THE GOODMAN CORPORATION

BENEFITS METHODOLOGY DOCUMENTATION

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FOUNDATIONS TO BENEFIT COST ANALYSIS

The following methodologies and/or general assumptions are used throughout quantification of the benefits and the cost benefit analysis.

DISCOUNT RATE

The Office of Management and Budget (OMB) Circular A-94 provides guidance on real discount rates. As a default position, OMB Circular A-94 states that a real discount rate of 7% should be used as a base-case for regulatory analysis. The 7% rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business capital as well as corporate capital. A 7% discount rate was applied to all costs and benefits.

COSTS

Land acquisition, design, environmental, plans, specifications and estimates, construction, other soft costs and contingency costs are included in the analysis. These costs are inflated to year of expenditure and then discounted at 7% to 2017 or 2018 dollars.

PLANNING HORIZON AND RESIDUAL LIFE

The analysis period for all projects is 20 years and discounted at 7% to 2017 or 2018 dollars. The 20-year planning horizon generally ranges from 2020-2039 or 2021-2040. However, most transportation projects are designed and build for a useful life of at least 40 years. As such, the residual life benefit assumes there will be one half of the asset life remaining. The residual life benefit only captures one half of the construction cost of the asset.

NEW BIKE AND PEDESTRIAN USERS & VEHICLE MILES TRAVELED (VMT) REDUCED

The benefits for back of curb and bicycle projects are mostly derived from the new projected users of the bicycle and pedestrian facilities. This in turn, leads to reduced vehicle miles traveled (VMT) which has a variety of benefits.

Sidewalk Projects

For sidewalk and other improvements that improve the walkability of an area, there is a presumed increase in pedestrian usage. The Houston-Galveston Area Council (H-GAC) assumes that back of the curb improvements will result in 26% of internal trips being converted from automobile to pedestrian trips. New and or significantly improved back of curb projects (based on the field inventory completed) do not currently support pedestrian activity. Thus, the back of curb improvements are assumed to allow the conversion of 26% of existing internal trips to pedestrian trips. Additionally, an average one-way walking trip length is 0.50 mile (one-way)[1]; thus the following formula is used to estimate new converted auto to pedestrian trips to reduced vehicle miles traveled (VMT).

Equation 1 Back of Curb – New Users to VMT Reduction

Annual VMT reduced = INT *0.26 *.5*260

VMT = Vehicle Miles Traveled
INT = Internal trips (derived from TAZ level forecasts)
0.26 = Trip conversion factor
0.5 = Average walking trip distance in miles

[1] This figure is based upon the methodology used in the 2013-2016 H-GAC TIP Call for Projects, which assumes ½ mile as the walking distance for the intra-TAZ trips.

260 = Days in the year (H-GAC value)

Bicycle Projects

Measuring and forecasting the demand for bicycling in a project area is vital to calculate the benefits of a given facility. Guidelines for Analysis of Investments in Bicycle Facilities, a National Cooperative Highway Research Program report hereafter referred to as the NCHRP report, indicates that people are more likely to ride a bike if they live within 2,400 meters or ~1.5 miles of a bicycle facility.[2] The likelihood to ride a bicycle increases the closer people live to the facility; therefore, existing and induced demands are calculated using 800-, 1,600- and 2,400-meter buffers around the length of the proposed facility. The steps below outline the inputs needed to calculate the demand for bicycling:

Step 1: Establish the number of residents within each distinct buffer using 2012-2016 American Community Survey (ACS) block group level data.

Step 2: Establish the existing bicycle mode share for the region (C) based on the U.S. Census Journey to Work share. For the Houston-Galveston Area Council (HGAC) region, the bicycle commute share is 0.3%.

Step 3: Establish the "all biking" mode share, comprised of both recreational and commuting users by assuming 1.5C + 0.3%.[3]

Step 4: Establish the recreational mode share of bicycles by assuming (1.5C + 0.3%) – C.

Step 5: Establish percentage of adults in buffer areas and the average percentage of adult commuters in buffer areas, through using 2012-2016 ACS block group level data. In Harris County, 63% of adults are considered commuters: total workers who do not work at home divided by the total population over 16 years old.

Next, estimate the existing bicyclists in each buffer area, through calculating the number of adults that commute via bicycle and the adults and children who are recreational bicycle users.

Step 6: Calculate the Daily Existing Bicycle Commuters in each buffer (adults only)

Equation 2 Existing Bicycle Commuters

Existing Bicycle Commuters = Number of residents in each buffer * existing bike mode share (C) * % of adults * % of commuters

Step 7: Calculate the Total Existing Recreational Bicyclists in each buffer

[2] Transportation Research Board. (2006). *NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities.* Washington, D.C.: Transportation Research Board.

[3] The NCHRP Report found that over large geographic areas such as metropolitan areas or states, the number of adults in the United States that ride a bicycle "could range roughly between about 0.3% and 2.5%. Over smaller areas such as specific parts of metropolitan areas, the range could go as high as 15%." Researchers conclude that a 'most likely' value for the MSA level, that also describes the United States as a whole would be 0.3% plus 1.5 times the commute share.

