THE EFFECTIVENESS OF BICYCLE LANE: THE CASE OF LEBU-JEMO ROAD IN ADDIS ABABA, ETHIOPIA

Betelhem Derese Eshetu

A Thesis Submitted to

The Department of Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Urban Planning and Design

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

June, 2022

THE EFFECTIVENESS OF BICYCLE LANE: THE CASE OF LEBU-JEMO ROAD IN ADDIS ABABA, ETHIOPIA

Betelhem Derese Eshetu

Advisor: Prof. Samson Kassahun

A Thesis Submitted to

The Department Architecture

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Urban Planning and Design

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

June, 2022

APPROVAL OF BOARD OF EXAMINERS

I, the advisor of the thesis entitled "**The Effectiveness of Bicycle Lane: The Case of Lebu-Jemmo Road in Addis Ababa, Ethiopia**" and developed by **Betelhem Derese Eshetu**, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

______________________	______________________	______________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by **Betelhem Derese Eshetu**, have read and evaluated the thesis entitled "**The Effectiveness of Bicycle Lane: The Case of Lebu-Jemmo Road in Addis Ababa, Ethiopia**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in **Urban Planning and Design**.

______________________	______________________	______________
Chairperson	Signature	Date
______________________	______________________	______________
Internal Examiner	Signature	Date
______________________	______________________	______________
External Examiner	Signature	Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

______________________	______________________	______________
Department Head	Signature	Date
______________________	______________________	______________
School Dean	Signature	Date
______________________	______________________	______________
Office of Postgraduate Studies, Dean	Signature	Date

DECLARATION

I hereby declare that this Master Thesis entitled "**The Effectiveness of Bicycle Lane: The Case of Lebu-Jemmo Road in Addis Ababa, Ethiopia**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

______________________	______________________	______________
Name of the student	Signature	Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**The Effectiveness of Bicycle Lane: The Case of Lebu-Jemmo Road in Addis Ababa, Ethiopia**" prepared under my guidance by **Betelhem Derese Eshetu**, submitted in partial fulfillment of the requirements for the degree of Mater's of Science Urban Planning and Design. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

__________________________ _______________________ ________________

Major Advisor Signature Date

ACKNOWLEDGEMENT

This research would not have been possible without the help and support of many people. First and for most, I would like to express my gratitude to my advisor, Professor Samson Kassahun, who guided me and stimulated suggestions throughout this study.

I would also like to thank officials from Addis Abeba Road Transport Bureau, Addis Abeba City Road Authority and Addis Abeba City Administration Traffic Management Agency for providing me relevant information.

Additionally, I would give my gratitude to my whole family who was there for me through ups and downs by encouraging and supporting me continuously. Also, my friends, thank you for sharing your ideas and your time to discuss, comment, and suggest your comments on this thesis.

Last but not least, my very special thanks goes to the almighty Lord who has been my strength and courage through all the way.

CONTENTS

CHAPTER **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF ACRONYMS

AACRA	Addis Abeba City Road Authority
AASHTO	The American Association of State Highway and Transportation Officials
AARTB	Addis Abeba Road and Transport Bureau
BCI	Bicycle Compatibility Index
BFC	Bicycle Friendliness Community
BLOS	Bicycle Level of Service
ETB	Ethiopian Birr
FHWA	Federal Highway Administration
GIS	Geographic Information System
HCM	Highway Capacity Manual
MS	Microsoft
NACTO	National Association of City Transportation Officials
NMT	Non-Motorized Transport
SPSS	Satictical Package for the Social Sciences
TMA	Traffic Management Agency

ABSTRACT

Cycling has become the new trend in developed countries as it is one of the NMT systems to reduce environmental challenges. Despite increased interest, cycling in Ethiopian cities has yet to garner widespread attention. Nonetheless, assessment of bicycle lane is often a neglected issue related to the effectiveness of the infrastructure. Additionally, Bicycle lanes in urban areas are sometimes rated only on their length, regardless of the network's overall quality or usefulness. The Lebu-Jemo cycling corridor, sharing an existing vehicular access road for a bicycle lane also poses issues. The purpose of the present study aims to evaluate the effectiveness of the bicycle lane and its impacts on other road network users and businesses. From the BCI calculation performed on the finding segment, the Lebu-Jemo route is very compatible for cycling and has a moderately high degree of service according to the BLOS calculation. In contrast, the qualitative analysis finding denoted that the majority of the participants are positive about the bike lane while some have been negatively impacted by the existence of the bike lane. In addition to that, the result from the key informants shows that many of the business adjacent to the bike lane are negatively impacted by the existence of the cycling corridor. The overall finding implies that despite the increment of the number of cyclists in the area the majority of them do not use the provided bike lane due to lack of safety, maintenance and unconnectedness of the bike way. In general, future studies should take into account that extensive research and analysis is prior to developing and installing the remaining bicycle corridors in a way that addresses the future flow of traffic, demand for parking space, location by taking notes from the issues faced in the previously established bike ways.

