Complete Streets Evaluation Tool for the City of Worcester

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Abstract

The City of Worcester is an industrial era city, currently working on ways to increase transportation accessibility for its residents. Worcester has adopted a complete streets policy that mandates accessibility upgrades whenever infrastructure construction occurs, with a focus upon accessibility for all users. The city is looking to expand their current plans in order to target specific areas around Worcester that need the most improvements. Currently, tools that evaluate the completeness of streets focus mainly on evaluating walking and biking access, while Worcester desires to increase public access for all users, including cars. The purpose of this project was to create an evaluation tool that creates an unbiased breakdown of accessibility for all types of transportation. This grading scale was created by first gaining a better understanding of what direction city government and local stakeholders wanted to take the complete streets policy. After interviewing local stakeholders existing street accessibility evaluation tools were analyzed and aspects from each one were selected and, if need be, modified in order to evaluate the transportation access of Worcester.

Acknowledgements

We would like to sincerely thank the local stakeholders that agreed to be interviewed in the course of our project. These people served as great sources for information as to specific needs of the city and future plans in Worcester, and were instrumental in creating a set of recommendations tailored to the needs of our specific city.

We would also like to thank Professor Robert Krueger for being an amazing advisor that was able to guide us in the right direction while allowing us enough autonomy to make important decisions that shaped the development of this project. Professor Krueger worked with us through any issues we came across to ensure that we had a rewarding and complete IQP experience.

Executive Summary

Worcester is an evolving city that is on the cusp of its next big change. The city was built in the industrial era, before cars were a part of the everyday transportation for the average citizen. Worcester was initially laid out to be walkable for the factory workers living in the urban center, with less dense housing in the surrounding area. As cars became more popular, existing transport networks had to be retrofitted to accommodate automobiles. Roads were constructed along existing transport corridors, leaving little space left for walkways or bicycle travel. As time progressed, travel accommodations became skewed towards the automobile, creating lapses in accessibility for people who do not, or cannot own cars. As the car gained popularity Worcester began to spread outwards, eventually exhibiting some indicators of urban sprawl. The initial design of Worcester did not account for the invention of the automobile, and the residents of the city still suffer from restrictive transport options stemming from the means by which cars were integrated into the layout of our city.

Today, Worcester is working on creating a new plan for its future development, with a renewed focus on increasing accessibility for all. Worcester City Council has created a Transit Advisory Group (TAG) that is in charge of directing implementation of these new policies. The TAG is in its initial stages, but is already creating goals for new projects, including increasing the accessibility for bikes, cars, and pedestrians across the city in a context sensitive manner. In order to accurately increase accessibility, the existing problems, bottlenecks, dangerous areas, and high traffic zones need to be located and remedied. The goal of our project was to work with local stakeholders to create an evaluation system able to assess transportation accessibility based upon the specific goals of the city. we worked to create a rubric that could be used to evaluate the "completeness" of streets in different locations across Worcester.

In order to achieve this goal, we compiled background research on the different types of complete streets approaches, the existing accessibility evaluation tools, and Worcester government/stakeholder opinions. Creating a solid background was very important when evaluating for completeness, and the information gathering stage of this project included research into the causes, effects, and proposed solutions to urban design problems of today. Alongside understanding the goal of complete streets initiatives, understanding how existing evaluation tools calculate accessibility was necessary to create an accurate grading tool. While most tools only evaluate based upon pedestrian or bicycle access, the key elements and features of each existing evaluation system were compiled and analyzed to see if their methods could be modified to evaluate both automobile and public transportation access as well. Usable elements from each evaluation tool were then compiled into a database and overlapping features were either combined or chosen based upon their implementability. These key features were then modified in order to work together to create a unique evaluation tool that focuses on evaluating the accessibility for pedestrians and bicyclists, while also maintaining a focus on access for the automobile.

In order to create an evaluation tool that better fits into the City of Worcester's development plans, we interviewed a selection of local stakeholders and government officials. We talked with members of city council, alongside the heads of local transportation advocacy and planning groups in order to familiarize ourselves with the goals of our various local stakeholders. These people were also asked about their experience with other street evaluation tools to get a better understanding of what features they found most useful. After gathering this information we proposed a system of evaluating the transportation landscape in specific areas by compiling scores for accessibility that measure each type of transportation independently. Along with the format of our proposed evaluation tool, we compiled key design elements that are responsible for the accessibility of the street into categories that can be made into a grading system.

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1. Introduction

Aging urban infrastructure struggles to keep up with the demands of today's commuters. According to the American Society of Civil Engineers “More than two out of every five miles of America’s urban interstates are congested” with a “significant and increasing backlog of rehabilitation needs” (ASCE, 2017). These roads were not designed for the amount of cars being used to commute today. This amount of traffic leads to increased levels of congestion, pollution, urban sprawl, and unsafe conditions for pedestrians and cyclists (Bhatta, 2010; Frank, 2004).

As the amount of people commuting by car in urban environments increases, the danger posed to pedestrians rises. Between the year 2006 and 2015 pedestrian deaths increased by 12% (NHTSA, 2016) up to 5376 pedestrian fatalities, with nearly 80% of them occurring in an urban environment. Many urban centers, especially in the northeast, were not designed for cars, leaving dangerously small gaps between speeding cars and pedestrians on their way to work.

Cities that are designed with a bias towards the car also open themselves up to public health problems. The sedentary nature of commuting by car negatively impacts heart health, with every extra hour per day spent commuting the risk of heart disease can increase by 6% (Frank, 2010). urban designs that create safer walkways and protected bike paths have been shown to encourage walking around city centers (Heath 2006). As cities begin to implement complete streets policies that encourage walking, residents will have more options to exercise and reduce their risk of heart disease. With obesity on the rise, cities must make every effort to encourage making healthier choices in day to day lives.

Areas that see heavy automobile traffic have also been linked to higher levels of airborne pollutants (Zhang 2013). Gasses emitted as exhaust contains harmful chemicals and particulate matter that negatively impact quality of life in urban centers. Cities that heavily rely on cars for transportation also see higher levels of asthma attacks along heavy traffic routes and in city centers (Kelly, 2017).

