HEALTH ASSESSMENT OF THE BRUCE ELEMENTARY SCHOOL COMMUNITY

Final Report

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About This Report

This report was prepared by Urban Design 4 Health, Ltd. (UD4H). UD4H specializes in applied research on the interactions between land use, transportation, air quality, climate change, and public health. UD4H's mission is to support clients with innovative and objective information and tools to realize health promotion, environmental, economic, and quality of life goals that are intrinsic in efforts to build new communities and to retrofit existing ones. Learn more at www.ud4h.com.

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Billy Bachman was the UD4H Project Manager for the *Community Health Assessment for Schools in the I-45N Freeway Expansion Area* and led the assessment of air quality exposure risk for the planned freeway design and developed exposure maps for site-specific challenges, and wrote this report. Eric Fox and Behram Wali helped with mapping of baseline conditions as estimated by NPHAM, conducted a sensitivity analysis of built and natural environment scenarios to improve health, and assisted with preparation and review of the analysis report. Nicole Alfonsin identified mitigation methods to reduce exposures based on Task 3A and 3B and assisted with preparation and review of the final report. Dr. Lawrence Frank reviewed the results and contributed to the analysis report.

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1. Baseline Conditions

The Bruce Elementary School community, comprised of the current school attendance zone as shown in Figure 1, lies east of downtown Houston and in close proximity to I-69, I-10, and the Buffalo Bayou. As part of an effort to explore the health impacts of the Texas Department of Transportation's proposed North Houston Highway Improvement Project (NHHIP), the Air Alliance Houston (AAH) team contracted with Urban Design 4 Health (UD4H) to evaluate the potential health impacts on the Bruce Elementary School community using the National Public Health Assessment Model (N-PHAM)[1]. This draft report discusses the initial findings of the baseline assessment of health outcomes, physical activity, and park accessibility.

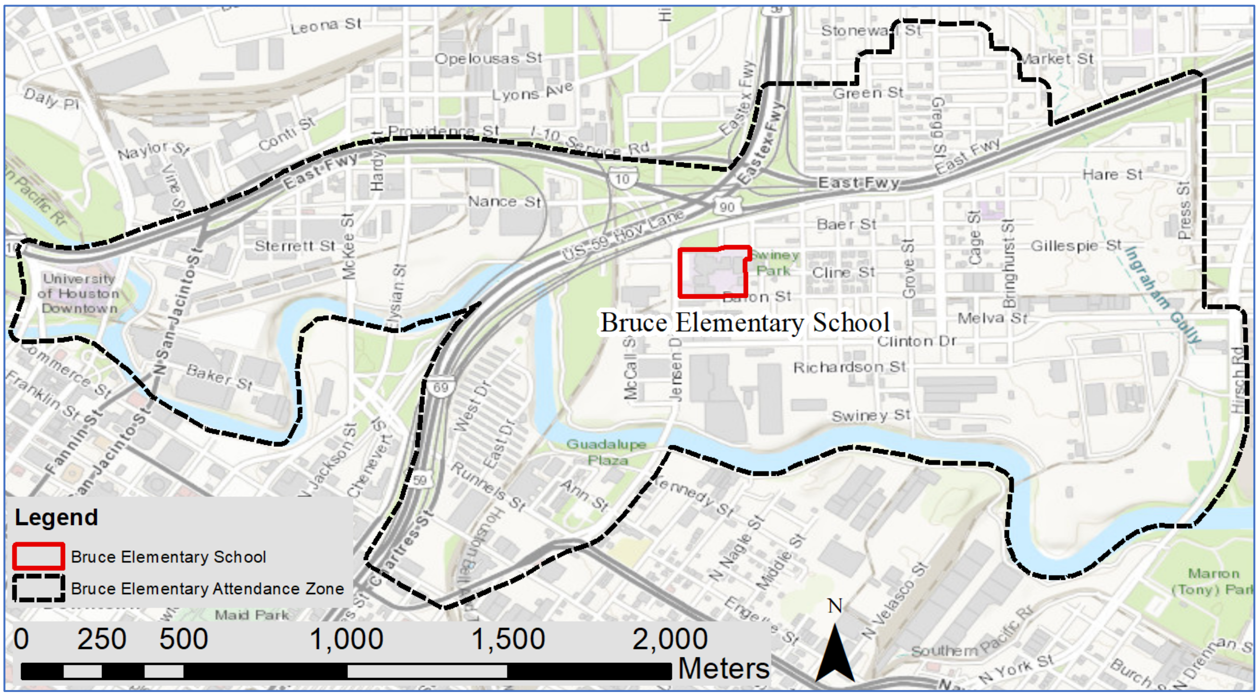

Figure 1 - Bruce Elementary School Attendance Zone

National Public Health Assessment Model (N-PHAM)[1]

N-PHAM is a model developed by UD4H with support from the US Environmental Protection Agency (EPA). It uses evidence-based inferential statistics to relate health outcomes with built, natural and social environment features. N-PHAM uses a pre-built national database developed by UD4H of baseline input conditions and estimates health outcomes using equations developed from the analysis of health interview surveys and household travel surveys[a], and built/natural/social environmental data. N-PHAM baseline conditions are estimated at the US Census block group geographic level (a geographic unit that is the minimum size for published sample demographic data) . N-PHAM supplements the Centers for Disease Control's (CDC) 500 Cities[2] US Census Tract level data in that N-PHAM has health outcomes and physical activity linked to built environment features. This linkage allows researchers and analysts to estimate changes in future health outcomes due to changes in environmental characteristics, such as those changes being planned as part of the NHHIP freeway expansion.

There is growing evidence of a *causal* relationship between the built environment and residents' opportunities to engage in healthy lifestyles relevant to chronic disease prevention[3-5]. Numerous studies have identified how exposure to different types of built environments impact physical activity, diet, and chronic disease[6-9]. These research findings suggest that tools such as N-PHAM could be helpful in identifying changes to the built environment that could have a significant impact on health and physical activity outcomes of communities such as the Bruce Elementary School community.

For predicting health and physical activity outcomes, N-PHAM relies on associations between the built/natural environment and health and physical activity outcomes; these relationships only explain a small amount of the variance in health outcomes[1]. Baseline estimates and subsequent model changes that indicate a positive or negative change should be considered as indicators, not as a deterministic outcome. Regardless, N-PHAM allows planners the ability to evaluate community investments in planned infrastructure based on their likely impact on community health.

The N-PHAM baseline assessment of the Bruce Elementary community includes the health and physical activity outcomes shown in Table 1 and Table 2, respectively. This initial assessment will include comparison metrics for the full NHHIP corridor, the city of Houston, Harris County, Metro Houston (Houston Metropolitan Statistical Area), and the state of Texas. The comparisons across these geographic levels will be useful in understanding how this particular community compares to others in and around Houston.

Childhood Health and Communities

All of the N-PHAM health outcome data used to generate the relationships between the health and the built environment are based on survey data for adults. One of the primary objectives of AAH's assessment of Bruce Elementary and other schools is to develop opportunities for protecting and improving the health of grade-school children. There is evidence to suggest that the health-related lifestyles related to obesity (e.g., diet and physical activity) of parents translate to children, however the correlation is not strong[10]. There is, however, sufficient evidence to support the notion that regular physical activity in school-aged children, defined as 60 minutes or more of moderate-to-vigorous aerobic, muscle-strengthening, and bone-strengthening physical activity each day, results in higher levels of cardiorespiratory fitness, stronger muscles, lower body fat, and stronger bones[11]. Importantly, regular physical activity also has brain health benefits for school-aged children, such as improved cognitive functions (memory, executive function, processing speed, attention, and academic performance) and reduced symptoms of depression[11]. While

[a] This model uses data from the 2011-2012 adult data from the California Health Interview Survey (CHIS) and the most recent edition of the California Household Transportation Survey (CHTS), which sampled 42, 431 households across California in 2010-2012.

chronic diseases (e.g., heart disease, hypertension, type 2 diabetes, osteoporosis) do not typically develop during youth and adolescence, obesity and other risk factors for these diseases (elevated blood lipids and blood pressure) are increasingly present among children and adolescents[11]. Regular physical activity can help to combat these risk factors, improving health and fitness not only during youth and adolescence, but also increase the likelihood of remaining healthy adults[11,12].

Despite these known benefits, many school-aged children do not meet the recommended levels of physical activity, and obesity remains a prominent health crisis in this age-group. Approximately 24% of children aged 6-17 years of age in the U.S. meet the recommended levels of physical activity[13] and 17.2-25% of youth in the U.S. are overweight or obese[14]. In fact, while there have been slight improvements in physical activity among adults in recent years, there has been a decrease in physical activity during adolescence. Overall, the 2018 U.S. Report Card on Physical Activity for Children and Youth indicated that 20-28% of children and youth meet overall physical activity guidelines, with a greater percentage of boys meeting recommendations compared to girls.

The neighborhood environments in which school-age children live appear to influence activity levels[15-19]. For example, children living in neighborhoods perceived as less walkable and not close to transit and recreation spaces engaged in less out-of-school moderate-to-vigorous physical activity (MVPA)[15]. Further, communities with more-walkable streets, access to a high-quality park, and healthier food outlets are negatively associated with the prevalence of adolescent overweight and obesity[18,19]. Brisk walking and bicycle riding are both considered examples of moderate-to-vigorous physical activity among school-aged children[12]. In fact, children who engage in active transportation (i.e., walking or biking) are more likely to meet physical activity recommendations compared to those who travel by motor vehicle[13].

In response to the current levels of physical inactivity and obesity rates among school-age children, researchers recommend a comprehensive, multi-sector strategy be implemented to increase physical activity among youth and adolescents[16]. Effective interventions include school-based physical activity programming and education, after-school physical activity programming, improving the built environment to include access and proximity to recreational facilities, activating youth sport participation, and re-normalizing active transport to school[16].

Health Outcomes for Baseline Conditions

The estimated health outcomes for the Bruce Elementary School community and other areas of interest are shown in Table 1. These results are household-weighted aggregations of US Census block groups. The Bruce Elementary attendance zone is highlighted in blue and Metro Houston is highlighted in orange. Figure 11 through Figure 14 (found in the appendix) provide US Census block group maps of the health outcome metrics. These maps include a "zoomed in" portion of the Bruce Elementary community as well as show the NHHIP corridor (yellow) and other schools of interest. For the Bruce Elementary inset map, a 1 KM network-based walking distance buffer, and a 1 KM Euclidean (or crow-fly) distance buffer are provided. The 1 KM walking distance on the network shows areas within a reasonable walking distance from the elementary school. The Euclidean distance buffer shows areas that should be accessible if road/trail connectivity was available.

Table 1 – N-PHAM estimated health outcomes (adults, age 20 – 65 years old)[b]

US Census Block Group Aggregation	Average Body Mass Index	% Obesity	% Psychological Distress	% Poor Health Status
Bruce Elementary Attendance Zone	28.26	31.13%	29.41%	28.57%
NHHIP Study Area	28.25	29.63%	27.65%	26.38%
City of Houston	27.91	26.25%	24.28%	17.02%
Harris County	27.97	26.73%	23.86%	15.89%
Metro Houston	28.00	26.82%	22.88%	13.82%
Texas Statewide	28.12	28.30%	22.93%	13.67%
Metro Houston Weighted Standard Deviation	*0.78*	*1.15%*	*4.87%*	*8.38%*

Body Mass Index (BMI) and Obesity

BMI is a common metric to estimate adiposity and for adults is calculated as weight in kilograms divided by the height in meters squared. Obesity is defined as percent of the adult population with a BMI over 30. In addition to a wide range of demographic variables (e.g., income, age, employment, education, etc.), which are controlled for in all the health-outcome and physical activity models in NPHAM, these metrics show an association to the following selected N-PHAM built environment metrics:

- Population density
- Tree canopy
- Job accessibility by transit
- Percent developed open space

Results indicate that the Bruce Elementary community has estimated average BMI values similar to Houston and Texas, however, the percentage of the community with obesity is higher than average. This difference could be explained by a higher than typical variability in BMI in this community. Maps of US Census block group BMI and Obesity are provided in the appendix, Figure 11 and Figure 12.

Psychological Distress

A measure of psychological distress was included based on the mental health benefits associated with increased physical activity. The N-PHAM metric of psychological distress was originally developed from analyses of surveys that followed the Kessler-6 protocol[c]. Psychological distress in N-PHAM is estimated primarily from economic and demographic variables (employment, home ownership, age, income, and

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[b] Health outcomes are based on 2011-2012 adult data from the California Health Interview Survey (CHIS).

[c] The Kesslet-6 is a 6-item, validated ental health instrument intended to measure non-specific psychological distress. It ranges 0-24 where a higher score indicates greater psychological distress. A score of 13 or higher indicates serious mental illness.

education). Results indicate that the Bruce Elementary community has a higher than average psychological distress at baseline values of key model inputs. A map of US Census blocks with the percent of the population under psychological distress at baseline is provided in the appendix, Figure 13.

Poor Health Status

The N-PHAM metric of Fair or Poor Health Status was originally developed from survey responses where participants provided a self-rating. In addition to a wide range of demographic variables (income, age, employment, education, etc.), Percent Poor Health Status shows an association to the following selected N-PHAM built environment metrics:

- Employment density
- Tree canopy
- Transit accessibility
- Population density

Results indicate that the Bruce Elementary community (and the full NHHIP corridor) has a higher than average Percent Poor Health Status. Maps of US Census block group Percent Poor Health Status at baseline are provided in the appendix, Figure 14.

Physical Activity

The estimated levels of physical activity for the areas of interest are shown in Table 1. These results are household-weighted aggregations of US Census block groups. The Bruce Elementary attendance zone is shown in blue and Metro Houston is shown in orange. Metro Houston (the metropolitan statistical area) is highlighted because this area captures all of the Houston area communities. Figure 15 through Figure 21 (found in the appendix) provide US Census block group maps of the physical activity metrics. These maps include a zoomed in portion of the Bruce Elementary community as well as show the NHHIP corridor (yellow) and other schools of interest. For the Bruce Elementary inset map, a 1 KM network-based walking distance buffer, and a 1 KM Euclidean distance buffer are provided.

Table 2 – N-PHAM estimated physical activity[d]

US Census Block Group Aggregation	% Walking for Utilitarian Transport	% Walking for Leisure	% Cycling for Utilitarian Transport	% Rec. Physical Activity	Walkability Index
Bruce Elementary Attendance Zone	15.39%	48.92%	2.07%	13.19%	37.41
NHHIP Study Area	15.52%	47.96%	2.06%	13.43%	34.37
City of Houston	13.24%	50.65%	1.45%	15.87%	26.57
Harris County	12.65%	50.70%	1.43%	15.80%	25.41
Metro Houston	11.46%	51.15%	1.30%	15.89%	23.57
Texas Statewide	10.68%	50.71%	1.36%	14.93%	21.82
Metro Houston Weighted Standard Deviation	4.32%	4.03%	0.80%	3.46%	4.81

[d] Based on data from the 2011-2012 adult data from the California Health Interview Survey (CHIS) and the most recent edition of the California Household Transportation Survey (CHTS), which sampled 42, 431 households across California in 2010-2012.

Walking for Utilitarian Transportation

The "percent walking for utilitarian transportation" is the percent of the population engaging in any daily walking for transportation (any trip purpose except leisure or recreation). Utilitarian transport is important to community health because higher levels suggest that residents typically have more physical activity in their daily activity patterns than those that live in auto-centric communities. Even small amounts of walking or biking, to access work, school, or retail, can have significant impacts on chronic disease risk. In addition to demographic variables (vehicle ownership, home ownership, employment status, age, income, education, and family size), the following select built/natural environment variables are used to estimate the percent Walking for Utilitarian Transport.

- Population density
- Employment density
- Tree canopy
- Job accessibility by transit
- % developed open space
- % forest landcover

Results indicate that the percentage of the population walking for utilitarian transport in the Bruce Elementary community (and the full NHHIP corridor) falls within the standard deviation (not statistically different) than Metro Houston. The value, however, is higher than average, which is a positive finding for community health. Evaluated at baseline values of model inputs, a map of US Census block group percent Walking for Utilitarian Transport are provided in the appendix, Figure 15.

Walking for Leisure

The "percent walking for leisure" is the percent of the population engaging in any weekly walking for leisure. In addition to demographic variables (vehicle ownership, home ownership, employment status, age, income, education, and family size), the following built/natural environment variables are used to estimate the percent Walking for Leisure.