Keywords: Non-motorized transport, bicycle corridor, effectiveness, bicycle lane

CHAPTER ONE

INTRODUCTION

Over the past decades, motorized vehicles have been utilized as the primary mode of transportation to satisfy the expanding request for urban advancement, particularly in creating nations (Abolhassani et al., 2019). A cycle lane is a portion of the road only saved for cyclists. Cars are not permitted to drive or stop on them. They are demonstrated by road markings on the carriageway (Sheet, n.d.). In urban areas, bicycle paths are usually executed on the roads to supply space for a bike to function (Pu et al., 2017). "The purpose of the line segmentation is to separate the bicycle traffic from the vehicle traffic to reduce conflicts between different trip modes" (Pu et al., 2017). Cycling has an insignificant share in the modal transport of the urban area because of many reasons (Tulu et al., 2019). Cyclists' advantage from progressed mental well-being, improved metabolic and physical working, and diminished dangers for obesity and resultant issues while communities get an advantage from less air and noise pollution, less traffic blockage, and fewer public health costs related to residents' physical dormancy (Morrison et al., 2019).

Cycling has become the new trend in developed countries as it is one of the ways to reduce environmental pollution (Bikeway Design Guide, 2011). The existence of bicycle lanes promotes more bikers and fewer drivers to the roads while it's also a mechanism to reduce travel speed and increase safety. In Ethiopia, Addis Abeba NMT strategy has planned to develop city-wide walking and cycling network that helps bring climate resilience. Following this, the first 3 km two-way bicycle corridor was launched in 2020 from the Lebu-Jemo route. Residents of the area often use this corridor for cycling and walking (Addis TV, 2020). The area is effectively used for car-free days and few cyclists use it mostly during the nighttime.

The importance of this research is to provide a better understanding of the impacts of cycling corridors on the existing vehicular road access and the users. It will also serve as a guide to assessing the upcoming bicycle lanes in Addis Abeba. This study assesses the effectiveness of the cycling corridor according to its use, maintenance, and its impacts to address the users' complaints. According to (Fistola et al., 2020), city bicycle lanes are typically judged solely on their length; regardless of the network's total quality or usefulness. Geometrical (width, slope, etc.) and construction (type of pavement) characteristics, as well as functional (reserved for bicycles or cycle-pedestrian), safety (visibility, signage, etc.), and connection (continuous network vs. isolated and separated cycle lanes) characteristics, all have a significant impact on the perception of the cycle network and the likelihood of using bicycles.

Based on the findings of the study, future planned similar projects may take this study as a guide to consider for improved quality service and help for the development of further knowledge. It takes an overview of the challenges faced in the area and uses the opportunities for expanding the use of NMT throughout the city.

1.1. Background of the Study

According to the Bikeway Design Guide (2011), bicycle paths are ordinarily on the right side of the road, between the adjoining travel path and curb, street edge, or parking path. Bicycle paths empower bicyclists to ride at their preferred speed without obstructions from prevailing traffic conditions (Bikeway Design Guide, 2011). Cycling that replaces car trips comes about in decreased greenhouse gas emissions and diminished utilization of natural resources helping cities accomplish air quality benchmarks. Economic benefits for bike commuters incorporate savings on gasoline and parking expenses (Boettge et al., 2017). Bicycle lanes are added to existing or new roads for cyclists to ride freely with safety.

Looking into the historical background of bicycle lanes, at the beginning of the 1890s when cycling went from a leisure activity to a mode of transportation, cyclists demanded better roads to ride on (The Evolution of Bikes and Bike Lanes – Public-Ation, n.d.). Before the late 20thc, the motor was suppressing cycling while after 1970 cyclist activists, policymakers, social scientists, and urban planners highlighted the advantages of cycling (Oosterhuis, 2016). Cycle lanes are added to cities due to their benefits including shorter commutes, less noise, cleaner air, and reduced consumption of fossil fuels and energy, urban spaces look set to become more suitable for walkers and cyclists. One of the main reasons behind this study is that cycling has become climate-friendly mobility that improves human health.

