Engineering Scoring System for Bicycle Lane Mapping Development: Case Study on Tyler, Texas, USA

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ABSTRACT

This study intends to showcase the up-to-date development of a Hub-and-Spoke Bicycle Lane Map for the city of Tyler, Texas, USA. The Bicycle Lane Engineered Scoring System (BLESS) will be utilized to map and identify the optimum feasible locations for bicycle lanes. The design process is comprised of attentive planning, progressive development and a collective effort by the transportation engineering research team at the University of Texas at Tyler to design an exceptional bicycle lane network. The BLESS consisted of traffic analysis, lane configuration, presence or absence of vehicle parking, presence or absence of night street light, road grade, proximity and presence or absence of existing bicycle lanes. The BLESS was then utilized to design over 55 miles of bicycle lanes. The presence of bicycle lanes will extend throughout the entire city due to the introduction of new connections between different areas of the city. This development will increase users' health and safety while decreasing current traffic congestions. Results indicated that the BLESS is a simple and useful way to compare and analyze roads for bicycle lane development. Since it selects the best road candidates, the bicycle users feel more comfortable using engineered bicycle lanes than riding in a shared lane.

KEYWORDS: Bicycle, Bicycle Lanes, Road Diet, Scoring System, BLESS.

INTRODUCTION

Worldwide, traffic is becoming a serious issue for big cities and is now affecting mid-sized cities. For this reason, alternative modes of transportation are being developed in order to decrease and facilitate traffic flow. Although a mode of transportation may be very effective for far distances, it may not actually be very effective for shorter distances. For instance, trains and busses have very rigid routes as well as low frequency. For this reason, bicycles are widely utilized to provide a direct, safe and reliable mode of transportation for short to medium distances within city limits.

As most bicycle lanes currently designed are prevenient simply re-striping the road, costs can be considered minimal compared to designing subways. This paper outlines the procedure taken, data collected and the engineering process behind designing an efficient numerical system for bicycle lane development and its implementation plan for the city of Tyler, Texas.

LITERATURE REVIEW

In 1967, city of Davis, California, had the first bicycle lane in the American history. Since then, bicycle lanes are being developed across the country (Flax, 2017). According to the American Association of State Highways Transportation Officials (AASHTO) Guide for the Development of Bicycle Facilities, the standards set for the width of the bicycle lane is a minimum of 4 feet, but it is recommended to use a width of 5 feet from

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the face of a curb to the bicycle lane stripe (AASHTO, 2012).

Amsterdam, Netherlands, is considered one of the most bicycle-friendly cities in the world. This is due to 38% of the 1.1 million habitants using bicycles as their main mode of transportation (Internet, 2017). Sao Paulo, Brazil, with a population of 12 million habitants, added 240 miles of bicycle lanes and bicycle routes into its transportation system (Sao Paulo Government, 2017). With a population of 8.4 million habitants, New York city, USA, has a bicycle network of over 400 miles (Internet, 2017). Austin, USA, has over 210 miles of bicycle lanes and a population of over 885,000 habitants (Austin Transportation Department, 2017).

The growth of bicycle usage was noticed in the State of California, where by 2020 it is predicted that 4.5% of the population will be cycling. However, a few states are facing even better results. New York, Oregon and Massachusetts faced an increase higher than 80%, 70% and 40% in cycling and walking, respectively (CALTRANS, 2017).

The addition of bicycle lanes has proven to promote economically, environmentally and socially sustainable travels. This fact aids in supporting the national development and connecting different cultures across different regions. Developing bicycle lanes will connect different cultures and promote the integration of people of different ages and incomes. In addition, bicycles are a great form of exercise for everyone. Promoting a healthier community will result in better citizens (Austin Transportation Department, 2014).

In order to create the necessary width for bicycle lane development, a road diet or lane diet technique can be used. Road diet is used in transportation to reduce the number of vehicle lanes in order to achieve systematic improvements. Road diet benefits include crash reduction by 19% to 47%. Lane diet, however, is a technique used in transportation to reduce the width of vehicle lanes in order to achieve systematic improvements. This process is used to develop the necessary width for the creation of bicycle lanes without decreasing the number of vehicle lanes (Stout, 2005; US Department of Transportation, 2016; Landis, 1997).