- Population density
- Employment density
- Employment entropy
- Percent natural open space
- Percent jobs near fixed transit

Results indicate that the percentage of the population walking for leisure in the Bruce Elementary community (and the full NHHIP corridor) falls within the standard deviation (not significantly different than Metro Houston) but, has an equivalent or slightly lower than average percent walking for leisure compared to all of Houston. This value contrasts with the percent of utilitarian travel suggesting that there are potential negative factors influencing walkability. Evaluated at baseline values of model inputs, a map of US Census block group percent Walking for Utilitarian Transport are provided in the appendix, Figure 16.

Cycling for Utilitarian Transportation

The "percent cycling for utilitarian transportation" is the percent of the population engaging in any daily biking for transportation (any trip purpose except leisure or recreation). In addition to demographic variables (vehicle ownership, home ownership, employment status, age, income, education, and family size), the following select built/natural environment variables are used to estimate the percent Cycling for Utilitarian Transport.

- Population density
- Network density
- Percent natural open space

Results indicate that the percentage of the population cycling for utilitarian transport in the Bruce Elementary community (and the full NHHIP corridor) falls within the standard deviation and has a higher than average compared to all of Houston. A map of US Census block group percent cycling for utilitarian transport (at baseline values) are provided in the appendix, Figure 17.

Recreational Physical Activity

The percent Recreational Physical Activity is the percent of the population engaging in any daily recreational physical activity. In addition to demographic variables (vehicle ownership, home ownership, employment status, age, income, education, and family size), the following select built/natural environment variables are used to estimate the percent Recreational Physical Activity.

- Population density
- Employment density
- Tree canopy
- Transit accessibility

Results indicate that the percentage of recreational activity in the Bruce Elementary Community (and the full NHHIP corridor) falls within the standard deviation but has a lower than average compared to all of Houston. A map of US Census block group percent Recreational Physical Activity are provided in the appendix, Figure 18.

Walkability Index

The N-PHAM Walkability Index is a composite metric that includes employment entropy (mix), intersection density, residential density, public transit density, and vehicle miles traveled. The index is shown on a 1-100 scale. This index is the National Walkability Index that was developed by UD4H for the Robert Wood Johnson Foundation(https://www.rwjf.org/en/cultureofhealth/taking-action/creating-healthier-communities/built-environment.html).

Results indicate that the Bruce Elementary community has a higher than average walkability score when compared to the rest of Metro Houston, likely due to it's access to transit, intersection density, and population density. This indicates that the community has many things working in its favor to encourage active transportation and physical activity. More detailed assessment of the influence of neighborhood level walkability using factors that are not readily available at a national scale, may reveal local realities that confirm or conflict this estimate. Figure 20 shows a map of walkability for the region.

Parks and Greenspace

Parks and greenspace are important components of a healthy and physically active community. Table 3 shows the US census block group average result of three metrics comparing the Bruce Elementary community to the rest of Houston.

Table 3 – N-PHAM estimated parks and greenspace

US Census Block Group Aggregation	% of Park Acreage	Total Park Acres Within 1km Walking Distance	Percent Tree Cover
Bruce Elementary Attendance Zone	0.83%	9.45	2.40%
Freeway Expansion Study Area	1.89%	17.75	9.41%
City of Houston	8.32%	28.00	14.75%
Harris County	6.61%	23.40	15.97%
Metro Houston	1.79%	18.45	18.37%
Texas Statewide	NA	NA	17.65%

Percent of Park Acreage and Total Park Acreage Within 1 KM Walking Distance

The percent of Park Acreage is the sum of actively managed park acreage within the US Census block group divided by the total land acreage. The Bruce Elementary community has lower than average acreage of active parks compared with Houston. Figure 2 shows the active parks in the Bruce Elementary area. Swiney Park and Community Center provide the only active park close to the school, but it is not large enough to contain active sports fields. Furthermore, the school campus does not house a dedicated gym or active sports fields.

The total park acreage within 1 KM walking distance from the center of the Bruce Elementary community US Census block group is less than average for the Houston area. The Buffalo Bayou Greenway is the primary source of park acreage accessible from this community.

Percent Tree Cover

Percent tree cover is developed from the National Land Cover Database[e] and is a metric in N-PHAM that is associated with a number of health and physical activity metrics. Figure 21 shows a map of US Census block group tree cover percentage for the Bruce Elementary Community and Houston area. It should be noted that the Bruce Elementary community has significantly less tree canopy coverage than other areas of Houston.

[e] https://catalog.data.gov/dataset/national-land-cover-database-nlcd-land-cover-collection

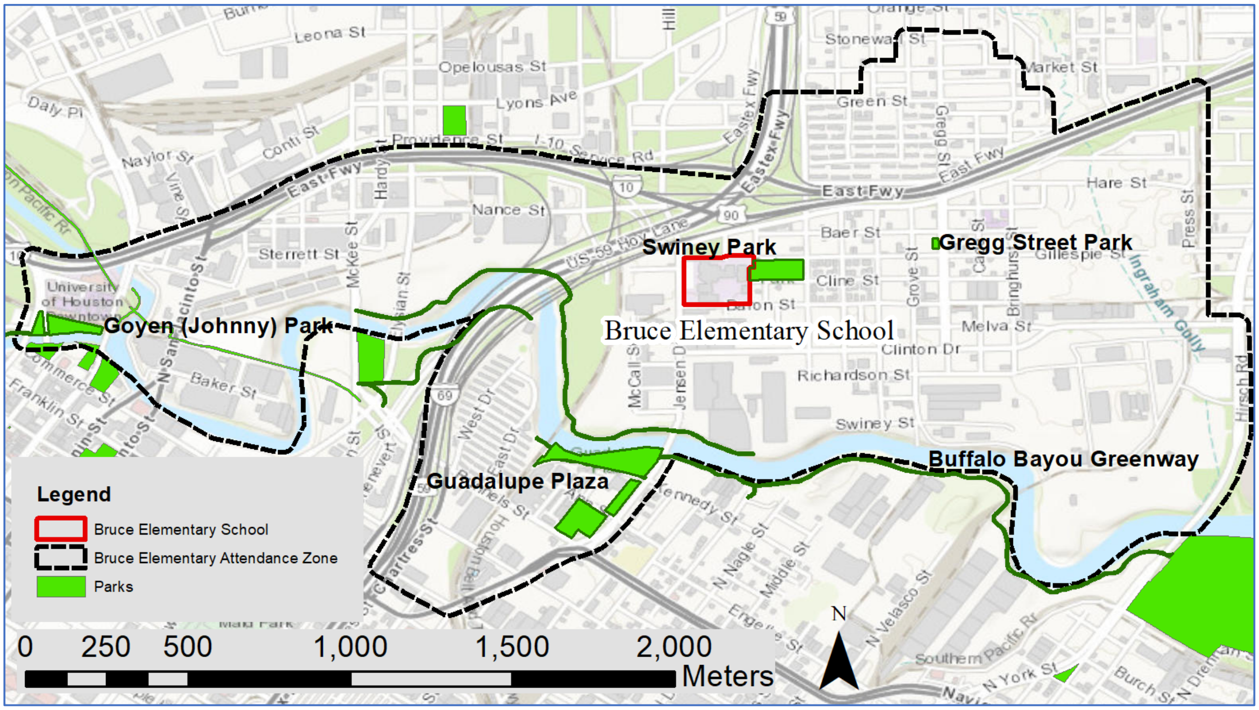


Figure 2 - Bruce Elementary School Community Parks

Discussion of baseline conditions

This initial review of baseline health and physical activity metrics provides a broad perspective of conditions in the Bruce Elementary community when using nationally available estimates at the US Census block group level . The Bruce Elementary community is lower than average in estimated health outcome metrics when compared to Metro Houston. Despite an abundance of vacant land, the Bruce Elementary community has less than average active park acreage and no managed sports fields within the school attendance zone. The community has opportunities for increases in health-related active transportation by taking advantage of its proximity to downtown and by increasing park accessibility.

Figure 3 shows the existing and proposed freeway alignments. Given the new alignment and proposed land use and connectivity changes, there are a number of opportunities to expand and improve active park space, tree canopy, greenspace, bike/pedestrian connectivity, and land use. These challenges and opportunities are further explored in the next section to find proactive solutions for preserving and enhancing the health of the students at Bruce Elementary School and the surrounding community.

Existing Freeway Alignment NHHIP Proposed Freeway Alignment

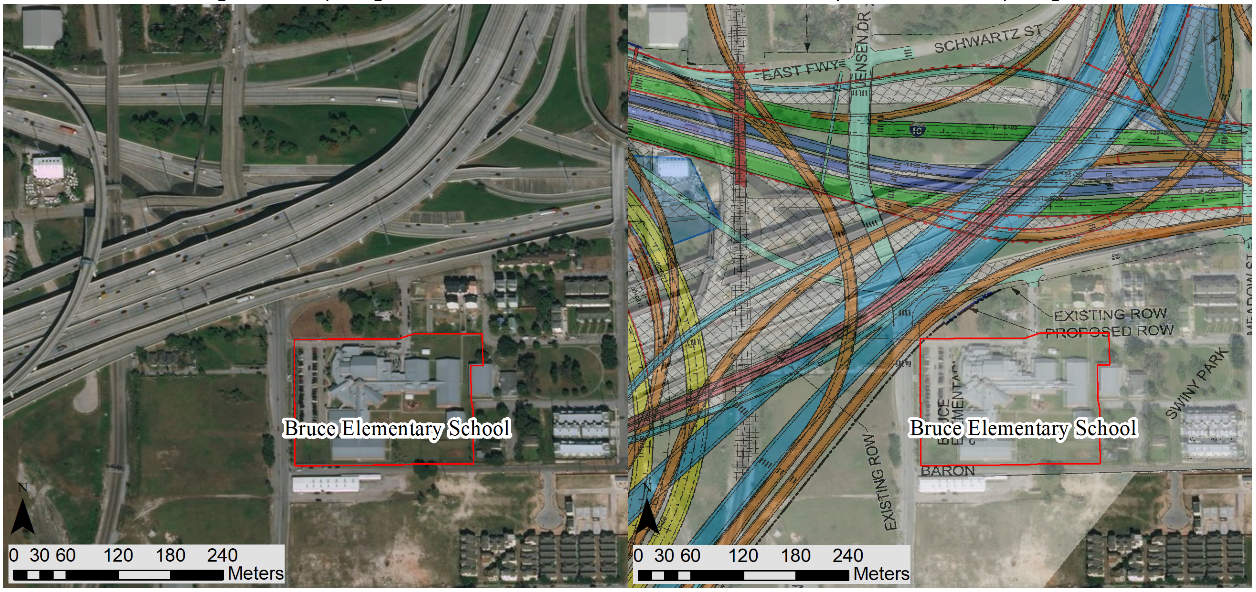


Figure 3 - Existing and proposed freeway alignment (Texas DOT: http://www.ih45northandmore.com/)

2. ANALYSIS OF FUTURE COMMUNITY HEALTH FACTORS

Air Quality Exposure Analysis

The burning of fossil fuels, along with the emissions from brakes and tire wear, make traffic a major contributor to air pollution[20]. Exposure to traffic-related air pollution has been linked to the development of cardiovascular, cerebrovascular, and respiratory diseases in children and adults, including stroke, heart disease, chronic obstructive pulmonary disease, lung cancer, and asthma[21]. Traffic-related air pollution aggravates existing asthma and can even lead to the development of asthma, especially for those living near high-volume roadways [22,23]. Persons with greater exposure to high concentrations of traffic pollution can suffer both short-term and long-term health consequences, and children in low-income areas who currently have asthma are especially vulnerable[20]. Children are especially vulnerable to reduced lung functioning, impaired lung development, and asthma-related impacts from air pollution because their respiratory systems are not fully developed and they have higher exposure rates due to more rapid breathing[24,25]. Recent research has linked traffic-related air pollution in schools to negative consequences for cognitive development (i.e., working memory and attention)[26,27], major depression[28], and metabolic dysfunction[30]. Collectively, the impacts of air pollution on population health and well-being are significant and necessitate careful consideration, especially among at-risk communities such as those near busy roadways.

The Bruce Elementary School currently lies approximately 75 meters from the I-69 NB to I-10 Eastbound Ramp and approximately 100 meters from the I-69 NB mainline. The proposed North Houston Highway Improvement Project (NHHIP) reduces those distance to 45 and 55 meters respectively and elevates the freeway 15-20 meters above the school property. A synthesis report by Karner et al. reported that most freeway-generated pollutants dissipated to background levels at a distance of 400 meters from the source and that the highest concentrations were found within 150 meters[72]. The impacts of increased freeway elevation on air quality dispersion are not as well understood. However, a report by the Texas Transportation Institute in 1997 indicated that increased road elevation increased the opportunity for dispersion, thereby reducing ground level impacts[74].

The Texas Department of Transportation (TxDOT) released a Draft Carbon Monoxide (CO) Traffic Air Quality Analysis report for the NHHIP in May 2018. The focus of the report was to assess the 1-hour and 8-hour CO levels to ensure adherence to the National Ambient Air Quality Standards. The 2040 worst case CO concentrations for the freeway right-of-way (ROW) near the school was 3.7 ppm for the 1-hour test and 2.6 ppm for the 8-hour test. These results are within the NAAQS limits. The report did note that this section of freeway showed the highest traffic volumes and therefore the highest concentrations of CO (?).

Bruce Elementary Air Quality Analysis Methodology

To aid in the evaluation of the location and intensity of air quality impacts on the school, Urban Design 4 Health conducted air quality modeling of the NHHIP proposed alignment in the area close to Bruce Elementary School. The modeling focused on the variability of community-level changes in pollutant concentrations instead of simply the maximum values in the TxDOT analysis. The team employed the use of the Community Line Source Model Version 3 (C-Line)[f] that was specifically designed by University of North Carolina and the US Environmental Protection Agency to help community residents better understand local air quality issues related to different transportation geometric and operational changes. Though this model is not yet used for regulatory purposes due to its simplified simulation techniques for some procedures, researchers have been working towards the goal of broad use of C-Line for official uses. C-Line can be accessed on the CMAS (Community Modeling and Analysis System)[g] website and the simulation model can be run on the server at the University of North Carolina at Chapel Hill. Users can run different scenarios for different pollutants as well as make changes to road centerlines, traffic volumes, traffic speeds, season, day-of-week, time period, and wind direction. There are twelve pollutants that can be modeled and each are associated with serious health risks (as sourced from CDC's Agency for Toxic Substances & Disease Registry (ATSDR):

- **CO** (carbon monoxide): Can cause irritation of the lower respiratory system, https://www.atsdr.cdc.gov/phs/phs.asp?id=1146&tid=253, OSHA 8 hour exposure limit: 9 ppm.
- **NOx** (nitrogen oxides): Risk of respiratory problems and an asthma trigger, https://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=396&tid=69, OSHA 8 hour exposure limit: 5 ppm.
- **SO2** (sulfur dioxide): Lower and upper respiratory irritant, https://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=46
- **PM2.5** (particulate matter with aerodynamic diameter less than 2.5 µm), **D-PM2.5** (PM2.5 emitted by diesel vehicles), **EC2.5** (elemental carbon portion of PM2.5), **OC2.5** (organic carbon portion of PM2.5): Risk of respiratory problems, an asthma trigger, and associated with cancer. https://www.cdc.gov/air/particulate_matter.html, https://ephtracking.cdc.gov/showAirHealth, https://www.atsdr.cdc.gov/HAC/pha/IndustrialPipeInc/Industrial_Pipe_Inc_EI-HC_08-21-2017_508.pdf, https://www.lung.org/assets/documents/advocacy-archive/health-and-medical-groups-1.pdf
- **Benzene:** Can cause irritation of the upper respiratory system, irritation of the eyes, can have an anesthetic effect, and associated with the development of Leukemia, https://www.atsdr.cdc.gov/mmg/mmg.asp?id=35&tid=14, OSHA 8 hour exposure limit: 1 ppm.
- **Formaldehyde, Acrolein, Acetaldehyde**: Can cause irritation of the upper respiratory system, headaches, and dermatitis, https://www.atsdr.cdc.gov/mmg/mmg.asp?id=216&tid=39, OSHA 8 hour exposure limit: .1 ppm
- **1,3-butadiene**: Affects the central nervous system, an irritant for the upper respiratory system, and consider a probable carcinogenic (Cancer Group 2), https://www.atsdr.cdc.gov/mmg/mmg.asp?id=455&tid=81, OSHA 8 hour exposure limit: 1 ppm

Additional details about each of these pollutants, their known impacts, and other details are available at the weblinks provided above. The C-Line simulation results provide outcomes in a tabular format (*.csv), allowing users to download these files from the server, and conduct additional processing and analysis. Additional details regarding C-Line can be found at https://www.cmascenter.org/c-tools/documentation/3.0/C-LINE_Users_Guide.pdf.

