Executive Summary

The primary objective of this assessment was to analyze and predict public health impact of transportation and land-use policies which are collectively referred to as the built-environment. While public health has always been a part of planning narratives, in recent years there has been an emerging trend to formalize public health considerations in planning processes. Health Impact Assessment (HIA) is a tool which can be used to integrate community health considerations into urban planning processes and policies. It can be used as a framework to inform decision-making and to compare policies or scenarios. The proposed HIA was conducted as part of the Long Range Transportation Plan for the Champaign Urbana Urbanized Area Transportation Study (CUUATS).

Review of the existing epidemiological studies revealed that the most direct impact of the built-environment on public health was manifested through levels of physical activity of the residents which were further linked to prevalence of obesity and other related diseases such as diabetes, hypertension, and cardiovascular diseases. Consequently, the assessment methodology was designed to establish a causal and quantitative relationship between the built environment and the local obesity rate. A wide spectrum of built-environment variables were considered for this assessment which were grouped into four categories: land-use, transportation infrastructure, accessibility, and safety. A broad array of socioeconomic variables was also considered to control for other determinants of health. The analysis revealed a significant correlation between the built-environment and obesity. The HIA revealed that the obesity rate is lower in neighborhoods that have higher population density, more diverse land-use mix, better street network connectivity, better transit connectivity, higher accessibility to employments and services, and a lower crime rate. Moreover, the predicted correlations were corroborated through a comprehensive literature review. The final product of the analysis was the health index based on the quantitative regression model. The proposed health index can be used to compare the relationships between the built environment and population health in different neighborhoods.

The HIA analysis revealed that characteristics of healthy neighborhoods are similar to those that have been shown to create vibrant and livable communities. There is a need to develop denser and more mixed-use neighborhoods to create more opportunities for walking and biking. Improving accessibility to services and business provides potential destinations which people can walk to or connect to using public transit system. Similarly, access to parks and trails encourage physical activity for recreational purposes. Proximity to grocery stores also is shown to improve health of residents. Moreover, local crime and perception of safety have emerged as critical determinants of levels of physical activity as it impacts likelihood of residents to spend time outside. Overall, the results of the HIA can be used to reinforce principles of planning that seek to develop sustainable, inclusive, and livable communities.
# Table of Contents

Health Impact Assessment 1  
HIA Case Studies 2  
Built-Environment & Health 3  
Socioeconomic Status & Health 5  
Public Input 6  
Data 7  
  Health Data 7  
  Input Data 8  
Study Area Selection 16  
Methodology 17  
Final Model 19  
  Design 19  
  Model Fit 20  
  Interpretation 21  
Health Index 22  
Index Scores 27  
  Land-use Score 27  
  Transportation Infrastructure Score 28  
  Accessibility Score 29  
  Safety Score 30  
  Final Score 31  
Results 32  
Limitations 38  
Recommendations 39  
Future Work 40  
References 41
Health Impact Assessment

A Health Impact Assessment (HIA) is a systematic methodology intended to integrate community health and environmental equity in development projects, planning, and policy-making. An HIA provides tools for assessing the potential health impacts of any policy, program, or project, including transportation and land use projects, as well as provides guidance for developing goals, strategies, and action items that can be used to improve the health of community residents through implementation. An HIA analysis can also serve to educate policymakers and stakeholders regarding the interconnection between policy and overall human health. This report presents conceptual framework and results of an HIA conducted as part of the Long Range Transportation Plan or LRTP 2040 for CUUATS.

The Gothenburg consensus paper, published by the European Center for Health Policy in 1999, was developed to create a common understanding of the purpose of Health Impact Assessment, broadly outline their core values, and provide guidance on how they should be conducted. Health Impact Assessment (HIA) is defined as a “combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of these effects within the population.”(1)

The Gothenburg paper also stresses every HIA should include four critical elements:
- Consideration of evidence
- Consideration of opinions of those affected by the program or policy
- Development of an informed understanding, based on facts, about potential health effects, and
- Proposals for adjustments and/or revisions to maximize positives and minimize negatives.

Health Determinants

There are many behavioral, environmental, social, and geographical factors affecting a person’s overall state of health. The Centers for Disease Control and Prevention (CDC) identifies five determinants of health generally accepted by scientists as impacting human health (2):

1. Genes and biology,
2. Health behaviors,
3. Social environment,
4. Physical environment, and
5. Health services or medical care.

According to the CDC, genes and biology and health behaviors comprise approximately 25% of the influence on the health of a population (2). The remaining 75% is influenced by what are called the social determinants of health which can also be described as certain economic, social, and environmental conditions potentially created or influenced by land use, transportation, and environmental policy decisions which can directly and indirectly contribute to a person’s state of health. Social determinants of health can affect behavior (levels of physical activity, mode choice), safety (rates of pedestrian fatalities, automobile crashes), air quality, access to goods and services, and opportunities for social interaction and community involvement.
Alameda County, California

Alameda County Public Health Department (ACPHD) has been working with various public agencies and non-profit organizations to evaluate implications of public transit funding and access on public health (3). Their main objective was to use a comprehensive health impact assessment to inform important policies in the Regional Transportation Plan (RTP) prepared by the Metropolitan Transportation Commission (MTC). The analysis established important interrelationships between allocation and affordability of public transit, and the health and well-being of the residents especially those dependent on public transit systems. For instance, service cuts and fare increase were linked to long wait times, reduced ridership, unhealthy cost burden on low-income households, less access to services, and less social activity (3). ACPHD formulated numerous recommendations based on the HIA such as increasing funding for bus transit service, providing a regional discounted transit pass to low-income riders, and incorporating a quality of service metric for performance evaluation.

Humboldt County, California

The HIA led by the Humboldt County Public Health Branch focused on the impact of land-use planning on several health outcomes such as obesity, heart diseases, cancer, mental health, etc. This HIA was incorporated into the Humboldt County General Plan Update (GPU). By relating land-use to public health, a variety of land-use indicators were identified which were used to evaluate three planning scenarios (4). The HIA framework was adapted from the Healthy Development Measurement Tool (HDMT) developed by San Francisco Department of Public Health which consists of a comprehensive checklist for various land-use, transportation, housing, safety, social, and environmental indicators. Overall, there have been many positive outcomes from this HIA process. Recommendations relating to housing and transportation have been included in the general plan update, and the HIA itself was included in the appendix to the GPU (5).