City governments are beginning to recognize and treat the problems that stem from the current urban design methods. In an effort to combat these problems, more than 1300 state and local governments have begun to implement complete streets policies (NCSC 2017). These policies use a variety of different methods in an effort to make streets more accessible to people of all ages, races, abilities and tax brackets. Complete streets policies create safer, greener, more appealing urban centers, aiming to mitigate urban spread and plan for a future where space is at a premium and our urban centers are even more densely packed. Some policies create special zoning rules to improve accessibility in all new construction projects, while others mandate that all infrastructure repair projects must be evaluated from a complete streets perspective and if need be changed in order to bring access to more constituents.

Access can be improved through the implementation of many different design aspects. To improve pedestrian safety many cities are improving walkways, separating pedestrians and automobiles, and reducing the designed road speed in urban environments. Green space is also a key element within complete streets projects, used both as a means of cleaning up air pollution and as a barrier between cars and people, while also improving the aesthetics of the city. The implementation of new public transport routes can be an effective means of improving access in communities that are lacking. Choosing which implementation strategy to follow depends heavily on surrounding land use, traffic patterns, and points of interest.

Various different groups have created tools that evaluate streets for a variety of different, accessibility based metrics. Most current evaluation tools look at street safety from a pedestrian point of view, grading based on metrics that prioritize walking and biking. Worcester's city government has a slightly different goal, focusing on improving accessibility for all transport including the automobile. To accurately evaluate streets for how well they meet this goal, a new evaluation tool needed to be created.

The goal of our project was to create a custom evaluation tool that is not biased towards one method of transportation. This tool was created by analyzing different aspects of each existing evaluation tool, and compiling each ones usable metrics or other key elements into a matrix of grading parameters. The new grading system is intended to be used to evaluate which locations need improvements to accessibility, but can also be used on a wider scale to evaluate possible future projects such as a protected biking or walking path through the city or moving more cars through specified corridors as opposed to directly through the urban center.

2. Background review

The purpose of this section is to lay out the different elements that guide our specific goals for this project. We gathered information to better understand the elements that make up a complete streets approach to urban design, as these practices show what proper street design entails. It is also important that we built a good understanding of different types of problems persisting in today's urban landscape of Worcester. We then conducted interviews with city officials and local advocacy groups to gain insight into what goals they have for the development of Worcester. From here, we researched the different existing evaluation tools and how they are applied to evaluate streets, detailing each ones different parameters and key features. With all of these elements in mind, we outline the key features of our custom evaluation tool and their relation to the specific needs of the City of Worcester.

2.1. Understanding the Problems

Walking through our nation's urban centers is becoming more and more dangerous. In the year 2014, 4,884 pedestrians were killed by cars, an increase of 105 over the previous year (Dangerous by Design 2016). these deaths mostly occur in urban settings, due to the close proximity of cars to people. According to the NHTSA, 78% of all traffic fatalities in the year 2014 occurred in urban settings (Pedestrian Traffic Safety Data 2014). Having cars travel at speed mere feet away from a sidewalk leaves little to no time for either party to react, with the pedestrian nearly always coming away worse than the automobile. Currently, most cities have traffic flowing in all lanes with a pedestrian walkway of some sort adjacent to the road. Traveling at only 25 MPH, it will take the average driver over 60 feet to stop, and at a more realistic speed of 30 MPH it takes nearly double this distance, 119 feet (NHTSA, 2015), which is too far to be able to safely avoid all incidents.

The current system favors accessibility for automobiles over less expensive alternative modes of travel, allocating more infrastructure upgrades towards increasing flow of/condition of the roads. At its core, this bias hurts people with lower income, as people who are able to afford a car tend to have higher incomes than people reliant on public transportation. On top of this, most housing located around urban centers is populated by people of minority descent or lower income. These people live in a part of most cities that has been taken over by the automobile, but many do not have a car to take advantage of this. It is these people who live in a smaller radius from urban centers that benefit most from complete streets policies. Minorities represent a higher population of traffic incident victims, with non-white pedestrians making up 46.1% of traffic deaths yet only comprising 39.5% of the nations population (Dangerous by Design 2016).

The designs of these urban neighborhoods favor high auto traffic flow over walkability which leads to the rise in risk posed to the residents, and as population density rises the effects become more pronounced. The urban population made up 80.7% of the population as of the 2010 census, and those numbers are predicted to rise by the 2020 census. Over the time period from 2000 to 2010 the population numbers in urban centers rose by 12.1%, and even this rate of increase has been increasing for the past 3 decades worth of census data. According to the ASCE, 2 out of every 5 miles of urban highways are congested at the current load (ASCE 2017). As more and more people move into our city centers, the flaws with the current system will become much more evident. The already crowded roads will become congested, and the current state of most cities public transport infrastructure will struggle to cope with increased ridership.

The transportation climate of today poses health risks to the general population. Cars emit pollutants and particulate matter into the air, increasing the risk of childhood developmental problems and asthma (Guarnieri, 2014). These cars generally commute into the urban center from wealthier suburbs, exposing people who live in poorer urban neighborhoods to higher levels of pollutants. These maps show road traffic emissions and asthma related hospitalization rates in the City of Baltimore, showing that the bustling urban center of the city has a higher level of asthma related health issues (Kelly, 2017).