Since 2015, with the affirmation of cycling as a climate inviting transport mode, the attention of the European approaches has been centered on the significance of cycling and on particular infrastructure planning able to improve the way of moving, mainly at an urban level (Fistola et al., 2020). "During the past decade, there has been an increasing use of bicycles in many countries around the world" (Chen et al., 2018, p. 1) Nevertheless, within transport planning, bicycling is quite marginalized and many solutions that are implemented for bicycle traffic are not always the best when considering e.g. accessibility, comfort, or safety (Ekblad et al., 2016). On continents like Africa, the modal share of bicycling in many cities is marginalized including Addis Abeba city. In addition, the center of bike research has most regularly been on the investigation of empirical evidence instead of on hypothetical issues (Koglin & Rye, 2014). Therefore it is important to have a deep understanding of the theoretical issues of bicycle planning as well.

1.2. Problem Statement

On urban streets with higher commercial activity, the area for bike riding is typically restricted. As bike flow will increase, some bikes would run closely to automobiles leading to conflicts between bikes and vehicles (Chen et al., 2018). The arrangement of a bicycle lane requires an intensive consideration of existing traffic levels and behaviors, satisfactory security buffers to ensure bicyclists from parked and moving vehicles, and authorization to disallow motorized vehicle infringement and double-parking (Bikeway Design Guide, 2011). To guarantee that future bicycle infrastructure is as secure and valuable as conceivable, design contemplations must take into consideration the bicyclists' encounters, including interaction with existing infrastructure and other street users (Berman et al., 2017).

The decreased vehicular access road influenced by the bicycle corridor poses different delays and accidents for the users. Similarly, sharing an existing vehicular access road for a bicycle lane also comes with challenges in Addis Abeba's cycling corridor. People's acceptance and use of the Lebu-Jemmo bicycle lane is doubtful with it causing congestion during peak hours, lack of parking area, the narrowness of the road, and encroachment of motorized transport on the bike lane. Business owners adjacent to the bike lane face a great problem of lacking parking spaces for their customers. Besides these challenges, the current status of the lane is in poor condition according to its physical maintenance.

The assessment of bicycle lanes is often a neglected issue related to the level of quality and effectiveness of the infrastructure. The effort of this research lies in searching methods of evaluating the urban lanes dedicated to cycling, considering their actual effectiveness. Cycle paths are mostly measured in terms of geometrical length, regardless of the quality and effectiveness of the bike lane distance (Pu et al., 2017). This study tries to blend both the geometrical length and quality assessment to evaluate the overall effectiveness of the Lebu-Jemo bike lane. As a result, the outcome will provide a comprehensive overview of the challenges encountered as well as the opportunities for cycling in Addis Abeba. It can also contribute significant scientific knowledge to the city of Addis Abeba's very limited cycling literature.

1.3. The Objective of the study

1.3.1. General Objective.

The overall research objective is to analyze the effectiveness of the cycling corridor installed from Lebu-Jemo and to examine its impact on its surrounding.

1.3.2. Specific Objectives.

2. To identify ways of measuring the effectiveness of the bike lane.
3. To assess the number of cyclists using the bicycle lane.
4. To demonstrate the impacts of the bicycle lane on other road network users and businesses.

1.4. Research questions

Based on the problem statement stated above, this research set out to answer the following questions;

1. How is effectiveness of the bike lane to be measured?
2. How effectively do cyclists use the bicycle lane?
3. What are the impacts of the bicycle lane on other road users and businesses?

1.5. Significance of the study

The importance of this paper is to provide a better understanding of the impacts of cycling corridors on the existing vehicular road access and the users which will also serve as a guide to assess Lebo-Jemmo, the first cycling corridor in Addis Abeba. The Addis Abeba city road authority has planned to install a 200 km bicycle lane throughout the city by 2028. Based on the findings of the study, future planned similar projects may take this study as a guide to consider for improved quality service and help for the development of further knowledge. It takes an overview of the challenges faced in the area and uses the opportunities for expanding the use of NMT throughout the city.