Since early 1990s, different methods had been developed to quantify the compatibility of a roadway in order to accommodate safe and efficient bicycle travel. This process is known as quality of service, or Bicycle Level of Service (Bicycle LOS). The Bicycle LOS evaluates the bicyclists' perception of the road safety and comfort with respect to motorized vehicle traffic present at the road used by bicyclists, where the user comfort rating is separated between A through F. The factors used are curb lane width, bike lane width, striping combination, traffic volume, pavement condition, motor vehicle speeds, on-street parking and presence of heavy vehicles' traffic (TRB, 2010; MeKuria et al., 2012). The problem faced with this method is that it does not provide a correspondence between the Bicycle LOS and user tolerance without providing a minimum requirement for the general population mainstream.

However, there is still a need for a structured engineering methodology to select the best roads and routes for bicycle users, since the existing methods are still presenting flaws. For this reason, the transportation research team at the University of Texas at Tyler (UT Tyler) is developing a numerical scoring system for bicycle lane route selection named Bicycle Lane Engineered Scoring System (BLESS), where roads can be objectively compared and analyzed in order to provide the best route option for bicycle lane development.

OBJECTIVES

The main objective of this study is to use the numerical engineered scoring system BLESS to design a Hub-and-Spoke bicycle lane map for Tyler. This will assist in implementing a safe and efficient bicycle lane network into the city's transportation system, connecting different neighborhoods and commercial destinations of Tyler to its downtown area. The design process is comprised of attentive planning to design an exceptional bike lane network that will provide the community with an alternative mean of transportation, generating development around the city. The bike spoke attempts to incorporate multiple factors to facilitate travel and complement present transit systems.

DATA COLLECTION

The selection of potential bicycle spokes required extensive data collection and analysis of the city of Tyler. Restrictions were included into the city's main roads, since they would significantly affect the vehicle level of service and would be a high risk location for cyclists. In order to facilitate and start the design, before comparing the roads utilizing the BLESS, an overlook into the area was necessary to start the design. The following bullet points were developed to assist in the creation and development of each spoke:

1. Identification of spoke starting point.
2. Identification of spoke ending point.
3. Identification of points of interest to be connected.
4. Identification of traffic light signals to safely cross major roads.

Field visits were implemented into the project design, with the following data being collected: lane width; number of lanes; presence of turning lane; presence of parking; presence of bicycle lanes; street lighting; road grade; traffic data; distance difference.

Number of Vehicle Lanes

The number of vehicle lanes is very important to ensure that the addition of bicycle lanes will not interfere with the vehicle traffic. For this reason, the higher the number of vehicle lanes, the easier it is to implement a bicycle lane, since instead of removing 4 feet from a single vehicle lane, it is possible to remove 2 feet from two vehicle lanes.

Vehicle Lane Width

Vehicle lane width was collected to ensure that the addition of a bicycle lane would not interfere with the current road width necessary to accommodate vehicles. AASHTO provides guidance for vehicle lane design, providing a minimum width necessary for different types of roads (Table 1) (AASHTO, 2001).

Table 1. Ranges for vehicle lane width

Type of Roadway	Rural (ft)	Urban (ft)
Arterial	11-12	10-12
Collector	10-12	10-12
Local	9-12	9-12

Presence of Turning Lane

Turning lane is a two-way center turn lane which allows drivers to pause before turning across from opposite direction traffic. On roads with low traffic volume and the presence of a turning lane, it is possible to remove the turning lane in order to create the necessary width for bicycle lane development, without affecting the road level of service.

Presence of Parking

Parking space is defined as a road location designated for vehicle parking. The space is delineated by surface markings on the pavement. It can be parallel, perpendicular or angled parking. Parking spaces range from 7.5 to 9 feet for angled or perpendicular parking. Depending on the location, parking is very important, but in certain locations, parking is not necessary and for this reason it can be removed.

Presence of Bicycle Lanes

The presence of bicycle lanes is noticed by visual inspection, followed by measurements of the bicycle lane width, since it is important to ensure that the width is in accordance with the AASHTO guide for bicycle facilities, where it sets as a standard a minimum width of 4feet for bicycle lanes (AASHTO, 2012).