Ingham County, Michigan

Ingham County Health Department (ICHD) has been working with local stakeholders to make health impact assessment a critical component of planning processes. Through surveys and data analyses, it was revealed that about 30% of the population in the region was physically inactive and more than 60% were overweight and obese (6). Moreover, residents of the region felt that the built environment and social cohesion were important factors affecting community health. As such, ICHD developed a performance matrix that could be used to evaluate the health impact or performance of development plans. The results of the HIA were incorporated into local planning in many ways. Planners held additional meetings with the developers where the HIA tool was used to discuss potential improvements to their development proposals. Over time, the region has witnessed some ideological changes due to formalization of the health impacts as developers too are becoming more conscious of health impact of their projects. The experience of Ingham County shows that it is possible to improve community health through a formal HIA framework.

Douglas County, Minnesota

In 2010, the Douglas County Public Health Department conducted an HIA of the county’s comprehensive plan update. Their objective was to identify major health issues in the region and analyze how they are linked to the comprehensive plan. They identified five broad health issues or indicators: aging population, social capital, access to places, safety (transportation), and water quality (7). Based on their preliminary identification of major health indicators, the public health department developed an extensive list of considerations and policy recommendations that could be integrated into the comprehensive plan update. As this process was to become part of the comprehensive plan update, its impact on community health is yet to be seen but it presents insight into how public health consideration can be incorporated into planning processes.
Land use and transportation infrastructure can have a significant impact on travel behavior, accessibility to resources, and general livability of the neighborhood. The combination of these related issues can affect public health in many ways. The most direct impact of the built-environment on health is manifested through the level of physical activity of residents. In fact, diet and physical activity are the two most important factors that affect prevalence of obesity (8). Urban development over the past few decades has resulted in sprawling, low-density cities that induce sedentary lifestyles making people continually more auto-dependent. Lack of physical activity and unhealthy diets have resulted in a rise in obesity and cardiovascular diseases. It is estimated that more than a third of adults and a sixth of youth in the U.S. are currently obese (9) (10). Moreover, obesity substantially raises the risk of hypertension, type 2 diabetes, coronary heart diseases, stroke, respiratory problems, and certain types of cancer (11). In fact, obesity is recognized as the second leading preventable cause of death and other diseases in the U.S. (12). Consequently, the primary objective of this health impact assessment is to extensively and holistically analyze the relationship between the built environment and obesity, and in the process develop a framework for guiding policies to improve the health and well-being of residents. The following sections summarize some of the existing literature on the relationship between physical activity/obesity and different aspects of land-use and transportation infrastructure.

Population Density

Population density is a straightforward and important measure for evaluating urban form. Population density has been linked to travel behavior and is a commonly used attribute of walkability. With long commutes and few destinations to walk to, low density neighborhoods tend to have a very high car ownership. Consequently a strong causal relationship has been established between obesity and low-density development due to urban sprawl (13). High population density, on the other hand, has been shown to increase physical activity and reduce obesity (14) (15). Low population density is one of the representative characteristics of postwar suburbanization.

Land-use Mix

Land-use is an important characteristic of urban development which shows spatial distribution of urban activities. Land-use mix is a commonly used indicator to measure presence or absence of different types of land uses in close proximity to one another. For instance, having a vibrant commercial neighborhood located close in proximity to a residential area is likely to encourage walking instead of driving for shopping or recreation. As such, presence of a varied land-uses increases vibrancy and walkability of neighborhoods which in turn results in a lower prevalence of obesity (16). Studies have found that a good land-use mix implies presence of “walkable destinations” which leads to increased physical activity and lower Body Mass Index (BMI) (17) (15).

Transit Connectivity

Use of public transportation is often governed by allocation of reliable and safe transit services. Improving access to public transportation has been associated with higher ridership and consequently higher levels of physical activity. In fact, using public transit has been linked to as much as 30 minutes of additional physical activity per day (18). It has been posited that the amount of walking associated with the use of public transportation may be enough to meet the daily physical activity requirements for adults in many locations (19). Physical activity induced by public transit use can be an important factor in reducing adult obesity and related medical costs (20).

Active Transportation

As is true for transit systems, a well connected network of bike lanes can induce mode change from driving to biking and walking (21). The existence of a comprehensive active transportation network is associated with low rates of obesity and the impact of active transportation on lowering obesity rates is well-documented in many studies. People biking to work are almost half as likely to be obese as compared to those driving to work (23). Active commuting has been shown to reduce the risk of cardiovascular diseases by
Built-Environment & Health

as much as 11 percent (24) (25).

Street-Network Design

Street network design can impact connectivity of origins and destinations which can influence the walkability of a neighborhood. Network connectivity is usually measured using indicators such as Beta Index which is a ratio of the number of links to nodes, and percentage of four-way intersections. For instance, a high percentage of four-way intersections indicate the presence of a well-connected grid network in which distances between different points are minimized. As such, high street network connectivity increases probability of walking and reduce use of personal cars (26) (27). Another important measure for street network design is block size which has been widely used as a measure of walkability (28). Smaller block lengths, in the range of 300 to 500 feet, are generally recommended to increase walkability (29).

Accessibility

Accessibility to fresh food, recreation opportunities, and other health-related goods and services can be an important factor in public health considerations and can, in many instances, dictate people’s travel behavior and habits. Availability of grocery stores and healthy food-outlets have been shown to improve the diet of the people in the surrounding neighborhood. Extensive quantitative analyses have shown that accessibility to and density of healthy food outlets have a significant and inverse relation to observed BMI values (30) (31) (32).

Another related issue is that of access to parks and recreational services. Proximity to parks and recreational services can encourage residents to increase their levels of physical activity. Studies have found significant negative correlation between access to parks and obesity suggesting that accessibility can be reliably used to model behavior (33) (34) (35).

People’s travel behavior is often represented as their mode choice when commuting to work. Large commuting distances tend to encourage excessive reliance on personal cars. People are more likely to use alternative modes of transportation if the distance to work is less. As such, it has been observed that commuting a long distance to the work place is positively linked to a higher risk of obesity and hypertension (36) (37).

Crime

Rates of active transportation use are particularly sensitive to perception of safety in a neighborhood. Living in neighborhoods with a high crime rate is likely to discourage walking and biking (38) (39) (40). In fact, the relationship between obesity and crime rate might even be bi-directional with obesity prevalence increasing the propensity to partake in criminal activities (36). Moreover, perception of safety might affect physical activity in many indirect ways. For instance, recreational facilities have been shown to be more effective in areas having relatively low rates of crime (42).
Socioeconomic Status & Health

While the primary objective of this health impact assessment is to analyze and quantify the impact of the built environment, it is essential to acknowledge and control for the impact of socioeconomic variables. Social determinants of health have been the subject of many studies that have found socioeconomic status to be the foremost determinant of physical health (43) (44). As such, the validity of the health impact assessment model hinges on duly addressing socioeconomic issues along with built environment variables for predicting health impact. The following sections identify some of the important demographic factors that have been linked to obesity and other related diseases.

