To what extent is transport in Houston, Texas sustainable?

Word Count: 3996

Abstract

This research question of this exploration is: To what extent is transportation in Houston, Texas sustainable? Sustainability has become a global concern, and this investigation aims to determine the extent to which Houston has developed its transportation systems in an effort to be sustainable.

Sites were chosen based on systematic and stratified sampling. Primary data collected included traffic counts, land use maps, environment quality survey, weather data and photos. Secondary data included walkability scores, costs of driving, and investment in Sustainable transport systems, ticket prices and casualties.

The hypotheses (Social, economic and environmental) that were investigated were as follows: Does sustainable transport

1. Conserve human health and provide access to daily services (Social)
2. Provide variety, affordability and efficiency for the population (Social)
3. Limit the emissions in the environment by discouraging the use of private vehicles (Environmental)
4. Provide economic benefits for both the consumer and business (Economic)

Hypothesis 3 was accepted, whereas hypotheses 1,2 and 4 were rejected. Transport systems ensure a sustainable environment where they are located, however the lack of profit, high risk of casualties and lack of efficiency proved that public transportation in Houston is not sustainable. It was determined that Houston's demographics and factors such as suburban sprawl, car dependency and low income populations need to be taken into account while developing the systems in order to be categorized as sustainable.

Word count: 227

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Definitions

STS – Sustainable transport systems including trains, buses, pedestrians and cycles

HOV – High-occupancy vehicle lanes – allow vehicles with 2+ people to use lanes for free in following hours: 5am to 11am and 2pm – 8pm

TMC – Texas Medical Center, a secondary peak area with high land values and the world's largest medical center

B-Cycles – A scheme which allows its user to rent bicycles from stations – free for the first hour, then charged $2 additional half hourly until the bicycle is docked back at station.

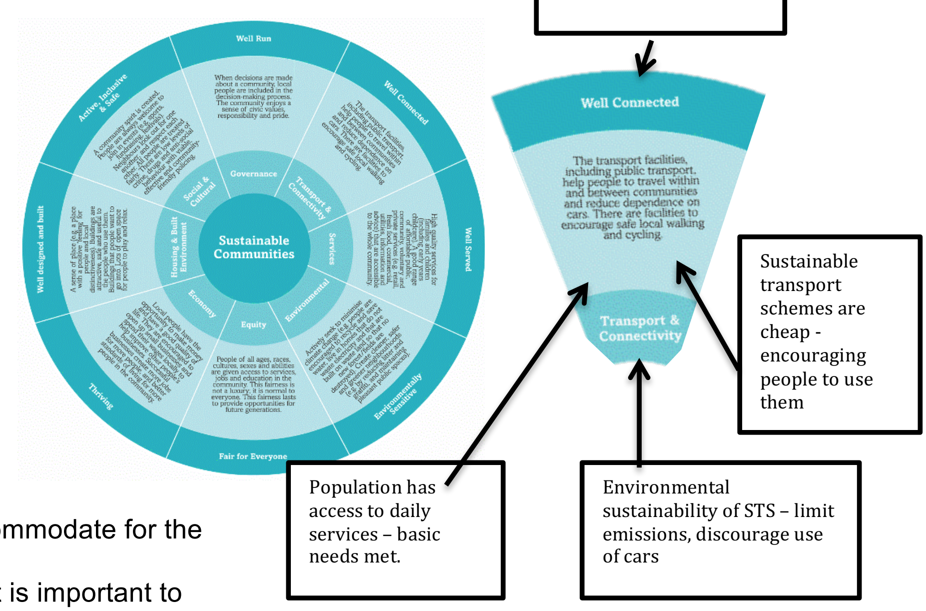
Question

To what extent is transport in Houston Texas sustainable?

Introduction

Worldwide sustainability is becoming an increasingly important matter due to the growing concern that human activity is contributing to climate change. The recent climate change conference COP21 held in France discussed this issue, where 177 countries (East, 2011) signed up to take action against climate change. President Obama is determined to increase fuel efficiency in the US and cut carbon emissions (COP, 2016) in half by 2025, while promoting the use of sustainable transport schemes (STS) such as electric vehicles, biking, car sharing and walking (COP, 2016) (some of which are already present in Houston) to cut emission and congestion.

Figure 1: Egan Wheel relating to STS



The aim of this investigation is to evaluate the extent to which transport in Houston is sustainable. This question is being researched, as different types of STS are located in different parts of Houston to accommodate for the differing demographics of the city. It is important to investigate the extent to which these different schemes are sustainable in order to raise awareness about using these schemes to positively impact climate change. Theories such as the Egan wheel (East, 2011) shown in figure 1 (specifically 'Transport and sustainability'), pillars of sustainability (Harich. Bangerter, 2014) (Figure 1.1) and the Propolis indicator of sustainability (Spiekermann. Wegener, 2016) (Figure 1.2) have been used and adapted in order to fit the idea of sustainability in transport systems.

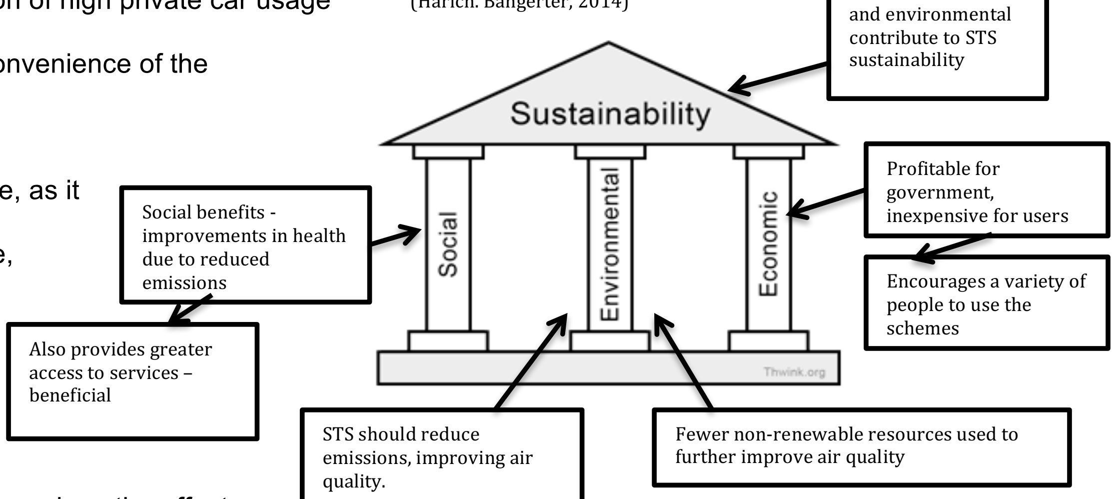
Some of the factors that influence the location of STS are the demographics of the population (age, wealth etc.), the density of the population, accessibility of urban areas and weather conditions.

A STS can be defined in terms of its social, economic and environmental characteristics that provide a cities population accessibility to communal services while reducing greenhouse gas emission by discouraging the use of private vehicles. A basic STS obeys the following criteria:

1. Basic needs of the population are met in a way, which preserves human health and includes access to daily services (Black, 2004). (Social)
2. City offers transport that is affordable, operates efficiently and offers a variety of means of transportation to the population (Black, 2004). (Social)
3. Limits the amount of emissions released into the atmosphere by minimizing the consumption of non-renewable resources and discouraging the use of private vehicles (Cormier. Gilbert, 2005). (Environmental)
4. Offers economic benefits for users, and operator revenues exceeding investment costs, allowing for healthy profit margin (Cormier. Gilbert, 2005). (Economic)

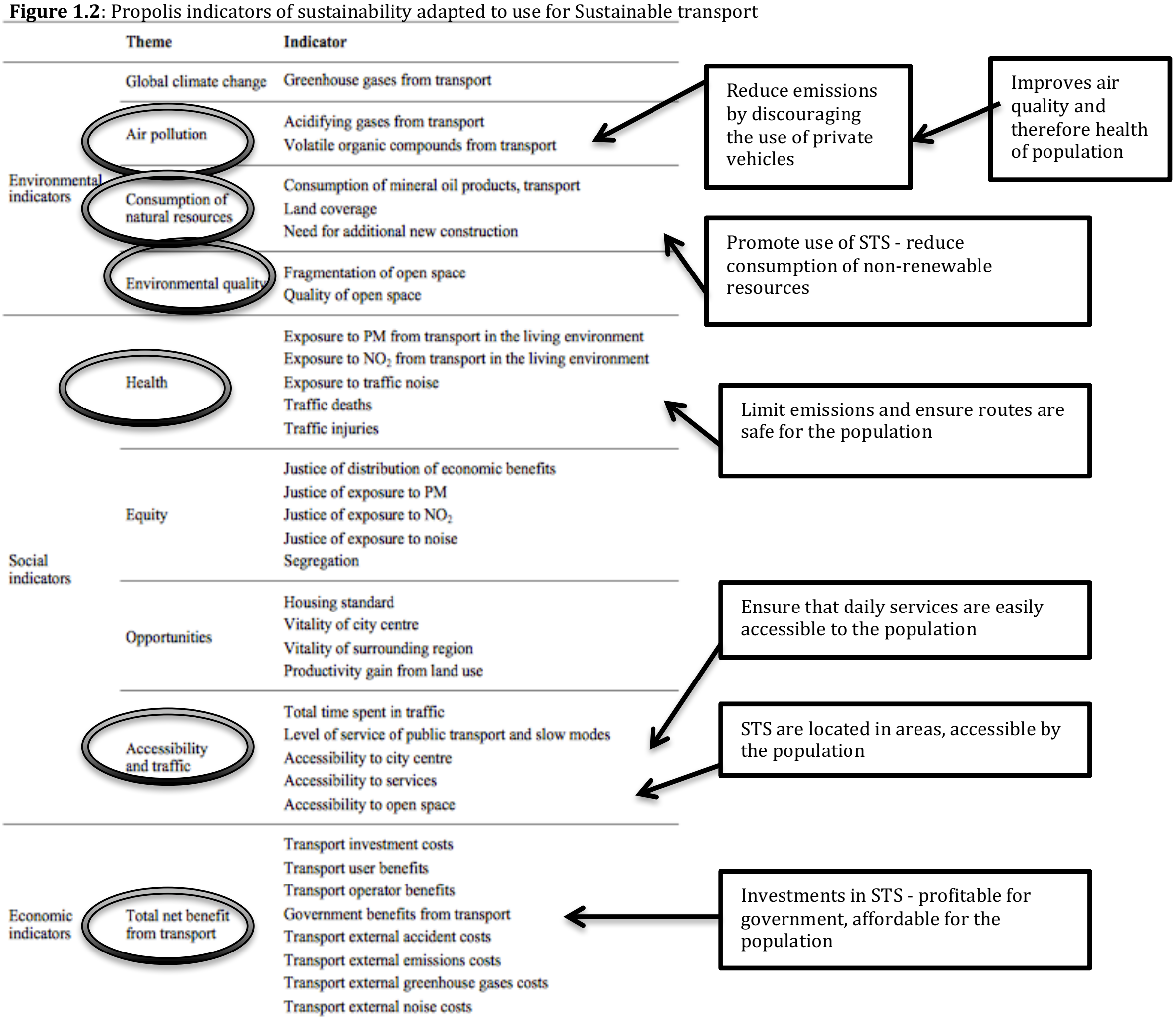
Houston (Figure 1.3) is the second largest city in the US with a total land area of 627 squared miles. Known for its continual suburban sprawling, it is increasing difficult to develop sustainable transport schemes in an area where the population travels to communal locations from diverse locations. Investing in large transport schemes, which span the length of the city, would be inefficient due to the vast spread of populated communities within Houston. Furthermore, due to the long commuter distances and humid weather, Houston has a tradition of high private car usage for the comfort and convenience of the population.

Figure 1.1: Three pillars of sustainability (Harich. Bangerter, 2014)



This topic interests me, as it is a very current issue, which needs to be acted upon with a local, regional and global scale in order to reduce the effects of climate change. My personal experience with STS in India was very different as due to a high population density, an abundance of different STS's were present. Upon moving here, I realized that Houston has a high dependency on cars, and therefore different approaches need to be adopted to minimize its carbon emissions and positively impact the environment.

Figure 1.2: Propolis indicators of sustainability adapted to use for Sustainable transport



	Theme	Indicator
Environmental indicators	Global climate change	Greenhouse gases from transport
	Air pollution	Acidifying gases from transport Volatile organic compounds from transport
	Consumption of natural resources	Consumption of mineral oil products, transport Land coverage Need for additional new construction
	Environmental quality	Fragmentation of open space Quality of open space
Social indicators	Health	Exposure to PM from transport in the living environment Exposure to NO_2 from transport in the living environment Exposure to traffic noise Traffic deaths Traffic injuries
	Equity	Justice of distribution of economic benefits Justice of exposure to PM Justice of exposure to NO_2 Justice of exposure to noise Segregation
	Opportunities	Housing standard Vitality of city centre Vitality of surrounding region Productivity gain from land use
	Accessibility and traffic	Total time spent in traffic Level of service of public transport and slow modes Accessibility to city centre Accessibility to services Accessibility to open space
Economic indicators	Total net benefit from transport	Transport investment costs Transport user benefits Transport operator benefits Government benefits from transport Transport external accident costs Transport external emissions costs Transport external greenhouse gases costs Transport external noise costs

Figure 1.3: Locating Houston

Figure 1.4: Locational context map of Houston

Key:

Wealthy areas

Poor areas

Investigation

Primary and secondary data collections were used in this research in order to investigate STS in Houston. Traffic data was collected on Saturday the 14th of May (Weekend) and Friday (Weekday) the 27th of May to compare the results that are expected to differ among the sites along the I-10 transect.

