20	56.25	0.00	20.00	38.75	25.00
Affordability	0.00	0.00	30.00	0.00	20.00	33.75	42.50	26.25	25.00

APPENDIX 3: FINDINGS OF THE BENCHMARKING TOOL

LA METRO

LA Metro scored 2nd out of 9 city transportation agencies, in part due to its comprehensive Countywide Sustainability Planning Policy. With regards to the issue categories, LA scored 1st in the environmental category, 2nd in social, and 5th in governance (please see total results in Appendix 2: Break Down of Individual Issue Scores per City).

Unlike some of the other city agencies, LA Metro addresses a range of sustainability issues across environmental, social, and governance categories. One area that stood out, was LA's approach to GHG emission. LA has been suffering the repercussions of climate change, which is why the City is making significant efforts to reduce its contribution to GHG emissions. Besides transitioning their bus fleet from diesel fuel to electric,¹⁹⁵ LA Metro is also engaging with external stakeholders and to better disclose their emissions. One such example is their collaboration with CDP to begin to disclosing their Scope 3 emissions¹⁹⁶. At present, it is one of two city transit agencies calculating its Scope 3 emissions (New York's MTA being the other).

Another strong point of differentiation is the manner in which LA Metro is addressing urban sprawl and improving public transit accessibility. LA Metro has an aggressive plan known as the First Last Mile Strategy, which aims to provide transit stations at a distance of 3 miles or less from 7.8 million LA homes. "The Pathway" is a concept that will aid in such implementation by expanding user access through:

- Decreased average time of transportation (reducing wait times for pedestrians and vehicles through timed traffic lights and improved street conditions)
- Decreased point to point distances by utilizing short-cuts and more direct paths
- Supporting multiple forms of transportation and linking different forms (e.g. bus stops, bike share kiosks, and stations).
- Integrating car share programs as another mode of transportation¹⁹⁷

¹⁹⁵ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016. http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

¹⁹⁶ "Metro's 2016 Energy and Resource Report." Los Angeles County Metropolitan Transportation Authority. 2016. 23 Nov 2016. http://media.metro.net/projects_studies/sustainability/images/report_sustainability_energyandresource_2016.pdf

¹⁹⁷ "First Last Mile Strategic Plan & Planning Guidelines." Los Angeles County Metropolitan Transportation Authority. March 2014. 23 Nov 2016. http://media.metro.net/docs/sustainability_path_design_guidelines.pdf

These initiatives are critical in cities that are expanding, in particular due to the impact this has on a city's workforce, economy and equitability.

CHICAGO

Out of 9 city transportation agencies, the Chicago Transit Authority (CTA) scored 9th out of 9 on the overall framework, as well as in each individual category. Compared to all the other city agencies, CTA has not allocated resources to create a report that addresses environmental, social and governance issues. On their website, the CTA has vague goals, shows an overall lack of strategy, metrics and data.

COPENHAGEN

Copenhagen scored 8th out of 9 city transportation agencies overall, with average scores for the environmental, social and governance categories. In regards to the issue categories, Copenhagen scored 5th in the environmental category, 5th in the social category, and 7th in the governance category (please see total results in Appendix 2: Break Down of Individual Issue Scores per City).

Out of all the sustainability issues, Copenhagen's transportation agency specializes in GHG emissions reduction. The city has a goal to become carbon neutral by 2025 and the city's transportation agency will help meet 10% of its total CO₂ reduction targets via reduced transport emissions: this represents about 50,000 tons of CO₂.¹⁹⁸ To reach their 10% goal, this agency performed infrastructural changes, defined policy and regulations, and invested in new equipment. The infrastructural change projects have included: changing street lighting to be more energy efficient, and building more bike paths, green bike routes and pedestrian bridges to promote the use of walking and biking as a mode of transportation rather than driving.¹⁹⁹ Under policy and regulations initiatives, they have include lobbying the government to introduce congestion charges as well as the right to establish environmental zones in dense downtown areas where only environmentally friendly cars and trucks are allowed, and have created an awareness campaign that focuses on more effective car use through car sharing, car pooling and climate-friendly driving techniques²⁰⁰. In order for the transportation agency to take the next step in reducing the city's overall GHG emissions they have decided to invest in new equipment.

¹⁹⁸ "Copenhagen Climate Plan - The short version" City of Copenhagen. August 2009. 23 Nov 2016. <https://www.energycommunity.org/documents/copenhagen.pdf>

¹⁹⁹ "Copenhagen Climate Plan - The short version" City of Copenhagen. August 2009. 23 Nov 2016. <https://www.energycommunity.org/documents/copenhagen.pdf>

²⁰⁰ "Copenhagen Climate Plan - The short version" City of Copenhagen. August 2009. 23 Nov 2016. <https://www.energycommunity.org/documents/copenhagen.pdf>

The new equipment includes technology for buses that would emit less CO₂ and convert the municipality's vehicle fleet to hydrogen-powered and electric vehicles.

MUNICH

Munich scored 6th out of the 9 transit agencies overall, with quite an even distribution across environmental, social, and governance categories. With regard to the issue categories, Munich scored 8th in the environmental category, 4th in the social category, and 6th in the governance category (please see total results in Appendix 1 and 2).

Out of all the sustainability issues, Munich's focus lies in energy management. Munich addresses energy management across its fleets and stations: heavy rails, light rails, buses, and stations, mainly focusing on energy efficiency and vehicle miles travelled reduction per capita. Initiatives include purchasing "Avenio Trams" which are more energy and resource efficient, expanding the use of double traction models which allow for the removal of carriages during off peak hours, expansion of trailer buses which have longer service life and are more energy efficient to accommodate for greater number of passengers, and pilot projects experimenting in groundwater use to supply heating circuit at two underground stations.