Age
Increase in age has been positively associated with obesity and cardiovascular diseases. For instance, BMI is shown to increase by as much as 0.12 kg/m² or 0.6 percentage points per year for adults in the U.S. (45). This relationship, however, might vary depending on race and sex and it might even be specific to the study area (46). So while a positive correlation is expected between obesity and age, there might be variations related to other demographic characteristics which are not fully accounted for in this assessment.

Education Attainment
Education attainment has been one of the most important socioeconomic variables considered in public health studies. Education is commonly linked to positive health outcomes and healthier behaviors. Lower levels of education attainment have been consistently associated with higher rates of obesity (47) (48) (49) (50). Moreover, the impact of education is closely correlated with race and income. For instance, the role of education attainment is possibly more influential in the African-American population (49).

Income
The impact of income on health has been extensively analyzed in numerous epidemiological studies. As a definite measure of socioeconomic status, income levels have been shown to have a strong correlation with obesity with most studies attributing high obesity prevalence to low income (47) (50) (51) (52) (53). For instance, price disparities between low-nutrient, high-calorie foods and healthier food options have been increasing, and are in turn reflected in the dietary habits of low-income groups (53). Consequently, studies have found increasing disparities in the prevalence of obesity by socioeconomic status in that low-income groups are facing disproportionately higher risks for obesity, diabetes, and cardiovascular diseases (54).

Race
Studies that have examined racial disparities in the prevalence of obesity have often found that the African American population is more susceptible to obesity and related cardiovascular diseases than other racial minorities (53) (47). Black women have been identified as the highest risk group when it comes to being overweight and obese (49) (55). The Asian population, on the other hand, has been consistently found to have the lowest rates of obesity among all the racial groups (56).
Public Input

Public participation has been a critical component of the 2040 Long Range Transportation Plan (LRTP) process and has informed goals and collective vision for the region. As part of the public outreach process, CUUATS engaged the region’s community and businesses through a variety of visioning sessions, public meetings, social media outlets, an interactive website, a public outreach bus and so on. These strategies have been successful in soliciting opinions and suggestions for the region’s land-use and transportation vision and infrastructure. Although, there were no public meetings specifically held for developing the Champaign-Urbana Health Impact Assessment, public input from the LRTP public outreach revealed many concerns and issues that the HIA is trying to address. The following is a list of some of the major issues that have been raised by local residents and businesses during LRTP outreach that are directly related to the HIA.

- Many comments were received regarding the utility and safety of pedestrian network. People identified lack of sidewalks in some areas making walking difficult and sometimes dangerous exposing pedestrians to automobile traffic on the roads.
- Many residents have expressed appreciation for the addition of bike lanes such as those on Washington St. People also think that adding bike lanes improves the safety on the roads by slowing down cars. Alternatively, some bikers have expressed safety concerns while sharing the road with cars.
- CUMTD bus service is seen as a major strength of the regional transportation infrastructure providing access to major commercial and education centers. Even so, there is demand for additional bus transit services especially in areas further away from the campus district.
- People voiced concerns about areas around the periphery of the urbanized area not having adequate access to basic amenities.
- Another common theme in input received was the desire to make the community more vibrant for the younger demographic with more community spaces, events, and more opportunities for active and accessible transportation.
Health Data

The health data from 2008 to 2012, used in this analysis consisted of records for requested disease codes along with the corresponding addresses provided by a local health agency. Having records for multiple consecutive years ensured that the spatial distribution of the data was representative of the actual disease distribution. These records were geocoded in ArcMap and aggregated at the Traffic Analysis Zone (TAZ) level. To account for the possibility of some people having multiple records, only unique records were considered. Ultimately, there were more than sixty-four thousand records that were geocoded and considered in this health impact assessment.

Disease Categories

Obesity
Records: 5,971
Includes obesity, overweight and adiposity

Hypertension
Records: 33,920
Includes all subcategories of hypertension

Diabetes Type I
Records: 2,271
Includes all subcategories of Type 1 diabetes

Diabetes Type II
Records: 14,303
Includes all subcategories of Type 2 diabetes

Pulmonary Diseases
Records: 278
Includes acute and chronic pulmonary embolism and infarction

Lung Diseases
Records: 4,001
Includes bronchitis, emphysema, and asthma

Hospital Data
Total Records: 4,728
Unique Records: 4,727

Clinic Data
Total Records: 79,991
Unique Records: 59,914

Total Unique Records: 64,641
Successfully Geocoded: 60,744
Input Data

The U.S. Census Bureau was the primary source of data for most of the socioeconomic variables. Collected at the block group level, these variables were estimated for each TAZ by using a simple area-weighted average approach. These estimates were judged to be reliable in the urbanized areas where the size of block groups is comparatively small.

Most of the built environment variables were adapted from the Local Affordability and Livability Index (LALI) model developed by CUUATS. All the selected variables are associated with population health in different ways and to varying degrees. Since a large number of variables were considered, similar variables were grouped into the following subcategories: land-use, transportation, accessibility and safety.

### Socioeconomic
- Per Capita Income
- Median Age
- Black Population %
- Asian Population %
- Less than Bachelor’s degree %
- Unemployment %
- Household Size
- Vehicles per household

### Built Environment
- Population Density
- Land-use Mix
- Residential Mix
- Block Size
- Urban Design
- Transit Connectivity Index
- Bike Index/Miles
- Sidewalk Network
- Beta Index
- Four-way Intersections %
- Service Access Index
- Employment Center Distance
- Center Driving Distance
- Parks Coverage
- Grocery Store Access
- School Proximity
- Crime Rate in 2013
- Streetlights
Population Density

The population density of each TAZ was estimated as number of persons living in the TAZ divided by the area in acres. While, there is no definitive pattern in the spatial distribution of population density, most of the TAZs near the edge of the study have relatively lower density. There is a noticeable drop in population density north of I-74. In most cases, higher population density correlates with either multi-family or mixed-use development. However, there are few neighborhoods near downtown Champaign and the university district which have high density in spite of being single-family residential zones.