Systematic and stratified samplings were used to pick the sites shown in figure 1.5. Sites were chosen along the I-10 transect (systematic) - a primary mode of transportation due to the car dependent nature of Houston - and allows effective comparison of STS found in different regions of Houston, along the same transect. However, in order to get a more holistic view of the STS in Houston, TMC (Texas Medical Center) and the third ward were chosen as sites away

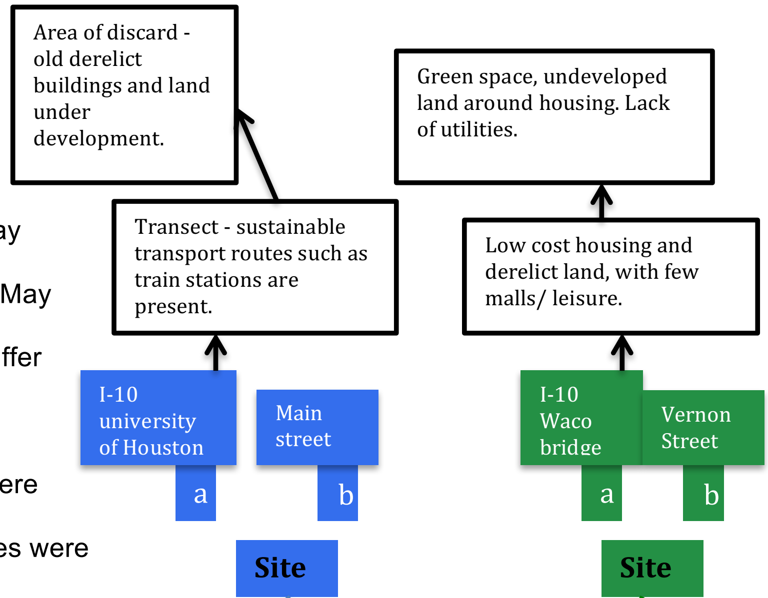
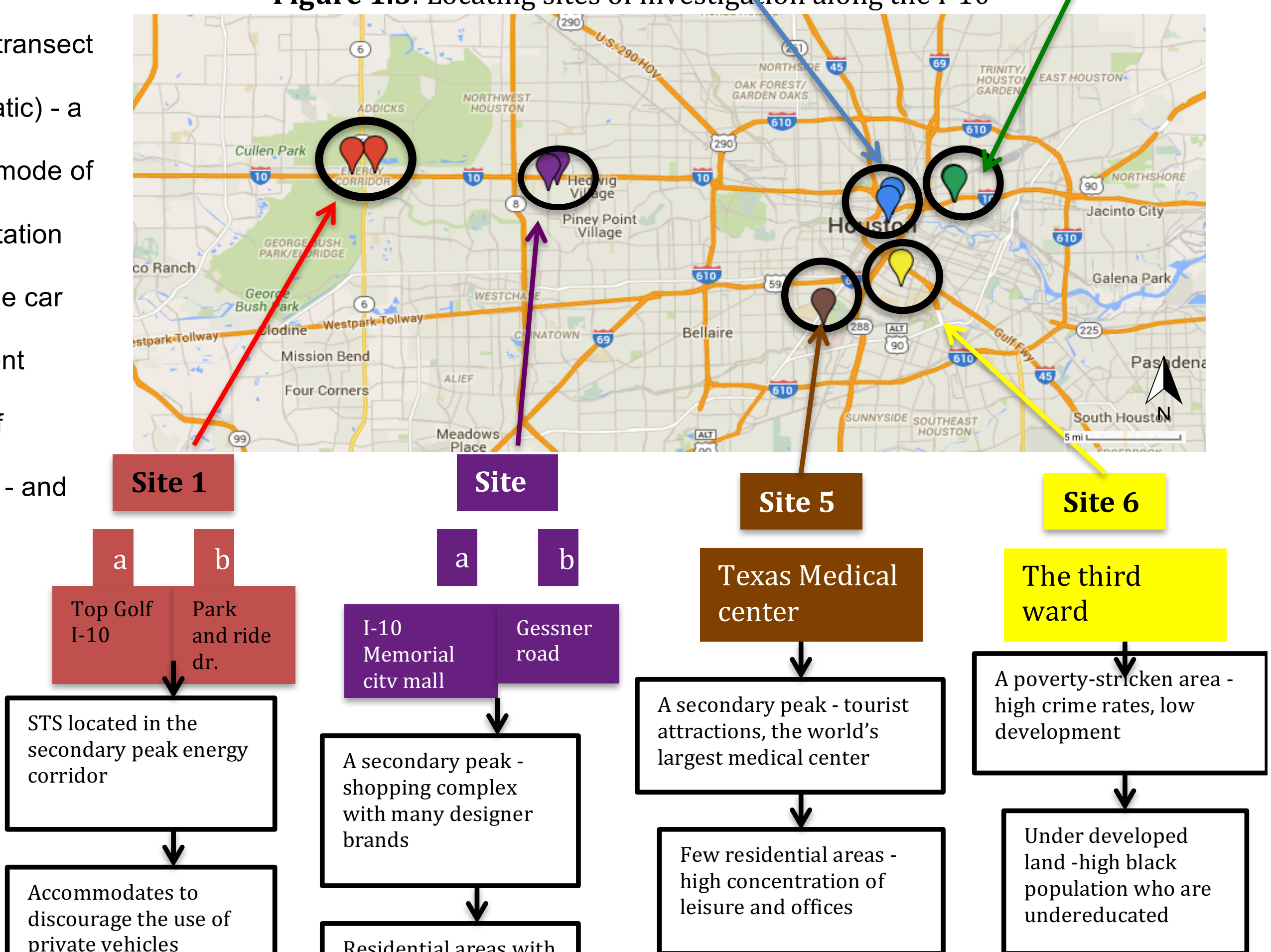
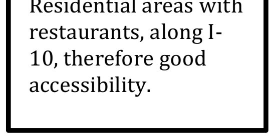


Figure 1.5: Locating sites of investigation along the I-10





from the transect (stratified) as they are secondary peaks and areas of decline respectively, and therefore these characteristics will impact the STS found in these areas.

Using characteristics of STS, the research question was answered using 4 hypotheses, which included the social, economic and environmental aspects of the 'three pillars of sustainability' theory, enabling us to see the reasons behind the sustainability and spatial distribution of STS in Houston.

1. The first hypotheses took into account the social aspects of sustainability of STS using theories such as the PROPOLIS indicator of sustainability to determine whether daily services are accessible to the population in a way, which is convenient and preserves human health.
2. Secondly, the social aspects of sustainability of STS using the PROPOLIS indicator and Egan wheel were taken into account again to determine whether a variety of STS are offered to the population and operate efficiently whilst being affordable.
3. Thirdly, the environmental sustainability of STS was accounted for through the 'well connected' section of the Egan wheel and the PROPOLIS indicator to determine whether STS discourage the use of private vehicles and reduce CO_2 emissions.
4. Finally, the economic aspect of STS was accounted for through the PROPOLIS indicator to determine whether there are economic benefits to both the population and the businesses.

Primary Data collection:

Technique	Description	Reason
Traffic Counts	Stood at sidewalk of at each site off the highway and an elevated point at the same site to record traffic on the I-10, counting transport for 5 minutes. Used a counter app, for accuracy, and same people counted type of transportation each time, ensuring a fair test.	Analyse the proportions of the different transports found at each site to evaluate sustainability at each site taking into account differing results for Saturday and Friday. (Criteria 2)
Land use maps	Annotated base maps of sites using color-codes according to land use. Diversity of land use and construction buildings difficult to determine, therefore GIS used.	Analyse services located around these areas, to evaluate accessibility of services in relation to STS. (Criteria 1)
Quality of environment	Bi-polar environmental quality survey carried (ranked -2 to 2) out by the same person at every site ensuring reliability. Statistical analysis carried on these results.	Analyse the environmental quality of each site in comparison to the STS found there, supporting usage and highlighting physical characteristics of area, which may

		impact use of STS. (Criteria 3)
Weather data	Weather measurements including cloud cover, humidity and temperature recorded using the location services of the 'accuweather' app for accuracy.	Impact the use of STS, helping to justify any anomalies.
Photos	Show holistic appearance and support land-use mapping.	Justify and support the physical appearance and environmental quality areas. (Criteria 1)

Secondary data collection:

Technique	Description	Reason
Walkability scores (Walk Score, 2016)	Website walkscore.com used to determine walk, transit and cycle scores of each site on a scale of 1-100.	Data used to determine the accessibility of the area (criteria 1) with approachability of services for the population.
Driving costs and pollution (HT index, 2016)	Average driving cost of cars found and directly corresponds with the amount of pollutants such as CO2 emitted. Used to evaluate environmental quality and health of population among the different sites.	Determine the driving costs and corresponding emissions (criteria 3) - comparing the environmental aspects of STS.
Investment in STS	Amount of investment and users in various types of STS were found.	Satisfies the economic benefit to the businesses (Criteria 4) being profitable for companies/users.
Ticket prices of STS	Ticket prices for STS were found accurate with distance and special schemes or member cards were also included.	Satisfies criteria 4 and 2, STS should benefit users by offering an affordable price so a variety of people are able to access these schemes.
Traffic deaths and injuries	The deaths and injuries for each of the STS were found in Houston.	Criteria 1, preserving human health, ensuring that STS are safe for users.

1) Social sustainability

Figure 2.1: Graph to show the number of deaths with vehicles in 2014 in Houston (City Data, 1975) (Begley, 2016) (Maciag, 2016)

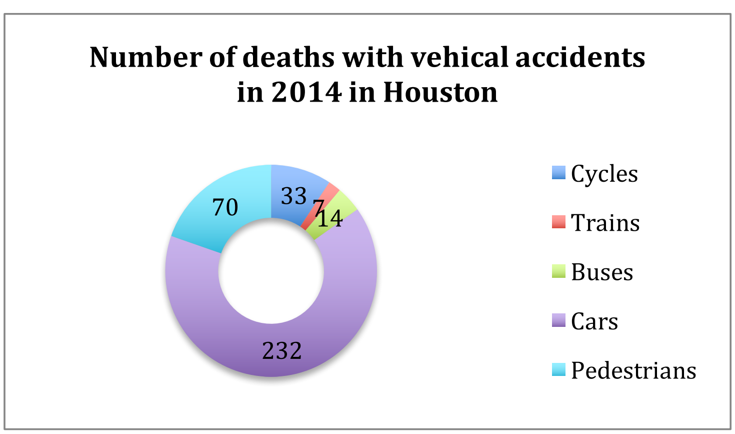


Figure 2: Showing the spatial distribution of walkability, transit and bikeable scores of the various sites.

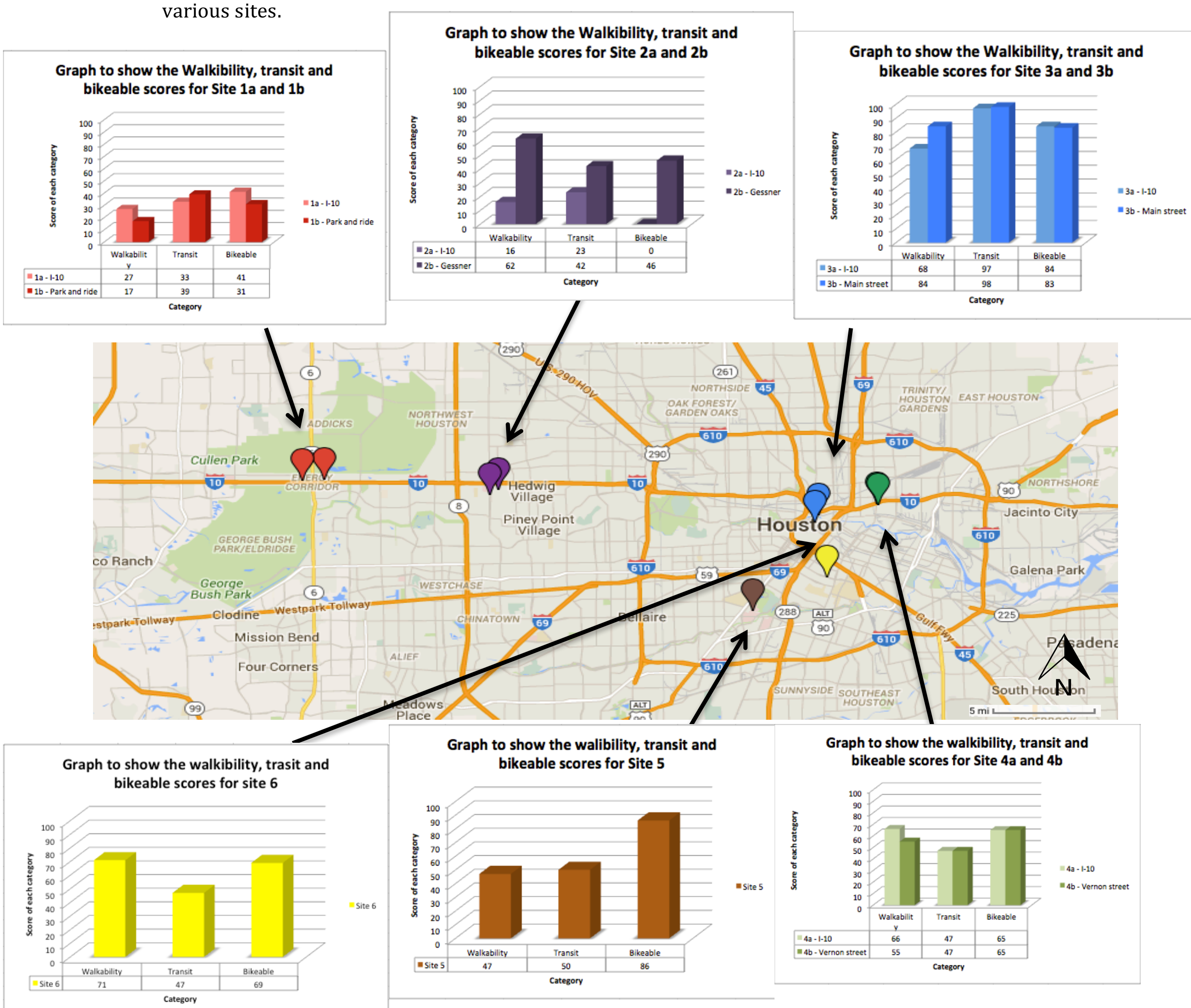
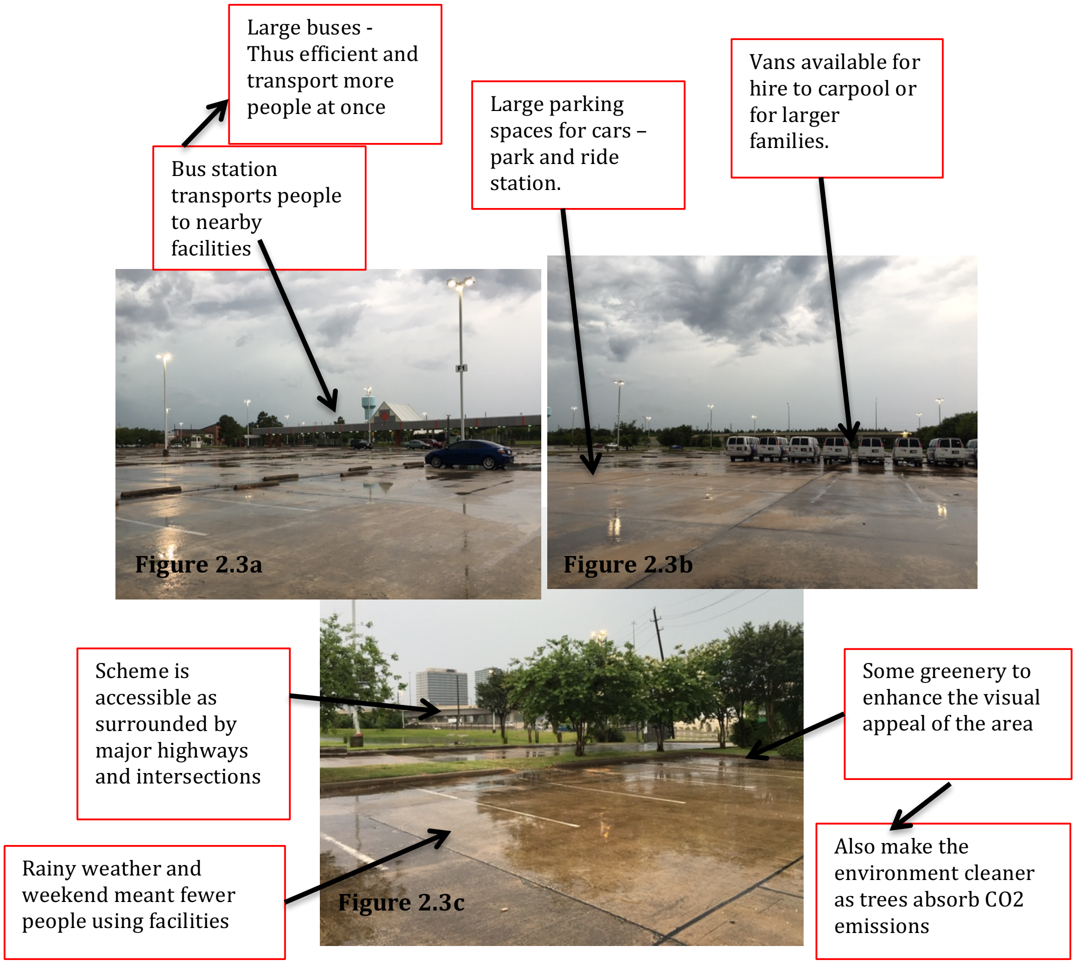