Munich scored the best in the social category out of the three European cities. This is mainly due to its emphasis on employee conditions (including support for diversity, promoting gender equality in its workforce, promoting a healthy work-life balance etc.) and the measures it has taken to address public safety. It must be noted, however, that Munich's current measures to address public safety mainly focus on petty crimes. Considering the increased threat of terrorism in European cities, it would not be surprising if Munich addresses this issue further and in greater detail in the future.

NEW YORK CITY

New York City's MTA scored 1st out of 9 city transportation agencies since the MTA thoroughly addresses a range of environmental, social and governance issues. With regards to the issue categories, the MTA scored 2nd in the environmental category, 1st in the social category, and 1st in the governance category (please see total results in Appendix 2: Break Down of Individual Issue Scores per City).

The MTA has particularly focused on energy management and GHG emissions and have done a diligent job of quantifying the outcomes of their projects. Their energy management and carbon emissions reductions strategies take a two-pronged approach. Firstly, MTA realizes that by expanding their own lines they are reducing the region's overall footprint because expansion reduces individual vehicle miles travelled.²⁰¹ Secondly however, MTA strongly believes in reducing their own impact, which is why they have taken on several major initiatives to better the environment and yield important financial benefits. An example is MTA's energy retrofits, where they switched to compact fluorescent lightbulbs in subways and tunnels and use LED light bulbs to illuminate the Verrazano Bridge. Additionally, in order to achieve their target of 80% electric power from green sources by 2050, the MTA has developed a partnership with the New York Power Authority to expand their use of renewable energy. This partnership has carried out 99 separate projects that save about 78,000 MWh of traditional electricity annually.²⁰²

Other energy projects conducted by the MTA include remote controlled third-rail heaters and a solar-powered water heater for their Coney Island Yard, among others. These two projects alone save the MTA about 12,000 MWh (usage) and \$793,000, and 156 MWh (usage) and \$94,000 per year, respectively.²⁰³

It must be noted that the MTA is also one of the few transportation agencies that address the topic of resiliency in a strategic manner. While some might argue that this is a result of NYC's PlaNYC, the MTA is certainly contributing a great deal to prepare the city for rising water levels and increased risk of storms. Besides replacing old power cables and establishing flood barriers and mitigation measures at subway stations in upper and lower Manhattan, the MTA has also purchased 600 deployable covers for sidewalk vents, among a variety of other initiatives.²⁰⁴

²⁰¹ "Greening Mass Transit & Metro Regions: The Final Report of the Blue Ribbon Commission on Sustainability and the MTA". Metropolitan Transportation Authority, State of New York. 2009. Nov 23 2016.
<http://web.mta.info/sustainability/pdf/SustRptFinal.pdf>

²⁰² "2011 MTA Sustainability Report." Metropolitan Transportation Authority, State of New York. 2011. Nov 23 2016.
<http://web.mta.info/sustainability/pdf/2011Report.pdf>

²⁰³ "2011 MTA Sustainability Report." Metropolitan Transportation Authority, State of New York. 2011. Nov 23 2016.
<http://web.mta.info/sustainability/pdf/2011Report.pdf>

²⁰⁴ "2015 Annual Report." Metropolitan Transportation Authority. 2016. Nov 23. 2016.
http://web.mta.info/mta/compliance/pdf/2015_annual/2015_Narrative.pdf

The MTA's focus on energy, GHG emissions, and resiliency are admirable and can be considered a best-practice. Not only is the MTA preparing itself for inevitable future problems, but it is doing everything within its power to reduce its own contribution to those problems.

PHILADELPHIA

Philadelphia scored 7th out of 9 city transportation agencies overall and the 3rd best in the environmental category. The Southeastern Pennsylvania Transportation Authority (SEPTA) scored 8th in the social category and 8th in the governance category (please see total results in Appendix 2: Break Down of Individual Issue Scores per City).

SEPTA has been doing a thorough job on creating environmental initiatives that have an overall strategy, quantitative & qualitative goals, and implement metrics. The environmental projects are broken down into 4 categories: GHG and Criteria Air Pollutants, Water Use and Pollutant Discharge, Energy Management, and Waste Management.²⁰⁵ Out of these four categories, SEPTA has excelled in energy management. Their 2012 Energy Action Plan provides a thorough breakdown of SEPTA's energy and GHG baseline profile, performance trends from 2009 to 2011 and the performance gap from 2012 to 2015, and goes into implementation strategies which include leveraging energy savings, grants and financial incentives and operational strategies. The core of the action plan breaks down projects and initiatives by energy source. The energy sources SEPTA consumes are: diesel, electricity, gasoline, natural gas, heating oil and steam.²⁰⁶

Projects that SEPTA have planned or completed vary from lighting to purchasing new efficient vehicle fleet. SEPTA has many plans for sustainability, but have not yet progressed greatly to implementing these.

PORTLAND

Portland's TriMet scored 3rd out of 9 city transportation agencies and 3rd best in the governance category. Two issues that Portland has been very diligent at addressing are accessibility and affordability. Portland has come out with a range of measures to promote ridership and make journeys more convenient and more affordable. Some of these include: developing applications

²⁰⁵ "Sept-ainable Annual Report". Southeastern Pennsylvania Transportation Authority. April 2015. Nov 23 2016.
<http://www.septa.org/sustain/pdf/septainable15.pdf>

²⁰⁶ "Septa Energy Action Plan". Southeastern Pennsylvania Transportation Authority. November 2012. Nov 23 2016.
<http://www.septa.org/sustain/pdf/energyaction12print.pdf>

that let you pay on your phone, reducing the time needed to stop at a machine to pay; providing real time transit information via phone or web²⁰⁷; expanding their frequent service bus lines by adding additional buses; partnering with local jurisdictions to improve local transit service²⁰⁸; expanding bike ridership by adding stations and making them more accessible²⁰⁹. Moreover, Portland also opened the Tilikum Crossing in 2015, a bridge that only allows transit, bikes and pedestrians to travel on it,²¹⁰ and reduced the fee for children to make it easier for children to get to and from school. Such initiatives clearly show Portland's commitment to increasing ridership and reducing the number of individual cars on the road.