[f] https://www.epa.gov/healthresearch/community-line-source-model-c-line-estimate-roadway-emissions
[g] https://www.cmascenter.org/

The C-Line system is pre-loaded with baseline transportation and climate data. For this analysis, the default data within C-Line was used as the baseline, including the alignments and the traffic conditions for I-69, I-10 and other ramps and surface streets. For the analysis conditions, we opted for modeling during the winter season, on typical weekdays, for an average morning (AM) peak-travel hour and an average midday hour (these are the times of day when the school is most active). The default wind rose was used, which has wind from multiple directions, but primarily from the south and southeast. Each of the ten pollutants was modeled for each time period resulting in 20 different baseline exposure datasets.

For the future post NHHIP air quality modeling, we only changed the freeway and ramp alignments and adjusted the forecasted average annual daily traffic (AADT) counts to be equivalent to the Texas DOT Draft Carbon Monoxide (CO) Traffic Air Quality Analysis report for this section. The altered transportation system model runs included the same ten pollutants for both the AM peak hour and average midday hour.

Limitations of this approach include both the simplified nature of the C-Line design and intent and results should be considered "sketch" estimates. Secondly, the future year model run did not include any vehicle or fleet technology changes. Lastly, the analysis does not consider the impact of freeway elevation on the resulting concentrations as this capability is not yet developed within the model. These results do, however, provide estimates of locations of higher exposure risk that can be considered when mitigation measures are being planned.

In addition to generating the pre and post exposure surfaces for each pollutant, the research team also selected 10 specific site locations for comparative analysis (see Figure 4). These sites were selected to specifically evaluate locations on the school property (1-4), the closest park (5), open space where development is expected (6-9), and a primary housing development (10). The sites are::

- Site #1 – Main entrance to Bruce Elementary School
- Site #2 – West side entrance to Bruce Elementary School
- Site #3 – Corner of the Bruce Elementary School property closest to the freeway
- Site #4 – Bruce Elementary School playground
- Site #5 – Swiney Park
- Site #6 – Vacant land between Hare St and Clinton Dr
- Site #7 – East River Development West End
- Site #8 – East River Development Central
- Site #9 – East River Development East End
- Site #10 – Kelly Village

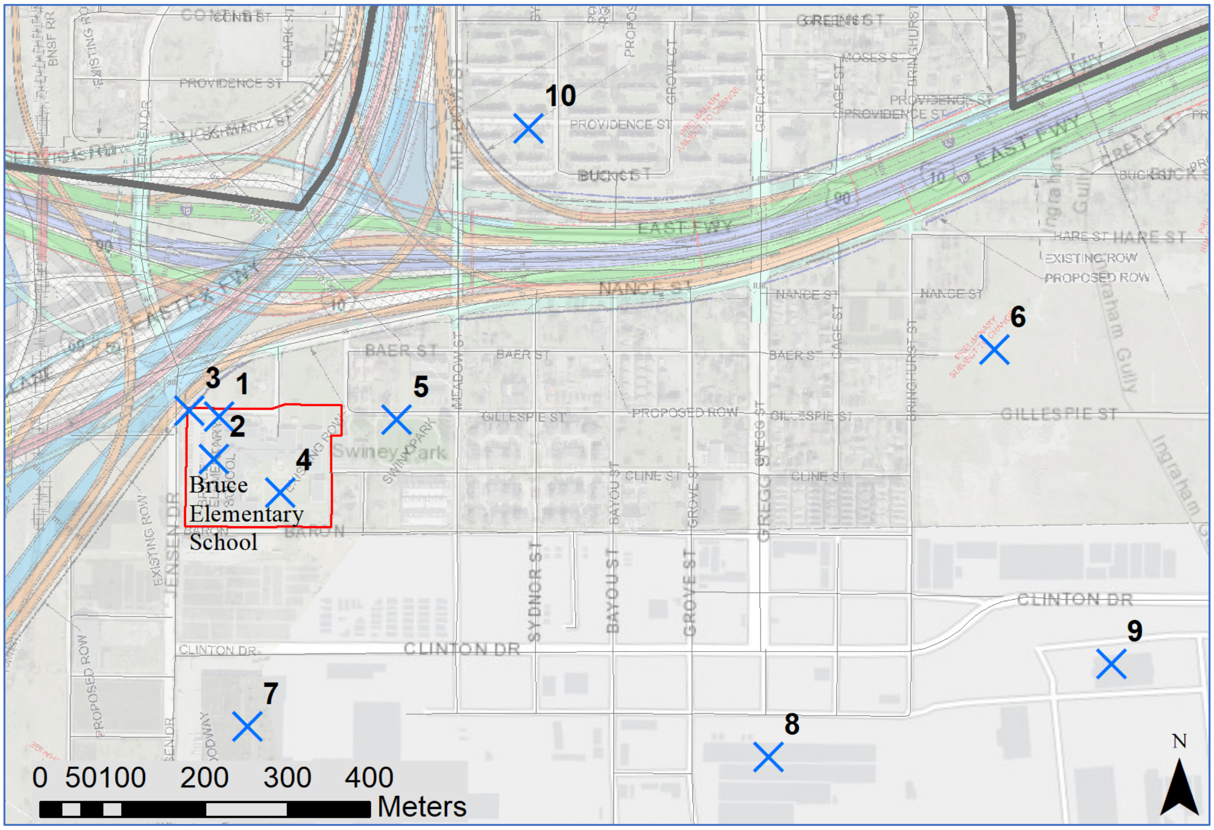


Figure 4 – Ten investigatory sites for air quality exposure comparison

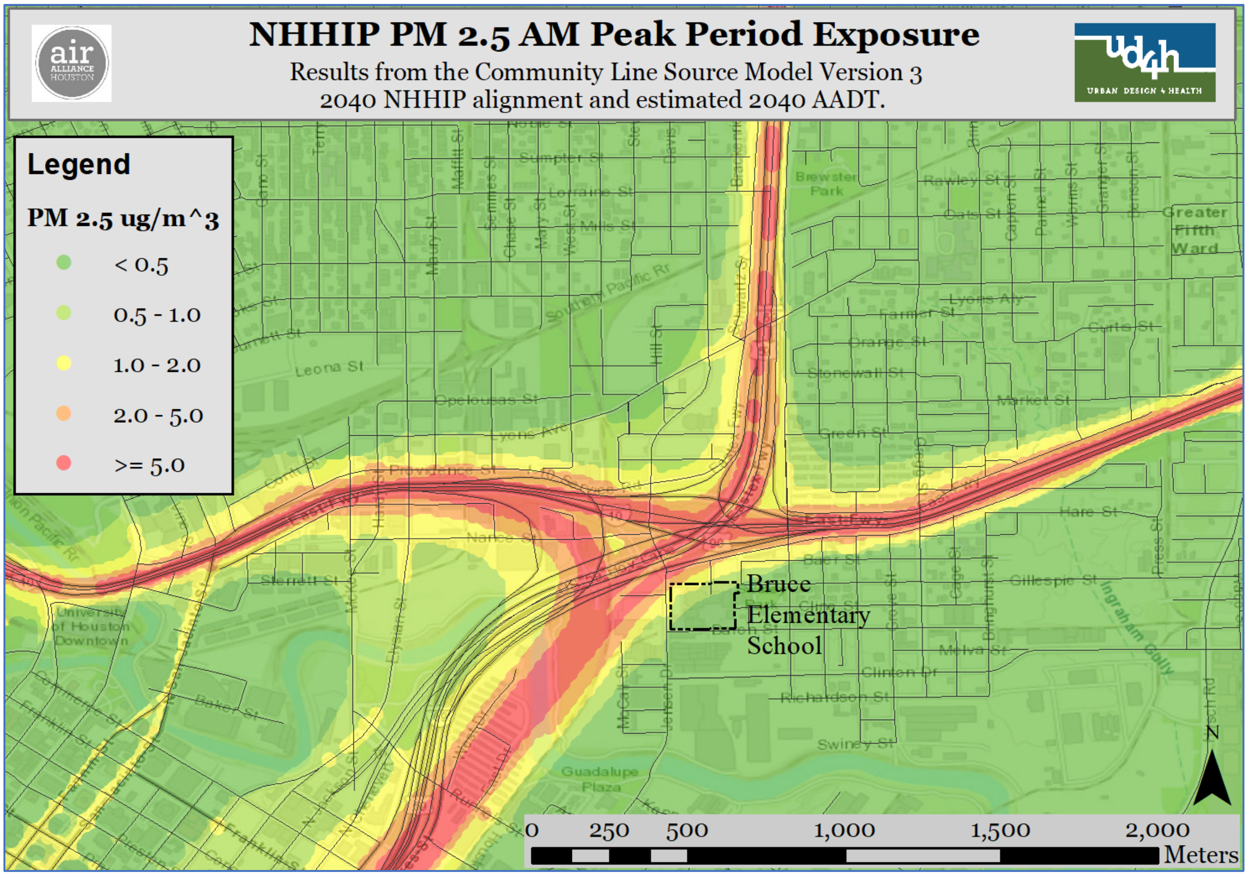


Figure 5 - AM peak hour PM 2.5 exposure (ug/m^3)

Table 4 – AM peak hour and midday average hourly PM 2.5 exposure (ug/m^3)

		AM Peak			Mid-Day		
ID	Description	Baseline	NHHIP	*Increase*	Baseline	NHHIP	*Increase*
3	Corner of School Property	0.6424	1.7757	*176.4%*	0.7386	1.8573	*151.5%*
1	Bruce Elem Front Door	0.4871	1.1169	*129.3%*	0.5055	1.1435	*126.2%*
2	Bruce Elem Side Door	0.3383	0.7224	*113.6%*	0.4060	0.8901	*119.2%*
4	Bruce Elem Playground	0.2137	0.4353	*103.7%*	0.2546	0.5294	*108.0%*
7	East River 1	0.1276	0.2500	*95.9%*	0.1549	0.3130	*102.1%*
5	Swiney Park	0.2393	0.4472	*86.9%*	0.2852	0.5499	*92.8%*
10	Kelly Village	0.4061	0.6992	*72.2%*	0.4795	0.8558	*78.5%*
6	Hare St Site	0.1523	0.2258	*48.2%*	0.1763	0.2869	*62.7%*
8	East River 2	0.0756	0.1109	*46.8%*	0.0859	0.1384	*61.1%*
9	East River 3	0.0778	0.0979	*25.8%*	0.0886	0.1246	*40.6%*

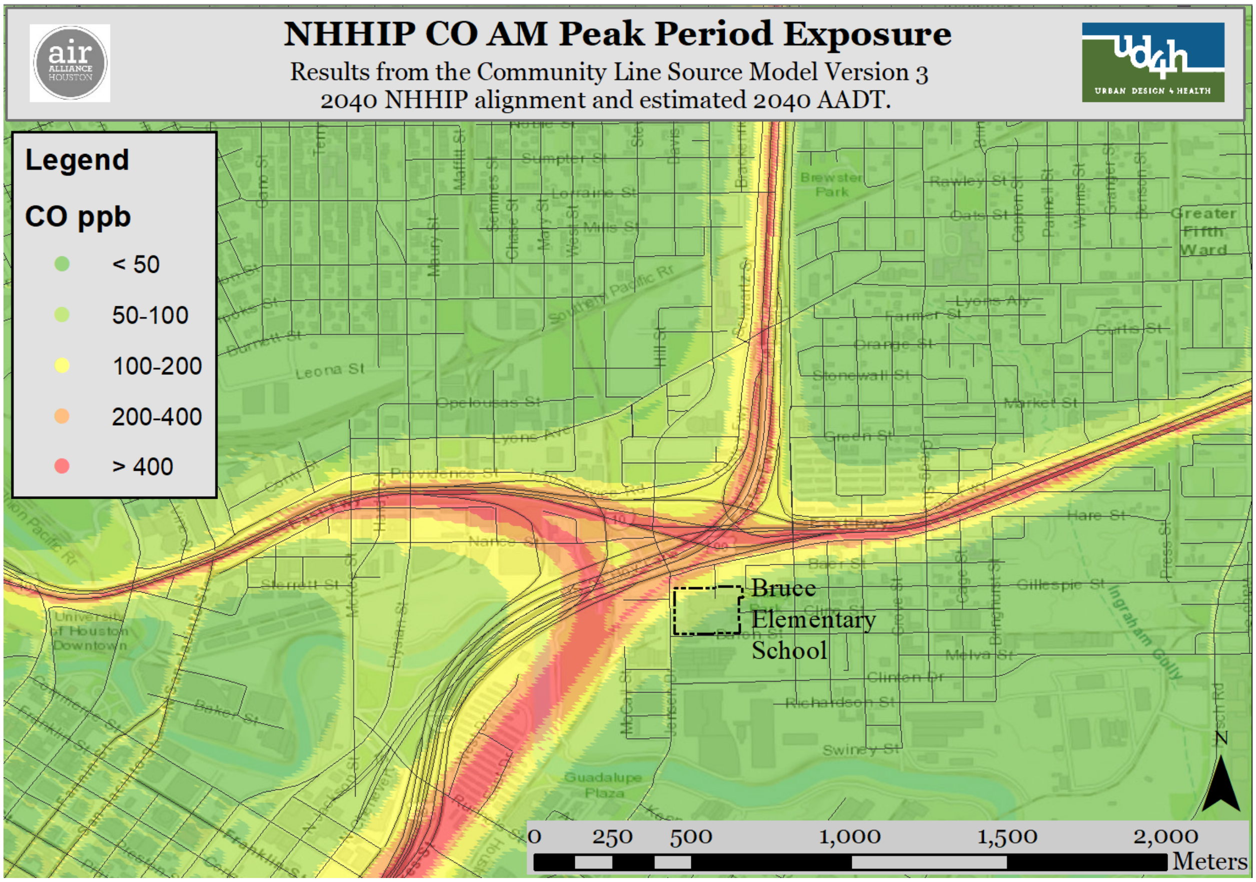


Figure 6 - AM peak hour CO exposure (ppb)

Table 5 – AM peak hour and midday average hourly CO exposure (ppb)

		AM Peak			Mid-Day		
ID	Description	Baseline	NHHIP	*Increase*	Baseline	NHHIP	*Increase*
3	Corner of School Property	63.1681	178.0360	*181.8%*	62.2280	157.6270	*153.3%*
1	Bruce Elem Front Door	49.6014	114.4320	*130.7%*	43.2233	98.0601	*126.9%*
2	Bruce Elem Side Door	34.0439	73.8019	*116.8%*	34.5403	76.3561	*121.1%*
4	Bruce Elem Playground	21.5167	44.5880	*107.2%*	21.6419	45.4581	*110.0%*
7	East River 1	12.4218	25.3327	*103.9%*	12.8111	26.6578	*108.1%*
5	Swiney Park	24.2429	45.8835	*89.3%*	24.3609	47.2881	*94.1%*
10	Kelly Village	41.4897	72.0849	*73.7%*	41.2440	73.9391	*79.3%*
6	Hare St Site	15.2705	23.1718	*51.7%*	15.0014	24.6957	*64.6%*
8	East River 2	7.3078	11.2475	*53.9%*	7.0793	11.7947	*66.6%*
9	East River 3	7.3301	9.7216	*32.6%*	7.1866	10.4559	*45.5%*