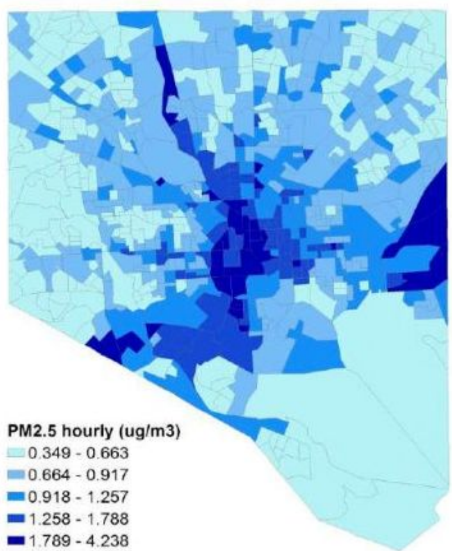

Figure 7. Hourly $PM_{2.5}$ Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

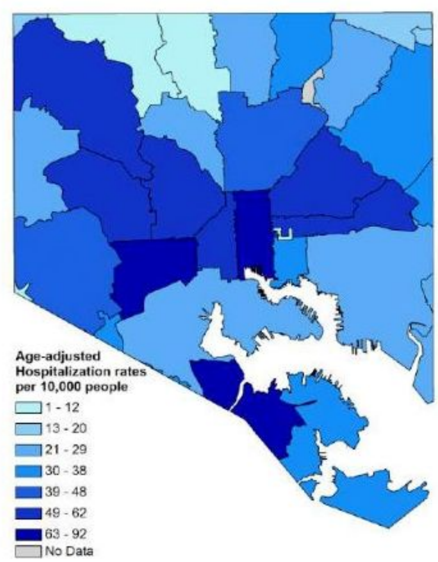

Figure 8. 2011 Asthma Hospital Discharge Rates

On top of the issues with pollution caused health problems, the unsafe conditions deter potential walkers, feeding back into the pollution problem but also exacerbating the obesity epidemic in America. Nearly a third of the United States population is obese (CDC 2006) with more than half of the nation not getting daily exercise or physical activity. For each additional kilometer walked above the average daily distance the likelihood of obesity goes down by 4.8% (Frank, 2004). Streets designs in the United States do not provide pedestrians with peace of mind, leading to less people wanting to walk places.

2.2. Understanding the Complete Streets Approach

The complete streets approach to urban design focuses on bringing accessibility to all people, regardless of social standing, age, or race. A "complete street" is one that has designed provisions to increase safety and walkability for pedestrians, encourages the use of public transportation, maintains green zones to mitigate pollution, all while maintaining a proper level of safety and efficiency for people who commute via car. These goals can be achieved through various different means, and can be enacted on all scales from small midwestern farm towns all the way up to some of the largest cities in the United States.

Complete streets are often implemented through different methods by the different local governments. Some policies regulate new construction, while others mandate that some money used for infrastructure surface repair be spent improving pedestrian and bicycle access. The regulation of new construction is a useful tool in a developing city with room for development, and it can help urban centers grow in a controlled and accessible manner. Cities that are already established benefit the most from the repair and replace method of converting old streets into complete streets. As cities get older they need more maintenance, and it only makes sense to complete upgrades to infrastructure at the same time. No matter what methods they use to implement their policy, each of these laws encourage changes to urban design which increase the usability of the street for all constituents.

Adopting a complete streets approach to urban planning is an effective way of mitigating pedestrian risk. Studies have shown that amenities including both on-roadway, and separated bike lanes served to increase bicycle safety in minnesota (Reynolds, 2009). At the same time, walkway upgrades like expanded sidewalks and improved buffers between automobiles and pedestrians encourages more use of these facilities. Other possible complete streets implementation strategies aim to impact our cities further down the road. Creating more walkable city centers encourages commuting into the city via public transportation or carpooling and then walking between places, allowing people to leave their cars outside of the congested urban center. Improving existing transportation infrastructure can also influence property values in currently less desirable urban neighborhoods, while also boosting jobs adjacent to major thoroughfares. After improving their pedestrian side of its transportation network by refurbishing walkways, planting street lining trees, and lowering the designed speed of auto traffic, property values in gainesville, FL increased by around 6%, along this same time period jobs adjacent to the main thoroughfare increased by 20% (NCTR, 2015). Complete streets policies serve to improve the existing problems in today's urban landscape while at the same time plan for an equitable, accessible future.

2.3. Complete Street Goals for the City of Worcester

To better understand the direction that the city wants to take with its complete streets implementation, we interviewed local government officials as well as members of local transportation and urban planning advocacy groups. These are people who have some power over city policy, or wish to influence the direction the policy goes. While their areas of expertise and pre-existing biases were spread across the realm of urban planning, the desire to increase levels of accessibility for everyday people was shared by every interviewee.

The focus of most local transportation advocacy groups has mostly rested on reducing our dependence on the automobile while increasing safe accessibility for cyclists and pedestrians. People who commute via self powered means (walking, biking, skating) have often been overlooked when designing roads, and streets are often not organized in the safest configuration for these commuters. In our conversations with the heads of a local transportation advocacy group, WalkBike Worcester, it was made clear that their priority rests in bringing safety to members of the community who do not have use a car to commute. The group focuses on advocating for less traffic in urban centers in an effort to reduce congestion and dangerous proximities between cars and people. In the past the WalkBike group has advocated for the installation of bike lanes, improvement of sidewalks, and narrowing of traffic lanes. Bike lanes and improved sidewalks make it more appealing and easy to commute via foot, while narrowing lanes effectively reduces the speed at which cars can travel on the roadway, altogether making the city a safer, easier place to walk.

City governments have to take a more conservative approach to implementing these practices, as an interview with Worcester Assistant Chief Development Officer Stephen Rolle revealed. Worcester and its government have the same level of concern for increasing pedestrian safety, yet they also have to answer to members of their constituency that rely on the automobile. The city is looking to increase accessibility for pedestrians, cyclists, the poor and the elderly, while not reducing accessibility to those who commute from the suburbs to work. There are many different methods of increasing accessibility, but most of them take away space, or ease of use for car commuters.

Mr. Rolle is also working on creating a 30 year master plan for development of Worcester, with the complete streets plan being a large part of its focus. As such, the city is working to decide which complete streets implementation methods to follow and where. One complete streets design in the works includes separated routes for the different methods of transportation, with a bicycle route, and a main road for automobiles. This would keep the different means of transportation mostly separate from each other, vastly reducing the risk of pedestrian injury. To help decide where these routes should be implemented, and also as a means of deciding locations which need improvements in the coming years, we suggested that a custom evaluation tool be created.