Land-use Mix

A measure to quantify diversity of land-uses in close proximity to each other, land-use mix is a commonly used attribute to evaluate land-use and zoning policies. There are multiple ways of measuring land-use mix. Land-use entropy or Shannon Index is used in this analysis to evaluate land-use mix which measures proportion of area allocated to different types of land-uses in a given neighborhood. As expected, areas near downtown have a more diverse land-use mix than those in the periphery. Although neighborhoods with greater land-use diversity often have high levels of residents walking, it is important to note that some neighborhoods around the north edge of the study area, such as the commercial area along North Prospect Ave., have a relatively high land-use mix according to the entropy measure even though they are not very walkable.
Residential Mix

Residential mix measures the diversity of the types of residential units in a neighborhood. For this HIA we used the Simpson diversity index. For instance, presence of multi-family units in a predominantly single-family area would translate to a higher residential mix than a neighborhood with only single-family homes. Mix of residential uses can be an important factor in livability of neighborhoods. Moreover, high residential mix would mean that residents have a larger variety of housing options. Lower residential mix means fewer options in terms of the type of residences and could also be an indicator for lack of affordable housing. High residential mix is mostly observed around downtowns where there is transition from multi-family to single-family housing.

Block Size

Blocks were considered as areas lying outside the public right-of-way. For each TAZ, median block size measured in acres was used in the analysis. Block length is an important variable as it has links to many built-environment characteristics such as population density, density of intersections, and connectivity to destinations through active transportation modes. Blocks tend to be smaller in areas close to the campus district and downtowns. Some relatively dense neighborhoods in Champaign have large block sizes which likely due to their irregular street network design. Areas along the edges of Champaign north of I-74 and west of I-57 have very large block sizes.
Transit Connectivity

Developed by the Center for Neighborhood Technology, the transit connectivity index represents the quality of a fixed-route bus service based on access distance, intensity, and frequency of service. The access area is defined by drawing a 0.25 miles buffer around the bus routes. Intensity and frequency are measured together by the number of trips made on a road segment by all routes. Transit connectivity decreases considerably as we move away from the university district. East-west connectivity seems to be much better than north-south connectivity and as such, there are some noticeable service gaps in north Urbana and south Champaign.

Bike Paths, Trails & Sidewalks

Access to bike paths, trails, sidewalks was defined as their collective density in each TAZi.e. available length normalized by area. Urbana has a relatively more well-connected and denser network of bike paths and trails than Champaign except for some neighborhoods towards the north of the city. The bike/trails network in Champaign is not only sparse but also more intermittent and disconnected. Similar patterns are observed in the spatial allocation of sidewalks. The sidewalk network becomes increasingly fragmented as we move away from the university district and downtowns. North Urbana, and neighborhoods around Mattis & Springfield Avenues are the most prominent areas that lack both bike paths/trails and sidewalks.
Beta Index

Beta index was one of the measures used to evaluate street network connectivity. It is basically the ratio of links to nodes in a given area. The contention is that as the number of links with respect to number of nodes or intersections increases the connectivity of the street network improves and it becomes easier to travel between any two points in the network. The beta index is much higher near the university district but decreases significantly away from the campus, especially north and south of the downtowns. In most cases, a higher beta index was observed in neighborhoods with a regular grid network.

Four-way Intersections %

Another way to evaluate street network connectivity is to estimate the percentage of different types of intersections such as one-way (cul-de-sacs), three-way, four-way, and so on. A well-connected street network would have a higher percentage of four-way intersections and lower percentage of one-way intersections. In a perfect grid network, for instance, all the intersections are four-way intersections. The percentage of four-way intersections has a similar spatial distribution as the beta index. The percentage of four-way intersections decreases as one moves further away from the university district.
Service Access Index

Adapted from the LEED for Neighborhood Development guidelines, the service access index measures proximity or access to service-related businesses such as convenience stores, restaurants, banks, community centers, theatres etc. Such businesses have been identified as destinations which residents are more likely to walk or bike to. Service access index measures density of service-related businesses in different neighborhoods. It is clear from the distribution that service-related businesses are very much concentrated near the university and downtowns, and as such, residents of neighborhoods along the edge of the study area have to travel much further to access services.

Employment Center Distance

Access to employment was estimated as a weighted-average of distance to all jobs in the area. A basic gravity model was used to estimate employment accessibility using number of jobs as the weight and distance as the impedance. Since most of the jobs are in the university district and downtowns, the spatial distribution of the employment center distance is rather skewed, similar to that of service access index. Overall, accessibility to employment and services is very low in many neighborhoods located far from the university.
Input Data

Parks Access

Parks coverage was used to determine accessibility to parks in each TAZ. For this study, access to parks in a neighborhood was defined as the percentage of the neighborhood that is within a 7 minute walking distance to a park using the existing sidewalk infrastructure. Only built-up parcels were considered for this calculation. Access to parks is relatively high on and near the university but is rather fragmented in other areas. Distribution reveals an absence of parks in north Champaign near I-74 and northeast Urbana.

Grocery Store Access

A kernel density approach was used to measure accessibility to major grocery stores which counts the number of grocery stores within a mile of any point in the study area and discounts that by the distance between the point and the grocery store. This ensures that stores that are located closer to a point are weighted higher than the ones located further away. Access to grocery stores can affect travel behavior and dietary habits. While the distribution of grocery stores is somewhat spaced out, there are some noticeable service gaps in south Champaign and north Urbana.
Crime Rate

Crime data was collected online from spotcrime.com website for the year 2013. Crime records have addresses which were geocoded and aggregated for each neighborhood. The number of crime incidents for each neighborhood was normalized by population in the neighborhood. In general, the crime rate in Champaign is lower than that in Urbana. Moreover, crime rates are higher close to university and downtowns. Crime rate can be a good indicator of the perception of safety and high crime rates could discourage walking/biking.
Study Area Selection

Starting with the entire Champaign County, the study area was progressively narrowed down depending on the availability of data. Many of the input variables were adapted from CUUATS’s Local Affordability and Livability Index (LALI) model which mainly focused on the Champaign-Urbana urbanized area. The analysis was done at the TAZ level so as to keep the model compatible with other models related to the transportation planning process. Even though this is a seemingly small study area, a robust health impact model for this study area could potentially be scaled to a larger area such as Champaign County.

Criteria for selection of study area

- Availability of input variables from LALI
- Availability of health records
- Adequate population count for modeling accuracy
- Elimination of TAZs with primarily student population
Methodology

Availability of large and diverse sets of data made it possible to develop an extensive quantitative regression model with health indicators as the dependent variable. The basic framework of the model was to relate count of diseases in each TAZ to the mean or aggregated socioeconomic and built-environment variables of the TAZ.

Assumptions

• The health data considered in the model was aggregated at the TAZ level such that the response variables consisted of disease counts in each of the TAZ. It was assumed that the available health data is representative of the actual distribution of the considered diseases, i.e. even if the data does not have records for all the incidents, it can be reasonably assumed, given the high number of records, that the available data is a statistically representative sample of the actual conditions. Consequently, the expectations from the model are to evaluate and compare the built environment in different TAZs and not to predict true count of diseases in every TAZ.