Other issues that Portland actively addresses are energy management and GHG emissions. In this regard, TriMet has taken several measures to reduce fuel usage. For example, TriMet implemented a drivetrain computer in the engine of each bus which improves fuel efficiency by monitoring the engine to adjust acceleration, braking and fuel injection.²¹¹ Additionally, in 2005, TriMet's maintenance crew made adjustments to transmissions, steering control arms and tire pressures, which have resulted in about 500,000 gallons of fuel per year.²¹² Other measures include expansion of its MAX light rail, which runs on electricity and uses recovery braking to reduce energy usage, and operating buses that are cooled by electric fans.²¹³

TriMet's measures to improve accessibility, affordability and fuel usage not only increases the use of public transportation but also reduce the city's overall GHG emissions, traffic, overall noise pollution, air emissions that are harmful to public health, and improve overall road safety. TriMet does not report on indirect impacts.

SAN FRANCISCO

San Francisco scored an overall ranking of 4th out 9 city agencies. In the environmental category, they scored 7th out 9, in the social category they scored 3rd out 9 and in the governance category

²⁰⁷ "TriMet-at-a-Glance." TriMet. 2016. Nov 23 2016. <https://www.flipsnack.com/trimet/2016-trimet-at-a-glance.html>

²⁰⁸ "Livable Portland: Land Use and Transportation Initiatives." TriMet. November 2010. 23 Nov 2016. <https://trimet.org/pdfs/publications/Livable-Portland.pdf>

²⁰⁹ "TriMet: Bike Plan." TriMet. June 2016. 23 Nov 2016. <http://trimet.org/bikeplan/bikeplan-web.pdf>

²¹⁰ "Tilikum Crossing." TriMet. 2015. 23 Nov 2016. <http://trimet.org/tilikum/>

²¹¹ "Conserving Fuel and Reducing Emissions." TriMet. 23 Nov 2016. <http://trimet.org/sustainable/fuel-emissions.htm#max>

²¹² "Conserving Fuel and Reducing Emissions." TriMet. 23 Nov 2016. <http://trimet.org/sustainable/fuel-emissions.htm#max>

²¹³ "Conserving Fuel and Reducing Emissions." TriMet. 23 Nov 2016. <http://trimet.org/sustainable/fuel-emissions.htm#max>

they scored 4th out of 9 (please see total results in Appendix 2: Break Down of Individual Issue Scores per City).

Out of the three categories (environmental, social and governance) San Francisco scored the lowest in environmental, yet the transportation agency has been diligent in addressing GHG emissions. In 2011, San Francisco's transportation agency created a Climate Action Strategy. The action strategy focuses on reducing GHG emissions by 80% which is below 1990 levels by 2050. The six strategies can be broken down into two groups, the first group is travel demand management and the second infrastructure support. Travel demand management are strategies that try to help decrease automobile travel and promote public transportation. The three strategies that fit into this are: travel choice & information, demand pricing and transit oriented development. Infrastructure support strategies that provide capacity to accommodate the mode shift.²¹⁴ The three strategies that fit into this area are: transit improvements, complete streets and electric vehicles.

Projects that the San Francisco transportation agency have implemented to help reduce GHG emissions include: converting 100% of the taxi fleet to low carbon vehicles; optimizing car share parking near transit centers and requiring sufficient parking for car share and bicycles in new developments; require charging infrastructure for new development, car sharing and electric bicycles; implementing bicycle sharing, and creating electric bicycle capacity. Even though this area rated high in San Francisco, other cities have a more detailed greenhouse gas emissions plan.²¹⁵

VIENNA

Overall, Vienna scored 5th out of the 9 city transit agencies, 6th out of 9, 7th out of 9, and 2nd out of 9 in the environmental, social, and governance categories respectively. Like Copenhagen, Vienna has a city-wide plan to become more sustainable, focusing on issues like energy management, GHG emissions, green building, and impact on community. That being said, some of these issues do not necessarily apply to the Wiener Linie. Since Vienna's Smart City

²¹⁴ "2011 Climate Action Strategy". San Francisco Municipal Transportation Agency. 2011. Nov 23 2016. <https://www.sfmta.com/sites/default/files/2011%20CAS%20060412%20-%20small.pdf>

²¹⁵ "2011 Climate Action Strategy". San Francisco Municipal Transportation Agency. 2011. Nov 23 2016. <https://www.sfmta.com/sites/default/files/2011%20CAS%20060412%20-%20small.pdf>

Framework Strategy is a city-wide plan, it delegates certain issues and targets to various sectors (e.g. energy management and reduction of GHG emissions in the transportation sector). That is why, with regard to the issues that are delegated to the Wiener Linie by the city of Vienna, it actually scores quite high. Some of the measures taken by the transit agency include: replacing 9,600 traditional lights with LED lighting in subways and stations, saving about 1.5 gWh per year²¹⁶ and installing recovery braking in almost all rail vehicles²¹⁷ and deploying pilot projects that would capture the energy emitted during braking to generate electricity for lighting, escalators and elevators in subway stations.²¹⁸ Additionally, all drivers are trained in energy efficient driving and Vienna's EcoTram has efficient air conditioning and heating systems to reduce energy use by about 13% (4,200 kWh) per year.²¹⁹