2.4. Existing Evaluation Tools

There are many tools that can be used to evaluate the function of streets, with each one being unique in some aspect. These tools are used to decide where the street is performing well, and where the design is not living up to its intended function. Evaluation tools serve to detect problems and hope to inspire change in that area. There are many different types of street evaluation tool, most being based in pedestrian safety awareness. Each one of these evaluation tools uses different methods of quantifying the streets performance, some using input performance indicators such as population number and trip destinations, while others measure outcome performance indicators such as increases in the number of pedestrians and cyclists. These different methods for evaluating streets are used to evaluate different aspects of street design, but they share some common or similar features. Each tool that we analyzed has some influence over the design cues of the custom tool, whether directly using evaluation methods of an existing tool or creating an understanding of things that will not help our goals.

2.4.1. Toronto Center for Active Transportation(TCAT) Complete Streets Evaluation Tool

The toronto center for active transportation (TCAT) created its evaluation tool in order to understand how effective its complete streets measures actually are by looking at outputs related to outcomes of the complete streets projects. These outputs can be represented as distances added to bike paths or width added to walkways, or any number of infrastructure improvements. Outcomes of the projects include any effects felt by civilians and road users caused by these changes, such as increases in pedestrian traffic flow or decreased total transit time are called output performance indicators. The TCAT evaluation tool uses 21 different outcome performance indicators separated into 4 broad evaluation categories including level of safety, level of service, active and sustainable transportation, and the surrounding environment. This method of evaluating streets is very useful for evaluating the effects of the changes brought by a complete streets policy, allowing city planners to see where their ideas are working and where they need to try something else. These methods can be applied to areas that have not had complete streets projects installed, but would most likely only be able measure the decline or improvement of road performance with fluctuations in traffic density or as time passes.

2.4.2. Local Access Score (LAS)

The Local Access Score is a metric created by the Metropolitan Area Planning Council (MAPC) to evaluate the current and or possible potential for use by walkers and bikers in any city in the United States. The LAS can evaluate whether a given route between two points would be used if it were more accessible to foot traffic, and can show if the roads are important connectors for residents to the community fixtures such as schools, workplaces, or city centers. This evaluation tool uses data on the population numbers and the destinations traveled to within the city to estimate how useful a stretch of road is to the residents of the city. The LAS evaluates trips started and ended between zones, the preferred mode of transportation between them, and the directness of the route between starting and ending census blocks. This tool can be used to direct the efforts of the complete streets projects to areas that are high in utility or in need of improvement, focusing the efforts of city development teams. Using the LAS, cities can evaluate where they should focus snow clearing efforts in the wintertime, as well as managing where signs are placed in locations that have heavy pedestrian flow, or are intersections of major walking paths so that more people walking see them.

This evaluation tool is useful for cities that want to see where they have heavy pedestrian and cycle traffic, and is great for directing the implementation of complete streets projects to places where they will be the most effective. With some modifications this tool could easily be broadened or modified to create a complementary tool that evaluates heavy utility zones for auto traffic in and out of the city, allowing for a more complete and less pedestrian biased evaluation of urban infrastructure.

2.4.3. Broward County Evaluation Toolkit

The Broward county complete streets initiative has compiled a selection of street evaluation worksheets that work together to provide a complete breakdown of street "completeness." These worksheets are broken down into 4 different, broad evaluation goals: balanced mobility, safety, health and sustainability, and economic vitality. Each goal has at least Three worksheet tools that measure a different aspect of the transportation landscape. Some worksheets measure the amount of pedestrians and cyclists on the roads, others measure crash statistics, while some measure the environmental and monetary impacts of commuting in the city. The Broward county evaluation toolkit creates a very wide spread of numerical data through the many different worksheets it contains, which can be interpreted by itself or brought together and evaluated based on the outcome of recent repairs to see if streets are being improved, or if they are falling into disrepair.

2.4.4. City of Henderson Complete Streets Evaluation Guidelines

The City of Henderson, NV has set up a much less rigid method of evaluating their streets, using a set of best practices and broad evaluation categories to guide their policy choices. This method evaluates the demand for complete streets through population metrics and land use intensity, evaluates the need for complete streets from a public safety, security and mobility standpoint, and evaluates for compatibility with complete streets by looking at road design and connectivity between roads.

The demand for complete streets projects in henderson is evaluated based upon Land Use Intensity, which takes into account the residential density, commercial density, density of other attractions, traffic, and transit ridership. Generally the higher the residential, commercial and other attraction density, the more demand for complete streets. Need for these projects is based on safety, crash statistics, and security, the ability for intentional harm to be caused, of the roadway. Road safety is evaluated through road audits, which take in depth looks conflict points along the corridor and through looking at the highway crash history report for any specific locations that have high numbers of traffic incidents. Security is measured by the amount of crime stopping features the road has such as adequate street lighting and bicycle locking racks. To evaluate the compatibility of a road the geometric design elements of the thoroughfare, such as right of way constraints and the amount of traffic lanes, are evaluated along with the connectivity of the road to other major corridors.

2.5. Creating a Custom Evaluation Tool

As the City of Worcester begins to build its plan for future development, the need for an evaluation tool that evaluates streets with these specific goals in mind is at an all time high. Worcester needs a way of looking at the existing road network to see which parts need fixing, and which areas would be most impacted by new developments. The goals of Worcester's complete streets plan demand that a new tool be created that takes key aspects from existing evaluation methods and combines them into a new tool that evaluates all types of transportation. Creating this evaluation tool relied heavily on the input of local stakeholders, especially the input of local government officials who will be writing the 30 year plan. In its final state the tool will give urban planners working in Worcester city government the ability to see where the current system falls short and in what way, while also providing accessibility ratings for each mode of transport between two places.

2.6. Understanding the Objectives

Understanding the reasoning behind how other cities create their evaluation tools was a key factor in creating our own custom evaluation tool. The factors that each different evaluation tool focused on reveal what each city government prioritizes when looking at complete street design. To create this level of understanding, our group first conducted research on what design cues and amenities are included in different complete streets projects across the country, while simultaneously researching the problems exhibited in non-complete streets designed streets. This provided base information on what to look for when evaluating the completeness of a roadway. After this we analyzed and catalogued the differences and similarities in multiple different evaluation tool kits. From this we can extrapolate the most important features of each evaluation system, drawing links between separate evaluation tools.