Figure 2.3: Annotated pictures of site 1 to show the types of sustainable transport schemes available to the population to access nearby services



Key for land use maps

Color	Category
(cyan)	Residential
(green)	Green spaces
(magenta)	Leisure (Clubs, gym etc.)
(orange)	Work (Offices)
(blue)	Transportation terminals
(purple)	Shops, restaurants
(black)	Major roads/ highways
(brown)	Education
(beige)	Government buildings
(grey)	Car parks
(red)	Construction sites
(yellow)	Utilities

Figure 2.4: Land use map of site 1 to show the types of services accessible to the population nearby

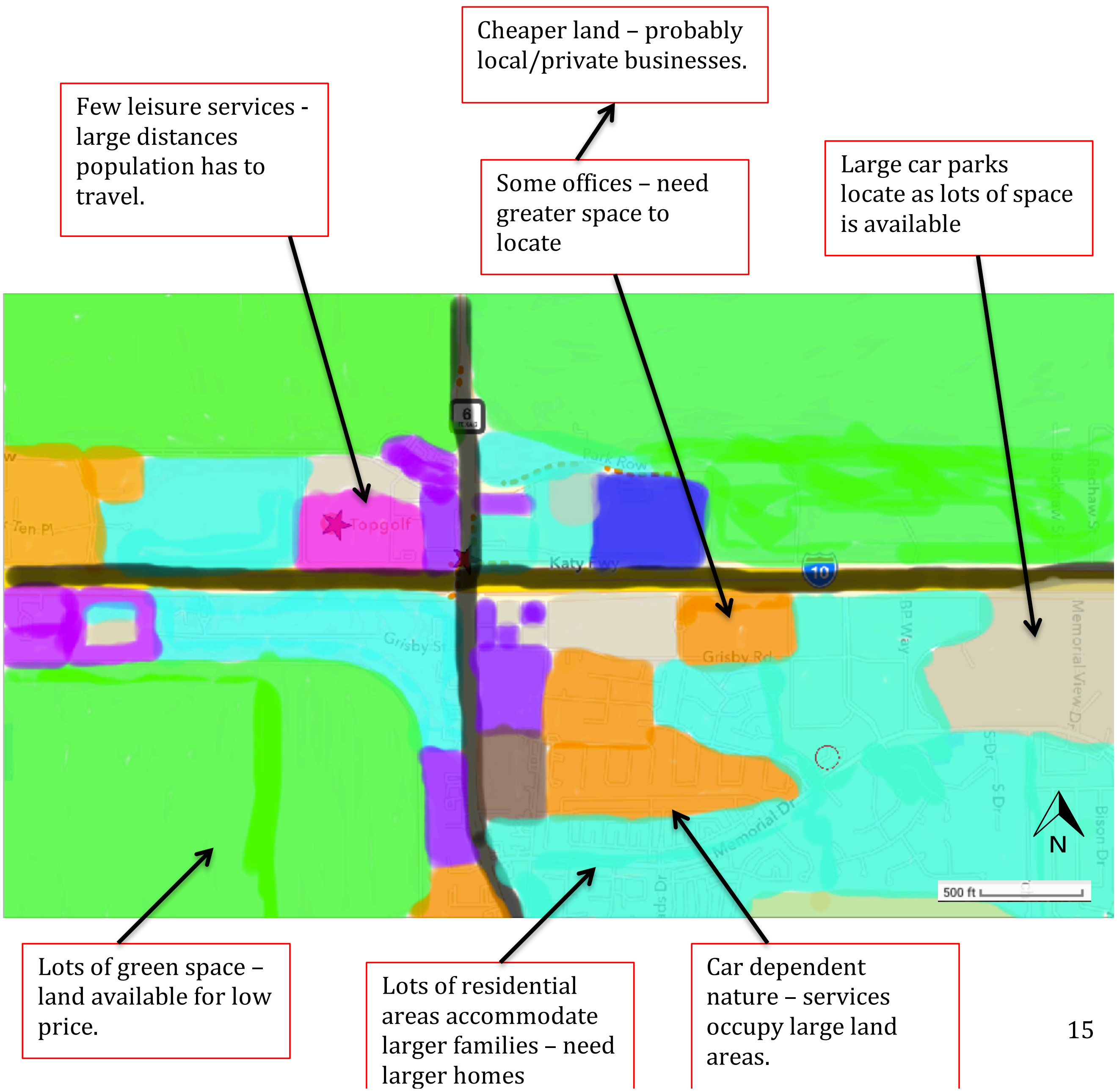
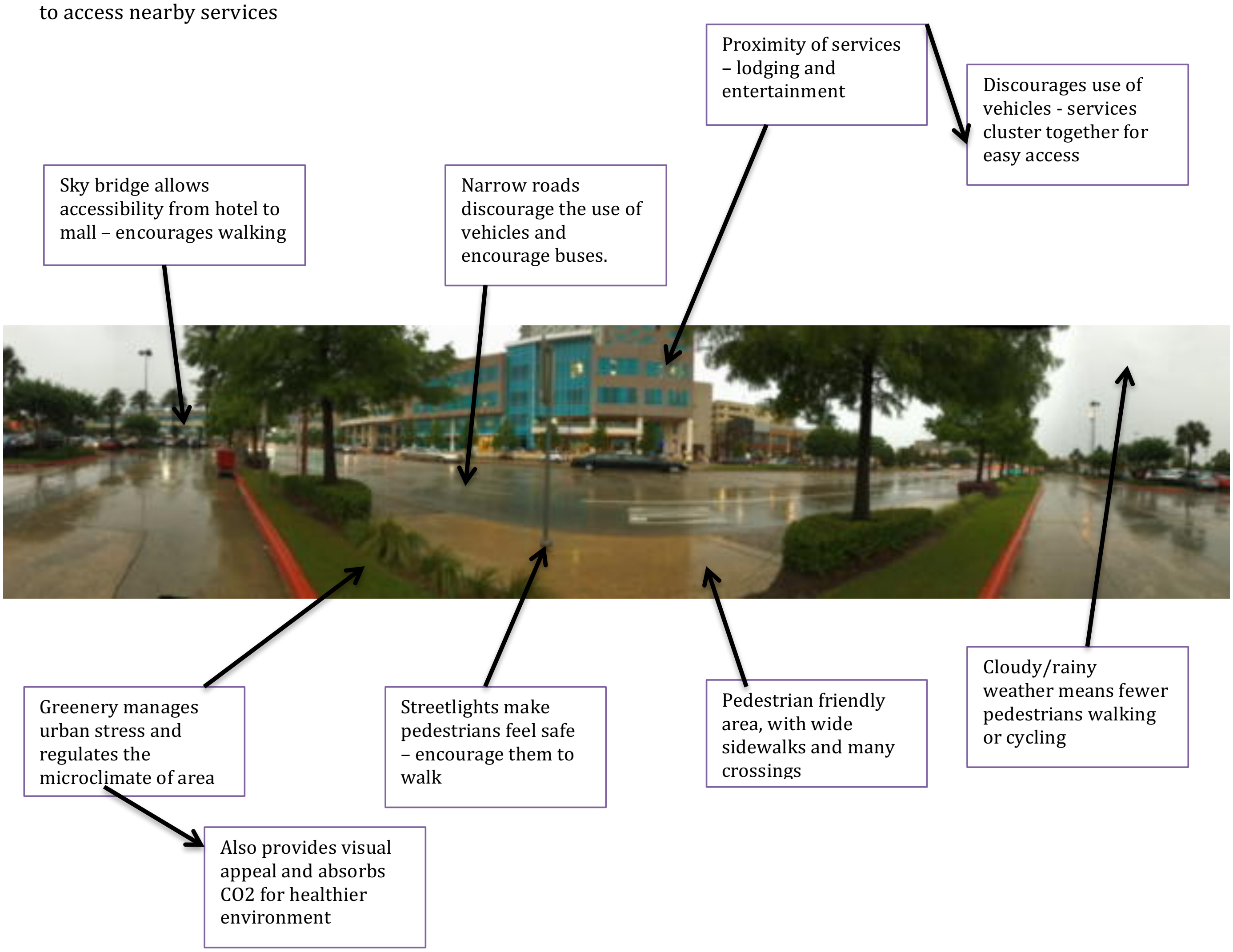


Figure 2.5: Annotated pictures of site 2 to show the types of sustainable transport schemes available to the population to access nearby services



Some offices – private/local requiring low cost land for location

Few government services – inaccessible by car

Prefer to locate centrally, example downtown.