Equation 3 Adult Recreational Bicyclists

Adult Recreational Bicyclists = Number of adults * recreational mode share

Equation 4 Child Recreational Bicyclists

Child Recreational Bicyclists = Number of children * 5%[4]

The number of children in each buffer is assumed to be those who are over the age of 16, as calculated from the 2012-2016 ACS. The share of children who ride a bicycle on a given day is 5%, as cited in the NCHRP report from the 2001 National Household Travel Survey (NHTS).

Step 8: Calculate the Total Existing Bicyclists for both children and adults in each buffer

Equation 5 Total Bicyclists

Total Bicyclists = Existing Bicycle Commuters + Existing Recreational Bicyclists

Next, estimate the future bicyclists in each buffer area, through calculating the number of new adults that commute via bicycle and the adults and children who will become new recreational bicycle users, using the facility.

Step 9: Calculate the Daily New Bicycle Commuters in each buffer (adults only)

Equation 6 New Daily Bicycle Commuters

New Daily Bicycle Commuters = Existing Bicycle Commuters * L[5]

Where $L_{800m}=0.51$
$L_{1600m}=0.44$
$L_{2400m}=0.15$

Step 10: Calculate the Daily New Recreational Bicyclists in each buffer

Equation 7 New Recreational Bicyclists

New Recreational Bicyclists = Existing Recreational Bicyclists * L

Where $L_{800m}=0.51$
$L_{1600m}=0.44$
$L_{2400m}=0.15$

Step 11: Calculate the Daily Total New Bicyclists in each buffer

Equation 8 Total New Bicyclists

Total New Bicyclists = New Bicycle Commuters + New Recreational Bicyclists

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[4] Krizek, K. J., Poindexter, G., Barnes, G., & Mogush, P. (2005, August 1). *Translating Demand and Benefits Research into Guidelines.* Retrieved from Ped Bike Info: http://www.pedbikeinfo.org/bikecost/docs/Guidelines.pdf, 1.

[5] Ibid., 2.

The calculations are made for each of the three buffer areas and summed up for each metric to be used in the analysis.

The demand is calculated based on existing demographic data. The number of bicyclists is expected to change each year, depending on the area's population forecasts. To determine population growth over the planning horizon, the compound annual growth rate is calculated from the Houston-Galveston Area Council (H-GAC)'s latest growth forecasts, for the traffic analysis zones (TAZs) within 1.5 miles of the improvement. The household population from 2015 to 2040 is used for the growth rate calculation.

Decreased Automobile Usage from New Bicycle Users

For bicycle related improvements that enhance bicycle access and mobility in an area, there is a presumed congestion benefit from automobile trips being converted into bicycle trips. This benefit is based on the additional commuters now using a bicycle as their mode of transportation.

To estimate this, the total number of new commuters are derived from the tool. To quantify the benefit, internal trips inside a 1.5-mile radius of the project corridor are assumed to be eligible for conversion from automobile trips to bicycle trips. An internal trip is defined as a trip with both the origin and destination inside the 1.5-mile radius of the project corridor.

It is assumed that the reduction in automobile commuting trips will increase in proportion to the total Home-Based Work (HBW) trips in the 1.5-mile area Traffic Analysis Zones (TAZs) derived from the H-GAC model.

Using the formula below, the VMT savings derived from auto trips converting to bicycle trips is estimated:

Equation 9 VMT Reduction from New Bike Users

Annual VMT Reduction = New Bicycle Commuters * 1.23 * 2 * 48 * 5

1.23 = Average bike trip length in miles according to the NCHRP Report and online tool
2 = work trips per day
48 = weeks of commuting per year
5 = days of commuting per week

The VMT saved is used to calculate the benefit from reduced emissions and reduced automobile maintenance required.

CONGESTION (DELAY REDUCTION) BENEFITS

Projects that increase capacity or divert traffic can possibly reduce delay on the existing or surrounding roadway network. The impact of a project on congestion can be measured through the Vehicle Hours Traveled (VHT) on the network.

ROADWAY PROJECTS

Vehicle hours traveled (VHT) has a direct relationship with overall network congestion. The more congested a roadway or network is, the longer the travel time is, thereby increasing vehicle hours traveled. The benefit from roadway projects is derived from modeling the increased capacity or new roadway

project in the regional travel demand model, or in a micro-simulation model and subsequently monetizing the benefit from reduced congestion as measured by VHT.

MACROANALYSIS

The Goodman Corporation (TGC) coordinated with the Houston-Galveston Area Council (H-GAC) to obtain baseline data associated with the Houston-Galveston region's transportation network. TGC received a network that contained conformity conditions (or the "no build" scenario) for the years 2018, 2025 and 2040.

TGC worked with H-GAC staff to modify the transportation network to include select improvements being proposed. The model was then re-run with the proposed projects. Using the build and no-build/conformity models, a small network was selected to analyze the impact of the projects. Model years 2018, 2025, and 2040 were used for evaluating the VHT impacts derived from the projects. The VHT savings between the two networks and the reduced VHT from the project can be monetized through value of time and user savings.

MICROANALYSIS

The other methodology for determining congestion benefits is through using Synchro software and analyzing delay reduction with a micro-level model. This method requires collecting traffic counts along the affected roadways and modeling traffic for both existing conditions and the future no-build and build scenarios. To derive the growth rate of the traffic in the area with the project, growth rates from the H-GAC Travel Demand model are used. The Synchro analysis shows the operational impacts of the proposed project, which includes intersection delay and emissions reductions.