To create a better evaluation tool for the City of Worcester we needed to combine these different elements into one cohesive unit that evaluates roads more comprehensively, fairly, and accurately than its predecessors. Having an understanding of the shortcomings of existing evaluation tools also became important, so that we can avoid making the same mistakes. This process created a hybrid evaluation tool, made of the best parts from many different tools or worksheets.

It was also important to have a good understanding of our stakeholder goals going into this project. As such our interviews focused on which direction they would like to see the city head in regards to complete streets implementation, and their thoughts on current evaluation models. Understanding The aspects of existing evaluation tools that were well liked by stakeholders helped us to understand which parts of existing tools work the best and which were less important. On top of this, understanding what each stakeholder thought would be most important to evaluate allowed the team to cater our evaluation tool to the specific needs of the City of Worcester.

3. Methodology

This chapter outlines the information collected, reasons behind collecting the data that we did, and the methods for collecting data that relate back to our goal of creating an unbiased evaluation tool for the City of Worcester. The goal of this project was to create a complete streets based evaluation tool that is catered to the needs of Worcester, as determined through our interviews with local government and advocacy leaders. Our tool would be based around the requests of local stakeholders, but is applicable in any city that is looking to create roadways where cars, bikes, and pedestrians all have adequate levels of access. Our project was broken down into three stages, the information gathering stage, the data organization stage, and finally the construction stage. The gathering stage of our project included building an understanding of the complete streets approach, along with the analysis and cataloging of existing street evaluation tools and their evaluation factors. In the organizational phase, unique factors were logged in an excel sheet as each tool was eventually broken down into its key elements and evaluation metrics. In the creation stage, we took elements from these key features and created a list of goals to focus on, with different evaluation factors grouped by goal. We then created evaluation worksheets for examining the pedestrian and bicycle accessibility and safety of the roads. These scores were then augmented by an expanded version of the Local Access Score that has been modified to include automobile transport routes. This modified LAS serves to evaluate the balanced mobility of the street design.

3.1. Information Gathering

The information gathering stage consisted of the majority of the time allocated to this project. It was during this phase that we conducted our background research and built an understanding of the problems of today and how a complete streets program can mitigate these issues. This provided a solid base to build an understanding of the reasons behind picking the different metrics for evaluation. Understanding features that make up complete streets allowed us to better understand what facets of urban design we should be evaluating. To further enhance our base of information, we gained insight into the opinions of local stakeholders about the future plans for Worcester, along with their opinions on existing transit evaluation tools. We also explored the different evaluation tools available and compiled a list of ones that were more applicable to our project. In order to narrow down the field of evaluation tools, only those which analyze effects of urban design changes, include a grading system that accurately represents results, while also being made publicly accessible were included in the final report. This does not mean that the other systems do not influence our suggestions, but they did not contribute direct measurement factors. Each one of these evaluation tools looks at street design from a complete streets perspective, with broad categories such as evaluation of street safety. These categories are made up of more focused evaluation metrics, including measures of pedestrian traffic fatalities and the quality of a specific type of transportation infrastructure.

3.2. Organizational Stage

In this stage of our project, we began working on how to store this data in an easy to understand, easy to access way. We decided to create an excel document to catalog the different parts of each evaluation tools. This catalog has been refined through various different iterations, starting off with only the key elements of each tool, eventually we hope to transition this into a database of each tools evaluation topics and the individual measurements that make up each segment. Similar evaluation practices appeared across the different evaluation tools, some even sharing very similar main evaluation categories. Forming the catalog of evaluation metrics allowed us to easily sort through the different tools to find common practices, saving great amounts of time in the process.

3.3. Compiling the Tool

Due to time constraints our evaluation tool was not able to be fully completed, instead we have compiled recommendations for layout and grading focus of a tool custom designed for the City of Worcester. We compiled three different sets of grading criteria that can be compiled into separate grading sheets for each type of transportation that the city wants to focus on.

In order to make our recommendations for the layout of a potential evaluation tool, we analyzed evaluation methods and metrics used by each tool to find aspects that were similar between methods. We found that most evaluation tools worked by breaking the focus of the evaluation into smaller evaluations of specific categories, many of which are nearly identical. Based upon similarities exhibited in our catalog of features we planned to focus our analysis on the road safety, sustainability, and accessibility of Worcester transportation networks. In order to evaluate the functionality of a roadway for multiple types of transportation we decided that creating separate evaluation surveys for automobiles, public transportation, and pedestrian/bicycle accessibility would lead to the most useful results for Worcester. Along with the previously mentioned evaluation format, our group proposed various design elements that can determine the accessibility of a roadway to focus on.

4. Findings

Every existing evaluation tool uses Different methods to evaluate the “completeness” of streets. These evaluation tools often had intermutual design aspects, such as a shared framework, common measurement factors, and similar focuses, but each had a different set of stakeholder goals for evaluation. In order to create the most effective evaluation tool the needs of local stakeholders must be considered when selecting aspects to measure. In our research, we found that effective evaluation tools: were often created by breaking down the task of street evaluation into smaller subgroups (such as accessibility or pedestrian safety), used a variety of different methods for evaluating streets, and followed the input of local stakeholders. Building a tool around the specific needs of the City of Worcester will optimize the results to help tell local stakeholders exactly what they need to know in order to make better informed decisions about complete streets implementation.

4.1. Proposed Layout of the Tool

Our proposed evaluation method was created to be easy to implement in order to measure of the accessibility and “completeness” of specific locations. Through compiling data from many locations it would be possible to evaluate areas to identify and address transportation bottlenecks. The tool we propose is intended to be used to measure both immediate completeness of roads and areas that need improvements, but could easily be adapted to measure how the design changes have affected the transportation landscape.