Street Lighting

Street lighting is a very important safety factor for the addition of bicycle lanes, since it helps the cyclist during nighttime by illuminating obstacles present on the road and helps the vehicle driver in the identification of cyclists on the road. The collection of street lighting data was carried out with visual inspection during daytime and nighttime in order to see whether the road has light poles and whether the lights are working. During nighttime, it is easier to notice dark spots on the street caused by bad artificial light; however, in some cases, the problem is just caused by a burnt light bulb.

Road Grade

Collecting grade data was possible using the veloroutes.org website. Data was collected point by point with distances of approximately 0.1mile. Locations where there was a hill required extra data points, with the point-to-point distance being proximate to 0.05miles.

Traffic Analysis

Traffic data was collected measuring the number, time and direction of vehicles crossing a certain intersection. Traffic volume counts were performed at three different key times; at 7am, 12pm and 4pm, since those times are representing the peak hour volume of vehicles at the intersection. Traffic counts were performed in at least two different locations for every spoke option. The average volume of vehicles utilizing all the roads analyzed was set as the city average. Each option was then compared against the city average that was calculated to be 408 vehicles per hour.

Distance Difference

Distance difference between different analyzed options is considered a factor that affects the selection of a bicycle spoke, since shorter options compared to longer options will be more direct, providing the user with shorter distances, saving time and energy of bikers.

BLESS

BLESS (Table 2) was then developed combining all the field data collected.

Table 2. BLESS

Factor	Points							Score
	3	2	1	0	-1	-2	-3	
Lanes per Direction	3 or more lanes		2 lanes		1 lane			
Passing Lane		Yes				No		
Avg. Lane Width	> 14ft		14ft to 13ft		13ft to 12ft		< 12ft	
Parking		Both Sides		One Side		None		
Traffic Volume	AVG-300	AVG-200	AVG-100	Average (AVG)	AVG+ 100	AVG+ 200	AVG+ 300	
Max. Grade	0% to 2%	2% to 4%	4% to 6%	6% to 8%	8% to 10%	10% to 12%	> 12%	
Street Lighting	Perfect		Good		Dark Spots		Without	
Distance Difference	Shortest Distance	>0.1 Miles Longer	>0.2 Miles Longer	>0.3 Miles Longer	>0.4 Miles Longer	>0.5 Miles Longer	>0.6 Miles Longer	
Presence of Bicycle Lanes		Yes		No				
Total Result								

IMPLEMENTATION STUDY:
CITY OF TYLER HUB-AND-SPOKE BICYCLE LANE NETWORK

The city of Tyler is located on East Texas and in central Smith County. It is the largest city in the Smith County both in land area and in population. Tyler is also the region's major economic, financial, medical, educational and cultural hub. More recently, Tyler has experienced substantial development across the city with significant increase in traffic volumes. With a total population of over 100,000 habitants, during the daytime, Tyler receives over 150,000 people. For this reason, the severity of traffic congestion is expected to increase in several areas around the entire city. With this growth in population, the number of bicyclists has also increased and given the incentive to the city to implement a much friendlier environment towards bicyclists.

This report outlines the procedure taken, data collected and the engineering process behind producing an efficient bicycle network for Tyler. A total of 11 spokes and 7 spoke connections were developed for Tyler, utilizing the BLESS. But, due to the word limitation, spoke 1 was selected and used for demonstrative purposes. For more information on the remaining spokes, refer to published report.

Development of Spoke 1

Spoke 1 was established at the southeastern side of the city, with the main goal to connect the UT Tyler campus with other commercial areas of the city due to high concentration of students and professionals working or involved with UT Tyler, but especially to connect it with Tyler Junior College campus, a junior college with more than 9,000 students and located 3.4 miles from the UT Tyler campus. With this possibility, two options were developed, Option A – McDonald Rd. and Option B – Old Omen Rd. (Figure 1).

Figure (1): Spoke 1

The starting points for both options were at Old Omen and Old Bascom Rd. and the finishing points were at the intersection between Donnybrook Ave and Lake St.; Old Omen was selected as the starting point for spoke 1 because of its good geographical localization, good possibilities for the continuity of the spoke and the presence of a bicycle lane.

Spoke 1 Option A

The starting point of spoke 1 – option A – McDonald Rd. is at Old Omen and Old Bascom Rd. and the spoke total distance is 6.1 miles. After analyzing the collected data, the route was evaluated and some important facts were noticed about it. The worst segment of the spoke is located on McDonald Rd. (Figure 2).