Figure 2.6: Land use map of site 2 to show the types of services accessible to the population nearby

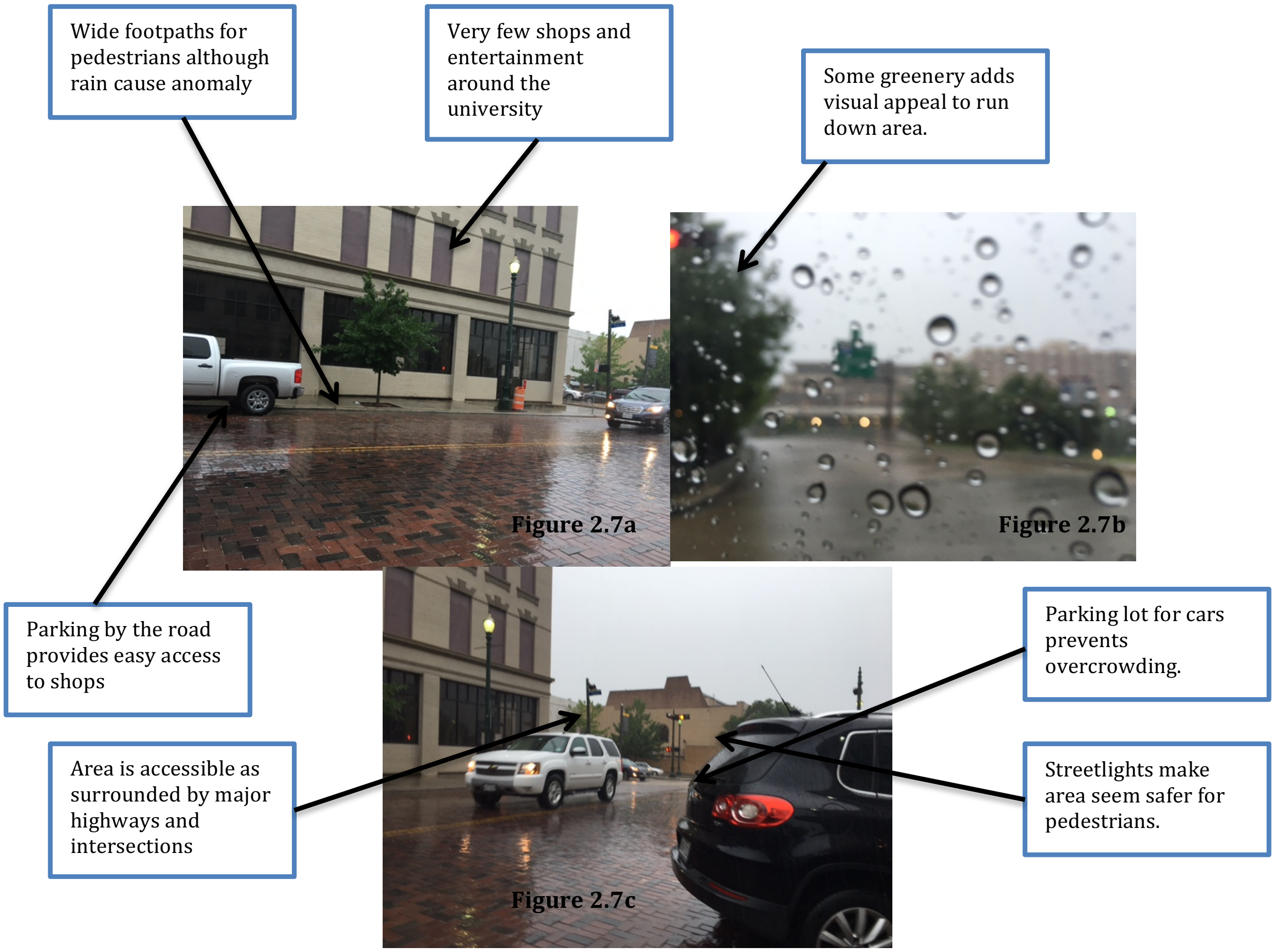
Lots of residential - large families that requiring low cost land

Local schools located here to accommodate for families living here

Lots of leisure related services providing entertainment in proximity

Suburbanization and movement of services outwards with changing trends

Figure 2.7: Annotated pictures of site 3 to show the types of sustainable transport schemes available to the population to access nearby services

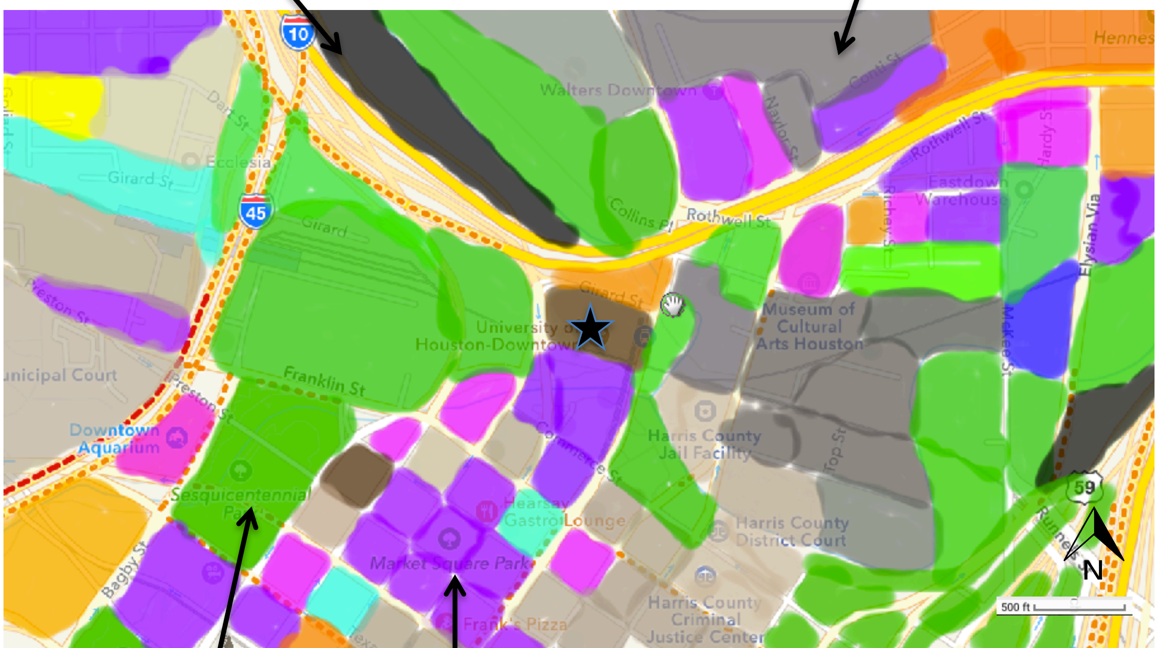


Regeneration adds value to depreciated land, attracting population back

Major roadways allow area to be accessible and convenient

Lots of construction sites – evident of redevelopment

Figure 2.8: Land use map of site 3 to show the types of services accessible to the population nearby

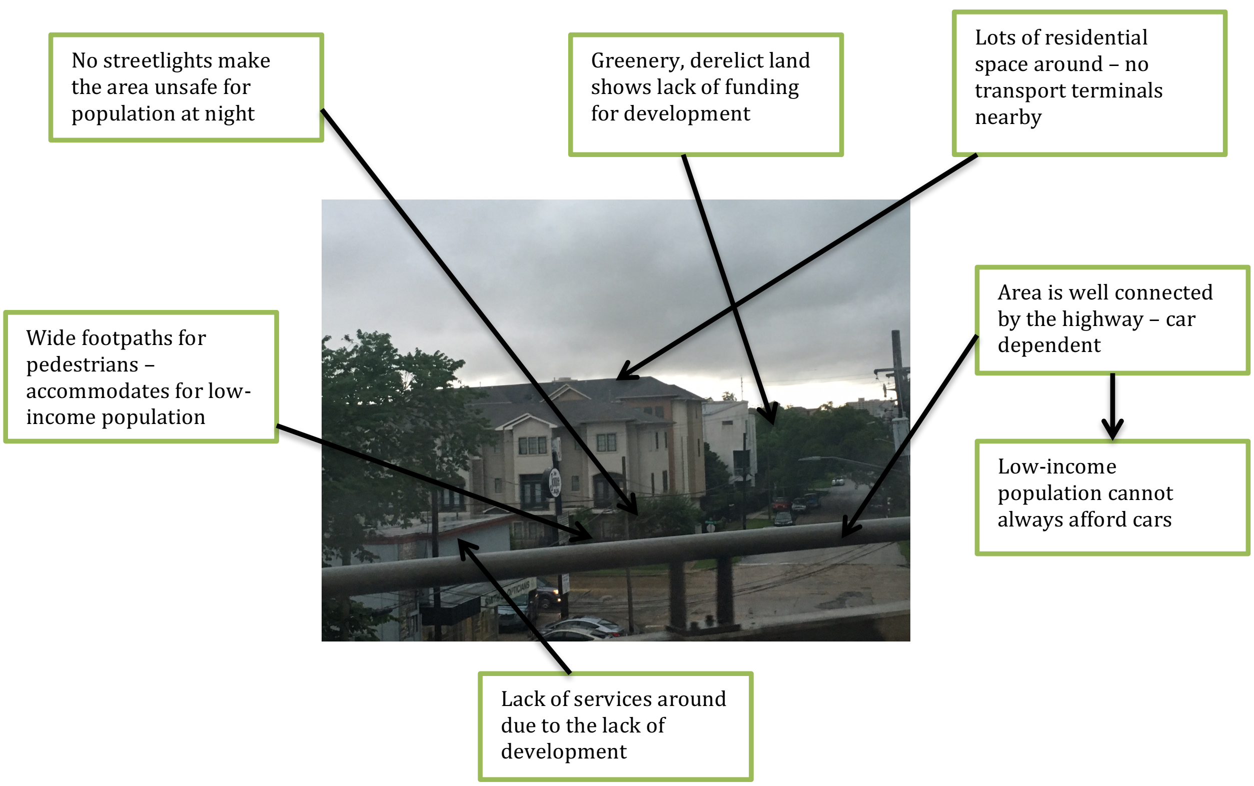


Lots of green space adds visual appeal, downtown – tourist attractions

Leisure areas clustered making these easily accessible for tourists

Also encourages competition, increasing quality of products and innovation

Figure 2.9: Annotated pictures of site 4 to show the types of sustainable transport schemes available to the population to access nearby services



Land is also available at a low price

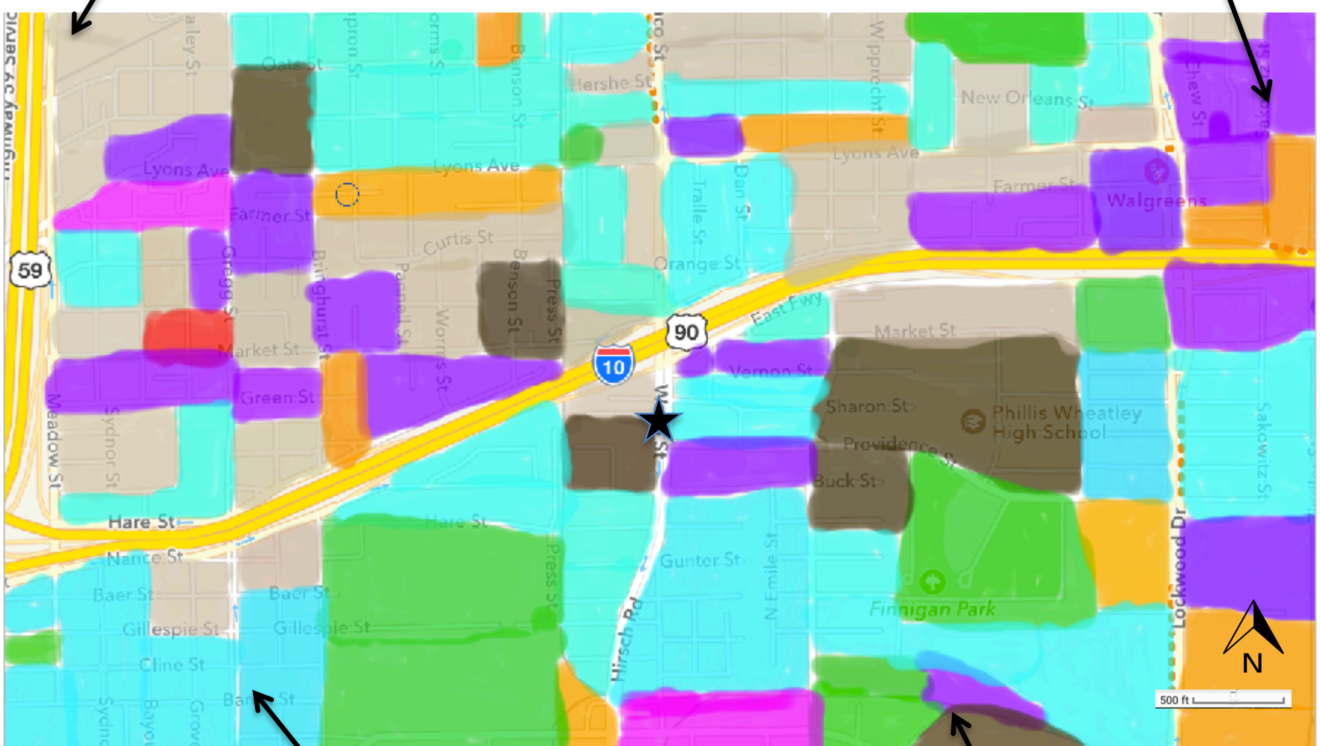
Evident of low cost area – lack of funding and maintenance

Lots of government services as located near downtown

Clustering makes them more accessible to population

Leisure shops are adult stores and thrift stores

Figure 2.10: Land use map of site 4 to show the types of services accessible to the population nearby



Lots of residential areas, as underdeveloped – low cost housing

Schools to accommodate for the families living around

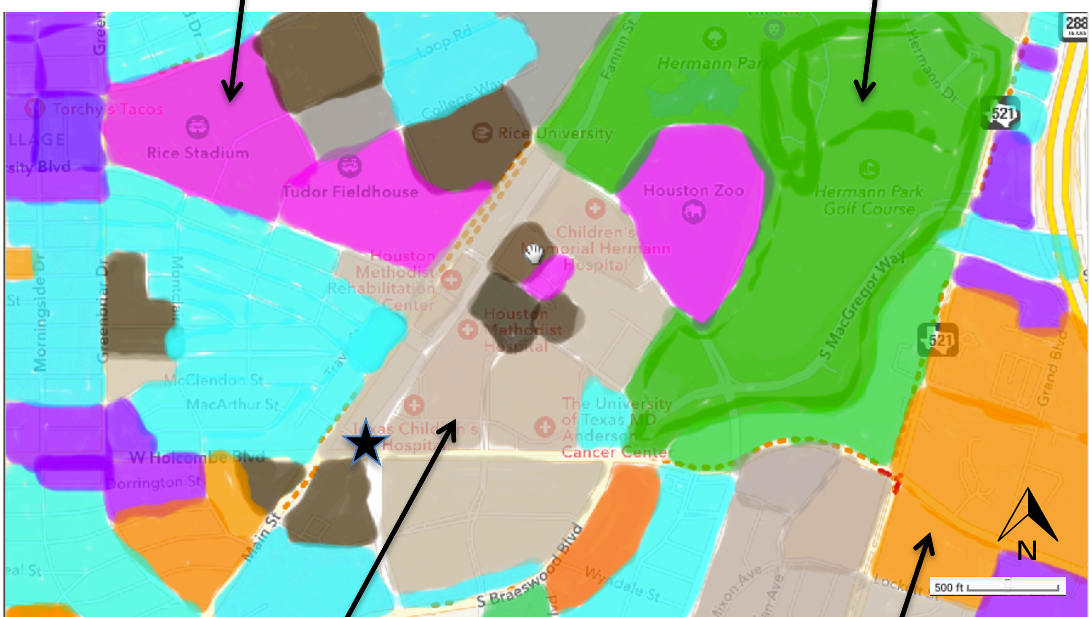
Figure 2.11: Annotated pictures of site 5 to show the types of sustainable transport schemes available to the population to access nearby services