In order to make our tool easy to use, we needed to make our evaluation sheets simple while still measuring access for all means of transport. Attempting to measure all forms of transport through one evaluation tool will create a very complicated system that requires more time to create, increases the complexity of data gathering, and will make it more difficult to interpret data. In order to simplify the evaluation tool while maintaining input from all modes of transport, we decided to break it into smaller surveys that focus on a single mode of transport. Through our talks with local stakeholders, we found three modes of transportation that were most important. These stakeholders emphasized the importance of public transportation networks, along with sidewalks and bike lanes that encourage self powered transit, while maintaining accessibility for people who commute via automobile. Using these three different evaluations we will be able to compile three different scores for each area surveyed, allowing for stakeholders to see which areas of the city have accessible transportation for a specific means of transport. It is important that we split the different means of transport into different evaluation frames because some designs that improve flow of one type of transport can negatively impact the flow of other modes of transport. One such example of this is shown when attempting to use a single survey that evaluates both automobile and pedestrian access. Some aspects of that area might be beneficial to one side of the transportation landscape while at the same time detracting from the accessibility of the other means of transportation. This poses a problem for cities that wish to create more access for all transportation as opposed to cities that need to improve in one specific area.

Our proposed tool will be able to measure accessibility for 3 types of transportation; automobile, public transport, and walking/biking. Local stakeholders, such as WalkBike Worcester, have placed an emphasis on reducing the need for residents to commute via automobile by making the roads safer for self powered transportation. Our tool will allow them to evaluate which areas of the city are less safe for pedestrians and work with the local government to implement changes. When talking with local city planners, they mentioned a potential plan that would split traffic flow into areas that are specifically laid out for each means of transport. Using the three different scores they will be able to identify areas that are currently better suited for one mode of transport in order to better plan out potential routes that segregate transportation types into contained areas.

4.2. Grading System

There are a number of existing transportation infrastructure grading tools, but in order to create a better tool for Worcester we found the need to create a brand new set of surveys. This customization allowed us to emphasize the needs of local stakeholders and work around constraints created by current urban landscape. In our discussions with local stakeholders, we decided to focus on evaluating individual methods of transport across many different areas. This method will create different scores related to each means of transport at each location, allowing city planners to focus on one transportation method at a time with no influence from the other scores. An added bonus of using smaller, simpler evaluation surveys is the ability for many people to be surveying at the same time, with less variation in their data collection. The sheets will be simple to understand and have no room for interpretation, meaning that data can be collected by large teams of volunteers with minimal training required.

To create a grading criteria that provides achievable goals for Worcester, we looked to other cities in the north-eastern United States. One such city, Boston has created a complete streets design guide with recommendations for size of sidewalks, bike lanes, buffer zones, green spaces, and other aspects of complete street design. While the City of Boston has many similarities to Worcester, they are still quite different. Boston is a much larger city with more money for reconstruction and a more densely packed layout of streets dating back to the colonial times. Taking into account these differences, guidelines relating to traffic flow, accessibility, and user safety were selected and modified to create survey questions that would focus on measuring flow of one type of traffic in a specific area.

Criteria that affect the flow of transportation were selected from categories such as street layout, surrounding land use, and presence of designed safety features. Some of the factors that would give high points when evaluating one type of transportation could be detractors when evaluating other means. This is most evident in the balance between pedestrian and automobile access, where more lanes and fewer speed controls will increase potential traffic flow while at the same time can make commuting by foot more dangerous in that area, highlighting the need for independent evaluation. Our design allows these contradicting designs to be evaluated both for the method of transportation they help and the ones that are hindered by its layout. Factors that will be evaluated for automobile access include: max vehicle size, number of lanes, speed limit, zoning district, intersection type, street type, size of pedestrian buffer zones, allocation of green space, proximity/connection to points of interest and types of engineered speed controls. When evaluating for pedestrian and bicycle access, aspects such as: sidewalk size, buffer spaces, type of curbside parking, slope, individual bike lanes, type of crosswalk, Bike storage, quality of sidewalk/bike lane surface, green space allocation, and ADA compliance are going to be most important. To evaluate public transport access the measurements include: number of bus stops, proximity between bus stops, designated bus lanes, frequency of public transportation, access for elderly/disabled, connections to points of interest, bus stop design and price.

Points will be awarded to designs that encourage safe traffic flow or designs that exhibit characteristics seen in complete streets guidelines across the United States. Some things such as amount of traffic lanes or speed limits are somewhat easy to assign points to, while other aspects of complete street design such as green space integration or presence of buffer zones proved harder to directly correlate to improvements in street completeness. We compiled a list of suggested points breakdowns that take from complete streets design guidelines as well as ADA compliance regulations that were compared with the specific goals of the future development plans for Worcester. These design aspects are suggestions that should guide what areas each survey focuses on, with some explanation as to why and how they impact street completeness.

4.2.1. Scoring for Pedestrian Access

- Sidewalk size
    - increasing sidewalk size makes it easier for more people to utilize them at a time, and makes it possible for people who require wheelchairs or other forms of assistance to commute via sidewalk. Sidewalks should aim to be 36" or wider in order to receive highest points as this is the minimum size put forth by the BCSDG for new construction.
- Buffer zones
    - buffer zones should be present on either side of the walkway in order to receive full points. Buffer zones provide safety from cars on the traffic side and relief from snow accumulation on the building side.
- Type of on roadway parking

    - Curbside parking has been shown to be less safe for pedestrians and motorists alike, as it can block drivers line of sight, reducing the time to react if a pedestrian walks into the street. Higher scoring options should include parking along a center median, bans on curbside parking near intersections, or simply no on roadway parking.
- Slope of the ground
    - The slope of a sidewalk directly relates to how accessible and enticing a route is for pedestrians. The ADA recommends a slope ratio of less than 1:20 in order to maintain accessibility for all Americans, with less points being awarded depending on how much higher the slope is.
- Bike lanes
    - Presence of safe bike lanes encourages more people to try commuting via bicycle, as such points should be awarded to the most safe designs of bike lane. Segregated bike lanes with some sort of divider are the safest and should receive maximum points, while shared or time dependent bike lanes receive fewer points.
- Crosswalks
    - Crosswalks should be well lit and frequent, while ensuring that all users have adequate time to cross. Points should be taken off for lack of frequent crossings, short cycles, or no indicators of a mid block crossing (signage, neck downs, chicanes).
- Storage for bicycles
    - Creating public bicycle storage encourages more use of bikes for transportation. Allocating space for bicycle parking incentivizes people who would otherwise be

paying for a parking space to use their bike. Points should be awarded based on the level of bike storage in the area.