Besides its heavy focus on energy management and efficiency, Vienna invested roughly 4 billion Euros over 5 years to construct a sustainable Main Station²²⁰. All the recycled material used in its construction was prepared on site and reinstated. Additionally, the building itself is highly energy efficient, using "geothermal energy, solar energy, district heating and cooling networks, an integrated CO₂ modulated ventilation system and grey water utilization."²²¹ These measures allow Vienna to produce 13% of its energy requirements on site. Moreover, considering its position in the city center, surrounded by traffic and inbound and outbound trains, development of the new Main Station also included 14,000 soundproof windows that significantly reduce noise pollution in the city center. Finally, Vienna has made an effort to transform the areas surrounding the Main Station to become more 'livable' and "to optimize the urban development landscape and to place greater focus on small-scale structures".²²² Projects to this end included building small-scale residential and commercial buildings, parks, and many open spaces that were mostly free of through-traffic. Overall, Vienna's Main Station has become a model project

²¹⁶ "Nachhaltig in die Zukunft: Energieeffizienz." Wiener Linie. 2015. 23 Nov 2016.

<http://www.wienerlinien.at/eportal3/ep/channelView.do/pageTypeld/66528/channelId/-48667>

²¹⁷ "Nachhaltig in die Zukunft: Energierückspeisung." Wiener Linie. 2015. 23 Nov 2016.

<http://www.wienerlinien.at/eportal3/ep/channelView.do/pageTypeld/66528/channelId/-48667>

²¹⁸ "Nachhaltig in die Zukunft: Energierückspeisung." Wiener Linie. 2015. 23 Nov 2016.

<http://www.wienerlinien.at/eportal3/ep/channelView.do/pageTypeld/66528/channelId/-48667>

²¹⁹ "Forschungsprojekt EcoTram." Wiener Stadtwerke. 2016. 23 Nov 2016.

<http://www.wienerstadtwerke.at/eportal3/ep/programView.do/pageTypeld/71282/programId/72365/channelId/-51789>

²²⁰ "Living in a Sustainable World Focused on Electrified Rail." Living Rail. 23 Nov 2016.

http://81.47.175.201/livingrail/index.php?option=com_content&view=article&id=551:vienna-main-station-hauptbahnhof-wien&catid=29:rail-terminals&Itemid=102

²²¹ "Vienna Main Station." Vienna City Administration. 23 Nov 2016. <https://smartcity.wien.gv.at/site/en/projekte/verkehr-stadtentwicklung/hauptbahnhof-wien/>

²²² "Vienna Main Station." Vienna City Administration. 23 Nov 2016. <https://smartcity.wien.gv.at/site/en/projekte/verkehr-stadtentwicklung/hauptbahnhof-wien/>

for other cities in terms energy efficiency, climate protection, and promotion of community living.

APPENDIX 4: WATER SUPPLY SOURCE BREAKDOWN LA 2011-2015 WITH MAP²²³

Water Supply Sources (5-year average) – Fiscal Year (FYE) 2011-2015	
LA Aqueduct (from Eastern Sierra Nevada)	29%
Purchased water (Metropolitan Water District)	57% (Bay Delta 48%, Colorado River 9%)
Groundwater	12%
Recycled water	2%



²²³ LADWP. "Facts & Figures." Facts & Figures https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-factandfigures?_adf.ctrl-state=5avlyuyvl_4&_afrcLoop=395738708774768 (Last Accessed November 25, 2016).

APPENDIX 5: ORANGE LINE SPECIFIC ANALYSIS

IMPROVED COMMUNITY MOBILITY & ACCESS THROUGH ACTIVE TRANSPORT

Step 1:

To determine the financial benefit to society, the mileage of bike lane and pedestrian ways were specifically added to the system as a result of the development of the orange line.

Step 2:

The benefits of active transportation per person per mile were determined. In this case, the Victoria Transportation Policy Institute evaluated costs and benefits of active transportation in their September 2016 report and values from this report were used as baseline for financial benefits per person per mile.²²⁴ However, default values should be adjusted to reflect specific conditions from the orange line.

Step 3:

In order to determine how many individuals are benefiting from the option of active transportation, beneficiaries were defined as the individuals living in the neighborhoods surrounding the orange line. In this case, six neighborhoods were considered (North Hollywood, Van Nuys, Reseda, Winnetka, Canoga Park, and Encino) for which 2016 population estimates were found from reports by the US Census Bureau last updated on 2015.²²⁵

Step 4:

The total number of miles added of active transportation was then multiplied by the financial value per mile per person. The result was then multiplied by the number of beneficiaries.

ASSUMPTIONS

- 14.2 miles of bike and walkable paths were added resulting from the development of the Orange Line based on data reported in the LA Metro report by CESEM.²²⁶
- The total financial benefit per person per mile is \$0.46.

²²⁴ Litman, T. "Evaluating Active Transport Benefits and Costs - Victoria Transport ..." 2016. <<http://www.vtpi.org/nmt-tdm.pdf>>

²²⁵ "Population of North Hollywood, Los Angeles, California - Statistical Atlas." 2015. 29 Nov. 2016 <<http://statisticalatlas.com/neighborhood/California/Los-Angeles/North-Hollywood/Population>>

²²⁶ "Environmental Life-cycle Assessment of Los Angeles Metro's Orange ..." 2013. 29 Nov. 2016 <<https://repository.asu.edu/items/14223>>

- According to 2015 data, 552,000 individuals live in the six neighborhoods considered herein.