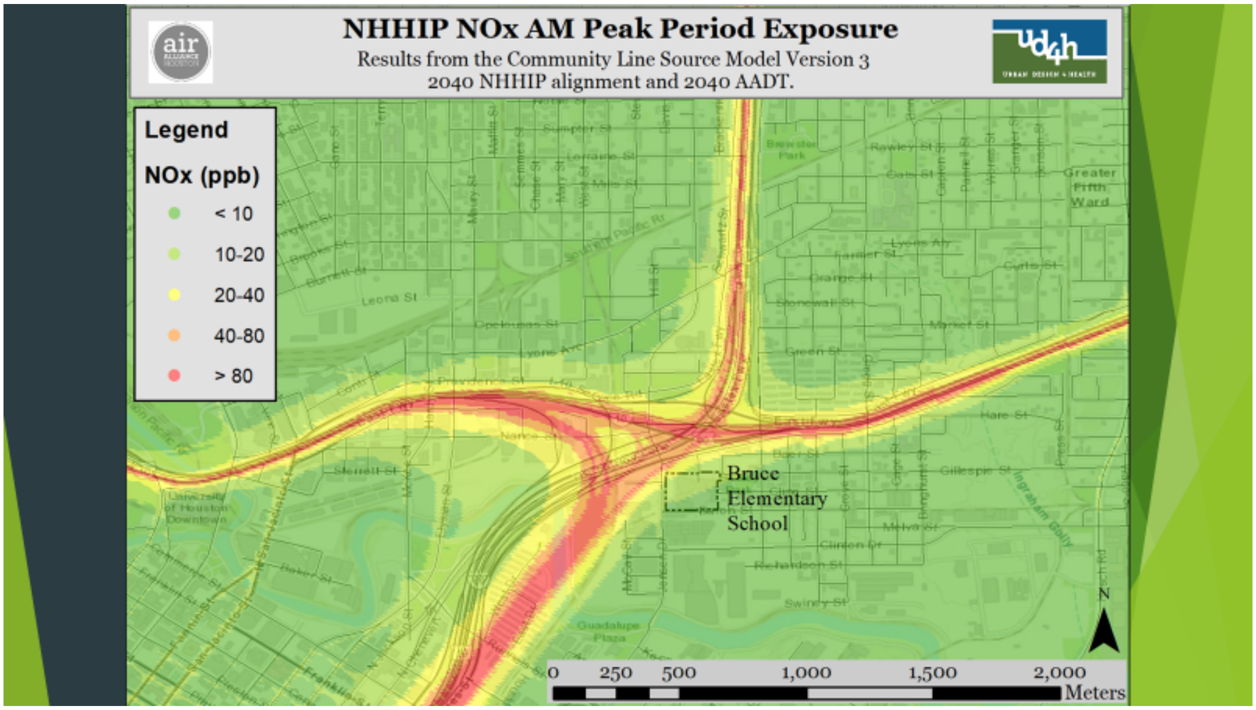


Figure 7 - AM peak hour NOx exposure (ppb)

Table 6 – AM peak hour and midday average hourly NOx exposure (ppb)

		AM Peak			Mid-Day		
ID	Description	Baseline	NHHIP	*Increase*	Baseline	NHHIP	*Increase*
3	Corner of School Property	10.2900	29.1382	*183.2%*	11.3302	29.1208	*157.0%*
1	Bruce Elem Front Door	8.1600	18.8372	*130.8%*	7.9734	18.1921	*128.2%*
2	Bruce Elem Side Door	5.5900	12.1413	*117.2%*	6.3511	14.1549	*122.9%*
4	Bruce Elem Playground	3.5400	7.3421	*107.4%*	3.9868	8.4324	*111.5%*
7	East River 1	2.0300	4.1616	*105.0%*	2.3253	4.9158	*111.4%*
5	Swiney Park	3.9900	7.5576	*89.4%*	4.4987	8.7763	*95.1%*
10	Kelly Village	6.8300	11.8836	*74.0%*	7.6365	13.7389	*79.9%*
6	Hare St Site	2.5100	3.8158	*52.0%*	2.7646	4.5760	*65.5%*
8	East River 2	1.2000	1.8481	*54.0%*	1.2943	2.1741	*68.0%*
9	East River 3	1.2000	1.5877	*32.3%*	1.2918	1.9010	*47.2%*

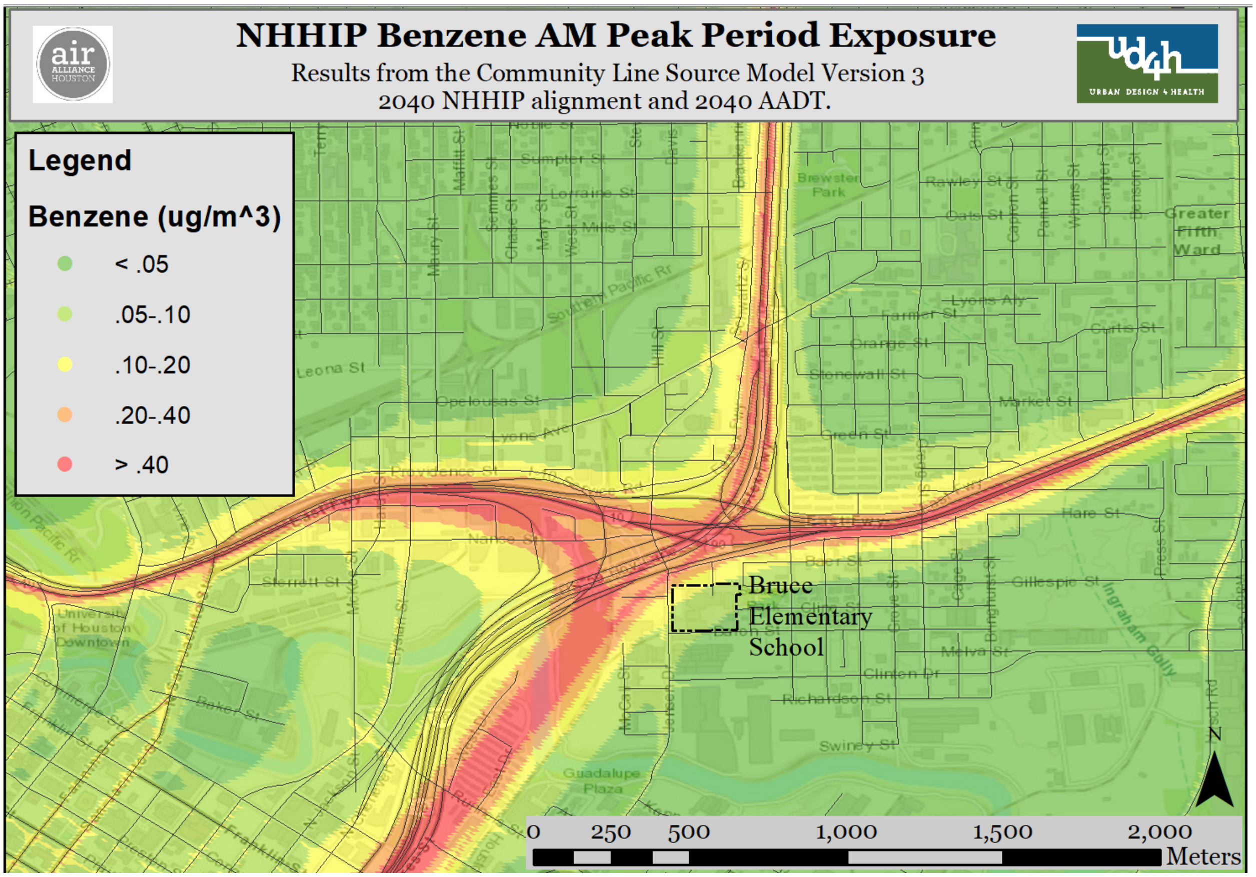


Figure 8 - AM peak hour Benzene exposure (ug/m3)

Table 7 - - Hourly Benzene Exposure (ug/m^3)

		AM Peak			Mid-Day		
ID	Description	Baseline	NHHIP	*Increase*	Baseline	NHHIP	*Increase*
3	Corner of School Property	0.0829	0.2193	*164.7%*	0.0815	0.1940	*138.1%*
1	Bruce Elem Front Door	0.0610	0.1377	*125.8%*	0.0542	0.1195	*120.6%*
2	Bruce Elem Side Door	0.0427	0.0896	*109.9%*	0.0439	0.0935	*113.2%*
4	Bruce Elem Playground	0.0268	0.0540	*101.0%*	0.0274	0.0556	*103.2%*
7	East River 1	0.0163	0.0313	*91.8%*	0.0172	0.0334	*94.2%*
5	Swiney Park	0.0300	0.0554	*84.9%*	0.0305	0.0577	*89.4%*
10	Kelly Village	0.0507	0.0868	*71.2%*	0.0510	0.0900	*76.5%*
6	Hare St Site	0.0191	0.0282	*47.6%*	0.0189	0.0304	*60.4%*
8	East River 2	0.0095	0.0139	*45.7%*	0.0094	0.0148	*57.6%*
9	East River 3	0.0100	0.0125	*25.2%*	0.0100	0.0138	*37.0%*

As seen from the previous tables and figures, the sites around the Bruce Elementary School have the highest changes in exposure for all pollutants compared to other sites. While only four of the pollutants are shown, results for all ten follow the same patterns. For the regulated pollutants, all of these numbers are below National Ambient Air Quality Standards, but the safe thresholds for short and long term exposure are not well defined, particularly for grade school children regarding mobile source air toxics. As mitigation solutions are being evaluated for Bruce Elementary School, minimizing exposure to higher concentrations of these pollutants should be given the highest consideration despite modeled values being within regulated thresholds. Not enough is known regarding the health impacts of long-term multi-year exposure to determine if current thresholds provide adequate life-long protection.

NPHAM-based Sensitivity Analysis of Neighborhood Built and Natural Environment

Methodology

There is mounting empirical evidence suggesting causal linkages between transportation land development and investments, and physical activity (such as walking and biking), which has implications for chronic disease prevention. However, the ability to apply this evidence in practice has been limited primarily due to the complexity, inconsistency of research methods, and lack of direct connection with the planning contexts in which decisions need to be made. Additionally, up until recently, practical tools that allow decision makers to evaluate alternative land development and transportation investment decisions in terms of preventing chronic disease outcomes have not existed. Recognizing this major need, the U.S. Environmental Protection Agency (EPA) funded Urban Design 4 Health (UD4H) to develop the National Public Health Assessment Module (N-PHAM)[74]. The first nationally consistent health assessment module adds physical activity (PA) and public health analysis capabilities to land use and spatial planning decisions at a range of geographic scales. The predictive models in N-PHAM are generated from large-scale place-based built and natural environment data at the block-group level and large population surveys to model the relationships of the environment with several PA and health outcomes. For a range of age and income groups, N-PHAM allows decision makers to explore how different transportation land development strategies can help improve PA and public health outcomes (obesity, diabetes, cardiovascular disease, mental, and general health).

Table 8 lists the built, natural, and social variables used within N-PHAM and

Table 9 lists the demographic co-variates. Table 10 lists the health and physical activity outcomes.

Table 8 - N-PHAM built, natural, and social variables

NPHAM Variable	Built, Natural, and Social Variable Description
popdens_ac	Gross population density in terms of people per acre on unprotected land (EPA Smart Location Database (SLD)[h] d1b)
empdens_ac	Gross employment density in terms of workers per acre on unprotected land (EPA SLD d1c)
jobacc45tr	Jobs within a 45-minute transit commute, distance decay, walk network and General Transit Feed Specification (GTFS)[i] schedule travel time weighted (EPA SLD d5br)
empentropy	Employment entropy index using 5-tier employment classification scheme (EPA SLD d2b_e5mixa)
p_wrkage	Percent of population that is working age (EPA SLD p_wrkage)
pct_autoo0	Percent of households that own zero automobiles (EPA SLD pct_ao0) Cube root 1.345 (0.975)
retailempl	Retail jobs within 5-tier employment classification scheme (EPA SLD e5_ret10)
totpop2010	2010 Census total population (EPA SLD totpop10)
empbytrans	Proportion of CBG employment within 1/4 mile of a fixed guideway transit stop (EPA SLD d4b025)
notrdata	Binary flag indicating transit data is missing (derived from EPA SLD)
ntwkdenped	Network density in terms of facility miles of pedestrian-oriented links per square mile (EPA SLD d3apo)

[h] https://www.epa.gov/smartgrowth/smart-location-mapping#SLD
[i] https://gtfs.org/ and https://transitfeeds.com/

intrsndens	Street intersection density, weighted, auto-oriented intersections eliminated (EPA SLD d3b)
trpequilib	Trip production and attraction equilibrium index - closer to one indicates more balanced trip making (EPA SLD d2c_tripeq)
opens_nlcd	Percent of land cover that is developed open space, e.g., parks, golf courses (derived from NLCD[j] classification layer)
treec_nlcd	Percent of land area covered by a tree canopy (derived from NLCD tree canopy cartographic layer)
forst_nlcd	forst_nlcd Percent of land cover that is forest (derived from NLCD)
natrl_nlcd	natrl_nlcd Percent of land cover that is natural (derived from NLCD)
topenspace	Percent of land cover that is developed open space or natural space

Table 9 - N-PHAM demographic co-variate descriptions

NPHAM Variable	Demographic Co-variate Variable Description
pct_autoo0	Household owns zero automobiles
avg_hhsize	Average household size (2014 American Community Survey (ACS)[k] 5-year estimates)
pct_ownocc	Households is owner-occupied (2014 ACS 5-year estimates)
pct_rentoc	Household is renter-occupied (2014 ACS 5-year estimates)
pct_popfem	Respondent is female (2014 ACS 5-year estimates)
pct_popmal	Respondent is male (2014 ACS 5-year estimates)
pct_worker	Respondent is employed (2014 ACS 5-year estimates)
pct_senior	Respondent is age 65+ (2014 ACS 5-year estimates)
pct_popwht	Respondent is white, non-Hispanic or Latino (2014 ACS 5-year estimates)
pct_lowinc	Household is classified as low income, $0-$35k (2014 ACS 5-year estimates)
pct_medinc	Household is classified as medium income, $35k-$100k (2014 ACS 5-year estimates)
pct_higinc	Household is classified as high income, $100k+ (2014 ACS 5-year estimates)
pct_nohsed	Respondent has educational attainment LESS THAN high school diploma (2014 ACS 5-year estimates)
pct_hseduc	Respondent has educational attainment of high school diploma (2014 ACS 5-year estimates)
pct_2ycoll	Respondent has educational attainment of some college or 2-year degree (2014 ACS 5-year estimates)
pct_4ypcol	Respondent has educational attainment of 4-year college degree or higher (2014 ACS 5-year estimates)
pct_hhkids	Household has with one or more children age 0–17 (2014 ACS 5-year estimates)

Table 10 – N-PHAM Health and Physical Activity Outcomes

NPHAM Variable	Health and Physical Activity Outcomes
autotr	Auto Travel (Sedentary)
biketr	Biking for Transportation (percentage)
recrpa	Recreational Physical Activity
walkle	Walking for Leisure
walktr	Walking for Transportation

[j] https://catalog.data.gov/dataset/national-land-cover-database-nlcd-land-cover-collection
[k] https://www.census.gov/programs-surveys/acs/

bmi	Body Mass Index
gen_health	Fair or Poor Health (percentage)
mnt_health	Mental Health
obese	Body Mass Index greater than 30 (percentage)
overweight	Body Mass Index between 25 and 30 (percentage)

In this project, N-PHAM was used to model the impact of policy-relevant transportation land development strategies on improving physical activity and public health in the Bruce Elementary School area. The Census block group (CBG) level analysis scheme used herein is two-fold:

1. Altering base values of natural environment variables to identify changes in health and PA outcomes.
2. Creating a future build scenario that included estimates of planned built and natural environmental variables to identify changes in health and PA outcomes.

Under the first scheme, the base values for five natural environment variables were individually increased, from current conditions, by 25% and 50% (while keeping all other inputs at CBG-level mean values) to predict the impact on PA and health outcomes in five Census block groups (including Bruce Elementary). In particular, current, or base, values were altered for tree canopy, percent developed open and natural space, percent developed open space, percent of land cover that is forest, and percent of land cover that is natural. See Table 8 above for details about these variables.

To avoid implications of ecological fallacy, the analysis was separately conducted for each CBG and the results then averaged across all five CBGs to deduce area-level (Bruce Elementary School area) inferences. Under the second scheme, an additional N-PHAM scenario was considered that altered built and natural environmental variables in line with the NHHIP and the planned future developments for 2040. In particular, base values for network density, intersection density, total employment, retail employment, employment density, job accessibility by transit, total households and population density, plus the five natural environment variables included in the first analysis, were altered to predict PA and health outcomes under planned built and natural environment estimates for 2040.

Scenario 1

In scenario 1, the team increased the percentages of the natural variables by 25% and 50% to test the response of the health and physical activity outcomes. The logic behind this test is that a likely mitigation strategy in the Bruce Elementary community is to increase park space, tree canopy, and natural space as part of the NHHIP development process. Therefore, the N-PHAM test holds all other variables unchanged (built environment, social environment, and demographics) and only alters those environmental variables that are likely to change. Results are hypothesized to indicate a positive impact on estimated physical activity and health in the community. The results will also identify the magnitude of the impact.

In the Bruce Elementary community, 0.83% of land is park space and 3.11% is developed open/natural space. On average, residents in this area have 9.45 acres of parks available within a 1 KM walk from the center of their CBG and 2.90% of the land in this area has tree coverage. Increasing the developed open/natural space by 25% and 50% is a reasonable and likely component of the planned NHHIP development based on stated goals and preliminary drawings. Results of these changes as calculated using N-PHAM show that these levels of change would have a minor but positive benefit to the community in terms of health and physical activity outcomes. Table 11 and Table 12 show the expected changes in comparison with other baseline estimates from the region (as shown in Chapter 1).