- ADA compliance
    - In order to maintain some level of accessibility during all weather sidewalks need to be constructed out of uniform material that is firm, non slip, and lacking of gaps larger than ½” as stated by the ADA. there should also be modern crossing interfaces that assist the blind, and feedback plates at the base of all ramps in the curb. points should be taken away for any lack of these requirements.

4.2.2. Scoring for Automobile Access

- Zoning district
    - Surrounding land use and zoning conventions drive the requirements and restrictions of the roadways. Business, manufacturing, or farming districts have less danger posed by pedestrians, allowing for larger roads with faster flowing traffic. City centers and residential areas are more populated with pedestrians and are safer when paired with a narrower road with lower speed limits.
- Street type
    - Boston complete streets guidelines lays out different street types and links them to types of land use. Points should be awarded for streets that match with their surrounding land use.
- Type of intersection

    - Roundabouts are a staple of complete streets design ideology and can improve traffic flow when compared to traditional traffic lights. Stop signs and uncontrolled intersections are less safe and create more backup and should be scored lower as such.
- Lane width
    - Narrower lanes can serve to make roadways safer by encouraging drivers to slow down, and reclaiming lane space and using it as a pedestrian buffer zone can increase safety and accessibility for all. Wider lanes should be scored lower because they encourage higher rates of speed and waste precious road space.
- Speed limit
    - The Boston Complete Streets Design Guidelines recommends a maximum speed limit of 25 miles per hour in city centers, with larger roads such as parkways being allowed to have somewhat higher speeds up to 35 miles per hour.
- Number of lanes
    - According to the BCSDG, a 2 lane street with a shared central left turn lane is the most safe and accessible layout for city streets. Points should be reduced for lack of a protected turn lane, excess lanes such as a right turn only lane unless needed for a specific reason, or too many lanes, 4 or more.
- Engineered speed controls

    - Certain design features are installed for the sole purpose of slowing down drivers in areas that have high pedestrian traffic. Speed bumps or tables, mid block neck downs in road size, and narrow lanes encourage drivers to slow down, giving them more time to react to pedestrians. Points should be awarded based on the presence of these designs and taken away if an area is lacking in speed controls.
- Green space allocation
    - Green spaces reduces the carbon impact of the automobiles commuting along a roadway and is considered an important part of complete street design.
- Smart sensors
    - Automation and optimization are becoming more accessible as technology advances and when applied to our cities, traffic flow can be vastly improved. Smart lights and crosswalk sensors should be implemented to keep traffic flowing on major traffic arteries when smaller streets are not being used. Points should be rewarded for presence of smart automation.
- Type of parking
    - Parking that is separate from the roadway creates the smallest negative impact on traffic flow, while designs like curbside or median parking have varying, but notably higher levels of impact depending on their layout.

4.2.3. Scoring for Public Transportation Accessibility

- Number of bus stops

    - Bus stops by nature should service the same locations in both directions to make public transit as easy for all people as possible. Points should be awarded for stops that service both directions, and taken off for lower levels of service.
- Proximity between bus stops
    - The average distance between bus stops should be low in order to encourage the use of public transit. Creating walking distances that are less than ½ mile encourages more people to walk to a bus stop over commuting via automobile.
- Bus or subway lane design
    - Bus lanes flow better and are safer for riders when they are separate from automobiles. Maximum points should be awarded for a separated bus/subway line, and points should be taken off for increasing levels of automobile intervention into the lane. No points should be awarded if there is no defined bus travel path.
- Frequency of public transportation
    - Public transportation should be frequent to minimize the wait times of commuters, thus making it more enticing to utilize.
- Access for elderly/disabled
    - Public transportation hubs should be designed around ADA standards to ensure that all residents have the ability to utilize these services. Busses and trains should be designed to be wheelchair accessible, and the surrounding area should conform to ADA standards. Points should be

taken off if there are obstructions that would make it so fewer people can use the service.

- Connections to points of interest
    - Public transport should connect important locations, making it possible for people to commute into the city center from residential areas, especially areas where car ownership is low.
- Bus stop layout
    - Bus stops should be located in the safest position along the roadway in order to maintain rider wellbeing and minimize risk of incident. Stops should be well defined and have no-parking zones on either side.
- Price
    - The suggested price is going to vary from city to city and will often depend on decisions made by city planners and transportation advocacy groups. Future teams should work out what an acceptable price would be or include some similar breakdown assigning points based on how the system functions to increase accessibility for all levels of income.

4.3. Data Interpretation

We decided to lay out our survey in this way because it can provide multiple different insights from the same set of data. The surveys will produce raw “accessibility scores” that measure how each area evaluated affects traffic flow. This data can then be viewed on a case by case or whole city basis, and in the future can be looked at to see changes in accessibility over time. City planners would be able to see what areas need the most immediate improvements, while local advocacy groups will be able to filter out transportation methods that they are less concerned with. As Worcester moves forward with its revitalization plans city planners be able to look back through past accessibility scores to measure how complete streets design implementation has impacted accessibility in specific locations.

5. Conclusions & Recommendations

Our team was able to compile a set of recommendations for creating a custom street accessibility evaluation tool that is specific to the needs of the City of Worcester. These recommendations were based on in depth research into complete streets design aspects and existing evaluation tools, along with interviews with multiple local stakeholders related to the future improvements of Worcester. Aspects from successful complete streets implementation and evaluation programs were taken and modified to work with the goals and limitations of the city. we then recommended that these aspects be broken down into three different evaluations, that would measure accessibility across multiple different means of transportation. In creating these recommendations we concluded that:

1. Existing evaluation tools all function well for their designed purpose and location, but creating a custom tool based around the needs of a specific city will be more able to accurately focus on specific goals of said city.
2. There are many different, highly complex ways of evaluating cities, but the most cost effective method is to simplify sampling and grading in order to minimize both biases, and training needed for surveyors.
3. Local stakeholders provided critical insights into the shortcomings of current designs and direction of future focus, allowing us to develop recommendations that will be effective both today, and 20 years in the future.