FACTORS AFFECTING BICYCLE NETWORK BENEFITS ACCORDING TO CESEM

- Magnitude of improvement:
 - o Located on or parallel to a busy roadway where cycling is otherwise difficult?
 - o A missing link that connects sections of the cycling network?
- Demand:
 - o Number of potential users, including children and young adults, people with lower incomes, and people who want to bicycle for exercise?
 - o Connects important destinations such as schools, shops, public transit stops and parks?
- Supports special planning objectives:
 - o In a commercial or resort area where access and recreation support economic development?
 - o If many residents are sedentary and would benefit from increased physical activity?
- Network and synergetic effects:
 - o Connects to a large cycling network?
 - o Is part of an integrated program of to improve alternative modes and support smart growth?

FACTORS AFFECTING PEDESTRIAN FACILITY IMPROVEMENT BENEFITS ACCORDING TO CESEM

- Magnitude of improvement:
 - o Significantly improves pedestrian conditions and walking is otherwise difficult?
- Demand:
 - o Number of potential users, including children and young adults, people with lower incomes, and people who want to bicycle for exercise?
 - o Connects important destinations such as schools, shops, public transit stops and parks?
- Supports special planning objectives:
 - o Located in a commercial or resort area where walkability supports economic development?
 - o Includes universal design to improve mobility for people with disabilities?
 - o Increases physical activity by otherwise sedentary people?

- Network and synergetic effects:
 - o Connects to a large pedestrian network (other sidewalks and paths)?
 - o Part of an integrated program to improve alternative modes and support smart growth?

RESULTS

The financial benefit of the Orange Line's contribution to active transport is \$6.48/per person for 14.2 miles, which totals a net financial benefit of ~\$3.5M.

Table 1. The Financial Benefit of the Orange Line: Active Transport

Miles added by LA Metro of Active transportation	14.2				
Increased walking & Cycling activity (per person-mile)					
Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
Fitness and health – walking	\$0.50	\$0.50	\$0.50	\$0.50	Benefits are larger if pedestrian facilities attract at-risk users.
Fitness and health – Cycling	\$0.20	\$0.20	\$0.20	\$0.20	Benefits are larger if cycling facilities attract at-risk users.
overall average benefit of active transport per person-mile	\$0.35				
overall average benefit of active transport per person-14.2 mile	\$4.97				

Table 2. The Financial Benefit of the Orange Line: Active Transport

Improved walking and cycling conditions (per person-mile)					
Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
User Benefits	\$0.250	\$0.250	\$0.250	\$0.250	The greater the improvement, the greater this value.
Option Value	\$0.035	\$0.035	\$0.035	\$0.035	Half of diversity value.
Equity Objectives	\$0.035	\$0.035	\$0.035	\$0.035	Half of diversity value. Higher if a project significantly benefits
total benefit averaged per person-mile				\$0.11	
total benefit averaged per person-14.2 mile				\$1.51	

Table 3. The Financial Benefit of the Orange Line: Active Transport

Total benefit per person-mile	\$0.46
Total benefit per person-14.2 mile	\$6.48
Population by neighborhood	
N. Hollywood	157,000
Van Nuys	123,000
Reseda	74,000
winnetka	66,000
Canoga Park	78,000
Encino	54,000
Total population	552,000
Total benefits of active transportation for surrounding neighborhood	\$3,579,536

**Please see appendix 8 and 9 for specifics on cost determinations and benefits of active transport and applicable financial definitions*

IMPROVED QUALITY OF LIFE: SAFETY

Step 1:

Determine the number of crimes taking place in LA Metro lines and buses. In this case, only data from 2011 was obtained from Los Angeles Times using data from the LAPD and Sheriff's Department—updated information is needed for present numbers.

Step 2:

Since data for the cost of crimes taking place particularly in the mass transportation system is not available, the cost of crime to society as evaluated by McCollister, French, and Fang was used. Costs of crimes that fall under Part 1 and part 2 crimes, as defined by the transit services summary report, were included when calculating the average cost per crime. Costs were reported in 2008 dollars; because crimes for LA Metro are from 2011 reports, inflation was used to define 2011 dollars for cost of crime.

Step 3:

Multiply the average cost per crime to society by the number of crimes.

ASSUMPTIONS

The cost of crime adjusted for inflation using a cumulative rate of 4.5% is \$1,228,956 per crime.

RESULTS

The average cost per crime is \$1.2M. This figure takes into account costs per crime for rape, sexual assault, robbery, theft, stolen property, and vandalism, which are all types of crimes that take place in LA's mass transportation system.

During the first two quarters of 2011 the orange line had 14 total crimes when compared to the bus line and blue line, which had 97 and 86 crimes correspondingly. This amounts to a savings of 80% in costs of crime allocated to the orange line, when compared to other lines for an 8-month period.

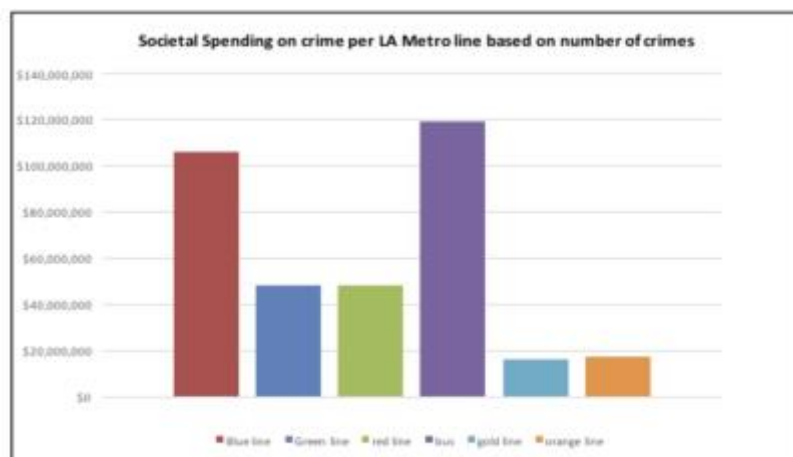
Table 4. The Financial Benefit of the Orange Line: Crime Reduction