Scenario 2

In scenario 2, the team estimated the full impact of the planned NHHIP and potential community developments in the US Census Block Group that contains Bruce Elementary School. Proposed development plans include the addition of 17 acres of park and open space, 3 miles of bike/walk paths, and a mixed-use development that includes retail, office, and residential properties. This planned development concept would actively promote a healthy lifestyle design with improved access to downtown Houston, and improvements and connections to the Buffalo Bayou bike and trail system.

The N-PHAM changes in scenario 2 included increases in the variables of population density, job accessibility by transit, retail employment, total population, density of bike/pedestrian facilities, walkable road network intersection density, employment, households, vacant land, total numbers of workers, and industrial acreage (see Table 8 for variable definitions). All demographic co-variates were held constant. Results of these changes from N-PHAM show that the levels of change would have a positive benefit to the community in terms of health and physical activity outcomes and bring this particular US Census block group into averages similar to the broader Houston community, and in fact exceeding average values for Physical Activity. Table 11 and Table 12 show the expected changes in comparison with other baseline estimates.

Table 11 - Health outcomes from improvement scenarios

US Census Block Group Aggregation	Average Body Mass Index	% Obesity	% Poor Health Status
Bruce Elementary Attendance Zone	28.26%	31.13%	28.57%
Scenario 1A -Bruce Elementary with a 25% increase in parks and/or tree canopy	28.25%	31.06%	28.51%
Scenario 1B -Bruce Elementary with a 50% increase in parks and/or tree canopy	28.24%	31.01%	28.45%
Scenario 2 -Bruce Elementary Block Group with full NHHIP and Community Development	27.71%	24.80%	16.50%
NHHIP Study Area	28.25	29.63%	26.38%
City of Houston	27.91	26.25%	17.02%
Harris County	27.97	26.73%	15.89%
Metro Houston	28.00	26.82%	13.82%
Texas Statewide	28.12	28.30%	13.67%

Table 12- Physical activity outcomes from improvement scenarios

US Census Block Group Aggregation	% Walking for Utilitarian Transport	% Walking for Leisure	% Cycling for Utilitarian Transport	% Rec. Physical Activity
Bruce Elementary Attendance Zone	15.39%	48.92%	2.07%	13.19%
Scenario 1A -Bruce Elementary with a 25% increase in parks and/or tree canopy	15.56%	48.97%	2.08%	13.28%
Scenario 1B -Bruce Elementary with a 50% increase in parks and/or tree canopy	15.66%	49.03%	2.09%	13.37%
Scenario 2 -Bruce Elementary Block Group with full NHHIP and Community Development	17.25%	52.46%	2.29%	15.51%
NHHIP Study Area	15.52%	47.96%	2.06%	13.43%
City of Houston	13.24%	50.65%	1.45%	15.87%
Harris County	12.65%	50.70%	1.43%	15.80%
Metro Houston	11.46%	51.15%	1.30%	15.89%
Texas Statewide	10.68%	50.71%	1.36%	14.93%

Discussion

The N-PHAM analysis showed improvements to the health and physical activity outcomes with the proposed changes to community. It is important to note that the current version of N-PHAM does not evaluate the health impacts of the air quality changes. The reported health impacts are due to the built environment changes. While the expected hourly thresholds are expected to be within safe limits, the long-term impacts, particularly on children, are unknown and could be significant. Current modeling capabilities are limited in the understanding of these direct impacts despite evidence from numerous studies suggesting elevated health risk with increased exposure.

An additional limitation of the N-PHAM analyses is that existing Bruce Elementary School community residents may not directly benefit from community development that might occur and raise rent premiums. Because existing residents may face displacement and gentrification as a result of community development projects, the health and physical activity benefits may only represent new residents. Existing residents may be displaced to other communities. More detailed models and policy review need development to better understand the micro-scale impacts of new connectivity, gentrification and displacement, and access to new jobs in the area.

With these recognized limitations, mitigation strategies should focus on community improvement concepts that encourage physical activity in areas further from the NHHIP alignment to avoid the higher concentrations of pollutants and on projects that encourage community connections with and use of new planned developments. Mitigation strategies should also consider implications for existing residents, including metrics for displacement and gentrification.

3. Community Health Improvement

Active transportation, such as walking, cycling, and their use to connect with public transit systems, not only improve air quality as a result of fewer vehicle emissions but also increase physical activity-related health benefits among children and adults. There are many ways that the design, placement and connectivity of buildings and communities can encourage more active transportation. These include increased sidewalk connectivity, greater land-use mix and residential density, walking and cycling facility maintenance, crosswalks at intersections, school zone signage and traffic calming, bike-lanes, street buffers and aesthetically pleasing routes (tree canopy, scenic, active store fronts, etc.). In addition, the Safe Routes to School initiative can improve safety related concerns through community policy and school programming, such as the Walking School Bus program. UD4H offers this discussion of important considerations and specific opportunities for the Bruce Elementary community.

Traffic-related air pollutant concentrations are highest outdoors, with the highest level of motor vehicle pollutant concentrations generally within the first 500 feet (~150 meters) of a roadway[11]. These pollutants can also elevate pollutant concentrations inside classrooms[24]. Mitigating negative health implications from traffic-related air pollution typically involves strategies that either decrease the concentration of the pollutants (i.e., vegetation, displace car travel with active travel, etc.) or reduce the duration of exposure to the pollutants (i.e., limit time spent at stop lights near idling car emissions, monitor outdoor air pollution and the opening of windows in buildings). Prevention strategies such as increasing alternative transportation options (transit, rideshare, walking, cycling), providing incentives to reduce vehicle miles traveled, promoting the use of electric and low emission vehicles and implementing land-use policies that limit new development close to heavy traffic areas, while also creating roadside barriers and improved ventilation systems in homes and buildings, help mitigate the impacts of emissions[20]. Prevention and mitigation strategies specific to schools should include both site-related strategies (i.e., transportation policy, site selection, vegetation) and building design and operation strategies (i.e., ventilation, filtration)[5]. Site related strategies include anti-idling and reducing idling near the school, upgrading buses and carpools, and encouraging more active forms of transportation. In addition, increasing the urban green space in the community, along with roadside vegetation, can help to mitigate traffic-related air-pollution.

Increasing the use of active transportation is a promising mitigation strategy, but certain safety and exposure considerations must be addressed. Safety concerns are not only about traffic-related injuries and fatalities, but also criminal activity and violence. To improve safety and the likelihood to participate in walking and biking to school, the Safe Routes to School initiative provides comprehensive set of strategies to address crime and violence in the community that might deter active travel[62]. The physical design of the community also influences crime and violence by reducing the opportunity for crime to occur and encouraging interaction among people. Crime Prevention Through Environmental Design (CPTED) principles are often used to inform design of outdoor spaces that foster safety. For example, the principle of natural surveillance (i.e., "eyes on the streets") can be fostered through Safe Route to Schools initiatives' walking school bus programs, corner captains and neighborhood watch programs, safe havens and passages, and regular programming and participation in shared use/public spaces. Similarly, natural access control is achieved when people are strategically directed through a space to reduce potential offenders' perceived ability to avoid observation. Territorial reinforcement involves creating a sense of ownership through placemaking and fostering social cohesion. The "broken windows theory" provides the basis for placemaking, a sense of ownership and cohesion, as people who have a sense of ownership in a community are likely to maintain the aesthetics of an area. Well-maintained and aesthetically pleasing spaces attract users in the space, which fosters natural surveillance and discourages criminal activity. Case Studies from Taking Back the Streets and Sidewalks[l] include:

- Safe Corridors in Philadelphia
  - "Taking Back the Streets and Sidewalks" page 21
- Pasos Seguros – Community Leadership for Safe Passages
  - "Taking Back the Streets and Sidewalks" page 24
- School Resource Officers in Denver
  - "Taking Back the Streets and Sidewalks" page 34
- Clarksdale, MS, Neighborhood Watch Association
  - "Taking Back the Streets and Sidewalks" page 31

Roadside vegetation has been shown to reduce exposure to air pollution, as plants' surfaces absorb gaseous air pollutants and airborne particles[31]. Noise barriers, when used in combination with vegetation, result in reduced particulate matter concentrations[31]. Vegetation in urban settings offers co-benefits known as "ecosystem services," which in addition to improved air quality, include temperature and stormwater regulation, noise reduction, opportunities to be active and interact with nature[32].

Vacant and underutilized spaces can be used for parks/green spaces in the community, which have been associated with greater general health[33], increased physical activity[34–42], reduced prevalence of overweight[43–45], increased social interaction[44] and collective efficacy (community impact on behavior)[46], and reduced stress[47], depression and anxiety[33], mental fatigue[48–50], and attention deficit hyperactivity disorder (ADHD) symptoms[51,52], while improving attention and self-discipline. There is some evidence, albeit limited, that suggests neighborhood vegetation may also improve air quality[53] and reduce obesity-related morbidities[33,54], asthma[33,55], and vehicular collisions[56–58]. Tree canopy, in particular, has been shown to be associated with better overall health as a result of lower prevalence of overweight and obesity and better social cohesion, and also slight associations with reduced type 2 diabetes, high blood pressure, and asthma in communities[59]. When designing and increasing green spaces, the quality, size, amenities, facilities, recreational opportunities and safety are all important factors to consider, as these influence the utilization and, therefore, impact of the space[60]. Green spaces can also be included in active transportation networks, further increasing health-related benefits from walking and biking space[61].

Vegetation, such as increased tree canopy and green space, have potential disadvantages that must be considered and addressed. For example, trees can obstruct visibility on the road, cause damage and injury if they fall, and can create hazardous debris on the road if not strategically planted[32]. In addition, the particles that trees "intercept" from the air can be returned to the air during windy, precipitous, or other natural weather conditions. They also require ongoing care and maintenance. To address potential negative environmental and health consequences from re-suspended particles, careful consideration must be given to the land-uses that surround roadside vegetations (bodies of water, species selected, etc.)[31]. Although urban tree canopy is known to remove pollution and improve air quality, several studies associate tree pollen with increased asthma prevalence and severity, and that tree pollen may exacerbate the impact of other air pollutants on asthma[65–67].

[ll] https://www.saferoutespartnership.org/sites/default/files/resource_files/taking-back-the-streets-and-sidewalks.pdf

While greening practices of increased and improved parks, green spaces and vegetation can help to mitigate traffic-related air pollution, these also can lead to gentrification if appropriate policies are not put in place. "Environmental" or "green" gentrification and displacement can result in worsening health outcomes for vulnerable populations[68]. As land-value increases as a result of improved spaces, some families are at risk of becoming displaced and may be forced to live in overcrowded conditions and unhealthy conditions, or face a high housing cost burden, which is associated with poor health outcomes[69]. Gentrification and displacement can cause vulnerable populations to be relocated to areas where they may not have access to resources, goods, and services that promote health (i.e., healthy food outlets, jobs, parks, sidewalks, etc.). Further, displacement undermines community stability and social cohesion, which are also known to be associated with improved health, well-being and crime. Another potential result of displacement is homelessness, which puts families at risk for communicable diseases, chronic conditions, behavioral and mental health conditions, and injury[70]. Thus, gentrification should be proactively addressed through zoning and affordable housing production, retention, and asset building[71].

Bruce Elementary School Community Ideas

The following specific mitigations methods are offered for the Bruce Community as early-stage concepts that have the objectives of:

- Increasing physical activity
- Increasing bike/ped transportation and leisure
- Increase access to jobs
- Minimizing exposure to poor air quality

Freeway Barriers

A California study by Lee et al. found that a combination of sound walls and vegetation had a significant impact on reducing PM 2.5 and the larger Ultra-Fine-Particles (UFPs, diameter ≤ 100 nm)[75]. The sound-wall barrier was more effective for reducing PM2.5 (25-53%) than UFPs (0-5%), and was most effective (51-53% for PM2.5) when the wind speed ranged between 1 and 2 m/s. Under the same range of wind speed, the vegetation barrier had little effect (0-5%) on reducing PM2.5; but was effective at reducing UFP (up to 50%). For both types of roadside barrier, decreasing wind speed resulted in greater net reduction of UFPs (i.e., total number particle concentrations; inversely proportional). While limited to particulate matter, this study suggests a combination of sound walls and vegetation along the freeway mainline and ramps in proximity to Bruce Elementary and other population centers could help reduce some of their negative impacts.

Bruce Elementary Site and Operations

The air quality exposure maps (Figure 5 through Figure 8) and supporting research suggest that outdoor exposure for students should be limited within 150 meters of the freeway. The current playground on the southeast side of the school is right at 150 meters from the NHHIP freeway alignment. The main entrance of the school, however, is approximately 50 meters and well within the increased exposure model estimates and foundation research.

A sound and vegetative barrier (see Figure 9) can help reduce exposure in these two areas. To further reduce exposure and increase physical activity, the team recommends that a walk/bike access point at the end Cline Street near Swiney Park to Bruce Elementary be converted to the main point of access. This access point could be combined with street treatments and plantings to make this an inviting entrance that is furthest from the potential air quality risks associated with the NHHIP.

Efforts to reduce vehicle idling in carpool or bus lines before and after school should be strongly considered if not already in place.

Monitoring of prevalent wind direction should also be considered at the school. The greatest exposure to pollutants will occur when the wind direction is light and out of the North or West. Fortunately for this community, these wind directions occur infrequently. Higher winds result in more dispersion of pollutants and lower concentration. On days with wind levels and directions that increase exposure, outdoor activity should be minimized on the school grounds.

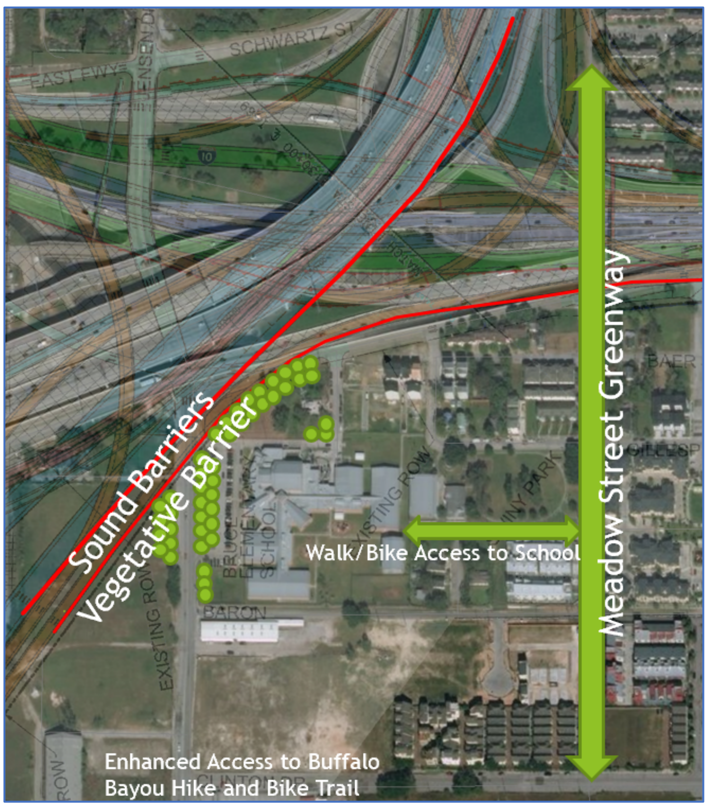


Figure 9 - Bruce elementary site specific mitigation concepts

Greenways

Also shown in Figure 9 is the suggested location of the Meadow Street Greenway. Greenways that alter streetscapes to promote more bike/ped activity are proven to be successful in increasing community physical activity. A recent study regarding a similar greenway development in Vancouver[76] found that residents along the greenway reduced vehicle trips and increased active transportation by as much as 20%.

A greenway concept that includes safety measures and visual appeal along Meadow Street from Kelly Village to Clinton Drive would encourage more north/south connectivity to the school, Swiney Park, the Buffalo Bayou Hike and Bike Trail, and the potential new retail developments in planned projects.