For both the regional travel demand model (macro) and the Synchro traffic impact analysis (micro), the average Value of Travel Time (VoTT) is $16.69/hour (2018$) and vehicle occupancy as 1.25 persons per vehicle, which is from H-GAC. Using the formula below, the user saving for each project is calculated.

Equation 10 Roadway Project – User Savings

User Savings = VHT * PPV * VoTT

VHT for year n = VHT for project build year*$(1+x\%)^n$

-x% is assumed to be the annual growth rate; this is derived from the H-GAC model

Persons Per Vehicle (PPV) = 1.25

VoTT = $16.69

Accumulated benefits for the 20-year horizon are summed up and discounted at a 7% rate.

SIDEWALK PROJECTS

For sidewalk and other improvements (such as shared use paths) that improve the walkability of an area, there is a presumed congestion benefit from automobile trips being converted into pedestrian trips. To quantify the benefit, internal trips inside a half mile radius of the project corridor are assumed to be eligible for conversion. An internal trip is defined as a trip with both the origin and destination inside the half-mile radius of the project corridor. The Houston-Galveston Area Council (H-GAC) assumes that back of the curb improvements will result in 26% of internal trips being converted from automobile to

pedestrian trips, with an average one-way walking trip length of 0.50 mile. The methodology involved in this report assumes (based on the field inventory completed) that the existing corridor conditions do not currently support pedestrian activity. Thus, the back of curb improvements are assumed to allow the conversion of 26% of existing internal trips to pedestrian trips. The reduction in the automobile trips will contribute to a reduction of VHT on roadways.

Equation 11 Back of Curb Project – VHT Reduction

VHT Reduction = RT * TT

RT = Reduced Trips $*(1+x\%)^n$

-x% is assumed to be the annual growth rate; this is derived from the surrounding network in the H-GAC model

-n is the year of analysis

TT = travel time of half mile trip in the area

-based upon the length of the corridor and speed derived from the surrounding network in the H-GAC model

Using the formula above, the VHT savings derived from auto trips converting to pedestrian trips is estimated. This value is not monetized, given that the user is expending the same amount or more time to reach their destination via a non-motorized mode. The VHT savings is not accrued to the user and only accounts for vehicles that will not be on the roadways because of the improvements.

SAFETY (TRAFFIC ACCIDENT REDUCTIONS) BENEFITS

Certain mobility improvements can improve safety along the project corridor, through reducing the number of crashes. Benefits can be derived from the projected reduction in the number of crashes and property damages incurred.

For all project types, when the number of crashes decrease with the improvements, benefits also accrue from reduced property damages. This methodology is documented in the TIGER Benefit-Cost Analysis Resource Guide.[6] The guide values each property damage only crashes at $4,898 in damages ($2018).

The analysis uses the average number of crashes by type over the last 5 years (2011-2015 in some cases, 2012-2016 in others) from TxDOT's CRIS database, along with the annual growth rate from the H-GAC travel demand model is applied to determine how many crashes will occur in future years. The appropriate reduction factor based on the 2015 HSIP codes is applied, and the damages avoided are quantified. Accumulated benefits are summed up and discounted at a 7% rate.

ROADWAY AND BACK OF CURB PROJECTS

To evaluate the existing conditions on the project corridor, crash records are obtained from Texas Department of Transportation's (TxDOT) Crash Records Information System (CRIS) for 2012 to 2016. Law enforcement data, such as found within the CRIS dataset, uses the KABCO Scale, which rates traffic crash injury on a five-point scale with categories designated as fatal (K), serious (A), moderate (B), minor (C), and none (O). The KABCO Scale is what TxDOT utilizes in the CRIS database.

The CRIS Data Conversion Table (Table 2) shows the conversion between the TxDOT crash classification system and the maximum Abbreviated Injury Scale (AIS). The AIS scale was developed by the Federal Highway Administration (FHWA) and ranks injuries on a scale of one to six, with one being minor, five severe, and six an unsurvivable injury. This represents the "threat to life" associated with an injury and is not meant to represent a comprehensive measure of severity. The AIS is not an injury scale, in that the difference between AIS 1 and AIS 2 is not the same as that between AIS 4 and AIS 5. Reductions in traffic incident rates that result from the project have economic value. Transportation Investment Generating Economic Recovery (TIGER) grant guidance recommends monetizing the value of injuries per the maximum AIS; however, accident data is not always reported as AIS numbers (Table 1), hence the conversion.[7]

[6] U.S. Department of Transportation. TIGER Benefit-Cost Analysis Resource Guide, 2014. Retrieved June 2016 from https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide

[7] U.S. Department of Transportation. TIGER Benefit-Cost Analysis Resource Guide, 2014. Retrieved June 2016 from https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide

TABLE 1 ESTIMATED MONETARY VALUE OF INJURIES FROM TRAFFIC ACCIDENTS			
AIS Level	**Severity**	**Unit value ($2013)**	**Unit value ($2018)**
AIS 0	No Injuries	$0	$0
AIS 1	Minor	$27,600	$31,687
AIS 2	Moderate	$432,400	$496,422
AIS 3	Serious	$966,000	$1,109,028
AIS 4	Severe	$2,447,200	$2,809,539
AIS 5	Critical	$5,455,600	$6,263,370
AIS 6	Unsurvivable	$9,200,000	$10,562,176