Figure (2): Spoke 1, option A: McDonald Rd.

McDonald Rd. has in its current road configuration only one vehicle lane per direction, with the average lane width being 18ft and without the presence of a turning/passing lane. Parking is allowed on both sides of this segment, with the average total cars utilizing this spoke option being 299 vehicles per hour; a number that can be considered low when compared to the city average of 408 vehicles per hour. However, as a negative point, the maximum grade found was 8%. Street lighting was present in every segment of the route, creating a good illumination during nighttime and bicycle lanes are present in some locations of option A located at Golden Road. This option's total distance is 1.9 miles. For this reason, the total points received by option A utilizing the BLESS are 6 (Table 3).

Spoke 1 Option B

The starting point of spoke 1 – option B – Old Omen Rd. is at Old Omen and Old Bascom Rd. and the spoke total distance is 5.8 miles. Once the collected data was analyzed, the route was evaluated and some important facts were noticed about it. The worst segment of the spoke is located on Old Omen Rd. (Figure 3).

Figure (3): Spoke 1, option B: Old Omen Rd.

Old Omen Rd. has a current road configuration with two vehicle lanes per direction, with the average lane width being 12ft and without the presence of a turning/passing lane. Road parking is not allowed on both sides of this segment and the average number of total cars utilizing the spoke was measured to be 1403 vehicles per hour, being higher than the total average that was calculated to be 408 vehicles per hour. The spoke option maximum grade found was 3%, with streetlights being present in every segment of the route, creating a good illumination during nighttime. It was also noticed that bicycle lanes are not present on any segment of option B and the spoke option total distance is 1.6 miles. For this reason, the total points received by option B utilizing the BLESS amount to -1 (Table 3).

Spoke Option Selection

After analyzing the collected data, the truthful points were given for each option following the BLESS and it was determined that **option A – McDonald Rd.**, would serve as a much more appealing option as opposed to option B – Old Omen Rd., since it received 7 points, while option B received 0 point, with a total difference of 7 points (Table 3).

Table 3. BLESS point analysis

	Spoke 1	
	Option A	**Option B**
Lanes per Direction	-1	1
Passing Lane	-2	-2
Avg. Lane Width	3	-1
Parking	2	-2
Traffic Volume	2	-3
Max. Grade	-1	2
Street Lighting	1	1
Distance Difference	0	3
Bike Lane Presence	2	0
Total Points	**6**	**-1**

DATA ANALYSIS

After all the data was gathered for each spoke, the best options were selected to the implementation of bicycle lanes (Table 4).

Table 4. BLESS points

	Spoke						
	1	**2**	**3**	**4**	**5**	**7**	**9**
Lanes per Direction	-1	-1	-1	-1	-1	-1	1
Passing Lane	-2	-2	2	-2	-2	-2	-2
Avg. Lane Width	3	3	-3	3	3	3	1
Parking	2	-2	-2	-2	2	-2	-2
Traffic Volume	2	2	-2	2	3	2	-2
Max. Grade	-1	2	3	1	2	2	1
Street Lighting	1	1	3	1	1	1	1
Distance Difference	0	3	3	3	3	3	3
Bike Lane Presence	2	0	0	0	0	0	2
Total Points	**6**	**6**	**3**	**5**	**11**	**6**	**3**

The difference in points for each spoke indicates that different types of road configurations can be modified to accommodate bicycle lanes.

HUB-AND-SPOKE TYLER BICYCLE LANE TYPICAL SECTIONS AND UP-TO-DATE BICYCLE LANE MAP

After collecting field data, roads were divided into five different categories. This separation occurred by separating roads according to the total road width, as seen in Table 5. Green Color represents the bicycle trails located on the city parks, where the developed bicycle lanes would be separated from vehicle lanes and be from 4 to 7ft wide. Purple color was assigned to roads with a total width ranging from 28 to 31 feet. Roads on this situation will require special accommodation, with 4 feet wide bicycle lanes being developed; however, due to the road network present at the city, surrounding roads present at the area are even smaller, causing purple roads to be the best option available at certain locations. Blue color represents roads with a total width ranging from 32 to 42 feet. In this case, the design will include a five feet wide bicycle lane per direction and one vehicle lane per direction. Gray color represents roads with a total width ranging from 43 to 49 feet. In this case, the road would suffer a road diet, changing into a road with one vehicle lane per direction and a turning lane. Finally, orange color was assigned for roads with a total road width wider than 50 feet, where the road is wide enough to accommodate a five feet wide bicycle lane and multiple vehicle lanes per direction, with the presence of a turning lane.