• Obesity was the focus of this initial analysis since it has the most direct relationship with the built environment and obesity has been positively linked to other diseases such as hypertension, diabetes, and cardiovascular diseases. The maps show that there is a strong spatial correlation between the three diseases.

• For the purpose of modeling, it was assumed that disease rates in each TAZ were directly affected by the built environment only in that TAZ. In reality, however, factors in any TAZ impact conditions around the TAZ as well.

• Comprehensive data for crime was available only for the year 2013, and it was assumed that crime rates in 2013 were comparable to the rates for the years for which the health data was collected (2007-2012).
Methodology

Modeling with count data presents distinct challenges as the distribution of the response variable is discrete and non-negative. Poisson regression model is the most commonly employed technique to deal with count data (57) (58). Based on Poisson distribution, Poisson regression model can be mathematically represented as,

\[ \mu_i = e^{x_i'\beta} \]

where \( \mu_i \) represents the mean parameter, \( x_i \) represents the vector of covariates or input variables, and \( \beta \) represents the regression coefficients. Another way to present the equation is,

\[ \ln(\mu_i) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_k x_{ki} \]

Estimation of regression coefficients is done by maximum-likelihood method which is based on the mathematical formula Poisson distribution which can be expressed as,

\[ P(k) = \frac{\mu^k e^{-\mu}}{k!} \]

Since Poisson distribution is parameterized by a single parameter, it can be too restrictive specially if the observed counts have an excess of zero values or if the observed variance is much higher than the mean i.e. in the case of overdispersion. Negative binomial and hurdle models are some of the commonly employed options to deal with overdispersion (57).

The basic model framework is presented below with obesity count as the response variable and socioeconomic and built environment variables as the input variables. It should be noted that obesity count and not obesity rate is the dependent variable. Poisson regression models use normalizing variables such as total population as the exposure or offset variable which are assigned a fixed coefficient of 1 in the model.

The modeling process involved trials of various combinations of input variables to obtain the best fit with the observed spatial distribution. The objective was to find the right mix of socioeconomic variables and built environment variables that best predict the prevalence of obesity in the study area. Certain variables, such as vehicles per household and existing mode share, were decided to be endogenous to the model because they represented behavior or outcome rather than cause, and as such were not included as part of the input. Another important consideration was to select variables such that they don’t conflict with each other. Natural log was taken of certain input variables if doing so improved the significance of the variables. The final selection of the model, presented below, was based on the following criteria.

- Maximize accuracy of the model
- Include a wide array of variables
- Seek expected correlation between input and output
- Achieve high level of significance for as many variables as possible
The final model was constructed using the Generalized Linear Models (GLM) in the R programming language with three different statistical distributions—Poisson, quasi-Poisson, and negative-binomial. Of the three, Poisson regression model was selected for this project as it had the best fit with the observed distribution. The summary of the final regression model consists of “Estimate” which is the coefficient of the variables and “Pr” value which can be interpreted as the significance of the variables with lower values implying higher significance. To improve the accuracy of the model, natural log was taken of some of the variables such as service access index, crime rate, and income.
Of all the variables considered only per capita income had an unexpected relationship with the obesity rate. Most of the prior studies suggest that the prevalence of obesity is higher in the demographic with the lower socioeconomic status. As such, it was expected that obesity would have a negative correlation with income. Spatial distribution of income in Champaign-Urbana provides one possible explanation to this observed trend. There is a high percentage of students living in the vicinity of the university which leads to lowering of average incomes in the area which, as one might expect for student population, also have lower rates of obesity. The final model was used to predict obesity count in each TAZ which was then compared to the actual observed count. The model fits the observed count very well and there is a 94% correlation between actual and predicted count. The map comparing obesity rates for predicted and actual counts suggests a good spatial correlation between observed and predicted counts. As such, it can be reasonably concluded that the model is a good representation of the relationship between the built environment and health.
Final Model Interpretation

The signs of the coefficients and their corresponding significance provide some insights into the impact of the independent variables on the dependent variable which is obesity count in each TAZ. All the socioeconomic variables were found to be very significant when predicting obesity rates. Age and education attainment were the two most significant demographic variables. Overall, the built environment variables were significant which is an important result given that health impact is very difficult to model. While some variables such as transit connectivity were not very significant, it must be noted that the model does not take into account possible interactions among the variables. For instance, transit connectivity tends to be correlated with population and employment density and even though these variables are independently represented in the model, there are interactions among these inputs which might have an impact on their significance in the model. Perhaps, the most important feature of the model is that all the built environment variables have the expected correlation with obesity rate. This reinforces the validity of the model as all the predicted correlations can be easily verified using current literature and similar studies.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Age</td>
<td>Positive</td>
<td>Very High</td>
</tr>
<tr>
<td>% Black Population</td>
<td>Positive</td>
<td>High</td>
</tr>
<tr>
<td>% Asian Population</td>
<td>Negative</td>
<td>High</td>
</tr>
<tr>
<td>% Under Bachelor's Degree</td>
<td>Positive</td>
<td>Very High</td>
</tr>
<tr>
<td>Per Capita Income</td>
<td>Positive</td>
<td>Very High</td>
</tr>
<tr>
<td>Transit Connectivity</td>
<td>Negative</td>
<td>Low</td>
</tr>
<tr>
<td>Bike Miles</td>
<td>Negative</td>
<td>Low</td>
</tr>
<tr>
<td>% Four-way Intersections</td>
<td>Negative</td>
<td>Very High</td>
</tr>
<tr>
<td>Population Density</td>
<td>Negative</td>
<td>High</td>
</tr>
<tr>
<td>Land Use Mix</td>
<td>Negative</td>
<td>Medium</td>
</tr>
<tr>
<td>Block Size</td>
<td>Positive</td>
<td>Medium</td>
</tr>
<tr>
<td>Grocery Stores Access</td>
<td>Negative</td>
<td>High</td>
</tr>
<tr>
<td>Parks Access</td>
<td>Negative</td>
<td>Medium</td>
</tr>
<tr>
<td>Service Access</td>
<td>Negative</td>
<td>Low</td>
</tr>
<tr>
<td>Employment Center Distance</td>
<td>Positive</td>
<td>Medium</td>
</tr>
<tr>
<td>Crime Rate</td>
<td>Positive</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Obesity Rate

Increases with
- Block Size
- Employment Center Dist
- Crime Rate

Decreases with
- Transit Connectivity
- Bike Miles
- % Four-way Intersections
- Population Density
- Land-use Mix
- Grocery Store Access
- Park Access
- Services Access
Health Index

The regression model discussed in the prior sections established a significant and robust relationship between the built environment and public health. The regression model, while a reliable measure to evaluate the built-environment, is not the most intuitive way of communicating and representing the implications of the health impact assessment. Indicators or indices, on the other hand, have long been used in public policy and other social sciences to present analyses and information in an accessible format. Indicators can provide a reliable foundation to decision-making processes by reducing complex analysis to simple measures that can be easily evaluated and reevaluated for policy analysis and monitoring. As such, the final deliverable of this health impact assessment is a simple and robust health index that can be used to evaluate and compare different neighborhood characteristics based on their impact on local population health.