Cost per crime	
Murder	\$8,982,907
Rape/Sexual Assault	\$240,776
Assault	\$107,020
Robbery	\$42,310
Larceny/Theft	\$3,532
Stolen Property	\$7,974
Vandalism	\$4,860
average cost of all crime types in 2008 dollars	\$1,173,672
Adjusted for inflation for 2011	\$1,228,956

Table 5. The Financial Benefit of the Orange Line: Crime Reduction

First 2Q of year 2011	Blue line	Green line	red line	bus	gold line	orange line
Total crimes	86	39	39	97	13	14
cost of crime	\$105,690,249	\$47,929,299	\$47,929,299	\$119,208,769	\$15,976,433	\$17,205,389
cost to LA Metro	TBD	TBD	TBD	TBD	TBD	TBD

Graph 1. The Financial Benefit of the Orange Line: Crime Reduction



JOB AND OPPORTUNITY CREATION

To provide some background, the EconWorks case study highlighted the number of jobs present in 2002 (prior to Orange Line completion) and a further study was conducted in 2012 to determine the associated impacts in terms of job creation, population growth and land use development. The EconWorks case study identifies several new residential and retail space additions around Orange Line after the 2012 study was conducted, which were not included in the initial jobs creation figures. These developments were predominantly in Warner Center and North Hollywood. To determine the new jobs created after 2012 in these two hotspots, the number of new additional square foot in retail and office space were identified (please see Table 6). The new square footage additions were divided by 215 square feet, a figure provided by the Mehigan Company Inc (TMC), which will be described in further detail later on.

The two original terminals of the Orange Line – North Hollywood (where the Red Line subways western terminus is located) and Warner Center – account for the majority of employment along the corridor, with the stations in between largely passing through residential areas.^{227 228} The land use within a half-mile radius of the Orange Line is mostly residential; commercial and industrial uses also make up a large portion of the area around Warner Center (third largest

²²⁷ "April 15, 2015 - Item 23 - Planning & Programming Committee ... - Metro." 2015. Accessed on 27 Nov. 2016
<http://media.metro.net/board/Items/2015/04_april/20150415p&pitem23.pdf>

²²⁸ Vincent, W. "Los Angeles Orange Line: Case Study - the National Bus Rapid ..." 2016. Accessed on 27 Nov. 2016
<https://www.nbrti.org/docs/pdf/Orange_Line_Preliminary_Evaluation_by_BTI.pdf>

employment center in Los Angeles County) and Chatsworth, respectively.²²⁹ Warner Center, in particular, is an economic engine for the region and for the San Fernando Valley, and will continue to grow with economic opportunity as a result of the recently passed Warner Center 2035 Specific Plan. A blueprint based on principles of sustainability, community connectedness, accessible public transit and jobs, Warner Center 2035 will stimulate job growth and economic development with a transit-orientated development approach that relies on the Orange Line.²³⁰ For these reasons, calculations for the estimated total number of direct and indirect jobs created as a result of the Orange Line will be specific to North Hollywood and Warner Center.

ASSUMPTIONS

- Estimated number of potential jobs created using TMC figures (a corporate real estate advisory firm) of 215 (forecasted 2017 figures) square feet per person was used to calculate the projected jobs created after 2012.²³¹ Several other values were assessed by looking at various real estate companies and their proposed square foot per person values before using the final value of 215, which proved to be neither in the higher end or lower end of the observed values
- The EconWork case study mentioned about 20% of the jobs created in Warner Center and North Hollywood are a direct result of the Orange Line. This figure was once again used to derive the direct forecasted employment figure from the indirect employment calculations.

RESULTS

Post-Project figures in 2012 were 141,562 jobs (refer to Table 7), an increase from the original Pre-Project figure of 137,638 in 2002. Hence there has been an increase of 3,924 new jobs created. This was further split into direct and indirect jobs created as a result of the construction of the Orange Line. The number of direct jobs created was 825, while the remaining 3,099 were indirect jobs created.

²²⁹ Vincent, W. "Los Angeles Orange Line: Case Study - the National Bus Rapid ..." 2016. Accessed on 27 Nov. 2016
<https://www.nbrti.org/docs/pdf/Orange_Line_Preliminary_Evaluation_by_BTI.pdf>

²³⁰ "Orange Line Leads to Jobs and Valley Transformation ..." 2014. Accessed on 27 Nov. 2016
<http://blumenfield.lacity.org/2014_orange_line_metro_blog>

²³¹ "What is the average square footage of office space per person? | The ..." 2016. Accessed on 27 Nov. 2016
<<http://mehiganco.com/wordpress/?p=684>>

The second part of the calculations involved factoring in the estimated jobs and opportunities created after 2012 using the mentioned value of 215 square feet. Consequently, the total estimated new jobs created between 2002 and 2015 was 25,353. Of this figure, 20,282 were indirect jobs created and the remaining 5071 were direct jobs created.

Table 6: Estimated job creations after 2012 in North Hollywood and Warner Center

			Completion Time	Estimated job creation post 2012 (as per area)
North Hollywood				
Office space development (square feet)	300,000		Completed prior to 2012	incorporated in 2012 figures
Retail space (square feet)	100,000		Completed in 2015	461
Direct jobs created between 2006-2008	1,150		completed prior to 2012	incorporated in 2012 figures
Warner Center				
Retail space (square feet)	1,450,000		Completed in 2008	incorporated in 2012 figures
Retail Space (square feet)	550,000		Completed in 2015	2535
Office space (square feet)- in the process	1,100,000		in process	5069
Residential units- in the process	10000000		in process	temporary jobs not included
Total projected jobs created				8065
Metro development plans				
Office space (square feet)	1,000,000		in the process	4608
Retail space (square feet)	150,000		in the process	691
Apartment units	1,250,000		in the process	temporary jobs not included

Table 7: Pre-Project and Post-Project results for Orange Line

Local Perspective	Pre-Project (2002 figures)	Post-Project (2012 figures)	% Change	Total Estimated job creation post 2012
Number of Jobs	137,638	141,562	2.85	25,353
Indirect job created		3,099		20,282
Direct jobs created		825		5071
Population	404,573	427,416	5.65	
Density (pp/sq mi)	7,841	8,283	5.64	
Population growth rate (%)		0.88		
Employment growth rate (%)		1.8		

PROPERTY VALUE

Another way to define financial growth stimulation is through the increase in property value. In this case, to define the Orange Line's contribution to financial growth of the surrounding bus terminal station of orange line, additional property tax revenue from the increase in property value were evaluated.