Aids hospitals for rehabilitation purposes – extra land

Leisure facilities are also clustered – easily accessible

Lots of green space makes the area attractive for tourists

Figure 2.12: Land use map of site 5 to show the types of services accessible to the population nearby

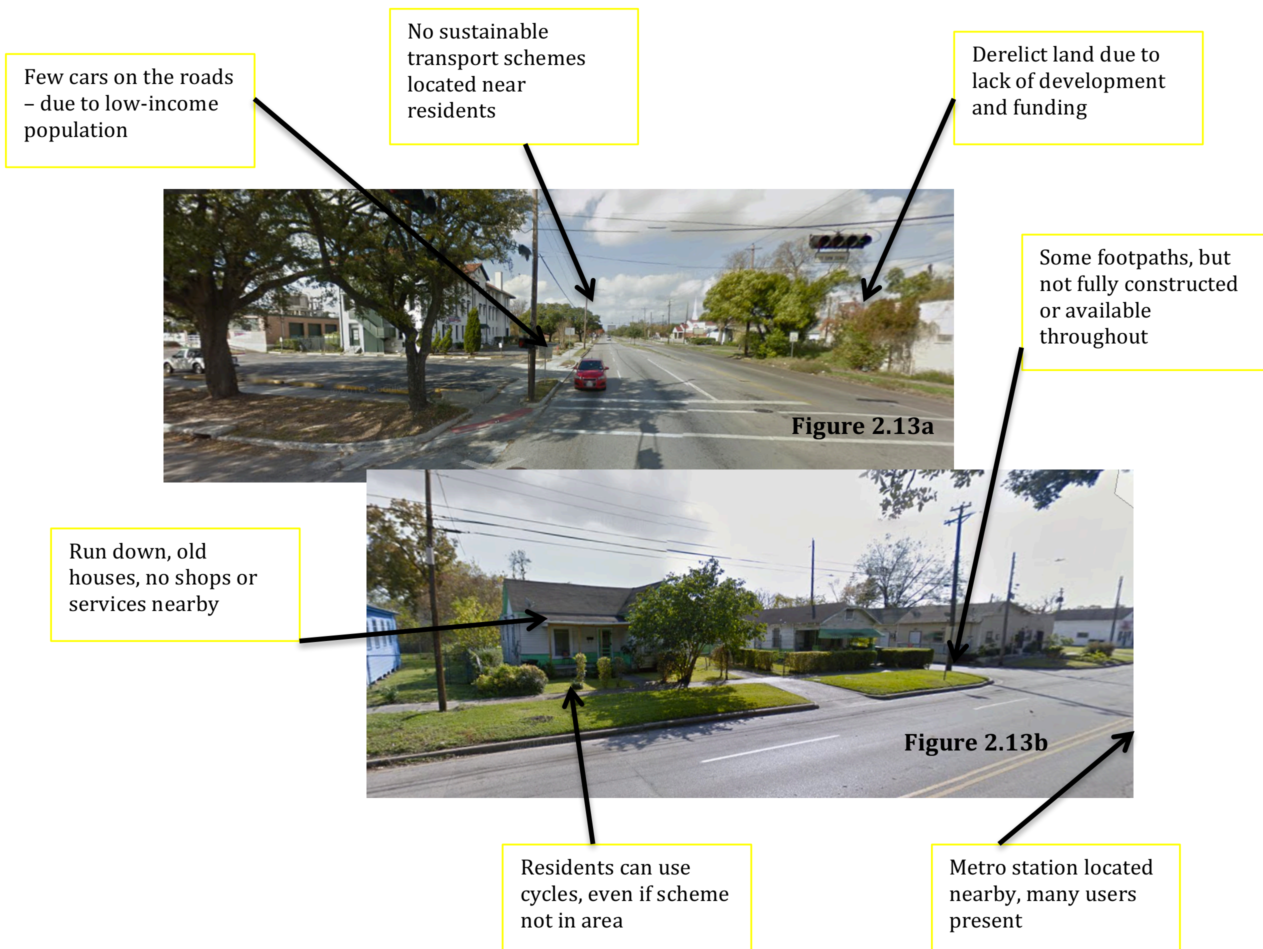


Lots of hospitals clustered close to each other centrally

Allows easy access and opportunities for collaboration and easy transfer

Some offices – TNC's – expensive land requires sufficient funds

Figure 2.13: Annotated pictures of site 6 to show the types of sustainable transport schemes available to the population to access nearby services



Small shops for leisure mainly thrift stores – evident of underdevelopment

Evident as lack of investment – area of decline

Green spaces add visual appeal – however areas unmaintained

Figure 2.14: Land use map of site 6 to show the types of services accessible to the population nearby

Mostly residential in character – underdeveloped dangerous area

University located – Government University requires large land – available cheaply

Government services scattered – provides accessibility to more people

Figure 2.15: Showing the spatial distribution of CO2 emissions per acre in Houston (HT index, 2016).

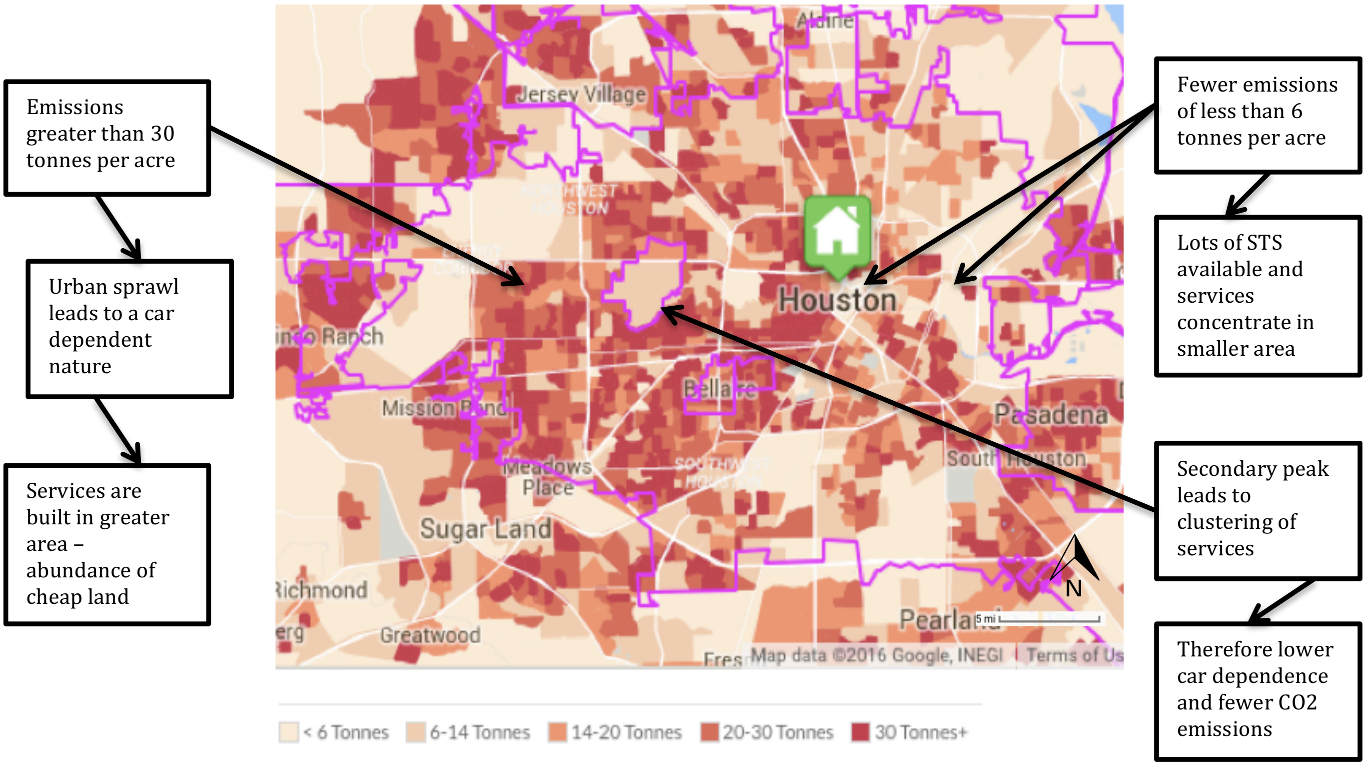
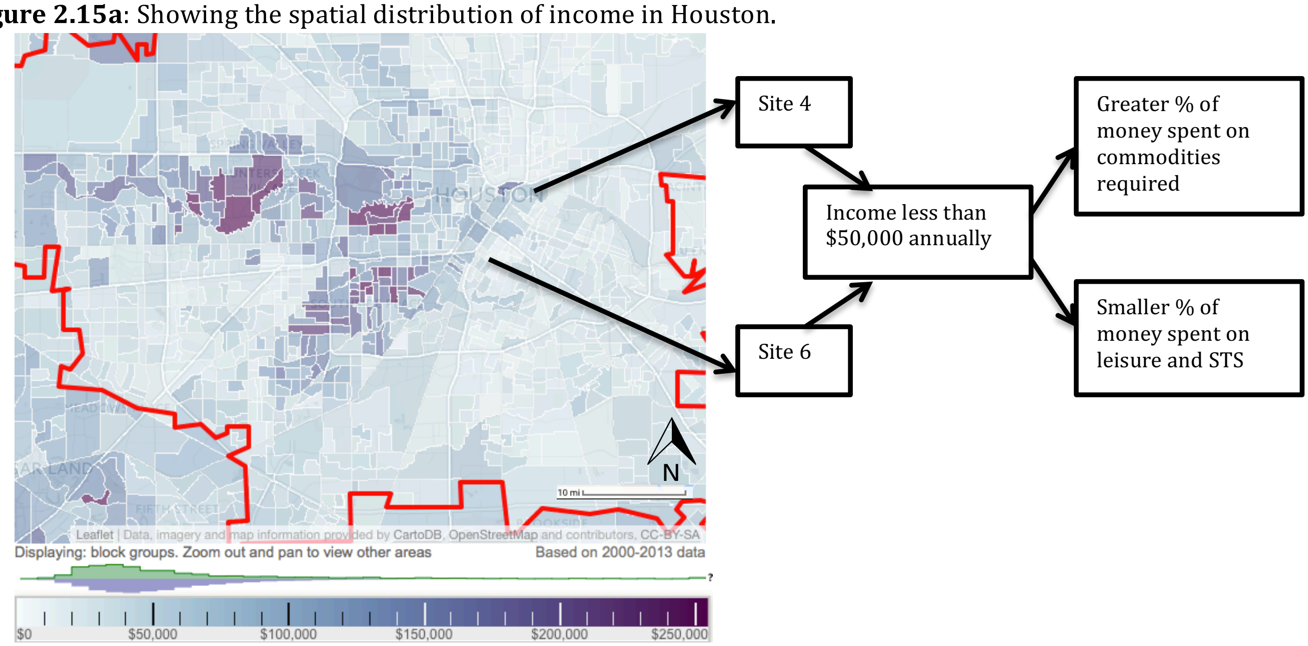


Figure 2.15a: Showing the spatial distribution of income in Houston.



As shown by figure 2, Site 3 is among the highest scoring for the various sustainable transport scores, making it safest for pedestrians. This is because figure 2.8 shows us the varied land use such as leisure, service and green land, which is clustered together in the same area, and thus needs to be made accessible. The limited amount of space in downtown also serves as a purpose to promote the use of STS, as space is costly, therefore only few car parks are available, but the proximity and variety of services reduces the use of these. However, Figure 2.1 shows that the second highest sector of deaths was due to pedestrian accidents. This not only contradicts the safety, but also shows the need of discouraging the use of private vehicles alongside encouraging the use of STS. For example in figure 2.16, site 5 has the highest footfall, and therefore the greatest chances for accidents, which needs to be considered when preserving human health. The highest footfall here is explainable as the surrounding land use is service based – medical – and therefore requires access by pedestrians and employees who work here. This relates to health aspect of the PORPOLIS indicator of sustainability - providing valid evidence for access to services, whilst taking into account traffic related deaths – ensuring the research is socially conscious.

Site 1a and 2a, which are closest to the highways, are the lowest scoring for sustainable transport. These sites located to the west of Houston are targets of suburbanization, heavily relying on cars to cover large distances in a short time. Furthermore, the land uses found around Sites 1 and 2 are not diverse, as due to an abundance of land and low land prices, service occupies so much land that fewer uses can cluster in a small area. Therefore residents are dependent on private vehicles to access these. The location of transport terminal at Site 1 contradicts the point above, however, the lot was empty in peak times, showing the lack of usage by the population. However, this could have been an anomaly caused by the rainy weather, as people would feel more comfortable and flexible in private vehicles.

Figures 2.9 and 2.13 that show sites 4 and 6 were part of the more underdeveloped areas of Houston towards the east of Houston. Here the land uses are residentially orientated with few leisure or green spaces. This is explainable as the populations in these areas have less disposable income (Figure 2.15a) to spend on leisure, and therefore mostly spend it on services, which are necessary such as medical or utilities, which are located around the residences. The various land uses here are scattered which emphasises the lack of planning and funding. However, the transport scores here are greater than the west side, but lower than the downtown area. This is because of the lack of funding in these areas, sustainable transport has not been developed, and its use restricted due to the lack of disposable income of people. However, Figure 2.16 shows that the most pedestrians and cyclists were found at sites 4 and 6, which is reasonable, as due to the underdeveloped nature of the area, majority of the people are seen using low cost transport which in turn benefits the environment.