There are multiple methods of developing an index such as factor analysis, principal component analysis, and cluster analysis (59). This health index is based on the final regression model as the model itself is very reliable. However, input variables that were used in the model have different units and different scales, and as such it is difficult to compare the impact of different variables. Designing a standardized regression model to estimate relative impact of different input variables overcomes these hurdles (60). Standardized regression models use “standardized” variables which are calculated by estimating a z-score for each value. Doing so ensures that all variables have a variance of one and a mean of zero and as such, all input variables have a common scale and are unit-less. The standardized regression was done using the same combination of input variables that were selected for the final regression model. The coefficients obtained in this type of standardized regression can be used to directly compare the impact of different variables. The proposed health index is, thus, based on a neighborhood’s different built environment parameters weighted according to the results of the standardized regression.

The standardized regression model, which consisted of the same combination of variables as Poisson regression model, predicted a similar correlation between the variables as discussed before. The significance of variables, however, had some noticeable differences. For instance, service access index and parks access were much more significant in the standardized regression model than that predicted by the Poisson regression model. Since the general relationship was the same, the results of the standardized regression model were considered to be valid. The coefficients of the standardized regression analysis give some insights into the relative impact of different built environment variables on obesity prevalence. As such, the coefficients were used to rank different variables in terms of their level of impact on obesity rate. The final weight assigned to each variable was based on the dual consideration their relative importance as predicted by the standardized regression and their significance as predicted by the Poisson regression. Moreover, the weights were scaled up so that the total added up to a 100.

### Built Environment Variables

- Service Access Index
- Crime Rate
- Block Size
- Grocery Store Access
- Transit Connectivity
- Population Density
- Land-use Mix
- Four-way Intersections %
- Bike Miles
- Employment Center Distance
- Parks Access

*Increasing Importance*
Health Index

Land-use
- Block Size: 10
- Population Density: 8
- Land-use Mix: 8
- Urban Design: 5

Transportation
- Transit Connectivity: 12
- Bike/Trails Miles: 6
- Four-way Intersections %: 6
- Sidewalks: 3

Accessibility
- Service Access Index: 12
- Grocery Store Access: 10
- Parks Access: 3
- Employment Access: 3

Safety
- Crime Rate: 12
- Streetlights: 2

Maximum Score: 100
The Health Index composition described in the previous section was based on the relative importance of variables when it comes to affecting levels of physical activity and hence obesity rate. The final calculation of the health index score for each TAZ required setting thresholds corresponding to different scores for each variable. These thresholds were based on the regression equation and the distribution of the variables. As per the regression equation, the thresholds should be based on linear divisions of the exponential of the z-scores. This scheme, however, was found to be too skewed for the observed data distributions. As such, an alternative scheme was applied that accounted for the distribution of the data. If the observed distribution was normal or uniform such as that for land-use mix and parks access, then the thresholds were based on dual consideration of the regression equation and quantile data classification. If the observed distribution was more skewed such as that for transit connectivity and service access index, then the thresholds were based on geometric interval classification along with the regression equation.
# Health Index

<table>
<thead>
<tr>
<th></th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Size (in acres)</td>
<td></td>
</tr>
<tr>
<td>Population Density (persons per acre)</td>
<td></td>
</tr>
<tr>
<td>Land-use Mix (Index)</td>
<td></td>
</tr>
<tr>
<td>Transit Connectivity (Index)</td>
<td></td>
</tr>
<tr>
<td>Bike Miles (ft per sq. mile)</td>
<td></td>
</tr>
<tr>
<td>Four-way Intersection (in %)</td>
<td></td>
</tr>
<tr>
<td>Sidewalks (ft per sq. mile)</td>
<td></td>
</tr>
<tr>
<td>Service Access (Index)</td>
<td></td>
</tr>
<tr>
<td>Grocery St. Access (Kernel Density)</td>
<td></td>
</tr>
<tr>
<td>Parks Access (% coverage)</td>
<td></td>
</tr>
<tr>
<td>Employment Center Dist. (miles)</td>
<td></td>
</tr>
<tr>
<td>Crime Rate (incidents per person)</td>
<td></td>
</tr>
</tbody>
</table>
An index is a simplification of a complex phenomenon and hence some loss of information is expected when designing an index. It is important, however, that the index does not skew the results of the analysis too much. Otherwise, the index might lead to simplistic and perhaps, inaccurate interpretation of the impact of the built-environment on obesity rate. As such, results of the health index were compared to the predictions of the final regression model to check the validity of the index.

To complete a validity check, each TAZ was given a rank based on its health index score which was then compared to the performance of the built environment as predicted by the Poisson regression model. To measure performance of the built environment as per the regression model, the Poisson regression equation was evaluated using the coefficients of only the built environment variables. This evaluation produced an output that can be interpreted as a predicted obesity rate for each TAZ based on its built environment parameters. Next, a rank was assigned to each TAZ based on the predicted obesity rate. This process, thus, led to two different ranking frameworks - as predicted by the health index, and as predicted by the Poisson regression model.

High correlation was observed between these two ranks suggesting that the proposed index is a good representation of the results of the regression analysis. The proposed health index, thus, can be reliably used to compare the built environment across different neighborhoods. There are, however, some noticeable outliers which are evident from the graph to the right. Further analysis of these outliers might reveal ways in which the health index might be modified and improved so as to be a more accurate representation of the Poisson regression model.
Land-use Score

Land-use mix

Population Density

Land Use Score

Block Size

Land-use Score

Low
High

Land Use Mix

Low
High

Population Density

Low
High

Median Block Size

Small
Large
Safety Score
Health Index
Total Score
Results

The regression model confirms and quantifies the impact of the built environment on the prevalence of obesity and consequently other related diseases such as type 2 diabetes and hypertension. Moreover, extensive review of existing epidemiological studies suggest a similar relationship between the built environment and population health which implies that correlation, as predicted by this model, is definitely causal and not just mathematical.