Step 1:

The incremental increase in value of home before and after the Orange line service (refer to Table 18) was calculated.

Step 2:

Average ridership for the Orange line was calculated.²³²

Step 3:

The number of individual riders using the Orange line on a daily basis was calculated based on data from the Federal Transit Administration study of the Orange line by factoring frequency of usage per person from the daily average ridership.²³³

Step 4:

Based on the usage per person figure derived from the above calculation, the number of home ownership was determined. There are approximately 3 people per every household (refer to Table 17 in Appendix) however 6 people per household was conservatively estimated.

Step 5:

Property appreciation was determined by multiplying the number of homes times the incremental increase in value of home. This result was multiplied by the average property tax in California to calculate increase in tax revenue.

ASSUMPTIONS

- A 5% discount rate to calculate NPV until 2030.
- Average ridership for the Orange line was based on 2015 metro line data and held constant through 2030.
- The average median value of homes within 2-mile radius was used as the basis for calculation.
- The percentage increase in average median value of homes within a 2-mile radius was used.

²³² "Ridership Statistics - Metro." 2015. 29 Nov. 2016 <<https://www.metro.net/news/ridership-statistics/>>

²³³ "Metro Orange Line B R T Project Evaluation, Columbia Demonstration ..." 2016. 29 Nov. 2016 <https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Research_Report_0004_FINAL_2.pdf>

- Ridership calculation was used as proxy to home ownership. Actual available data to calculate total value of property appreciation within 2-mile radius was purposefully not used in order to link ridership to an increase in value of property.
- Average property tax in Los Angeles County is approximately 1%.

RESULTS

Table 8. The Financial Benefit of the Orange Line: Property Value

Headings	Figures	Assumptions
Average median property value in 2002	\$ 360,000	based on study from Brown, A.E. UCLA Luskin School of Public Affairs
% Increase in value	29%	based on study from Brown, A.E. UCLA Luskin School of Public Affairs
Expected property value in 2005	\$ 462,960	calculated based on % increase in value
Increase in value	\$ 102,960	
Ridership per day	25,000	average 2014/2015 ridership (LA Metro report)
Frequency		
2X per day	30%	reported by Federal Transit Administration 2004 Orange line review
4X per day	70%	reported by Federal Transit Administration 2004 Orange line review
Usage per person	8,125	calculated based on daily frequency and average ridership
Number of homes per person using Orange Line	1,354	an average household is family of 6 ;divided usage per person by 6
Calculations		
Increase in property value	\$ 102,960	
Number of homes	1,354	
Total Increase in Residential Property Value	\$ 139,425,000	
Financial Benefit		
Increase in property tax revenue	1,394,250	1.0% property tax on incremental property value
Net Present Value	\$20,042,602	discounted at 5% from 2005 to 2030

APPENDIX 6: PROPOSED COMMERCIAL, INDUSTRIAL, GOVERNMENTAL AND TEMPORARY CONSTRUCTION CUSTOMER RATES (CONVERTED TO PER 1000 GALLONS) IN 2015 REAL/CONSTANT DOLLARS²³⁴

Fiscal Year	FY 2014-15	FY2015-16	FY 2016-17	FY 2017-18	FY 2018-19	FY 2019-20
Tier 1	\$6.76	\$5.95	\$6.16	\$6.58	\$6.93	\$7.11
Tier 2	\$7.89	\$9.17	\$9.67	\$10.35	\$10.84	\$11.72

APPENDIX 7: PROPOSED COMMERCIAL, INDUSTRIAL, GOVERNMENTAL AND TEMPORARY CONSTRUCTION CUSTOMER RATES (PER HCF) IN 2015 REAL/CONSTANT DOLLARS

Fiscal Year	FY 2014-15	FY2015-16	FY 2016-17	FY 2017-18	FY 2018-19	FY 2019-20
Tier 1	\$5.06	\$4.45	\$4.61	\$4.92	\$5.18	\$5.32
Tier 2	\$5.90	\$6.86	\$7.23	\$7.74	\$8.11	\$8.77

²³⁴ Based on rates converted from per hundred cubic feet (HCF) from LADWP Water System Rate Action Report, Chapter 5: Water Rate Design, July 2015, p. 15. https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-financesandreports/a-fr-waterrates/a-fr-wr-rateactionreport?_adf.ctrl-state=11w6842hn6_112&_afrLoop=396747693461170

APPENDIX 8: FINANCIAL DEFINITIONS FOR ACTIVE TRANSPORTATION BENEFITS ACCORDING TO THE VICTORIA TRANSPORT POLICY INSTITUTE

USER BENEFITS

“Improving active mode conditions (better sidewalks, crosswalks, paths, bike parking, traffic speed reductions, etc.) directly benefits existing users (people who would walk or bicycle even without improvements) and new users (people who increase walking or cycling in response to improvements). Just as a faster or safer roadway benefits motorists, safer and more convenient walking and cycling conditions benefits users of those modes.”