Figure 2.15 supports all the points above, as the west of Houston is shown to have the greatest CO2 emissions. However the general population is unaffected by this due to their car dependent nature. The more vulnerable people are the homeless who are exposed to this harmful atmosphere. Areas in the east have fewer emissions, therefore the low-income people that walk or cycle are less prone to lung diseases that spread due to the polluted environment. Downtown has the least emissions due to the greatest number of transport schemes located here and the clustering of services. This means that the health of people using the STS is more preserved, and additionally, they have greater access to services due to the clustering of services. This point is also valid for Site 5, as the secondary peak means land is expensive, which automatically causes the clustering of services, leading to lower CO2 emissions. This also relates to the environmental aspects of the PROPOLIS indicator – ensuring the population is exposed to a healthy, pollution-free environment.

2) Social sustainability

Figure 2.16: Showing the spatial distribution of various types of vehicles in the sites of investigation (Site 1-6) on Saturday

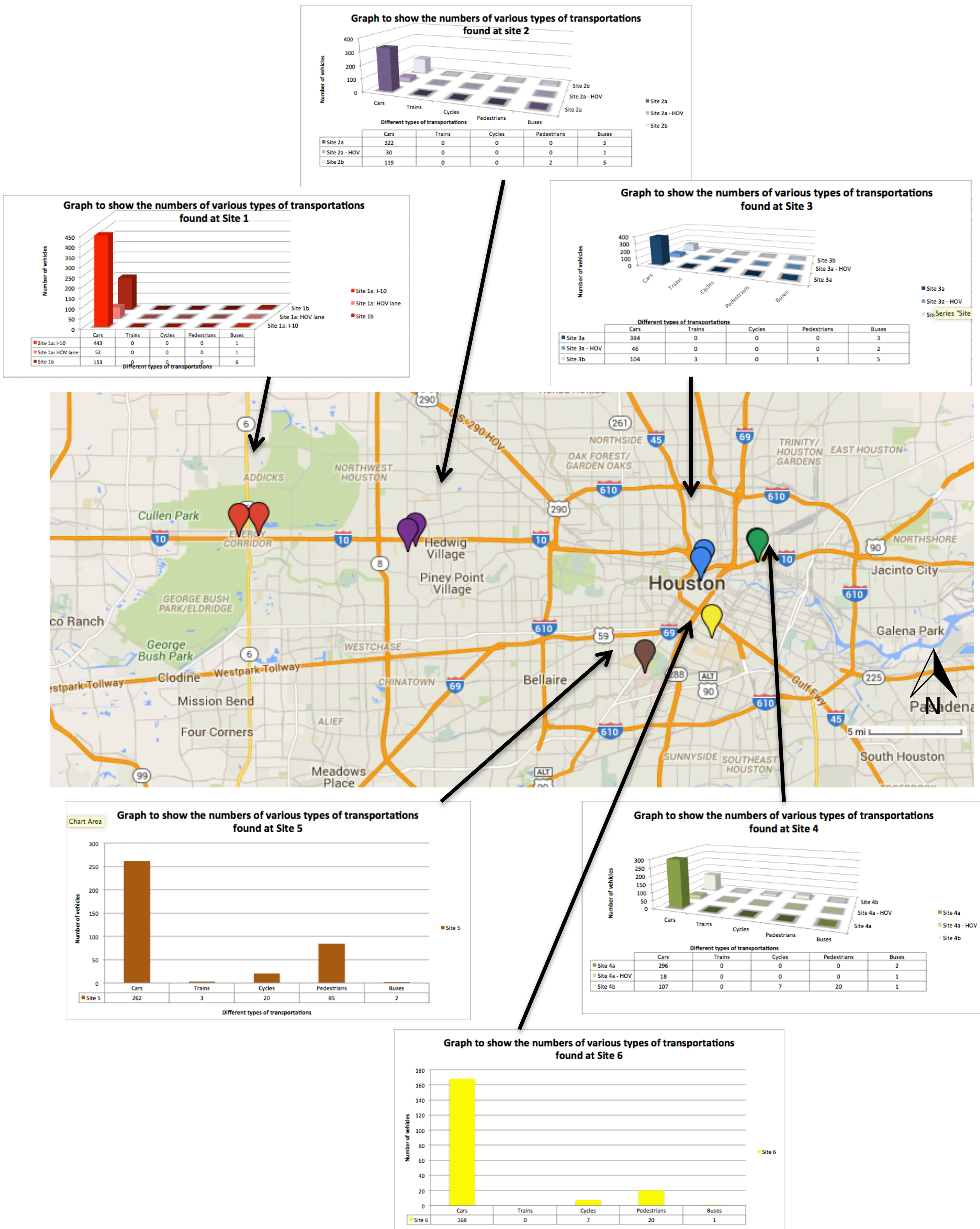
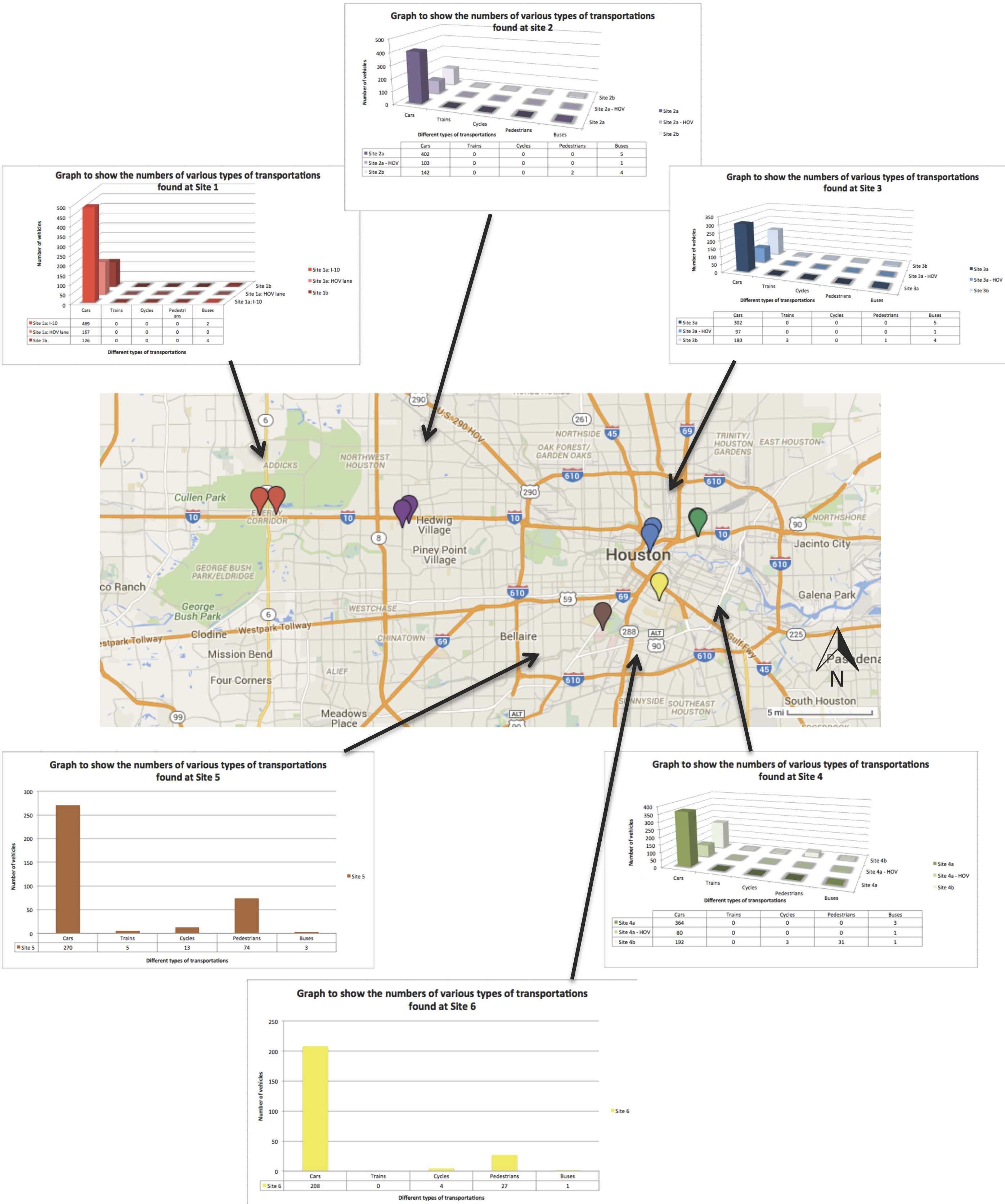


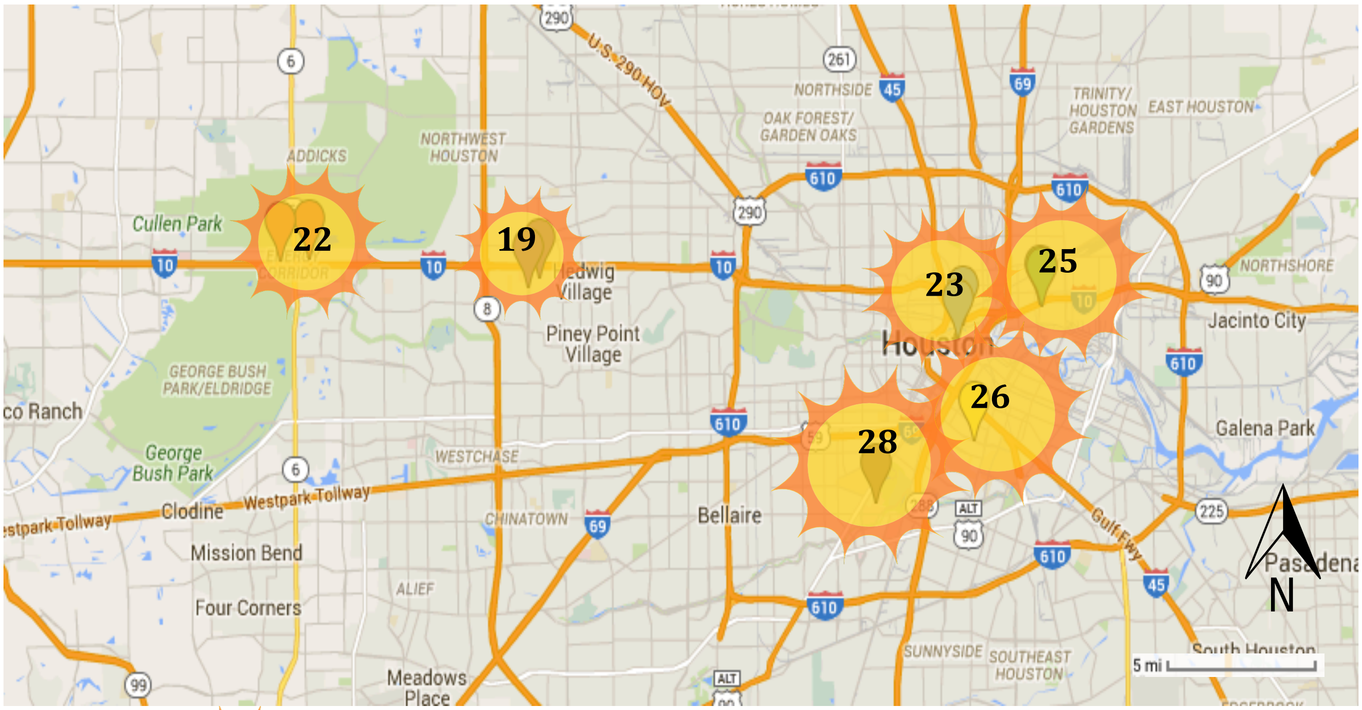
Figure 2.16b: Showing the spatial distribution of various types of vehicles in the sites of investigation (Site 1-6) on Friday

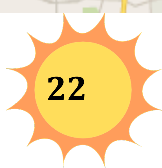


Sites 1 and 2 have the greatest number of cars, with least STS. Referring to the land use at these sites, due to urban sprawl, Houston has a car dependent culture so even if B-cycle stations and buses are provided, they will not be used. However, figures 2.3 and 2.5 show that there is a lack of availability of B-cycles and rail lines, so the population is not given the opportunity to use STS. Moreover, the fares of a single ride would be as high as $4.5 due to the distance, therefore discouraging people from using the metro busses that are available near malls. Therefore the lack of people using these services – buses – in the outskirts, results in the scheme being inefficient and inconvenient for the population's needs – expense and lack of flexibility. Due to this car dependent nature of Houston, schemes such as HOV have been developed to help reduce traffic congestion, and increase the flow of traffic by allowing cars with 2 or more people to travel through these lanes for free in peak times, to improve the temporary air quality of the area. This relates to the social aspect of accessibility in the PROPOLIS indicator as the car dependent nature of Houston subverts this indicator of sustainability. However, the traffic count survey was done at 7:30pm – close to the hours cars will be charged to enter these lanes – therefore the car counts at the sites were lower than expected. This hints the need of developing transport systems, which take into account the particular needs and trends of a city – for example car orientated STS would benefit the demographics of Houston more as the urban sprawl and expanse of the city doesn't make cycles, buses and trains efficient as transport mediums throughout the city.