Based on the parameters used for defining the health index, it is not surprising that the areas around the university district and downtowns have a relatively higher health index. While the focus of this study was on land-use and transportation infrastructure, crime and accessibility to services have emerged as critical factors in predicting health impact of the built environment. The role of active transportation, however, is not as significant. One possible explanation could be that active transportation infrastructure might be more effective in areas with favorable land-use and transportation infrastructure. As such, active transportation infrastructure may not be as influential independently as it might be in conjunction with other built environment variables when it comes to shaping the travel behavior of residents.

Of the different aspects of the health index, accessibility seems to have the most skewed spatial distribution. Accessibility to services and employment is relatively high near the University of Illinois campus and Champaign-Urbana downtowns, and decreases significantly in the peripheral zones. While this pattern is expected for the distribution of employment, not having adequate access to grocery stores and other vital services also seems to be negatively impacting the health of the residents living outside the central areas.

To better understand the implications of the built environment on the walkability and livability of neighborhoods, five analysis zones are described on the following pages to give a more detailed review of the results of this health impact assessment. Such analyses might also help in visualizing how the proposed health index is able to characterize the built environment in a neighborhood. Starting from the TAZs that scored low on the health index to those that scored relatively higher, a closer look at these neighborhoods reveals how different built environment factors work together to influence travel behavior of population health.
The neighborhood just west of I-57 between Windsor Road and Kirby Avenue scored very low on the health index. Apart from safety, all other aspects of health index had a very low score and in fact, the neighborhood did not score a single point for its transportation infrastructure.

Primarily a residential neighborhood, there are no service-oriented businesses or grocery stores nearby and most of the neighborhood is not within walking distance of a park.

This neighborhood has a very irregular and disconnected street network design. Moreover, the road network is very sparse creating very large blocks which are not conducive for active modes of transportation.

Low population density, homogeneous land-use, and a disconnected street network have created spaces that are empty and witness little or no activity from the residents.

Not served by transit services and far from major employment centers, the residents of the neighborhood have no incentive to use active modes of transportation for commuting. Moreover lack of destinations within walking distance discourages physical activity even for recreational purposes.
The neighborhood north-east of Windsor Road and Mattis Avenue is another analysis zone that scored low on the health index. The overall transportation infrastructure was rated better than the previous neighborhood.

Accessibility is the primary area of concern for this neighborhood as there are no grocery stores within walking distance and access to parks is very limited. Moreover, located far from businesses, there are not many destinations that the residents can potentially walk or bike to; and the situation is aggravated by the absence of bike paths or trails.

Even though there is a seemingly denser network of streets, the network connectivity is very low which is evident from the high number of cul-de-sacs in the area. Low density and disconnected street network are also manifested as very large block sizes. Transit connectivity is also too low to have any significant impact on the travel behavior of the people especially since businesses and employment are too far to incentivize use of active modes of transportation.

The neighborhood almost exclusively low-density residential which combined with the that lack of opportunities for recreational activities, the residents don’t seem to have any reason to engage with the built-environment of their neighborhood.
Health Index Score

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Size</td>
<td>6</td>
</tr>
<tr>
<td>Population Density</td>
<td>5</td>
</tr>
<tr>
<td>Land-use Mix</td>
<td>2</td>
</tr>
<tr>
<td>Transit Connectivity</td>
<td>3</td>
</tr>
<tr>
<td>Bike/Trails Miles</td>
<td>4</td>
</tr>
<tr>
<td>Four-way Intersections</td>
<td>4</td>
</tr>
<tr>
<td>Sidewalks Network</td>
<td>2</td>
</tr>
<tr>
<td>Service Access Index</td>
<td>7</td>
</tr>
<tr>
<td>Grocery Store Access</td>
<td>7</td>
</tr>
<tr>
<td>Parks Access</td>
<td>2</td>
</tr>
<tr>
<td>Employment Access</td>
<td>1</td>
</tr>
<tr>
<td>Crime Rate</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

East of Prospect Avenue, and bound by Green Street and Hessel Boulevard, this neighborhood have a relative above average health index score. This neighborhood scored significantly better for its transportation infrastructure and accessibility than the previously discussed neighborhoods. This is reflected in the overall score even if the safety score is relatively low. Accessibility is boasted by the presence of parks and many grocery stores in the adjoining areas. Moreover, proximity to downtown Champaign brings service-oriented businesses and employment locations closer if not within walking distance.

Perhaps the biggest point of concern for this neighborhood is lack of transit connectivity. Given the proximity of the downtown, there is a possibility of increasing use of public transit by improving transit connectivity. Large parts of the neighborhood have a street network that somewhat resembles a grid and as such, the network connectivity was found to be good. The block sizes, however, are too large for the grid system to be effective in shaping travel behavior.

In spite of being a residential neighborhood, relatively high population density and its location close to the downtown give this neighborhood a more vibrant feel that should encourage some physical activity for work-related or even recreational trips.
### Health Index Score

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Size</td>
<td>10</td>
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<tr>
<td>Population Density</td>
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<tr>
<td>Land-use Mix</td>
<td>3</td>
</tr>
<tr>
<td>Transit Connectivity</td>
<td>7</td>
</tr>
<tr>
<td>Bike/Trails Miles</td>
<td>4</td>
</tr>
<tr>
<td>Four-way Intersections</td>
<td>4</td>
</tr>
<tr>
<td>Sidewalks Network</td>
<td>3</td>
</tr>
<tr>
<td>Service Access Index</td>
<td>5</td>
</tr>
<tr>
<td>Grocery Store Access</td>
<td>9</td>
</tr>
<tr>
<td>Parks Access</td>
<td>2</td>
</tr>
<tr>
<td>Employment Access</td>
<td>3</td>
</tr>
<tr>
<td>Crime Rate</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td><strong>59</strong></td>
</tr>
</tbody>
</table>

The neighborhood defined by Main Street, Washington Street, Vine Street, and Cottage Grove Avenue is in many ways similar to the previous neighborhood with its location close to downtown Urbana. This neighborhood, however, scored better on the health index due to some crucial land-use and transportation improvements over the previous neighborhood. The overall accessibility of this neighborhood was evaluated to be high as there are many grocery stores nearby and almost the entire neighborhood is within walking distance of a park. Also proximity to downtown Urbana ensures high access to businesses and employment opportunities.

The neighborhood has a predominant grid network with very high network connectivity. Moreover, the block sizes are small making walking/biking very conducive.

Another strength of this neighborhood is high transit connectivity which along with the presence of bike paths and trails create conditions that should encourage use of active modes of transportation.