Table 1 Estimated Monetary Value of Injuries from Traffic Accidents

The National Highway Traffic Safety Administration (NHTSA) provides a conversion matrix that allows KABCO-reported and generic accident data to be re-interpreted as AIS data. It is understood that an injury observed and reported at a crash site may actually end up being more or less severe than the KABCO scale indicates. Similarly, any accident can, statistically, generate a number of different injuries for the parties involved. Each column of the conversion matrix represents a probability distribution of the different AIS-level injuries that are statistically associated with a corresponding KABCO-scale injury or a generic accident. DOT's 2014 Guidance on Treatment of the Economic Value of a Statistical Life was used to determine monetary values of potential safety improvements. The methodology to calculate the monetary cost of crashes, where such benefit exists, used values from Table 1 and the percentages from Table 2.

TABLE 2 CRIS DATA CONVERSION[8]							
AIS Level	Severity	Death	Incapacitating Injury	Non-Incapacitating Injury	Possible Injury	No	AIS Level
AIS 0	No Injuries	0.0%	3.4%	8.3%	23.4%	92.5%	43.7%
AIS 1	Minor	0.0%	55.4%	76.8%	68.9%	7.3%	41.7%
AIS 2	Moderate	0.0%	20.9%	10.9%	6.4%	0.2%	8.9%
AIS 3	Serious	0.0%	14.4%	3.2%	1.1%	0.0%	4.8%
AIS 4	Severe	0.0%	4.0%	0.6%	0.1%	0.0%	0.6%
AIS 5	Critical	0.0%	1.8%	0.1%	0.0%	0.0%	0.3%
AIS 6	Unsurvivable	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sum (Probability)		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2 CRIS Data Conversion

DOT's 2014 Guidance on Treatment of the Economic Value of a Statistical Life was used to determine the monetary value of potential safety improvements. The methodology uses the reduction in crashes

[8] National Highway Traffic Safety Administration

associated with each roadway improvement, as identified in the Highway Safety Improvement Program (HSIP). The version used for the majority of analyses was published in 2015.

The Highway Safety Improvement Program (HSIP) Work Codes correspond to different enhancements (e.g., new sidewalks, added through lanes, raised medians, additional stop signs). TxDOT has a work code table that provides associated definitions, reduction factors, service lives, applicable maintenance cost, and preventable crash codes. Preventable crashes are those with defined characteristics that may be affected by the proposed improvement as described by the work code. The codes correspond to numeric codes assigned in CRIS to the indicated variable. Information is collected from law enforcement crash reports and converted into a coded format (Table 3). The table below shows one example, which is based on what crashes can be avoided with the conversion of a 2-lane facility to a 4-lane divided.

TABLE 3 538: CONVERT 2-LANE FACILITY TO 4-LANE DIVIDED[9]	
Definition	TxDOT HSIP Work Code 538: Convert an existing 2-lane facility to a 4-lane divided facility.
Reduction Factor	45%
Service Life	20 years
Preventable Crash	(Roadway Related = 2,3,4) OR (Vehicle Movements/Manner of Collision = 10, 13, 14, 320, 21, 22, 24, or 30).

Table 3 Convert 2-lane facility to 4-lane divided

Using the average crash data from the five years in the CRIS dataset, eligible crashes are reduced by 45% (reduction factor above) and monetized based on the AIS values. The growth rate from the Houston-Galveston Area Council (H-GAC) travel demand model is used to project the increased number of crashes per year, based upon the increase in traffic volumes. Accumulated benefits for the specified service life and are summed up and discounted at a 7% rate.

BICYCLE PROJECTS

Separated bike lanes can improve the safety of bicyclists along a project corridor, through reducing the number of crashes. Benefits can be derived from the number of crashes and property damage reduced.

Currently, the Highway Safety Improvement Program (HSIP) Work Codes that correspond to different enhancements (e.g., new curbs, raised medians, additional stop signs), have not identified crash reduction factors associated with bicycle improvements. Therefore, this methodology uses a 38% crash reduction factor, derived from a Transportation Research Board working paper. Rothenberg et al. analyzed crash data five years before and three years after the implementation of separated bike lanes in 17 different sites.[10] Fourteen of the 17 separated bicycle sites saw decreases in crashes. The crash reduction factor of 38% is the mean of the average annual bicycle crashes per bicycle volume of all sites.

[9] Texas Department of Transportation (2015. Oct). TxDOT Highway Safety Improvement Program Work Code Table. Retrieved June 2017 from http://ftp.dot.state.tx.us/pub/txdot-info/trf/hsipworkcodestable.pdf

[10] Rothenberg, H., Goodman, D., & Sundstrom, C. (2016). Separated Bike Lane Crash Analysis. *Transportation Research Board 95th Annual Meeting.* Washington: Transportation Research Board.

Using the average crash data from the five years in the CRIS dataset, the number of total bike related crashes are reduced by 38% (reduction factor above) and monetized based on the AIS values. The network growth rate taken from the Houston-Galveston Area Council (H-GAC) travel demand model is used to project the increased number of crashes per year. Accumulated benefits for a 20-year useful life and are summed up and discounted at a 7% rate.