Sites 4, 5 and 6 have the greatest use of STS such as cycles, trains and pedestrians, as the area shown by figures 2.11 and 2.13 are the most pedestrianized and have services clustered together due to the increasing value of land due to a secondary peak at site 5. This provides evidence of the large number of pedestrians found here as the clustering of services and proximity

Figure 2.17: Showing the spatial distribution of the temperature in Celsius of the sites of investigation (1-6)



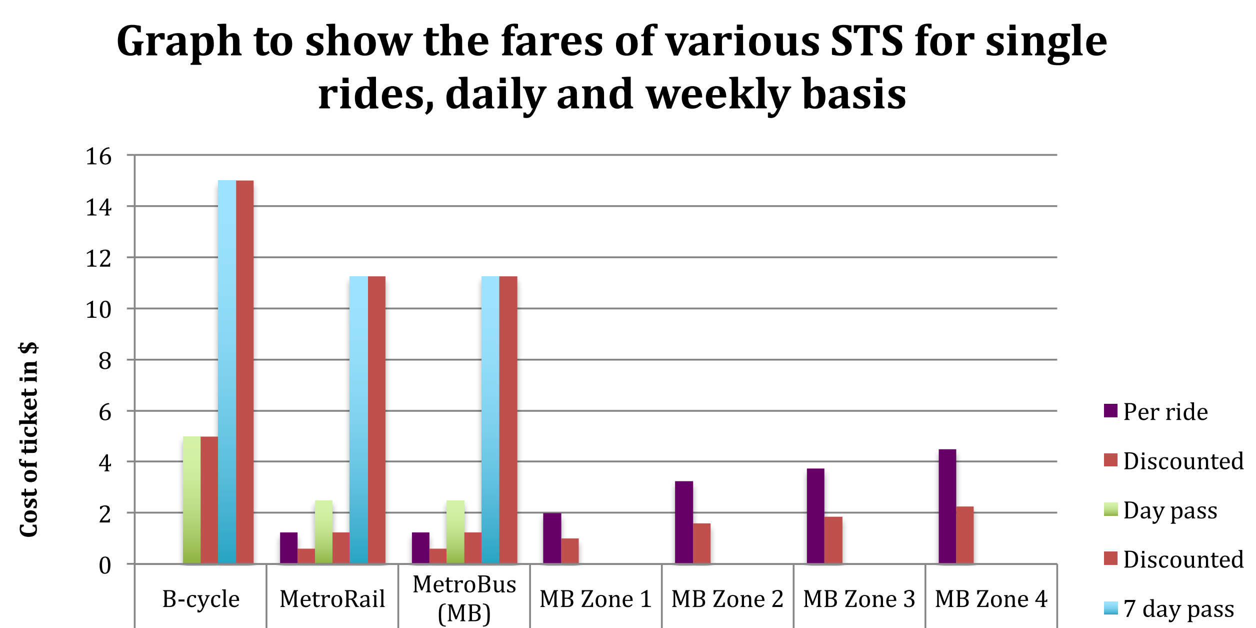
Key: 

Temperature values scales down by 1/10th of original value
Example: Diameter of 2.2 cm is 22 degrees Celsius

means that services are accessible and approachable by people. Site 4 and 6 are underdeveloped areas, however they had a large use of STS such as B-cycles because as shown by figure 2.19, the cost of a ride is free, as long as the bike is returned before an hour of use. This makes this STS a convenient, efficient and affordable means of transport for the low-income people. However, the population here doesn't have much of a choice as the train lines do not extend up to here and the buses are expensive due to the increasing distance of travel. The price of $3.25 or $3.75, which is expensive for the population who don't have much disposable income. Therefore, even if more types of STS are provided at site 4 or 6, there is no guarantee that the poor will effectively use them. This reinforces the idea of access to services and the PROPOLIS indicator of sustainability, as all the demographics of Houston have not been considered when these schemes were designed. Therefore variety doesn't always benefit the population as the unaffordability of STS could cause social unrest in the area. The cars at these 3 sites were high again and can be justified by the hot temperatures and high humidity in Houston showed by figure 2.17 and 2.18 respectively makes cars the most flexible and comfortable means of transportation.

Finally, Site 3 had one of the most trains and buses out of all the sites, which is justified as downtown shown by figure 2.8 shows the clustering of services due to the increased price of land due to the presence of the PLVI at chase tower (tallest building means most expensive land and therefore highest vertical height). The narrow roads here discourage the use of cars, however the

Figure 2.18: Graph to show the price of tickets of STS used on a per ride, daily and weekly basis (Bcycles, 2012) (Metro, 2016) (Bayer, 2016)

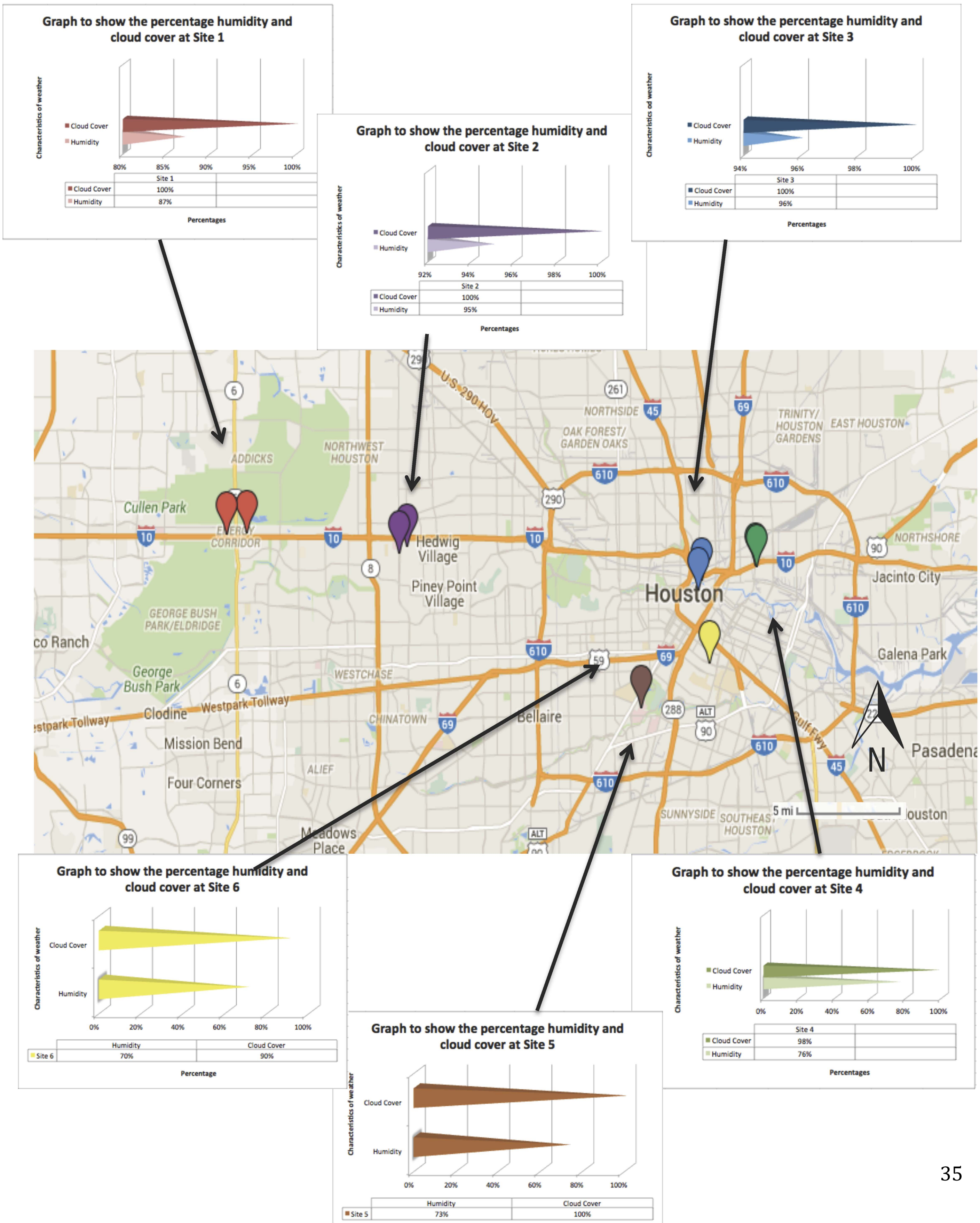


	B-cycle	MetroRail	MetroBus (MB)	MB Zone 1	MB Zone 2	MB Zone 3	MB Zone 4
Per ride	0	1.25	1.25	2	3.25	3.75	4.5
Discounted	0	0.6	0.6	1	1.6	1.85	2.25
Day pass	5	2.5	2.5				
Discounted	5	1.25	1.25				
7 day pass	15	11.25	11.25				
Discounted	15	11.25	11.25				

Type of sustainable transport

variety of STS present here encourage the population to effectively make use of it. The large number of buses and trains here shown by figure 2.16 and 2.16b is justified by the minimal fare that needs to be paid of $1.25 due to the short distances, making it affordable and efficient for the population. Moreover, the discounted price of $0.60 for the disabled and students is aimed at the vulnerable population, making the scheme accessible to niche groups of a population. The traffic counts on Saturday and Sunday were similar, however greater numbers of cars were counted in HOV lanes of all sites possibly due to office rush hour.

Figure 2.19: Graph to show the % cloud cover and humidity at each of the 6 sites of investigation



3) Environmental sustainability

Figure 2.20: Graph to show the quality of environment at the 6 sites of investigation using the bi-polar survey

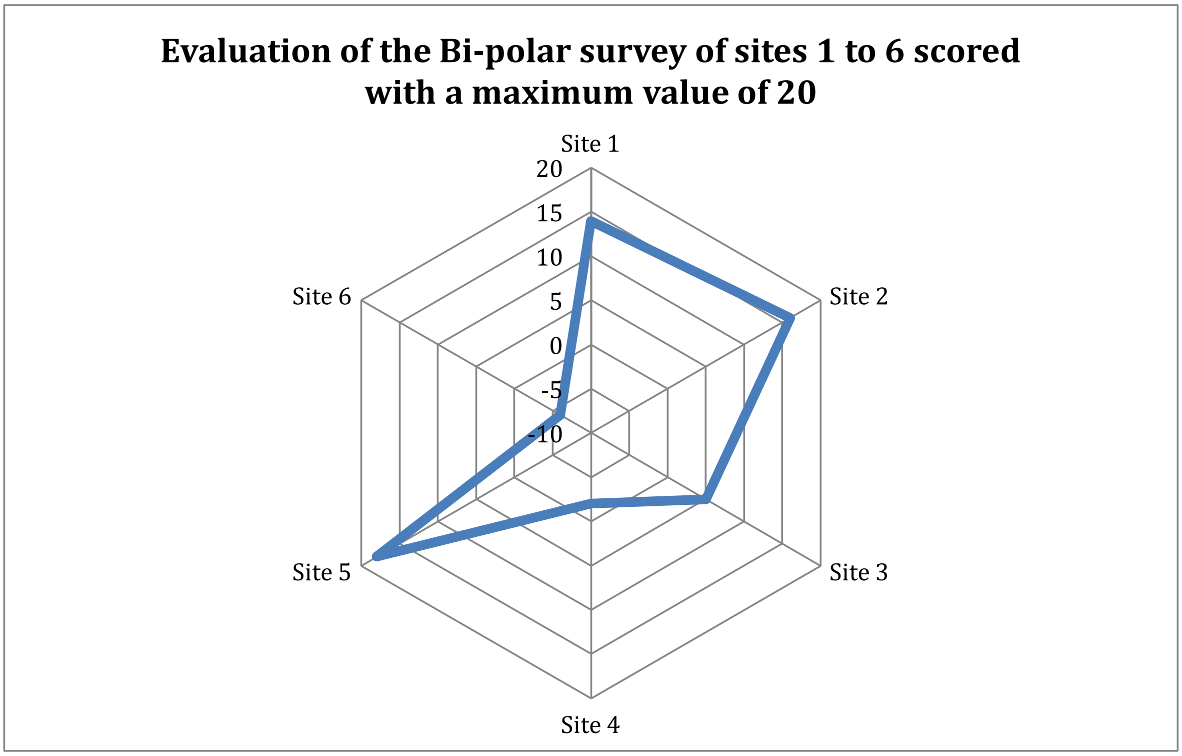
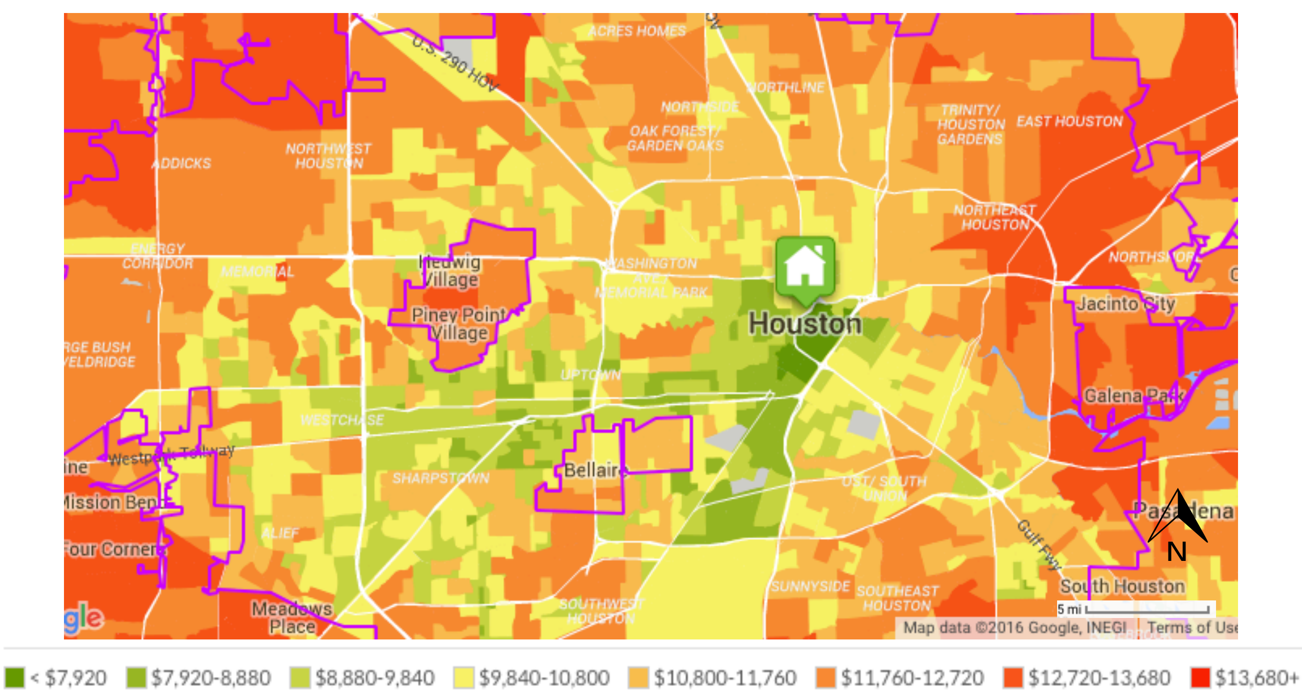


Figure 2.20 shows that site 5 has the highest value, indicating the good quality of environment. This is evident in figures 2.15 and 2.21, where the CO_2 emissions are lowest at 6-14 tonnes, and the driving costs are the least at below $7000-$8000 annually. These factors enhance the environmental quality of the area, ensuring that people are exposed to air that is healthy. Furthermore, the proximity and clustering of services provides evidence for these figures, and thus encourages people to use sustainable transport or walk rather than their private vehicles. This conforms to the criteria of environmental quality under the environment section of the PROPOLIS indicator.