Table 5. Road typical sections

Typical Section	Map Color	Pavement Width (ft)	Bicycle Lane Width (ft)	Vehicle Lane Width (ft)	Turning Lane
1	(green)	8 to 14	4 to 7	*	No
2	(purple)	28 to 31	4	10 to 11.5	No
3	(blue)	32 to 42	5	11 to 16	No
4	(gray)	43 to 49	5	11 to 13	Yes
5	(orange)	50+	5	>10	Yes

*No vehicle lanes, since it is a bicycle trail.

The hub-and-spoke bike lane map reached the full development of 55miles of bicycle lanes. In Figure 4, it is possible to see the location of each road typical section, indicated by the color for each road segment.

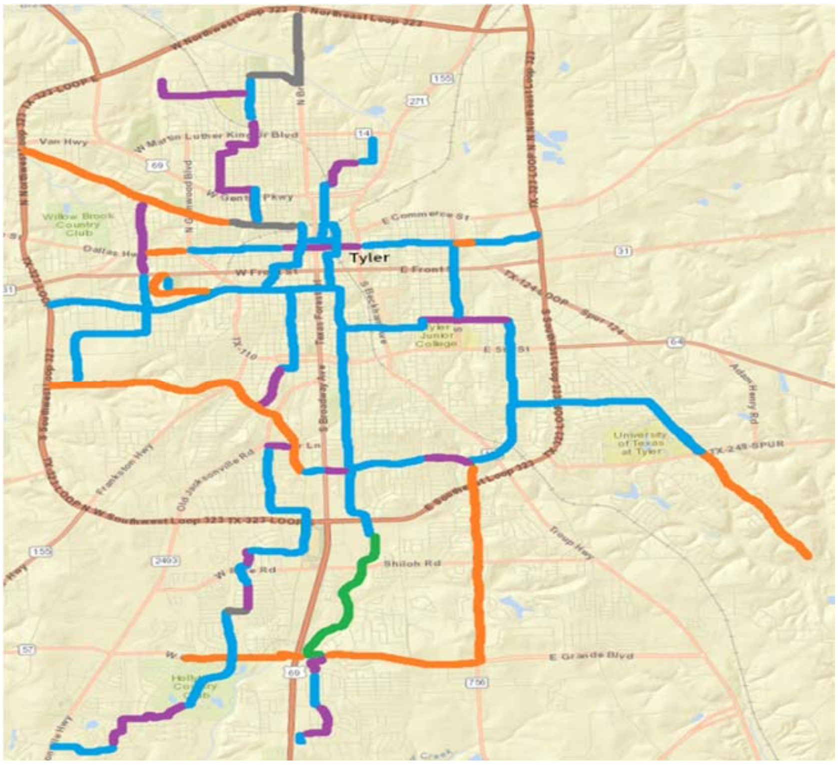

Figure (4): Hub-and-spoke Tyler bicycle lane map

CONCLUSIONS AND RECOMMENDATIONS

The presented study summarizes the progress of the development of the hub-and-spoke bicycle lane map implementation for the city of Tyler. The presence of bicycle lanes will assist the entire city in attracting more people to use their bicycles, since it will create new and safe connections between all the areas of the city.

After creating different options for the addition of each spoke, the data was gathered and compared using the BLESS criteria. After the points were assigned, the winning option was then selected as the best route for the bicyclist. As noticed, the total points received for each road were different, showing that different road configurations can accommodate bicycle lanes.

After analyzing all the collected data, it has been proven that the BLESS is a simple way to evaluate and compare different roads that can be used for the development of bicycle lanes. Since the BLESS is shown to select only the best suitable road candidates, cyclists will feel comfortable while using a road with a designed bicycle lane than sharing a road with motorized vehicles. Finalizing the design with over 55 miles of bicycle lanes, the BLESS was confirmed as a reliable tool to identify the best streets for the addition of bicycle lanes.

The process of data collection, consisting of road data and traffic count data, is time-consuming; however, cities, in most cases, already have an updated management system, where pavement data is already available, turning the mission of selecting the best routes a simple task for the BLESS.

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