STATE OF GOOD REPAIR BENEFITS

Maintenance costs should be considered when evaluating benefits of a particular roadway or mobility improvement project. While a roadway reconstruction might be initially costly, rehabilitation/repair of the existing roadway might be more costly and expensive over same life-cycle analysis period.

ROADWAY PROJECTS

Life Cycle Cost Analysis (LCCA) Methodology

A life-cycle cost analysis (LCCA) is a tool to determine the most cost-effective option among different competing alternatives to replace or maintain a paved roadway surface, when each option is equally appropriate to be implemented on technical grounds. It is important to note that in this situation most projects will include the replacement of sub-surface drainage, water, and sanitary sewer upgrades that make it necessary to reconstruct the entirety of the facility. As such, the LCCA is being completed not to programmatically justify the reconstruction, but to explore the benefits associated with reconstruction as opposed to continued on-going preventive maintenance of the existing paved roadway surface. These benefits include an analysis of agency costs (actual reconstruction versus repair) as well as user costs (time delay associated with one-time reconstruction versus more frequent repair).

The methodology used in this report assumes that if the proposed project is not implemented, then a full depth concrete panel repair/replacement or mill and overlay would be conducted at select intervals to maintain the functionality of the roadway. Full-depth repair reinstates the structural integrity of the roadway and fixes localized structural problems. The expected life extension for full-depth repair or mill and overlay maintenance is between 6 and 12 years, and concrete panel repair is 12 to 18 years, per the City of Houston[11]. Thus, the analysis assumes that the service life of mill and overlay for asphalt is 10 years, and concrete repairs is 15 years.

Two to three iterations of full depth repair of jointed concrete and mill and overlay repairs would be required over the next 20 years (Table 4) The table below shows the schedule for each project.

TABLE 4
ROADWAY REPAIR SCHEDULE

Project	*Type of Repair*	*2020*	*2030*	*2035*	*2040*
A	Concrete	X		X	
B	Mill and Overlay	X	X		X

Table 4 Roadway Repair Schedule

A life cycle savings of roadway repair is quantified for each project using the following methodology:

Agency Cost from Concrete Pavement Full Depth Repair

According to TxDOT's 2017 Average Low Bid Unit Prices, the cost for full-depth repair of joint concrete pavement is $205 per square yard (2017$). The total cost of full-depth repair can be calculated using the following formula:

[11] https://www.houstontx.gov/council/committees/tti/20140513/Maintaining_Houston_Streets.pdf

Equation 12 Agency Cost - Full Depth Repair

Cost (Full-Depth Repair) = L * W * 0.11111 * P * C

L = project length
W = width of concrete pavement
P = the unit price of full-depth repair of jointed concrete pavement (2018$)
C = percentage of concrete in need of repair
0.11111 = conversion factor between square feet and square yards

An additional 15% of the estimated total cost is added for traffic control and mobilization and 6% is added for design.

Agency Cost from Pavement Mill and Overlay
According to TxDOT's 2017 Average Low Bid Unit Prices, the cost for mill and overlay is $174,640 per mile (2017$). The total cost of mill and overlay can be calculated using the following formula:

Equation 13 Agency Cost – Mill and Overlay

Cost (Mill and Overlay) = L * W * P

L = project length
W = width of concrete pavement
P = the unit price of mill and overlay (2018$)

An additional 15% of the estimated total cost is added for traffic control and mobilization and 6% is added for design.

User Costs (Build and No-Build Alternatives)
During either the reconstruction (build alternative) or maintenance treatment cycles (no-build alternative), there will be a user cost incurred due to delays. During construction (in both repair or reconstruction), a driver would have to merge lanes, reduce speed, or even wait in a queue. Thus, travel time during construction is anticipated to be increase by 50% during construction periods. The total free flow time that was calculated (assuming standard free flow at the speed limit) would be doubled along the roadway segment.

Repairs are assumed to take approximately 240 days per mile for the reconstruction (build alternative) and 60 days per mile for the maintenance treatment cycles (no-build alternative). Per H-GAC, the average Value of Travel Time (VoTT) is $16.69/hour for each person, and vehicle occupancy is 1.25 persons/vehicle. Traffic volumes are obtained from the latest H-GAC conformity model runs and/or 2016 TxDOT urban saturation counts. The annual growth rate for traffic volumes is calculated through looking at a small network surrounding the project. The repair cost would be incurred multiple times, and the annual traffic volume should be adjusted for the year of repair.

The total user cost during the construction period would be calculated as follows:

Equation 14 Roadway Reconstruction and Maintenance - User Costs

Cost (User) = AADT * PPV * VoTT * T * D

AADT for year n = AADT for current year*$(1+x\%)^n$
-x% is assumed to be the annual growth rate; this is derived from the H-GAC model
PPV = 1.25 person/vehicle
VoTT = $16.69
T = Travel time (in hours) during construction
D = number of weekdays during construction period

Analyzing Results

The agency and user costs are combined for an estimated cost for conducting repairs during the next 20 years, summed up and discounted at a 7% rate. The proposed project would reconstruct the concrete pavement along the corridor, and the service life of the reconstructed roadway would be 40 years. With the new concrete pavement in the reconstruction, no full depth repair of existing pavement would be required. Therefore, the life cycle cost savings from the roadway maintenance during the next 20 years would be the cost of maintenance of the concrete of pavement or mill and overlay. The no-build alternative cost is reflected as a cost in the final benefit cost ratio.