Parks and open space

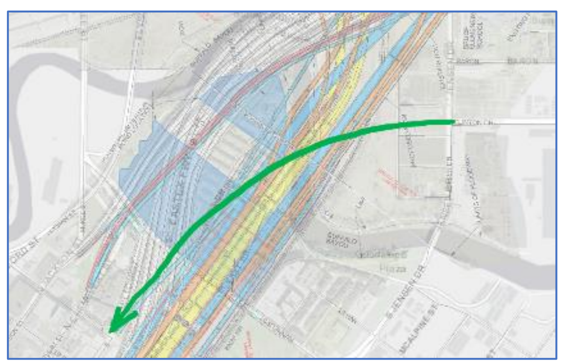
Additional parks and greenspace in close proximity to the Bruce Elementary community are indicated in the NHHIP development plans. There are two challenges to existing plans that limit their benefit to this study area. First, the recommended space is in close proximity to the revised alignment. In fact, it is directly under the freeway main lines and ramps and therefore well within the highest thresholds of air pollution exposure. Secondly, access to this area is blocked by the rail line that runs north/south through the study area. The only access points would be from Nance Street on the north and from the Buffalo Bayou Hike and Bike Trail (that currently has no direct street access from the North side of the river).

Active park spaces with sport fields are absent from this area and currently not planned. Increasing active sports, particularly among youth and teenagers, is a direct way of improving health and community interaction. The closest fields to the Bruce Elementary community is Marron (Tony) Park on the south side of the river off of Hirsch Road (2.5 km from Bruce Elementary School).

Active transportation connectivity

At the heart of an active and healthy community is a well-connected active transportation system. Outside of the maintenance and repair of existing sidewalks and crossings, improving access to downtown Houston and the Buffalo Bayou Hike and Bike Trail should be considered. Currently, the Buffalo Bayou Hike and Bike Trail on the North side of the river is only 350 meters from the Bruce Elementary School, yet access points are over 800 meters away, inconvenient, and under-developed. Planned new developments may improve the access and connectivity to downtown, however the details of those connections are not finalized, including the private/public nature of those trails. Improving access to downtown and to the Hike and Bike system can occur along Jensen street. Bike/pedestrian safety measures along this road and direct street level access to both sides of the river would improve this community's connectivity to important destinations and engage local residents in the use of these spaces.

Additional improvements to the Hike and Bike trail system and connectivity to surface streets on the west side of the Bruce Elementary community are already planned as part of the NHHIP development.



NHPP reconstructs and expands transportation for vehicles between the neighborhood and downtown and must leverage the opportunity to also create two additional key connections for people walking and biking.. The first is a safe, direct and inviting bike/pedestrian facility from this neighborhood to downtown Houston where jobs, events, and retail establishments are in abundance. This path could be included in the NHHIP construction plan and cross Buffalo Bayou as well as the rail lines east of the river.

Figure 10 - Bike/ped access option to downtown

Similarly, there should be a safe access to the northwest area where jobs are available.

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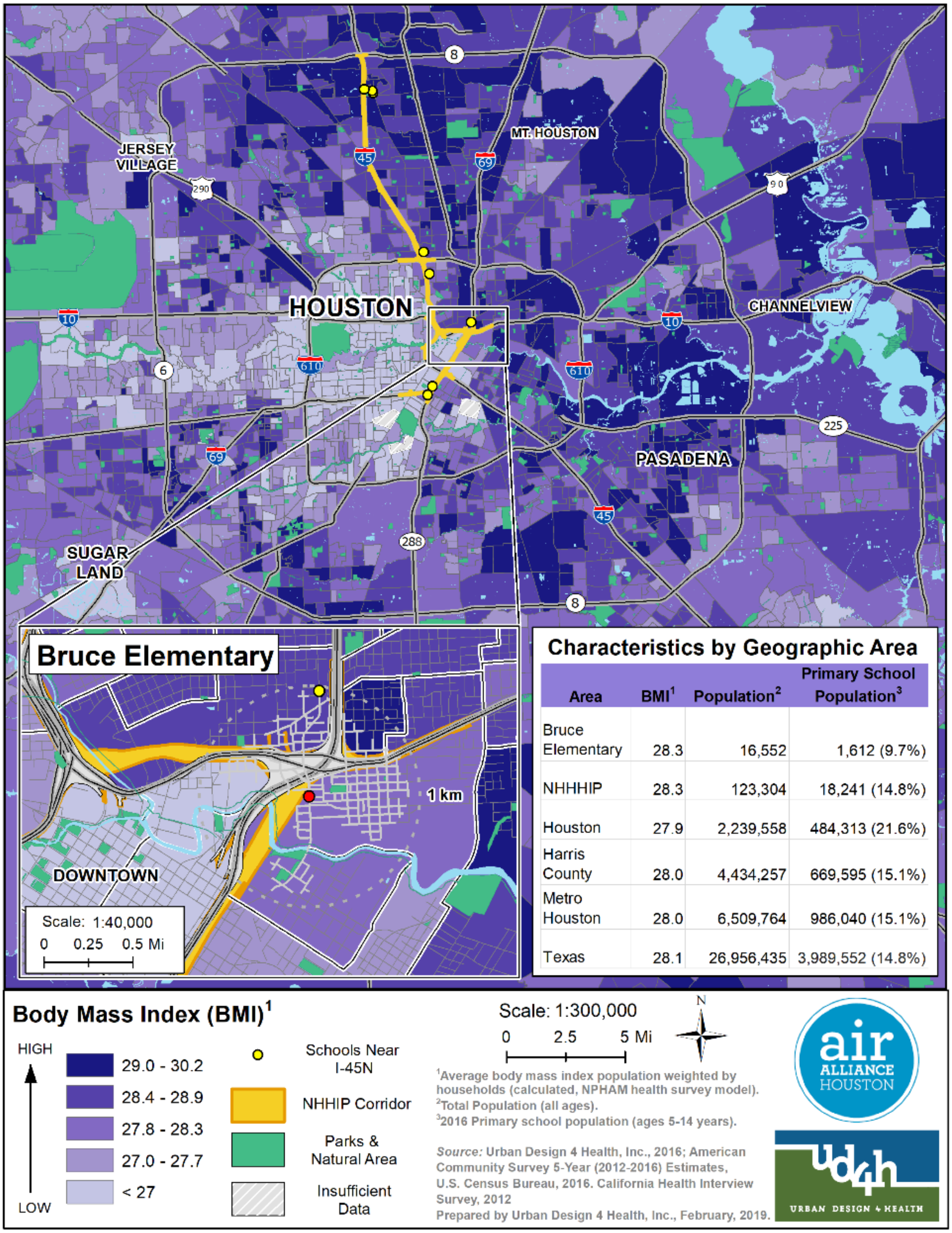
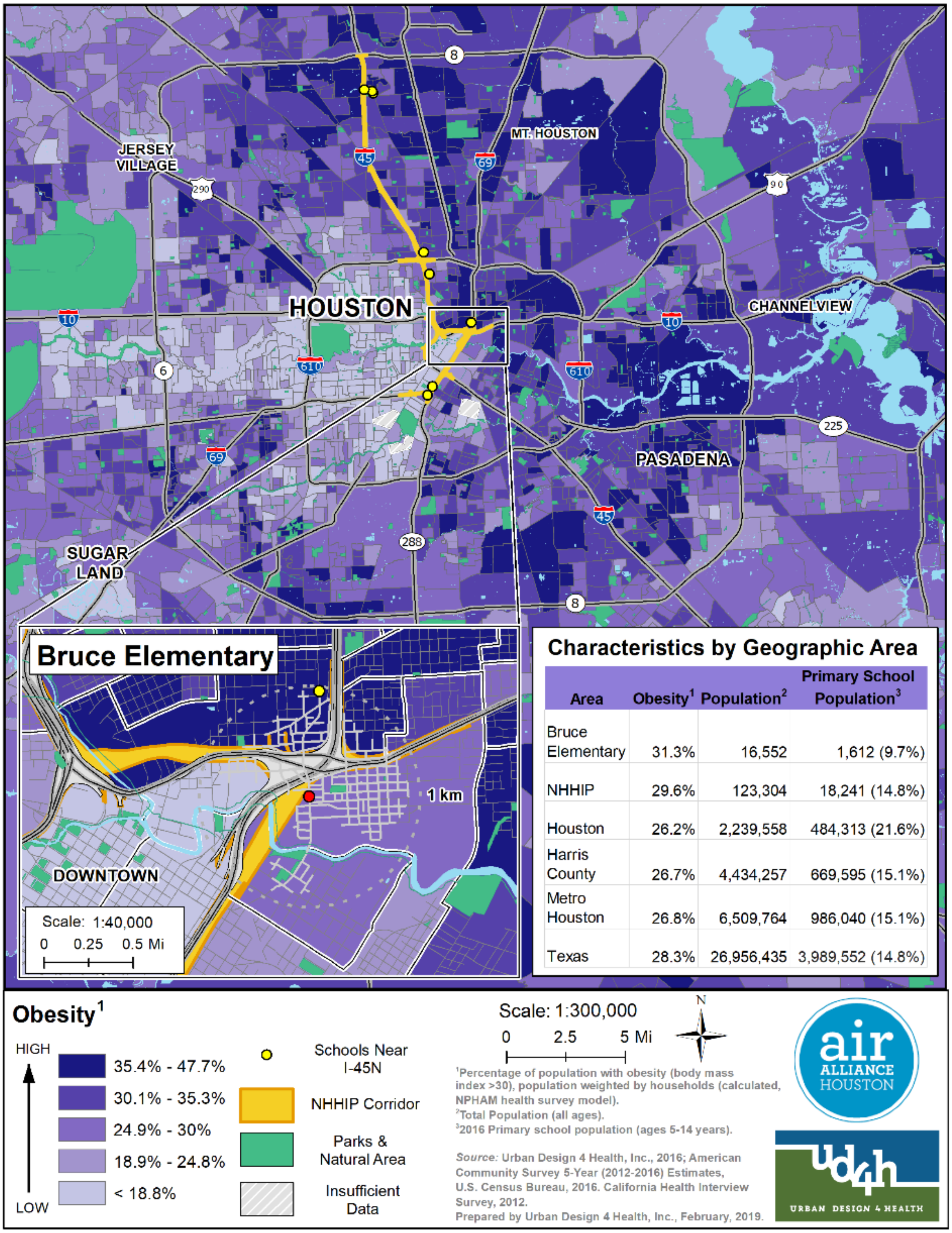
Appendix – Maps



Characteristics by Geographic Area

Area	BMI[1]	Population[2]	Primary School Population[3]
Bruce Elementary	28.3	16,552	1,612 (9.7%)
NHHHIP	28.3	123,304	18,241 (14.8%)
Houston	27.9	2,239,558	484,313 (21.6%)
Harris County	28.0	4,434,257	669,595 (15.1%)
Metro Houston	28.0	6,509,764	986,040 (15.1%)
Texas	28.1	26,956,435	3,989,552 (14.8%)

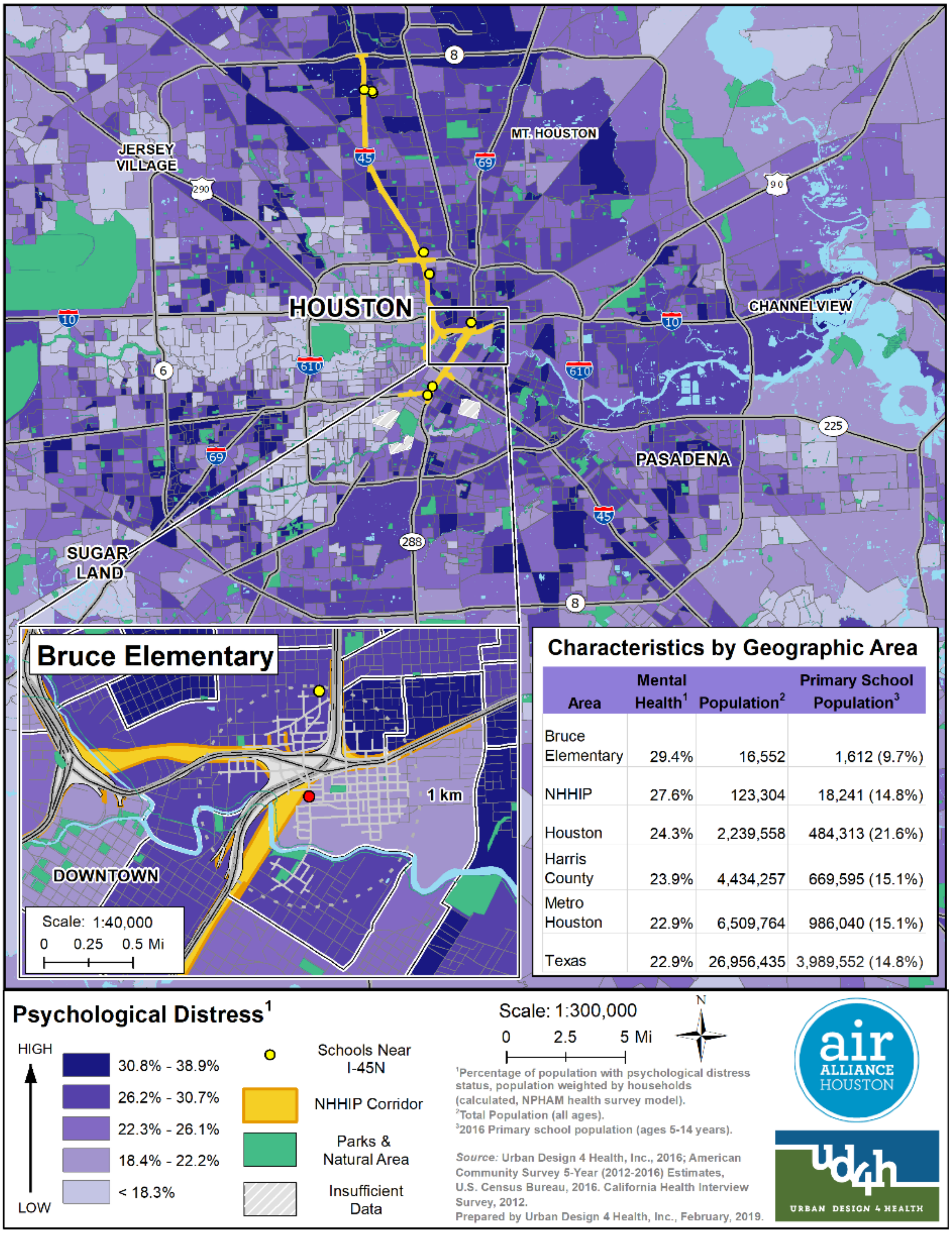
Figure 11 - Baseline conditions: Body Mass Index (adult population)



Characteristics by Geographic Area

Area	Obesity[1]	Population[2]	Primary School Population[3]
Bruce Elementary	31.3%	16,552	1,612 (9.7%)
NHHIP	29.6%	123,304	18,241 (14.8%)
Houston	26.2%	2,239,558	484,313 (21.6%)
Harris County	26.7%	4,434,257	669,595 (15.1%)
Metro Houston	26.8%	6,509,764	986,040 (15.1%)
Texas	28.3%	26,956,435	3,989,552 (14.8%)