Even though density and overall land-use patterns are similar to the previous neighborhood, smaller block sized and transit connectivity make it very convenient to walk to nearby destinations such as service-oriented businesses in downtown Urbana.
## Results

The neighborhood between Race Street, Lincoln Avenue, Green St, and Washington Street had one of the highest health index scores. With its location between the campus and downtown Urbana, the neighborhood had high scores on all aspects of the health index.

There are multiple transit routes that connect the neighborhood with major commercial and employment centers. Also proximity to the university, and downtown Urbana make public transit a viable and attractive option for commuting.

### Health Index Score

<table>
<thead>
<tr>
<th>Block Size</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Density</td>
<td>8</td>
</tr>
<tr>
<td>Land-use Mix</td>
<td>4</td>
</tr>
<tr>
<td>Transit Connectivity</td>
<td>9</td>
</tr>
<tr>
<td>Bike/Trails Miles</td>
<td>3</td>
</tr>
<tr>
<td>Four-way Intersections</td>
<td>5</td>
</tr>
<tr>
<td>Sidewalks Network</td>
<td>3</td>
</tr>
<tr>
<td>Service Access Index</td>
<td>9</td>
</tr>
<tr>
<td>Grocery Store Access</td>
<td>9</td>
</tr>
<tr>
<td>Parks Access</td>
<td>2</td>
</tr>
<tr>
<td>Employment Access</td>
<td>3</td>
</tr>
<tr>
<td>Crime Rate</td>
<td>7</td>
</tr>
</tbody>
</table>

**Total Score** 70

The street network in the neighborhood is primarily a grid network with very high connectivity. Small block sizes and a connected street network combine to increase the number of destinations that residents can easily walk/bike to. The primary strength of this neighborhood is the high level of accessibility to services and employment that residents have by virtue of its location and connectivity.

The neighborhood has a balanced mix of single-family and multi-family units which not only increases the density but also creates a compact and vibrant neighborhood that engages the residents, and creates opportunities for high level of physical activity.
Limitations

• The regression model does not account for possible interactions between input variables. A detailed analysis of these interactions might reveal a possibility of synergistic impact of certain combinations of variables which would further strengthen our understanding of the relation between built environment and population health.

• Aggregating data at the TAZ level can lead to omission of internal variations within a TAZ which might affect evaluation of certain TAZs.

• The regression model assumes that obesity rate in a TAZ is an outcome of socioeconomic and built environment variables only of that TAZ. It is, however, expected that built environment of neighboring TAZs should impact travel behavior to some extent.

• The validity of the health model and the index could only be verified for the study area itself due to limited availability of data. True validation of the model, however, would require testing it for a different geography such as other urbanized areas in Champaign County.

• The relation between input variables and health was assumed to be geographically static i.e. it does not change from one location to another. Analysis techniques such as Geographically Weighted Regression (GWR) can be used to check if spatial variations exist in the relation between the variables. For this project, however, such variations were ignored given the small size of the study area.

• The health index has two variables, urban design and streetlights, which were not included in the regression model due to lack of data and as such, their respective weights were based on expert opinion. As and when more datasets become available, they can be easily integrated into the proposed framework.
Recommendations

• The health index reveals that there are multiple attributes of the built environment that work in conjunction and have to be taken into account while designing policies oriented towards realization of healthy communities. For instance, transit connectivity alone or accessibility alone is not enough to ensure healthier neighborhoods. When planning for healthy communities, a holistic approach is required to achieve any significant improvements in health of the residents.

• Transit connectivity has a significant impact on people’s travel behavior. Allocation of additional transit services to areas that are currently underserved will probably have to be in conjunction with land-use policies aimed at increasing density and accessibility. Such complementary measures can ensure sizable ridership gains to justify investing in additional transit capacity.

• Creating opportunities for active transportation can result in significant gains in levels of physical activity and health of the residents. Transportation policies should focus on developing a well-connected network of bike paths and trails that seamlessly integrates with the public transit system. Moreover, there is a need to create an environment suitable for walking/biking through complementary land-use policies and urban design initiatives.

• While significant alterations to the existing street network design may not be possible, long term policies can certainly prioritize development of a better connected street layout such as a more regular grid network.

• Identifying and actively promoting opportunities for infill development can significantly improve the urban form and encourage more physical activity. Infill development projects can, among other things, increase density, improve land-use mix, achieve better job-housing balance, and therefore build healthier communities.

• The spatial distribution of grocery stores and other service-oriented businesses reveals large service gaps in south-west Champaign and north-east Urbana. These also happen to be the areas with relatively higher rates of obesity, diabetes and hypertension. As such, there is a need to improve the spatial allocation of services.

• Crime and perception of safety have been identified as key elements of walkability and vibrancy of neighborhoods. As such, policies and investments targeted to improve safety of crime-prone neighborhoods can now be justified by public health considerations along with existing considerations related to safety and well-being of residents.

• The health index focuses on modeling physical activity but diet is an equally important factor which is, to some extent, corroborated by the significance and weight of accessibility to grocery stores. As such, planning for healthy communities should involve policies targeted to improve dietary habits by improving accessibility to healthy foods and also raising awareness about healthy eating.
• Results of this HIA can be used to formalize and quantify public health considerations in regional planning processes and development projects. This assessment is going to be used in scenario planning analysis for the LRTP 2040. Health index can be used to compare performance of alternative scenarios in terms of their impact on public health.

• Neighborhoods scoring very low on the health index can be targeted using small area plans aimed at improving the built environment and hence the physical well-being of the residents. For instance, future commercial developments can be planned to fill service gaps in access to employment and services.

• This assessment and its formal inclusion into planning processes exhibit CUUATS’ commitment to working towards creating healthy and livable communities. This study can, thus, be used to apply for grants that can support more targeted programs.

• This HIA framework focuses on spatial distribution of different built-environment variables and health indicators. There is, however, possibility of including temporal variations in the analysis. A time-series analysis would allow monitoring impact of plans and developments on public health. This would require setting up an institutional and procedural framework to periodically collect and analyze health and built-environment data.

• The HIA is meant to be more of an exploratory analysis that can act as a springboard for a more comprehensive and broader impact assessment framework. Results from this analysis reveal the importance of built environment in public health considerations and it can justify a more comprehensive study involving more stakeholders.
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22. Walking, Cycling, and Obesity Rates in Europe, North America, and Australia.
References


23. Inverse associations between cycling to work, public transport, and overweight and obesity Findings from a population based study in Australia. Wen, Li Ming and Rissel, Chris. 2008, Preventive Medicine, pp. Volume 46, 29-32.


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