Due to time constraints we were not able to fully deliver a finalised version of our evaluation system for Worcester. It was concluded that we should focus on creating a solid background of usable information in order to assist the next team that works on this project. Our recommendations for next steps for this project are as follows.

5.1. Implement the Tool

The features that we have compiled have the ingredients required to create a cohesive evaluation tool, but it needs to be implemented. Aspects of the tool including defining the specific point breakdowns and locating areas to survey are not yet complete and will need additional stakeholder inputs to be most accurate for Worcester. We compiled data on specific design aspects that should be evaluated, but future teams should work with local advocacy groups to determine how each aspect should be measured and weighed against the others. Certain design cues might become more or less important as the development plan becomes more defined, and the focus of our proposed tool would have to change in order to stay relevant. On top of this, future teams should work to create a database that will be able to display important parts of the collected data in an easy to understand manner. In order to assist future teams we have compiled all of our applicable research into the various local stakeholders and members of city government that helped us, along with research we completed into the various types of evaluation tools and complete streets programs that have been successful across the country.

5.2 Apply the Tool

Our next recommendation would be to make steps towards applying the tool and gathering data. Working towards the use of our recommendations to form a complete evaluation system would show which aspects are most useful and what parts that are less applicable than we first recommended. Future teams should work with the Worcester city government to begin data collection as soon as possible because the data gathered is more valuable when there are many data points from other locations that can be used as comparisons. In order to assist future teams in this we have created a short list of places in Worcester that are high traffic areas, and would be prime candidates for early evaluation.

5.2. Update the Tool

As Worcester moves forwards with its revitalization plans, smaller goals within this scope may change. As such it will be important for future teams to maintain contact with local stakeholders in order to make sure that their evaluation tool maintains its usability for the city it was designed around. Even if the goals of the complete streets implementation team do not change, feedback from these groups can help to clarify which parts of the tool are most important and can help to refine custom evaluation tools over the years. It is vital that the tool develop alongside the complete streets landscape in Worcester. With all of these things we are confident that the ideas we have put forth will be able to not only come together into a valuable evaluation tool, but also be able to adapt over the years to suit the specific goals of the City of Worcester.

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Appendices

Appendix A.

Table 1: Unique procedures implemented by complete streets policies in cities across North America

Location	Unique aspects of complete streets policy
Baltimore, Maryland	● Brings focus to underserved communities ● Mandates portion of budget for research ● Encourages cycling/walking/use of public transport
Las Cruces, New Mexico	● Form based zoning laws ● Creates a more walkable central plaza ● Influences future construction ventures, public and private
Stoneham, Massachusetts	● Created a public shuttle system for sick or elderly ● Expanded existing public transport routes ● Increases accessibility to voting centers
Québec City, Montreal	● Created a planning prioritization tool ● Plotted results on easy to understand map
Florida Department of Transportation	● Created a system for classifying surrounding land use ● Context classifications for land use ● Utilizes lower designed speed as opposed to speed limits

Philadelphia, PA	• Closed 10 mile stretch of road to open as a community space for a day • Selected area based upon its high pedestrian danger, and its proximity to underserved neighborhoods
Warsaw, MO	• Created extensive network of walking paths through neighborhood • Increased accessibility to schools and town center • Created a more walkable rural town
Bloomfield, NJ	• Directly engages communities most affected by prior urban design policy • Called for the installation of stop signs in many intersections to increase pedestrian safety • Created ad campaign calling for safer driving around children
Bonita Springs, FL	• Installed bike lanes, roundabouts to improve traffic flow and safety • Lowers designed speed through the use of on street parking and trees, textured pavement • Widened sidewalks to 9 feet
Alexandria, VA	• Evaluates streets for completeness when they need to be resurfaced • Measures traffic flow, including bicycle and pedestrian flow
Rochester, NY	• Filled in part of central sunken expressway to create a complete street at surface level • Turns existing streets surrounding expressway into green zones
South Bend, IN	• Transformed roads from high speed one-ways to lower speed two-way • Landscaped medians, street trees, energy efficient lighting • Raised sidewalks and crossways, protected bike lanes and bus shelters

Appendix B.

Contact information for Local Governmental and Advocacy Groups

- Planning and Regulatory Services Office
  - Stephen Rolle, Director
  - 508-799-1400 ext. 31434
  - rolles@worcesterma.gov
- Walkbike Worcester
  - Karin Valentine Goins or Jerry Powers, Directors
  - KVgoins@gmail.com or walkbikewoo@gmail.com
- Massachusetts Smart Growth Alliance
  - Andre Leroux, Executive Director
  - andre@ma-smartgrowth.org
- Central Massachusetts Regional Planning Commission
  - Sujatha Krishnan, Deputy Director of Transportation
  - Sujatha@cmrpc.org
  - 1-508-459 ext. (3335)

Appendix C.

Figure 7. Hourly $PM_{2.5}$ Concentrations from Road Traffic Emissions (Peak Afternoon, Summer)

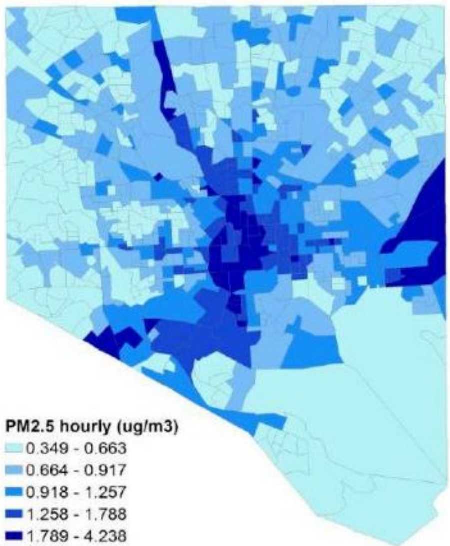

Figure 8. 2011 Asthma Hospital Discharge Rates