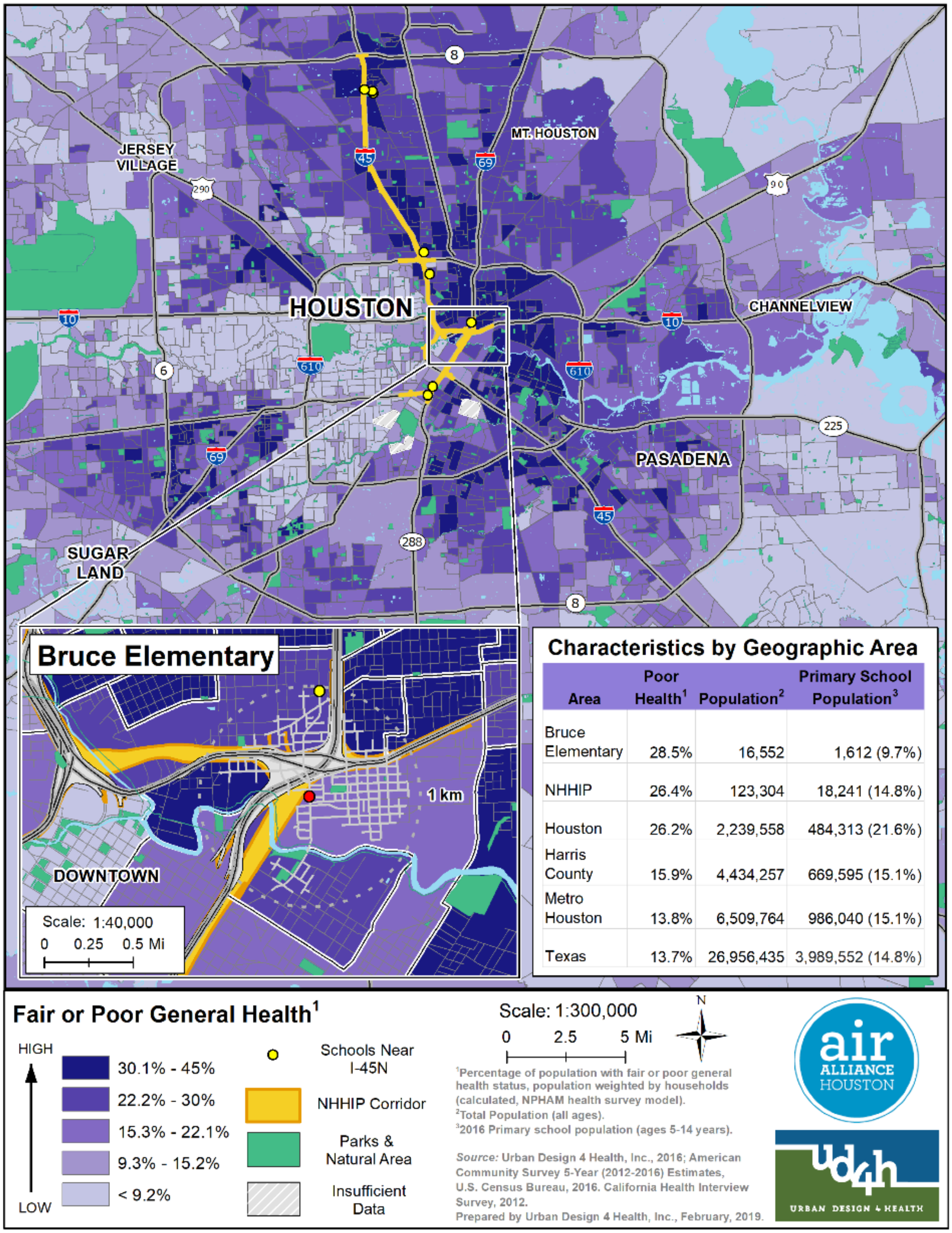
Figure 12 - Baseline conditions: Obesity (adult population)



Characteristics by Geographic Area

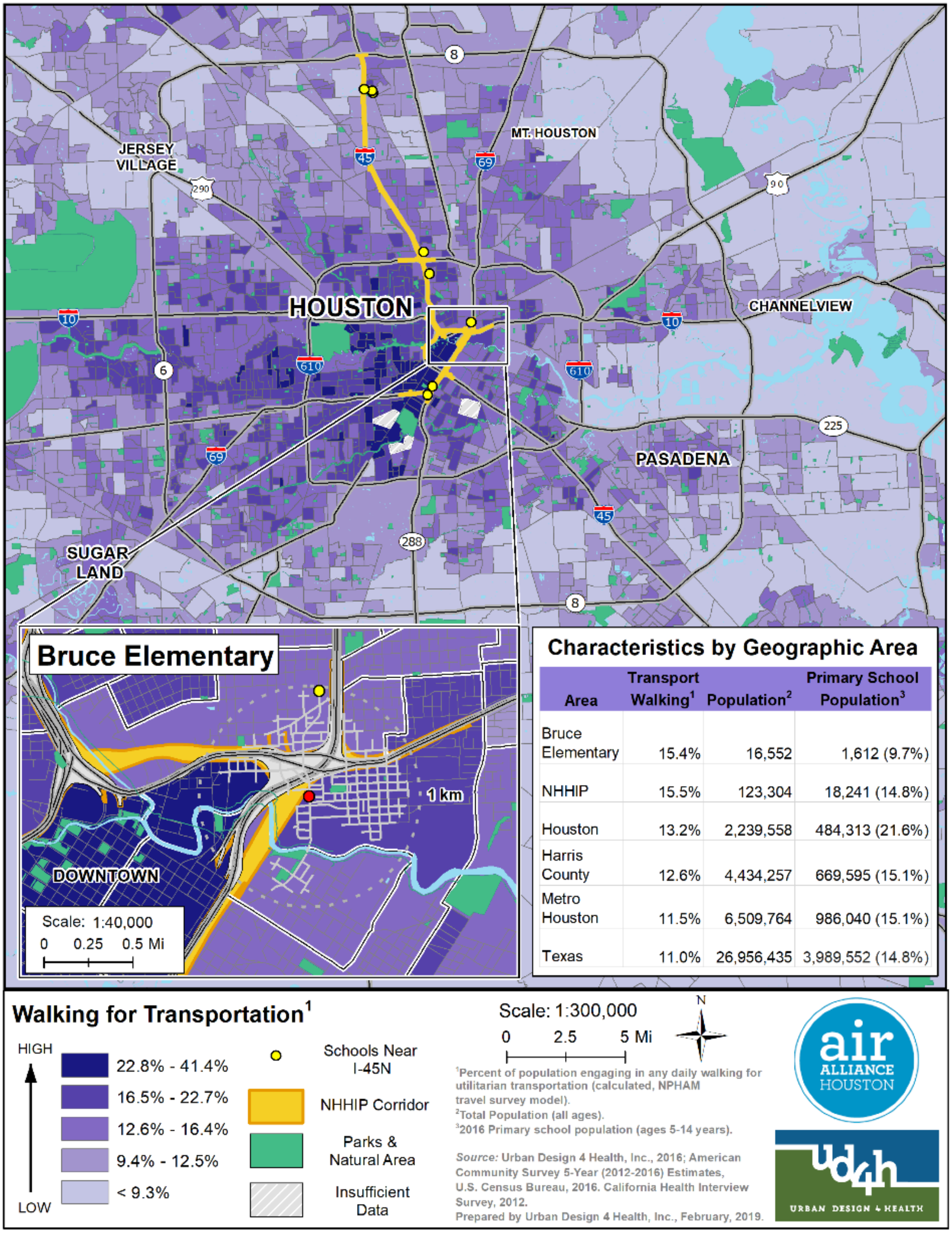
Area	Mental Health[1]	Population[2]	Primary School Population[3]
Bruce Elementary	29.4%	16,552	1,612 (9.7%)
NHHIP	27.6%	123,304	18,241 (14.8%)
Houston	24.3%	2,239,558	484,313 (21.6%)
Harris County	23.9%	4,434,257	669,595 (15.1%)
Metro Houston	22.9%	6,509,764	986,040 (15.1%)
Texas	22.9%	26,956,435	3,989,552 (14.8%)

Figure 13 - Baseline conditions - Psychological Distress (adult population)



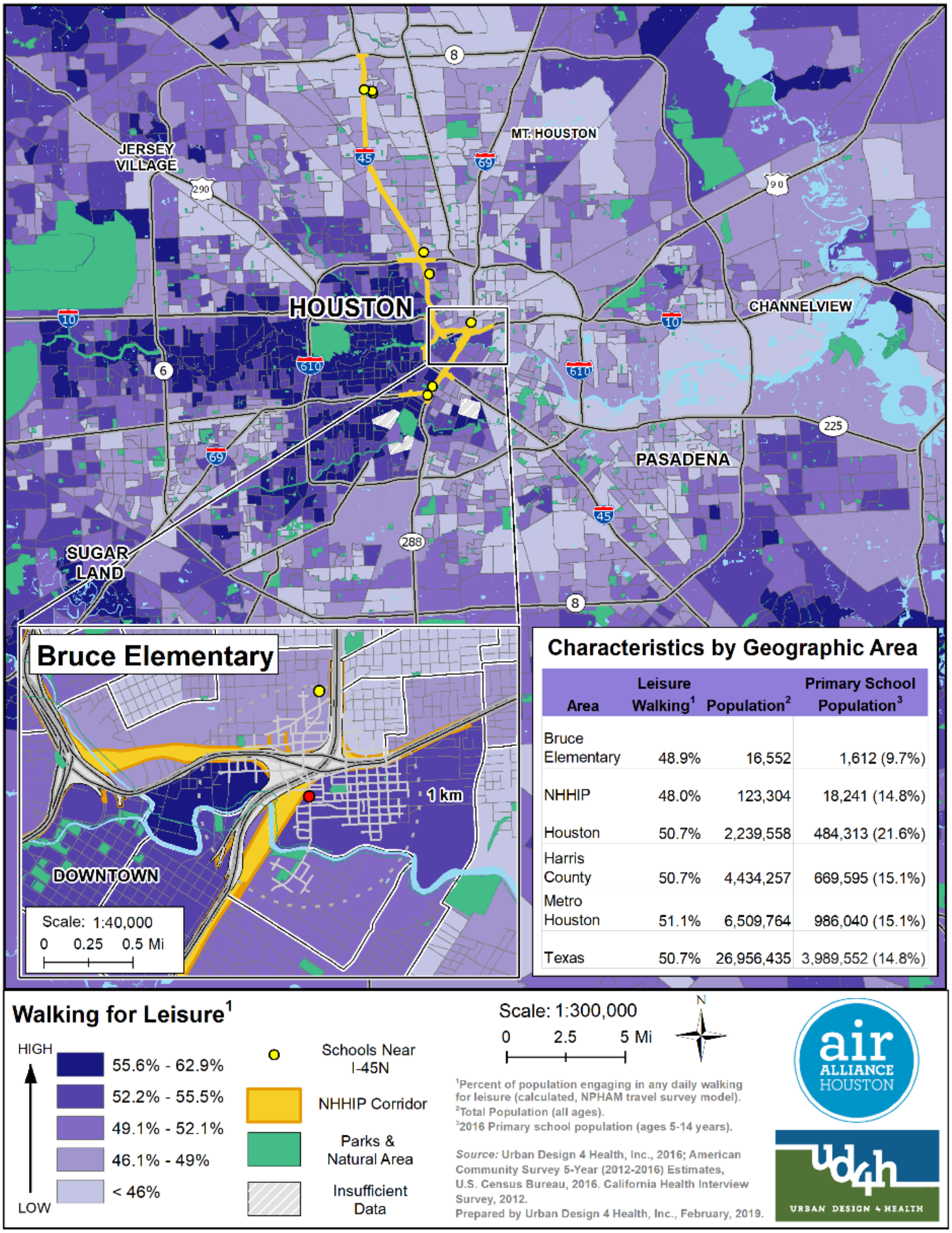
Area	Poor Health[1]	Population[2]	Primary School Population[3]
Bruce Elementary	28.5%	16,552	1,612 (9.7%)
NHHIP	26.4%	123,304	18,241 (14.8%)
Houston	26.2%	2,239,558	484,313 (21.6%)
Harris County	15.9%	4,434,257	669,595 (15.1%)
Metro Houston	13.8%	6,509,764	986,040 (15.1%)
Texas	13.7%	26,956,435	3,989,552 (14.8%)

Figure 14 - Baseline conditions - Fair or Poor General Health (adult population)



Area	Transport Walking[1]	Population[2]	Primary School Population[3]
Bruce Elementary	15.4%	16,552	1,612 (9.7%)
NHHIP	15.5%	123,304	18,241 (14.8%)
Houston	13.2%	2,239,558	484,313 (21.6%)
Harris County	12.6%	4,434,257	669,595 (15.1%)
Metro Houston	11.5%	6,509,764	986,040 (15.1%)
Texas	11.0%	26,956,435	3,989,552 (14.8%)

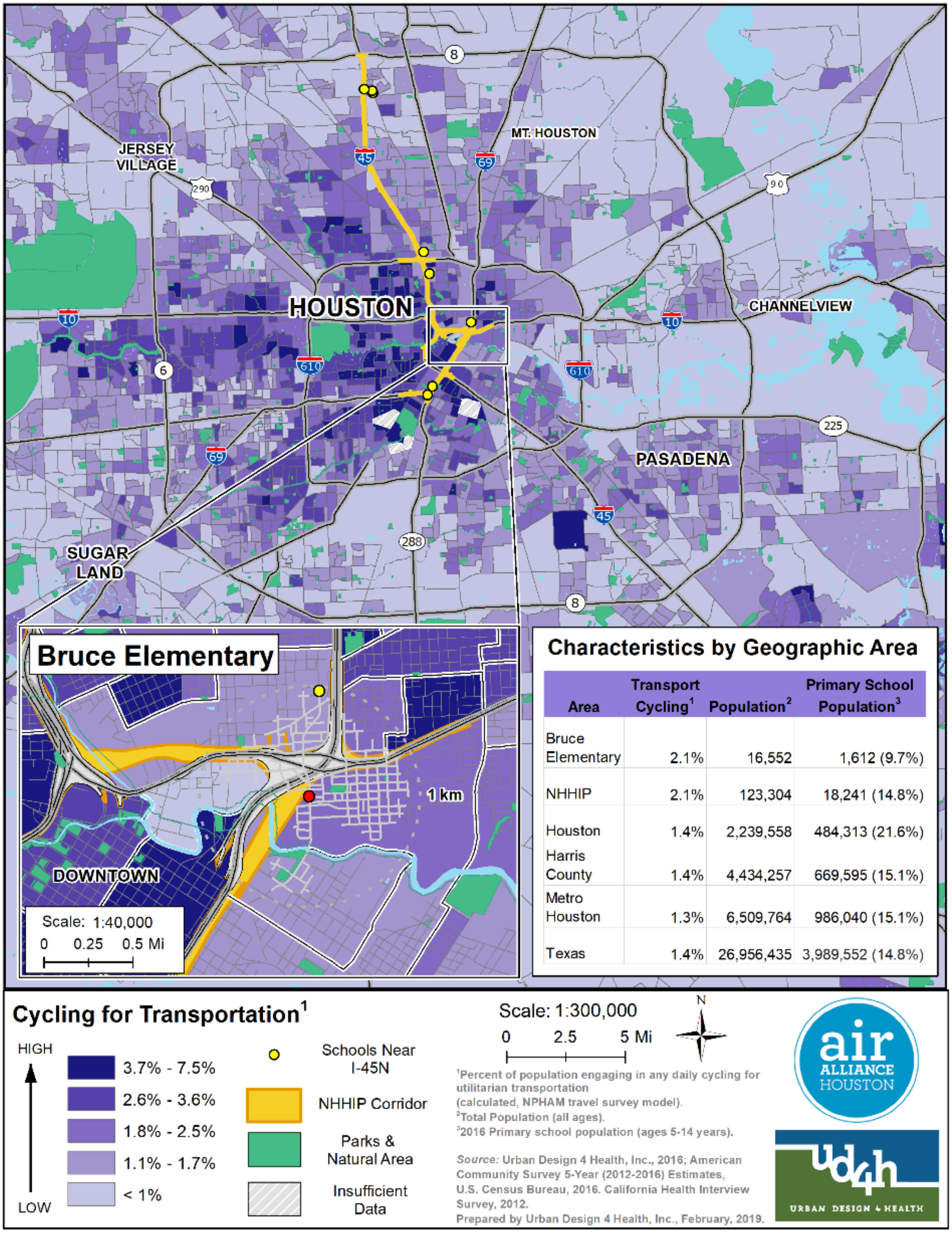
Figure 15 - Baseline conditions - Walking for Transportation (adult population)