BACK OF CURB PROJECTS

For sidewalk and other improvements that improve the walkability of an area, there is a presumed maintenance benefit from automobile trips being converted into pedestrian trips, as there will be fewer miles traveled on the roadway. The vehicle miles traveled (VMT) reduced from the back of the curb improvements is calculated by multiplying the number of trips reduced by the half mile average trip length. The reduction in VMT traveled on roadways thereby reduces the need for maintenance on roadways. Research conducted by the Victoria Transport Policy Institute found that the average maintenance cost per VMT is 5.27 cents in urban areas (2017$).[12] Therefore, the total maintenance avoided by reducing VMT is as follows:

Equation 15 Back of Curb - Maintenance Savings

Maintenance Savings = VMT * MC

VMT = VMT reduced in project opening year*$(1+ x\%)^n$
-x% is assumed to be the annual growth rate; this is derived from the H-GAC model
-n is the number of years
MC = Maintenance Costs per VMT (assumes $.0527)

Accumulated benefits are summed up and discounted at and 7% rate.

ECONOMIC BENEFITS

The improvement of transportation infrastructure, i.e. bike lanes, sidewalks and roadways, has been proven to improve existing property values and/or boost local sales tax. Research as shown that the installment of a sidewalk, on-street and/or multi-use bike lane will improve existing property values and thereby provide an increase in the overall property taxes generated. A new roadway will provide developers with the ability to develop the area with new homes or commercial uses, which in-turn will increase property tax generation, purchasing power of the area through in-migration residents, and

[12] Victoria Policy Institute. Transportation Cost and Benefit Analysis II – Roadway Costs. Retrieved in July 2017 from http://www.vtpi.org/tca/tca0506.pdf.

provide a one-time local stimulus through the construction of new development. The increased revenue and benefits for community can be used to support additional services and provide opportunities for reinvestment of funds in the community.

ROADWAY PROJECTS

New roadways will provide accessibility to vacant land that otherwise might not develop. Therefore, new roadways have the potential to spur development and generate both property and sales tax revenue. However, property taxes are typically seen as a zero-sum game, meaning that the revenue that the taxing jurisdiction generates from new development is typically used to support that development. Therefore, it is not included as a benefit in this methodology. Instead, the taxing jurisdiction will see an increase in sales tax generated from new in-migration residents, commercial uses and one-time stimulus of sales taxes through the construction of the development.

Thera are several sources that provide the economic impact for the construction and new activities. For this analysis, IMPLAN, a nationally recognized modeling software, was primarily used to estimate the economic benefits to the region derived from the project.[13] The following steps are used to project the future sales tax revenue.

Step 1: Determine the number of new single-family structures and square feet of all other structures.

i) Identify, with a graduated build out plan, the number of single/multifamily structures and square feet of non-residential structures through an existing land plan using H-GAC's current and future land use database. The database provides the number of vacant parcels within 500 feet of the proposed project, which will aides in determining commercial and residential acres available for development. Vacant land can be categorized based on surrounding land use.
ii) Determine the share of vacant land that would be available for residential or commercial development. In the absence of more precise information or zoning codes, the default assumption is 75% for residential and 100% for commercial.
iii) Assume .25 acres per household structures
iv) Assume a local floor to area ratio (FAR) for all other structures

Step 2: Estimate the Sales Tax Generated from In-Migration Households.

i) Multiply the number of new households (HHs) by the in-migration rate for the H-GAC region; which is 25.21%.[14]
ii) Using geographies close to the project, determine the developed area's Median Household Income using the latest U.S. Census American Community Survey data.
iii) Multiply HH median income by new in-migrated HHs, which is the total new HH income change for the project area.
iv) Assume a standard 1.2% H-GAC wage increase.
v) Input the New Regional HH Income in Project Area into the corresponding income bracket sector of IMPLAN under the Activity Type, Household Income Change.

[13] IMPLAN Group LLC, IMPLAN System (data and software),16905 Northcross Dr., Suite 120, Huntersville, NC 28078
[14] United States Census Bureau. American Community Survey County-to-County Migration Flows: 2011-2015. Retrieved January 2018 from https://www.census.gov/data/tables/2015/demo/geographic-mobility/county-to-county-migration-2011-2015.html.

vi) Accumulated sales tax benefits over the 20-year analysis period are summed up and discounted at a 7% rate.

Step 3: Estimate the Sales Tax Generated from New Retail Uses.

i) Use building size data from Step 1 to determine the new jobs by sq. ft. through data derived from the U.S. Green Building Council.[15]
ii) Input the new jobs, by year, into the corresponding sector code in IMPLAN under the Activity Type, Industry Change.
iii) Accumulated sales tax benefits over the 20-year analysis period are summed up and discounted at a 7% rate.

Step 4: Estimate the One-Time Sales Tax Generated from Construction of Residential and Non-Residential Structures

i) Use building size data from Step 1 to determine total new developed sq. ft. of residential and non-residential space and determine a growth rate for development (each new building stage is treated as a separate one-time benefit).
ii) Using industrial standard costs rates, calculate the costs to construct the all structures, by type.[16]
iii) Multiply total sales price by the following and input into IMPLAN :[17]
   (1) Construction – 76.6% (less engineering/architectural: 10% of construction)
   (2) Real Estate – 23.4%
iv) Input the construction activity into the corresponding sector code in IMPLAN under the Activity Type, Industry Change.
v) Accumulated sales tax benefits over the 20-year analysis period are summed up and discounted at a 7% rate.