1.6. Scope of the research

Whilst the importance of cycling infrastructure has been well documented, the effectiveness of the cycling infrastructure is quite a neglected issue. This study aims to evaluate the bi-directional cycle lane from Lebu to Jemo which is a kick start to a comprehensive plan of Addis Ababa NMT Strategy to improve the city's cycling infrastructure. The spatial coverage of this study is bounded in the most populated city at Nifas Silk Lafto sub-city, Addis Abeba. Ethiopia. Moreover, the study is limited to covering 384 people found only within the study area route. This is because the number of people passing by this area is unlimited.

1.7. Limitation of the Study

Due to the lack of recorded bicycle accident data the researcher is limited to studying the bicycle accident level of the bike lane while assessing the impact of the bike lane on other road users. The study utilized the data that are available from different offices and using default values from previous works in some cases the researcher used judgments as suggested by the model while calculating bicycle compatibility index and bicycle level of service models.

1.8. Organization of the Research

The thesis is organized into five chapters. Each chapter systematically and effectively examines the content and data of the study accordingly. The fundamental chapter in the thesis is further demonstrated as follows.

Chapter One discusses an introduction and overview of the background of the study. This part of the thesis includes highlights of the main topics of the study: research problem, objectives, research questions, significance, and scope, limitation, and organization of the study.

Chapter Two takes a look at literature reviews which discusses the main definitions of bicycle lanes and the fundamental concepts, functions, principles and guidelines, effectiveness of cycle lanes, best practices in different countries, impact of bicycle lanes on users and surroundings, and the method of analyzing the numbers of cyclists. It also includes both empirical and theoretical frameworks about bicycle lanes and their impact on other road users and surroundings.

Chapter Three focuses on research methodology and puts directions on the materials and methods used for each objective. Sampling techniques and sample size, data collection methods, and data analysis techniques for the study.

Chapter Four discusses the result and discussion the collected qualitative and quantitative data findings. Qualitative data are obtained from observations, perceptions of surveyed people, secondary data sources, and case studies while quantitative ones are the results of counting bicycles and previous statistical data from offices.

Chapter Five is the final part of the thesis that summarizes the whole study based on the findings from the surveys and bicycle counts.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

The following subjects that will be examined in the literature review are the theoretical framework theories such as the definition of bike lanes, integrated sustainable bikeway design, the evolution of the bicycle, and the theoretical concepts of bicycle planning. First, a thorough examination of a wide range of theoretical scientific studies, strategic and policy reports, books, articles, and blog posts focusing on the significance/benefits of cycling and cycling infrastructures to demonstrate that bicycling is a viable and sustainable mode of urban transportation. Secondly, concepts empirical about bicycle compatibility and level of service calculation, variables for bike lane installation, functionality of bike lane and social and physical effects of bike lane.

2.2. Theoretical Review

2.2.1. Effectiveness of on-street Bicycle Lane.

The effectiveness of on-street bicycle lanes varies depending on location and on-network factors. Examples of such on-network characteristics that influence bicyclist safety include traffic flow (resulting in unfavorable conditions for bicyclists), traffic speed (or speed limit), the number of lanes, the width of the right-most travel lane, and the number of driveways, unsignalized approaches, and signalized intersections per unit distance (Pulugurtha & Thakur, 2015). Recently, as the need for vehicle parking has increased, several bicycle spaces in emerging countries have been converted into vehicle parking spots (Chen et al., 2018). The efficiency of bike lanes varies depending on other road conditions. Bicycle lanes, for example, provide greater protection where there is a bigger speed disparity between bikes and motor vehicles (Morrison et al., 2019). Bicycling and Bicycle facilities satisfaction among cyclists and non-cyclists needs to be evaluated in order to measure the effectiveness of cycle lanes (Tulu et al., 2019).

One issue leveled against many bicycle network audit tools is that the criteria and standards are set a priority, with standards imported from locations other than the one in question

(Boettge et al., 2017). Based on Ekblad et al (2016), when examining the motives for cycling, attitude appears to be a very powerful explanatory factor. Typically according to there are two distinct types of suitability criteria. The first, stress levels, basic evaluation criteria based on curb lane vehicle volumes, curb lane vehicle speeds, and curb lane widths. Second, roadway condition, traffic volumes, curb lane width, speed limit, pavement variables, and location factors were all shared by all criteria (Turner et al., 1700). Therefore, it is critical to ensure that the system is accessible throughout the city.