OPTION VALUE

“Refers to the value people may place on having an option available that they do not currently use, such as the value ship passengers place on having lifeboats available for emergency use (“Transport Diversity,” Litman 2009). Because walking and cycling can serve various roles in a transport system, including basic mobility for non-drivers, affordable transport, recreation and exercise, their potential option value is high.”

Note on evaluation methods: Option value can be quantified using contingent valuation surveys which ask people how much they would be willing to pay for walking and cycling facilities and services that they do not currently use. The UK Department for Transport developed specific guidance for evaluating option value (DfT 2003). The “Transport Diversity Value” chapter of Transportation Cost and Benefit Analysis (Litman 2009) estimates that improvements in affordable alternative modes can be valued at 7¢ per passenger-mile, although this value can vary significantly depending on conditions and assumptions.

EQUITY BENEFITS

“Refers to the distribution of impacts and the degree that they are considered appropriate and fair. Major categories of transportation equity include:

- Horizontal equity – assumes that people with similar abilities should be treated similarly. This implies that, unless specifically justified, people should bear similar costs and receive a similar share of public resources.

- Vertical equity with regard to income – assumes that policies should protect the interests of lower-income people.
- Vertical equity with regard to transportation ability and needs – assumes that policies should protect the interests of mobility impaired people (such as people with disabilities).”

APPENDIX 9: DIRECT BENEFITS OF WALKING AND CYCLING IMPROVEMENTS

Table 16, below, highlights the benefits that arise from walking and cycling improvements. These values are multiplied times the number of person-miles of travel on the improved facility.

Table 16 Improving Walking and Cycling Conditions (Per Person-Mile)

Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
User Benefits	\$0.250	\$0.250	\$0.250	\$0.250	The greater the improvement, the greater this value.
Option Value	\$.035	\$.035	\$.035	\$.035	Half of <i>diversity value</i> .
Equity Objectives	\$.035	\$.035	\$.035	\$.035	Half of <i>diversity value</i> . Higher if a project significantly benefits disadvantaged people.

This table summarizes the estimated value of improved walking and cycling conditions.

Table 17, below, summarizes typical benefit values, measured in cents per mile of travel of increased walking and cycling activity. Higher values may be justified if an unusually large number of users would otherwise be sedentary.

Table 17 Increased Walking and Cycling Activity (Per Person-Mile)

Impact Category	Urban Peak	Urban Off-Peak	Rural	Overall Average	Comments
Fitness and health – Walking	\$0.500	\$0.500	\$0.500	\$0.500	Benefits are larger if pedestrian facilities attract at-risk users.
Fitness and health – Cycling	\$0.200	\$0.200	\$0.200	\$0.200	Benefits are larger if cycling facilities attract at-risk users.

This table summarizes the estimated fitness and health value of increased walking and cycling activity.

APPENDIX 10: AVERAGE MEDIAN HOME VALUE IN 2002 AND 2013

The below table is based on the study from Anne Brown from UCLA School of Public Affairs, 2015 on impact of Orange Line; <http://docs.trb.org/prp/16-5359.pdf>

	2000†				2013‡				
	Half-Mile	Two-Mile	Five-Mile	LA County	Half-Mile	Two-Mile	Five-Mile	LA County	
<u>Socioeconomic</u>									
Total Population	190,191	486,744	1,079,011	9,519,338	202,007	520,437	1,140,970	9,893,786	
% with Bachelor's Degree or Higher	21.9%	24.9%	24.8%	20.6%	35.1%	34.1%	33.0%	27.8%	
Median Household Income	\$ 55,184	\$ 65,175	\$ 72,608	\$ 62,575	\$ 58,123	\$ 62,743	\$ 67,254	\$ 60,706	
% Households with 0 vehicles	11.0%	9.1%	8.6%	12.6%	9.2%	7.6%	7.1%	9.7%	
% Households with 2+ vehicles	43.8%	49.7%	54.7%	50.5%	47.6%	54.3%	58.6%	55.2%	
<u>Race/Ethnicity</u>									
White	62.9%	64.5%	62.4%	48.7%	65.4%	64.9%	64.3%	53.3%	
Black	5.6%	4.1%	3.7%	9.8%	6.3%	4.0%	3.6%	8.4%	
Asian	6.0%	8.1%	9.4%	11.9%	8.2%	9.8%	11.1%	13.9%	
Hispanic	36.3%	34.9%	37.0%	44.6%	37.5%	38.2%	41.0%	47.9%	
<u>Housing</u>									
Total Occupied Housing Units	75,294	184,415	381,987	3,133,774	79,301	188,800	388,606	3,230,514	
% Owner Occupied	36%	45%	52%	48%	34%	45%	51%	47%	
% Renter Occupied	64%	55%	48%	52%	66%	55%	49%	53%	
Median Home Value	\$ 303,699	\$ 360,246	\$ 372,959	\$ 317,341	\$ 436,633	\$ 463,223	\$ 446,243	\$ 414,584	
Median Rent	\$ 1,038	\$ 1,153	\$ 1,229	\$ 1,077	\$ 1,366	\$ 1,428	\$ 1,513	\$ 1,361	
<u>Commute⁴</u>									
% Car - Drive Alone	64%	66%	66%	63%	72%	73%	73%	72%	
% Car - Carpool	12%	12%	13%	13%	9%	9%	11%	11%	
% Transit	6%	5%	4%	6%	8%	6%	6%	7%	
Number of tracts	50	127	281	2,381	50	127	281	2,381	
†Source: 2000 U.S. Census									
‡Source: 2008-2013 5-year American Community Survey									

Note 1: used 2-mile radius as basis to calculate median property value prior and post Orange line construction.

Note 2: ratio of total occupied housing units to total population for 2- mile radius was 2.6.