Step 5: Estimate the One-Time Sales Tax Generated from Construction of Transportation Asset

i) Determine cost of asset.
ii) Multiply total cost of asset by the following:
   (1) Construction – 90%
   (2) Engineering/Architectural – 10%
iii) Input the construction activity into the corresponding sector code in IMPLAN under the Activity Type, Industry Change.
iv) One-Time sales tax benefits from construction are summed up and discounted at a 7% rate.

SIDEWALKS

Research has shown that the improvement of walkability can increase the property values of residential and commercial properties.[18] An "improved Walkscore[19] can increase the property values from $4,000 to $34,000 per residential property and 9% to 54% per square foot for commercial properties." The methodology involved in this report assumes (based on the field inventory completed) that the existing corridor conditions do not currently support pedestrian activity; therefore, the Walkscore would improve if pedestrian improvements are installed. For residential properties, the $5,129 (inflated value to 2018$)

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[15] United States Green Building Council. *Appendix 2 Default Occupancy Counts*. Retrieved January 2018 from https://www.usgbc.org/credits/new-construction-existing-buildings-commercial-interiors-core-and-shell-schools-new-constr-3.

[16] Craftsman. *2018 National Building Cost Manual.* Retrieved January 2018 from https://www.craftsman-book.com/.

[17] Ford, Carmel December 2017. *Cost of Constructing a Home*. Housing Economics.

[18] The University of Delaware. Healthy and complete communities in Delaware: The walkability assessment tool. Retrieved in June 2017, from http://www.ipa.udel.edu/healthyDEtoolkit/walkability/benefits.html.

[19] https://www.walkscore.com/

is assumed to occur once; the 9% commercial property value is applied similarly. This analysis assumes the lower end of this range to be conservative. Benefits are only attributed to the increment for each property. The following formulas were used to calculate the increase in property taxes by use:

Equation 16 Back of Curb – Residential Tax Increase

Residential Tax Increase = # of properties abutting corridor * $5,129 * Tax Rate

Equation 17 Back of Curb – Commercial Tax Increase

Commercial Tax Increase = sq. ft. of improvement abutting corridor * 9% * Tax Rate

A 3% increase is applied to the increment each year for the annual increase in property and land values. Accumulated benefits are summed up over the 20-year analysis period and discounted at a 7% rate.

BICYCLE FACILITIES

Bicycle facilities can spur increased property values, which would then result in increased appraisal values that provide additional property tax benefits to the municipality.

On-Street

For on-street bicycle facilities, researchers found that in Portland, Oregon each quarter mile closer to the nearest bicycle facility, increases property values for single-family and multi-family homes by $1,571 and $211 respectively.[20] Using home prices from the Economist Home Index, Houston metro area home prices are valued at 57.5% of Portland's, using data from first quarter of 2015 to second quarter of 2016.[21] The property value increases were adjusted for the Houston Metro Area based on that factor and inflated to in 2018 dollars, resulting in a one-time improvement of $848.50 for single-family and $114 for multi-family homes.

Equation 18 On-Street Bike Facility –Tax Increase

One Time Property Value Increase = Residential units within ¼ mile of improvement · Unit improvement factor (in $)

The tax rate is applied to the incremental value of the improvements. A 3% increase is applied in the increment each year for the annual increase in property and land values. Accumulated benefits for the 20-year analysis period are summed up and discounted at a 7% rate.

Greenways/Off-Street Bike Trails

People are willing to pay more for a property located close to a greenway with trails than for a home that does not offer this amenity.[22] For off-street bicycle facilities, the increased property values of proximate landowners is expected to occur within 600 feet of the facility. To calculate the increase in property values, John Crompton—in measuring the economic benefits accruing from the expansion of Houston's Bayou Greenway Network—applied a conservative 5% premium to all residential units within the 600-feet buffer.[23] Furthermore, researchers of a different study found that trails, greenbelts, and trails with

[20] Liu, J. H., & Shi, W. (2016, November 14). Impact of Bike Facilities on Residential Property Prices. Portland, Oregon

[21] The Economist. (2017, 10 25). *American house prices: realty check*. Retrieved from Graphic Detail: https://www.economist.com/blogs/graphicdetail/2016/08/daily-chart-2

[22] Crompton, John L. Estimates of the Economic Benefits Accruing From an Expansion of Houston's Bayou Greenway Network. *Journal of Park and Recreation Administration*, 30(4), 83-93

[23] Ibid.

greenbelts (or greenways) are associated with roughly 2, 4, and 5%, price premiums, respectively.[24] For this benefit analysis, a 5% premium is applied to all residential units within the 600-feet buffer around a trail or greenway.

Equation 19 Greenways Bike Facility –Tax Increase

One Time Property Value Increase = 5% · Current value of Residential Improvements within 600 feet

The tax rate is applied to the incremental value of the improvements. A 3% increase is applied to the increment each year for the annual increase in property and land values. Accumulated benefits are summed up over the 20-year analysis period and discounted at a 7% rate.