Site 2 also had a high value for the environmental quality, however the CO_2 emissions are high at 20-30 tonnes and above and driving costs $12,000+ annually. Therefore as the environmental quality was subjective, the visual appearance and development of the area do not always indicate its accurate environmental well-being. As explored previously, the lack of proximity of services and availability of sustainable transport, dependency on cars is higher, leading to greater emissions, higher driving costs and more pollution, and thus worsening air quality. This subverts the criteria of environmental quality under the environment section of the PROPOLIS indicator.

Finally, although Site 6 had the worst visual appeal as shown by figure 2.20, due to the presence of an underdeveloped area, the CO2 emissions are low at below 6 tonnes. This could be a result of the economic structure of the population as low-income families are unable to afford private vehicles and therefore rely on sustainable transport as a means of transport. This is reinforced by the low driving costs in the area, which results in a better air quality for the population. However, the fact that these families rely on sustainable transport (no access to private vehicles) contradicts the variety that should be offered to the population, thus raising social concerns, as the factor of disposable income and affordability arise. For example, using a greater % of income to travel to work than on necessities such as food is not socially sustainable and contradicts their accessibility.

Figure 2.21: Graph to show the annual driving costs in various areas of Houston (HT index, 2016)



4) Economic sustainability

Figure 2.22: Graph to show the amount in millions of $'s associated with various business concerns of the B-cycles scheme (Mondon, 2015) (Begley, 2014)

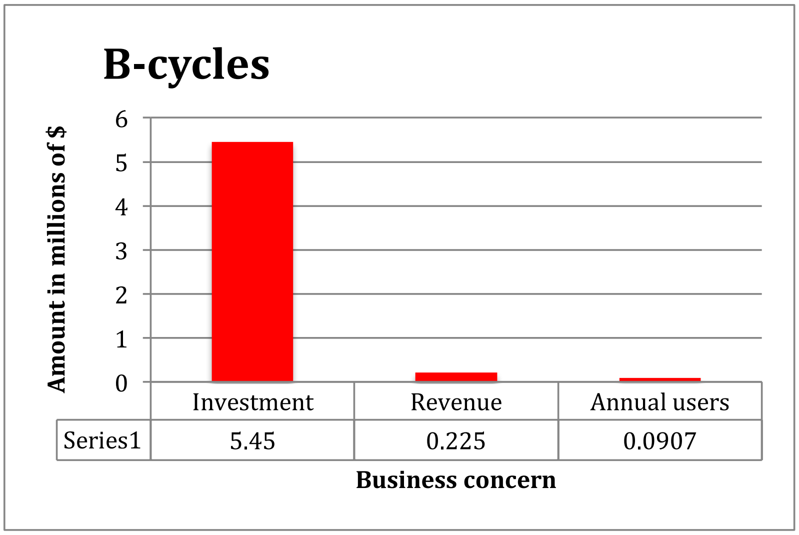
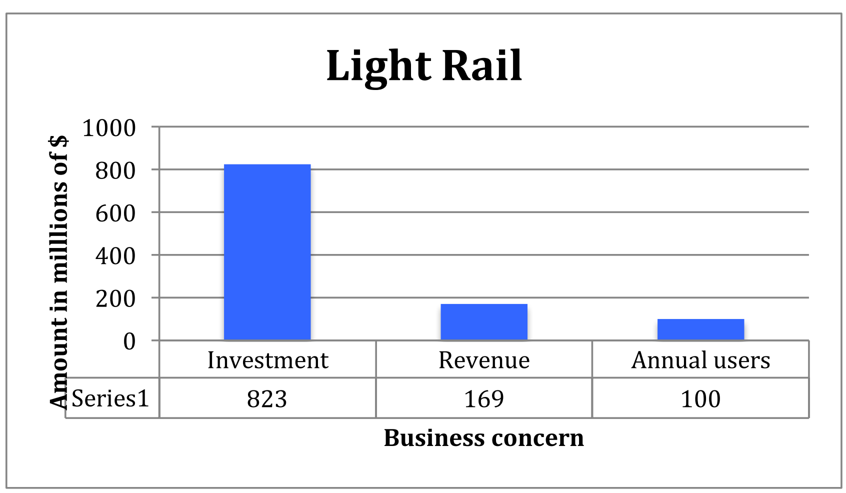


Figure 2.23 show that the light rail scheme had the greatest investment and also the greatest annual **revenue*** of 20.5% of the total investment compared to the other schemes shown by figures 2.22 and 2.24. This could be a result of the large number of passengers one ride can carry, and the restricted route of the rail in downtown, encouraging people to use this system. Furthermore, the low price of $0.6 to accommodate for the disabled further encourages a wider population to use this scheme, resulting in greater revenue. This also relates to the economic section of the PROPOLIS indicator as there is a net benefit, which benefits the consumers and company to a certain extent.

The B-cycle scheme have less profit possibly due to the hot humid weather of Houston shown by figure 2.17, which discourages people from using the scheme even at its low price.

Figure 2.23: Graph to show the amount in millions of $'s associated with various business concerns of the Light rail scheme (Grabar, 2014)



Furthermore, the location of the schemes in highly urbanized areas – downtown – enhances the urban heat island effect, due to large amount of concrete, which absorbs and emits more heat.

However, this scheme benefits from

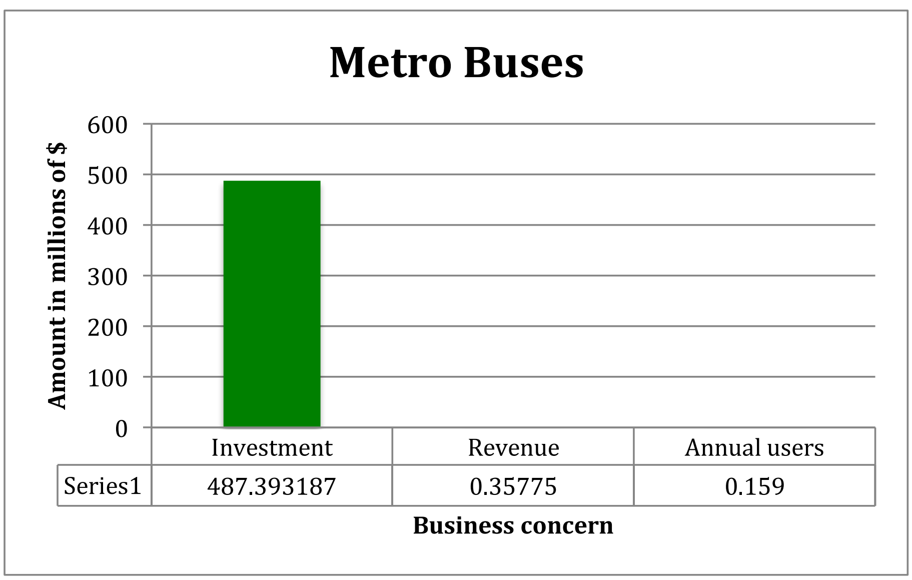
locating near tourist areas, increasing annual users, thus revenue.

Finally, the buses have the least revenue generated annually due to the sprawl of the service. The locations in energy corridor run with few or no passengers, making the rides unprofitable and inefficient. Furthermore, the expanse of the scheme has not benefitted the companies due to Houston's car dependent nature, and high fares that passengers have to pay for the distance they travel.

Therefore STS in Houston are not as profitable as the companies will due to reasons mentioned above, however, these schemes do benefit the disabled, underprivileged and population in many areas, allowing them access to services.

***The revenue was calculated due to the lack of accurate information on the Internet using the annual users and average ticket price to give an approximate value.**

Figure 2.24: Graph to show the amount in millions of $'s associated with various business concerns of the Light rail scheme (Garcia, 2014)



Conclusion

The findings show that STS in Houston doesn't successfully in-corporate all three factors of sustainability into any of its STS, as explored by various components of the PROPOLIS indicator of sustainability. While most schemes have proved to be uneconomical and inefficient for the businesses, they provide environmental sustainability where they locate, improving societal health through reduced pollution. However, there are social consequences of STS due to the increased risk of accidents as vulnerable pedestrians are exposed to more hazards. Therefore Houston's STS are in the developing stage of the process, and need to accommodate the demographics of the city to be categorized as sustainable and due to this the hypotheses are rejected, as Houston's car dependent culture continues to overpower the transportation system.

Evaluation

Overall, it's extremely important to point out the limitations of the investigation, which may have impacted the results. The time span between the two data collections was small, and possibly justifies the similarities in the data. However if the investigation were carried out for a longer period of time, the larger database would provide a more accurate representation of STS in Houston. Furthermore several other individuals could have done the environmental quality survey (carried out by one person), which would provide a fair test, as the average would provide a more reliable bi-polar survey statistic. Finally, it would have been useful to obtain the public's opinion on STS through surveys, which would have provided a more holistic outlook on how the government can encourage them to use STS and what can be done to meet the public's requirements.

Although this investigation was carried out in the city of Houston, it can be extended to the state of Texas, as similar STS locate in cities such as Austin and Dallas, providing a greater view on STS in cities with differing demographics, structure and population. Furthermore, many factors affect the accessibility of STS such as disparities, which could have been further analyzed to support our findings by providing data of social demographics of neighborhoods in Houston.

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Appendix

Figure 3: Table to show where the traffic count data was recorded for Saturday

Type of transport / Sites	Cars	Trains	Cycles	Pedestrians	Buses
Site 1a	443	0	0	0	1
Site 1a - HOV	52	0	0	0	1
Site 1b	153	0	0	0	6
Site 2a	322	0	0	0	3
Site 2a - HOV	30	0	0	0	1
Site 2b	119	0	0	2	5
Site 3a	384	0	0	0	3
Site 3a - HOV	46	0	0	0	2
Site 3b	104	3	0	1	5
Site 4a	296	0	0	0	2
Site 4a - HOV	18	0	0	0	1
Site 4b	107	0	7	20	1
Site 5	262	3	20	85	2
Site 6	168	0	7	20	1

Figure 3.1: Table to show where the traffic count data was recorded for Friday

Type of transport / Sites	Cars	Trains	Cycles	Pedestrians	Buses
Site 1a	489	0	0	0	2
Site 1a - HOV	167	0	0	0	0
Site 1b	126	0	0	0	4
Site 2a	402	0	0	0	5
Site 2a - HOV	103	0	0	0	1
Site 2b	142	0	0	2	4
Site 3a	302	0	0	0	5
Site 3a - HOV	97	0	0	0	1
Site 3b	180	3	0	1	4
Site 4a	364	0	0	0	3
Site 4a - HOV	80	0	0	0	1
Site 4b	192	0	3	31	1
Site 5	270	5	13	74	3
Site 6	208	0	4	27	1

Figure 3.2: Table to show the calculation of the results of the environmental bi-polar survey

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Visual appeal	1	2	-1	-2	2	-1
Graffiti	2	2	-1	-1	2	-2
Litter	2	2	1	0	2	0
Pedestrianization	2	2	1	-1	2	0
Smell	1	2	2	-1	2	0
Greenery	2	1	-1	0	2	-2
Pollution	2	2	1	0	2	-1
Parking	2	2	0	0	1	-2
Trafic congestion	1	1	1	2	2	1
Noise	-2	0	2	1	1	1
Total (out of 20):	14	16	5	-2	18	-6
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Total (out of 20):	14	16	5	-2	18	-6

Figure 3.3: Table to show the results for the weather data at the 6 sites of investigation

	Humidity	Cloud	Temperature
Site 1	87%	100%	22
Site 2	95%	100%	19
Site 3	96%	100%	23
Site 4	76%	98%	25
Site 5	73%	100%	28
Site 6	70%	90%	26

Figure 3.4: Table to show the results for the weather data at the 6 sites of investigation

Site name	Site	Walkability	Transit	Bikeable
1a – Top golf for I-10	1a	27	33	41
1b – Park and ride	1b	17	39	31
2a – Memorial city mall for I-10	2a	16	23	0
2b – Gessner road	2b	62	42	46
3a – University of Houston for I-10	3a	68	97	84
3b – Main street	3b	84	98	83
4a – Waco bridge for I-10	4a	66	47	65
4b – Vernon street	4b	55	47	65
5 – Texas medical center	5	47	50	86
6 – Third ward	6	71	47	69

Figure 3.5: Key to show the results for the walkability, transit and bikeable scores

90–100	**Walker's Paradise** Daily errands do not require a car
70–89	**Very Walkable** Most errands can be accomplished on foot
50–69	**Somewhat Walkable** Some errands can be accomplished on foot
25–49	**Car-Dependent** Most errands require a car
0–24	**Car-Dependent** Almost all errands require a car

Transit:

90–100	**Rider's Paradise** World-class public transportation
70–89	**Excellent Transit** Transit is convenient for most trips
50–69	**Good Transit** Many nearby public transportation options
25–49	**Some Transit** A few nearby public transportation options
0–24	**Minimal Transit** It is possible to get on a bus

Bikeable:

90–100	**Biker's Paradise** Daily errands can be accomplished on a bike
70–89	**Very Bikeable** Biking is convenient for most trips
50–69	**Bikeable** Some bike infrastructure