Characteristics by Geographic Area

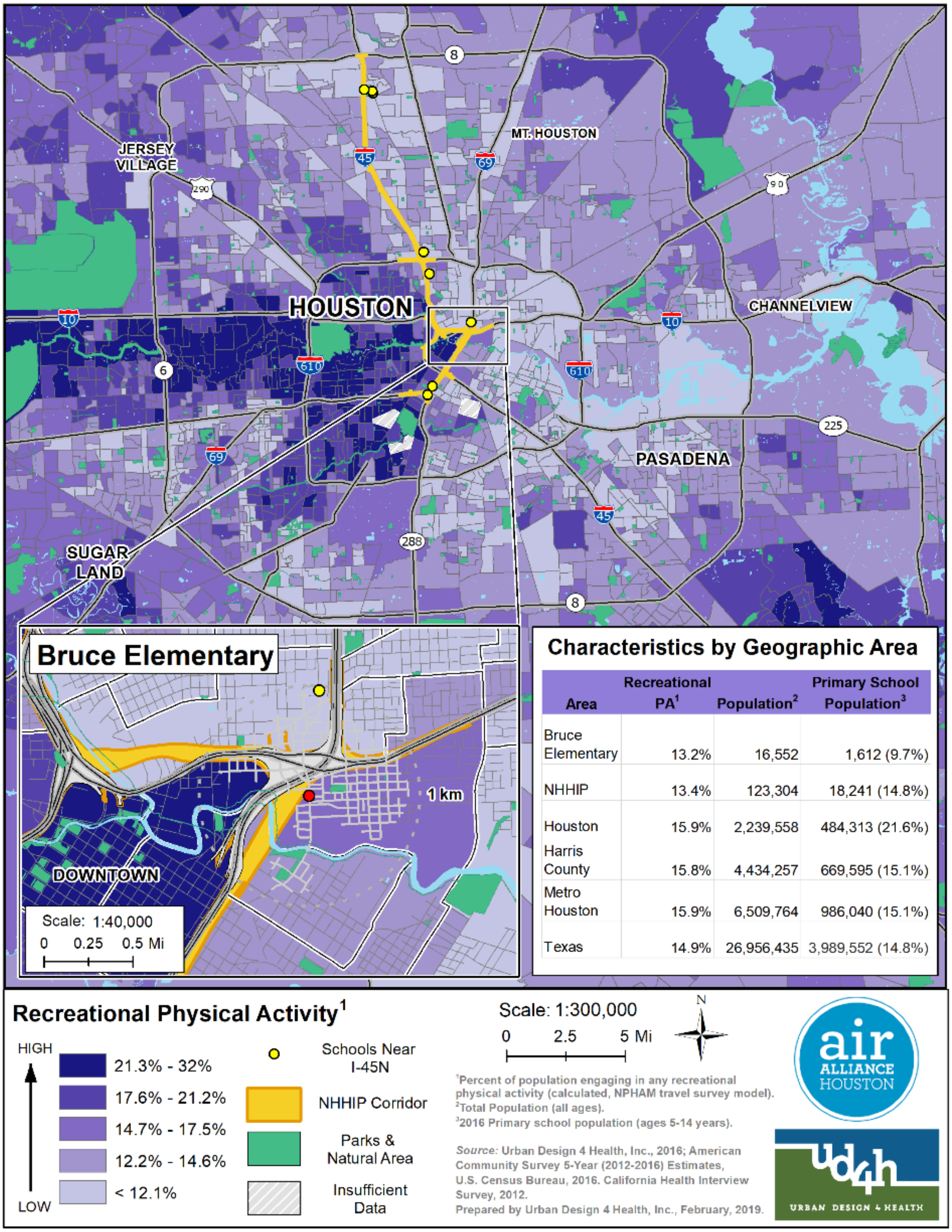
Area	Leisure Walking[1]	Population[2]	Primary School Population[3]
Bruce Elementary	48.9%	16,552	1,612 (9.7%)
NHHIP	48.0%	123,304	18,241 (14.8%)
Houston	50.7%	2,239,558	484,313 (21.6%)
Harris County	50.7%	4,434,257	669,595 (15.1%)
Metro Houston	51.1%	6,509,764	986,040 (15.1%)
Texas	50.7%	26,956,435	3,989,552 (14.8%)

Figure 16 - Baseline conditions - Walking for Leisure (adult population)



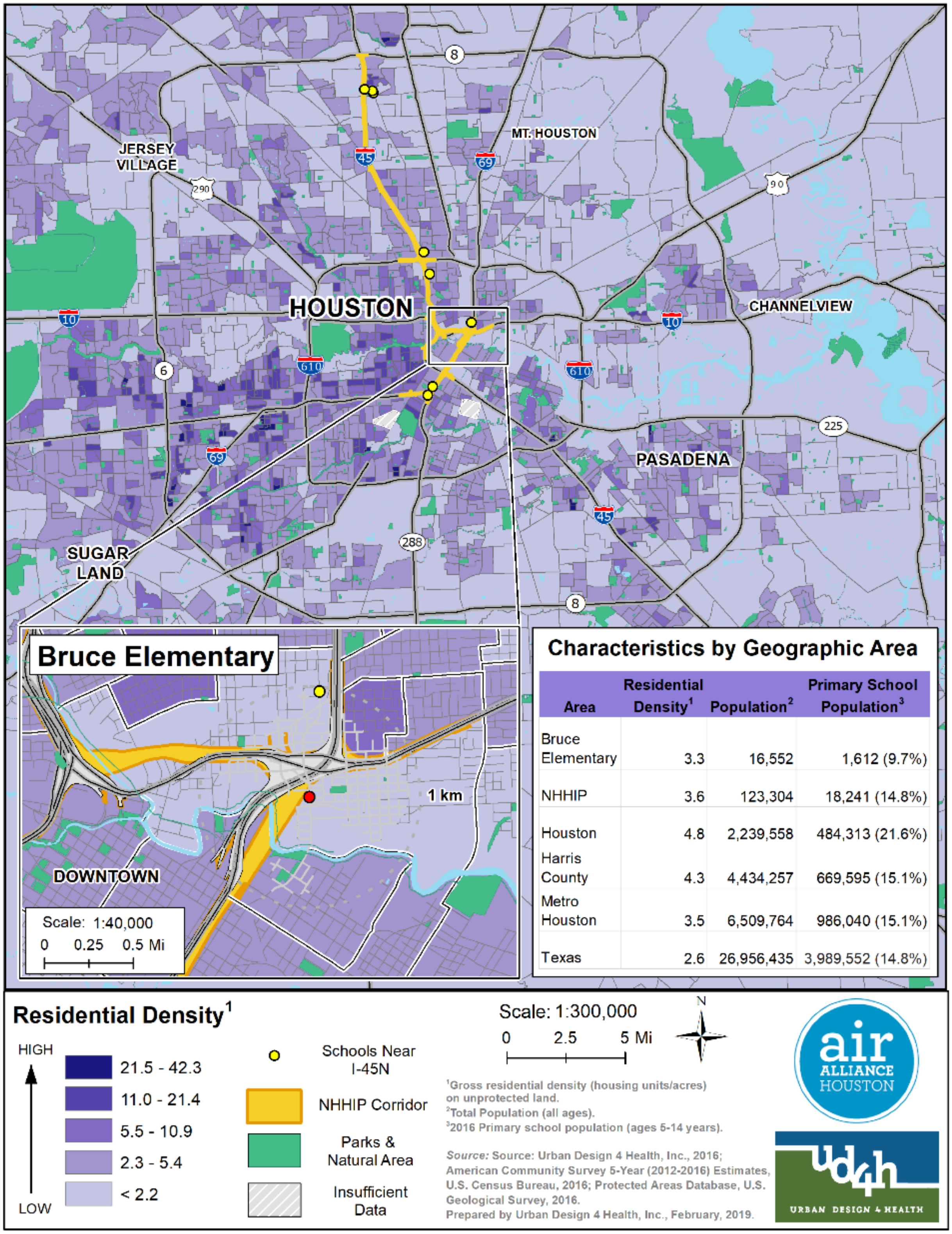
Area	Transport Cycling[1]	Population[2]	Primary School Population[3]
Bruce Elementary	2.1%	16,552	1,612 (9.7%)
NHHIP	2.1%	123,304	18,241 (14.8%)
Houston	1.4%	2,239,558	484,313 (21.6%)
Harris County	1.4%	4,434,257	669,595 (15.1%)
Metro Houston	1.3%	6,509,764	986,040 (15.1%)
Texas	1.4%	26,956,435	3,989,552 (14.8%)

Figure 17 - Baseline conditions - Cycling for Transportation (adult population)



Area	Recreational PA[1]	Population[2]	Primary School Population[3]
Bruce Elementary	13.2%	16,552	1,612 (9.7%)
NHHIP	13.4%	123,304	18,241 (14.8%)
Houston	15.9%	2,239,558	484,313 (21.6%)
Harris County	15.8%	4,434,257	669,595 (15.1%)
Metro Houston	15.9%	6,509,764	986,040 (15.1%)
Texas	14.9%	26,956,435	3,989,552 (14.8%)

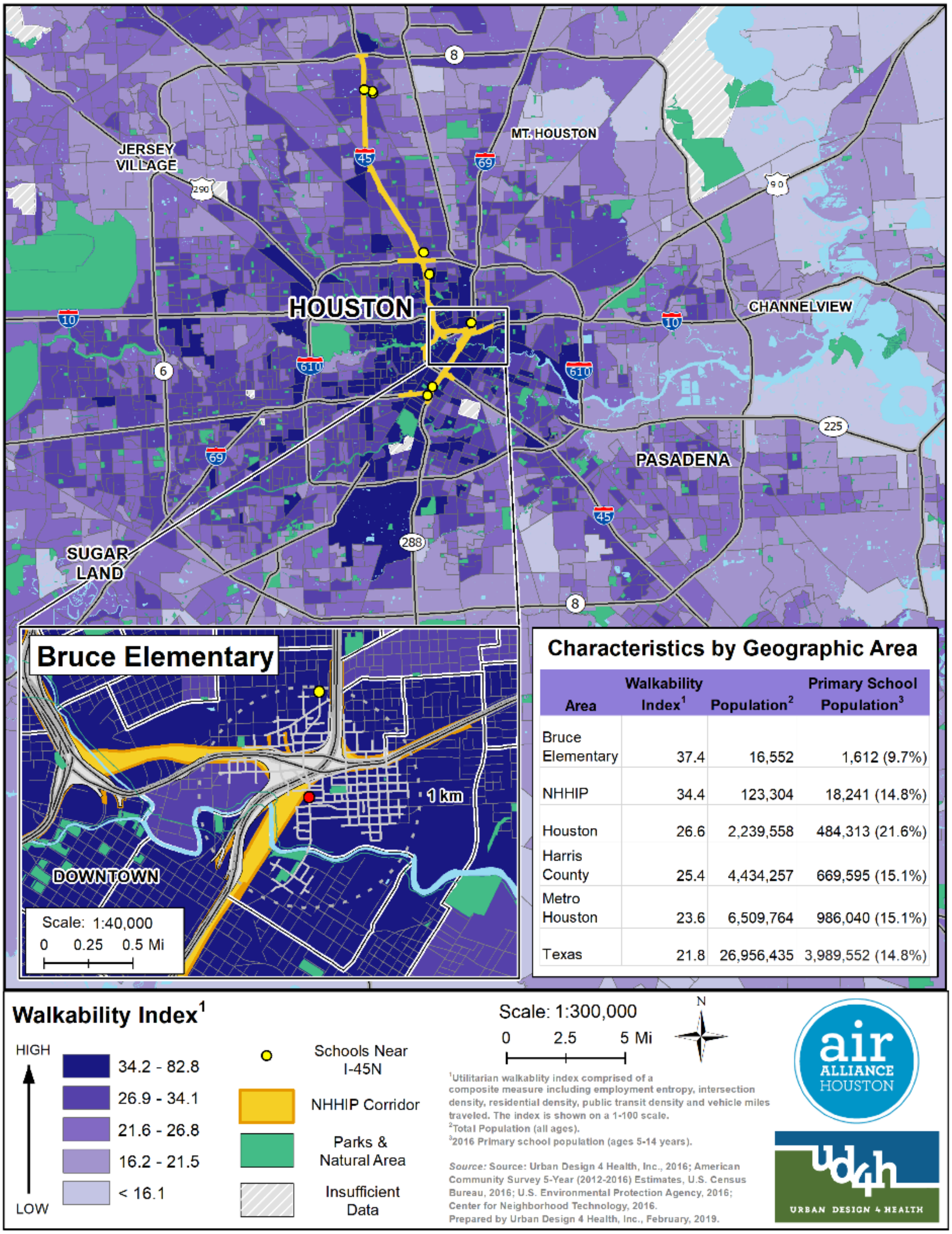
Figure 18 - Baseline conditions - Recreational Physical Activity (adult population)



Characteristics by Geographic Area

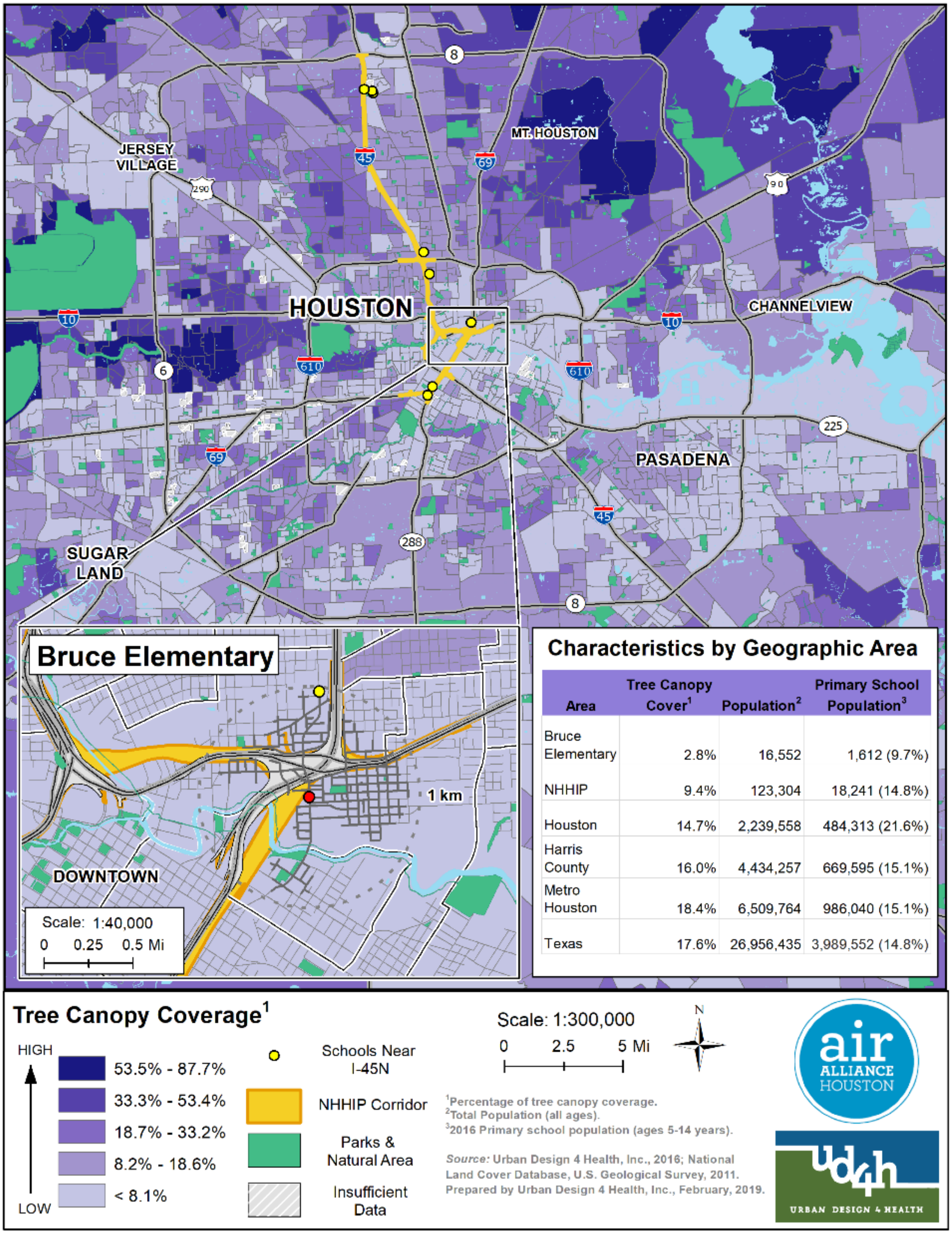
Area	Residential Density[1]	Population[2]	Primary School Population[3]
Bruce Elementary	3.3	16,552	1,612 (9.7%)
NHHIP	3.6	123,304	18,241 (14.8%)
Houston	4.8	2,239,558	484,313 (21.6%)
Harris County	4.3	4,434,257	669,595 (15.1%)
Metro Houston	3.5	6,509,764	986,040 (15.1%)
Texas	2.6	26,956,435	3,989,552 (14.8%)

Figure 19 - Baseline conditions - Residential Density (adult population)



Area	Walkability Index[1]	Population[2]	Primary School Population[3]
Bruce Elementary	37.4	16,552	1,612 (9.7%)
NHHIP	34.4	123,304	18,241 (14.8%)
Houston	26.6	2,239,558	484,313 (21.6%)
Harris County	25.4	4,434,257	669,595 (15.1%)
Metro Houston	23.6	6,509,764	986,040 (15.1%)
Texas	21.8	26,956,435	3,989,552 (14.8%)

Figure 20 - Baseline conditions - Walkability Index (adult population)



Area	Tree Canopy Cover[1]	Population[2]	Primary School Population[3]
Bruce Elementary	2.8%	16,552	1,612 (9.7%)
NHHIP	9.4%	123,304	18,241 (14.8%)
Houston	14.7%	2,239,558	484,313 (21.6%)
Harris County	16.0%	4,434,257	669,595 (15.1%)
Metro Houston	18.4%	6,509,764	986,040 (15.1%)
Texas	17.6%	26,956,435	3,989,552 (14.8%)

Figure 21 - Baseline conditions - Tree Canopy Coverage (adult population)