[24] Asabere, P. K., & Huffman, F. E. (2009). The Relative Impacts of Trails and Greenbelts on Home Price. *The Journal of Real Estate Finance and Economics*, 408-419

ENVIRONMENTAL BENEFITS

The Environmental Protection Agency (EPA) has classified the Houston-Galveston-Brazoria area in severe nonattainment of the eight-hour ozone standard: air quality does not meet federal standards. The investment in mobility infrastructure could produce environmental benefits due to decreased automobile use or vehicle delay which will reduce air pollutants, which is important to the region's future growth.

SIDEWALK AND BICYCLE PROJECTS

The Houston-Galveston Area Council (H-GAC) models the following harmful air pollutants: Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs) and Carbon Dioxide (CO_2); the MPO has emissions factors as follows:

- NOx: 0.19 grams (g) per vehicle mile traveled (VMT)
- VOC: 0.32 g/VMT
- CO_2: 3.06 g/VMT

Additionally, both NOx and VOC have a measurable societal economic impact on the economy. The United States Department of Transportation's TIGER Benefit Cost Analysis Resource Guide provides recommended monetized values for NOx ($9,043 per metric ton in 2018$) and VOC ($2,295 per metric ton in 2018$)[25] ($CO_2$ does not have a widely accepted monetization factor). These values are used to calculate the project's benefit derived from the reduction of harmful air pollutants.

For sidewalk and other improvements that improve the walkability and/or bikeability of an area, there is a presumed environmental benefit from automobile trips being converted into pedestrian or bicycle trips. The methodology for trip conversion and VMT reduced is explained in a prior section of this methodology document. The VMT benefit is derived and converted into the amount of VOC and NOx grams reduced, which is then monetized based on the emissions factors above. VMT is assumed to grow annually at the same rate as the TAZ level population, as derived from the H-GAC TAZ-level forecasts. Accumulated benefits are summed up over the 20-year analysis period and discounted at a 7% rate.

[25] The United States Department of Transportation. 2015. TIGER Benefit Cost Analysis Resource Guide. Retrieved on April 2016 from https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide.

AUTOMOBILE MAINTENANCE BENEFITS

Operating a vehicle is one of the most expensive budgets items in American households. The reduction in VMT from automobile trips converted to pedestrian or bicycle trips results in a benefit for automobile owners.

SIDEWALK AND BICYCLE PROJECTS

The TIGER grant program estimates the benefit of each mile reduced as 40 cents (2016$) for the automobile user.[26] The value per mile includes operating costs, such as gasoline, maintenance and depreciation. The benefit omits fixed costs of owning a vehicle, such as insurance, registration, etc. The total automobile maintenance avoided by reducing VMT is as follows:

Equation 20 Automobile Maintenance Savings

Automobile Maintenance Savings = VMT * MC

VMT = Vehicle Miles Traveled Reduced (see methodology above)
MC = Automobile Maintenance Costs per mile (assumes $.41 in 2018$)

VMT is assumed to grow annually at the same rate as the household population, as derived from the H-GAC TAZ-level forecasts. Accumulated benefits for the analysis period are summed up and discounted at a 7% rate.

[26] The United States Department of Transportation. 2017. Benefit Cost Analysis Guidance. Retrieved in April 2018 from http://www.dot.ca.gov/hq/tpp/offices/eab/docs/INFRA_TIGER_benefit-cost-analysis-guidance-2017.pdf

BICYCLE ONLY BENEFITS

For bicycle projects, peer reviews show benefits for recreation and health; these studies are used to estimate benefits accruing from bike projects only. The methodology document explains how recreational and new bicyclists are calculated in a prior section.

RECREATION BENEFITS

Based on a number of studies of outdoor recreational activities, the NCHRP Report assumes that the typical day involves about 1 hour of total bicycling activity, valued at $10 in 2004.[27] The average adult cycling day includes approximately 40 minutes of bicycling, and an additional 20 minutes of preparation and cleanup time. To estimate benefits, it is assumed that there are 120 days of recreational available per year, which includes weekends and federal holidays.

Equation 21 Bicycle Projects - Annual Recreation Benefit

Annual Recreation Benefit = D * 120 * Total New Recreational Bicyclists

D = $11.80 is the value of 1 recreational hour in 2018 dollars; the value is assumed to increase by 1.2% per year to reflect wage increases, consistent with other H-GAC methodologies
120 = days of recreation available per year

The number of new recreational bicycle users are assumed to grow annually at the same rate as the TAZ level population, as derived from the H-GAC forecasts. Accumulated benefits for the analysis period are summed up and discounted at a 7% rate.

HEALTH BENEFIT

To calculate the health benefit, the NCHRP Report determines an annual per-capita cost savings from physical activity of $128 by taking the median value of ten studies. This value is inflated from the 1995-value to 2018 dollars, which amounts to $241.60.

Equation 22 Bicycle Projects - Annual Health Benefit

Annual Health Benefit = Total New Bicyclists · $241.60

The number of total new bicyclists is assumed to grow annually at the same rate as the TAZ level population, as derived from the H-GAC forecasts. Accumulated benefits for the analysis period are summed up and discounted at a 7% rate.

[27] Transportation Research Board. (2006). *NCHRP Report 552: Guidelines for Analysis of Investments in Bicycle Facilities.* Washington, D.C.: Transportation Research Board.