According to (LTSA, 2004) and RTA (2003), they identified five fundamental conditions for an appealing cycling network that facilities must strive to meet in order to be effective cycle routes. These are cohesion, directness, safety, comfort and personal security of bicycle users. Cohesion deals with the provision of a comprehensive path that corresponds to the necessity for travel (Cookson & Stirk, 2019). It is the extent to which a bicycle network joins up with origins and destinations - with all sites of departure and arrival. A coherent network is one in which people who want to pedal are only a short distance away from easily accessible cycle routes.

Directness is in terms of distance and travel time, directness is preferred (and minimal stopping). In terms of time, directness refers to minimizing the amount of time spent waiting at intersections. The number of times cyclists have to stop or do not have right of way should be as near to zero as practicable on all types of cycle routes, though this will, of course, be difficult to achieve in practice.

Safety is a treatment aimed at avoiding confrontations; in terms of crossing vehicles, speeds, and separation from vehicle kinds, in a uniform manner. Comfort is about prevention of inconvenience for all users by eliminating the need to stop, providing smooth surfaces, and minimizing obstacles from other cars. Personal security, feeling of safety, and the attractiveness of the environment are all examples of attraction.

While every effort should be made to meet all of these conditions whenever bicycle facilities are considered, the ideal situation is not always possible to accomplish (Cookson & Stirk, 2019). Due to constraints such as topography or a lack of funds, compromises will be necessary. However, it is critical that while creating a strategic network of cycling routes, the network is at the very least cohesive (LTSA, 2004) and (RTA, 2003).

2.2.2. Definition of Bike Lanes.

According to NACTO urban bikeway design, “A Bike Lane is defined as a portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use of bicyclists” (*Bikeway Design Guide*, 2011).

A bike lane is also defined by the AASHTO Guide for the Development of Bicycle Facilities as "a segment of a roadway marked by striping, signing, and pavement markings for the preferential or exclusive use of bicyclists" (Smith et al., 2019). A cycle lane is a legally designated driving area on the road that visually separates cyclists from traffic (Sheet, n.d.).

The FHWA defines separated bike lanes as one of many types of bicycle facilities that exist within a larger context shaped by demographic and land-use changes, as well as interconnected transportation, public health, environmental, and economic factors. Separated bike lanes are ways for the cyclist on the adjacent side of the road designated with a vertical separator. Separated bike lanes are one of many bicycle facility types that can be used to create connected bicycle networks (Federal Highway Administration, 2015).

2.2.3. Function of Bike lanes.

In starter cycling cities, the cycle lane is possibly the most common solution for cycling infrastructure because it allows for a quick rollout of a large and noticeable cycling network within an established street network (Sheet, n.d.).

Compared to a cycle track, a cycle lane is simpler, quicker, and less expensive to install: only road markings and probably surface coloring are needed (no road construction work). A bike lane gives cyclists a highly visible legally designated area on the road, signaling to all road users that cyclists are to be respected. A bike lane takes up less space, so it is more convenient. Bicycling, on the other hand, is a green mode of transportation that does not pollute, poses few risks to other road users, is a healthy mode of transportation, and takes up very little space when compared to, say, a car (Ekblad et al., 2016). The effectiveness of an on-street bicycle lane varies by location and is dependent on the characteristics of the on-network. On-network characteristics that affect bicyclist protection include traffic flow (resulting in unfavorable conditions), traffic speed (or speed limit), the number of roads, the width of the right-most travel path, and the number of driveways, unsignalized approaches, and signalized intersections per unit distance (Pulugurtha & Thakur, 2015).

2.2.4. Principles and guidelines to bicycle transportation planning.

Technical guidance on the design of different bikeway lanes has been provided by different bodies so far. Bicyclist-friendly provisions should be included if streets are built or rebuilt, in accordance with federal policy (Shinkle et al., 2008). The city, as well as international collaborators working on road safety in the city under the Bloomberg Initiative for Global Road Safety, acknowledge the value of the design guide for bicycle infrastructure (e.g. The World Bank, NACTO, and World resource institute) (Tulu et al., 2019). There are different options of the bikeway design such as: Shared lanes, Marked shared lanes, Paved shoulders, Bike lanes, Bicycle boulevards, and Shared use paths.

Cycle lanes are recommended for low-traffic distributor roads where motorized traffic is too quick to encourage cyclists and cars to share the road. Where space is limited, bike lanes may be used as an alternative to a cycle track, at least if the speed is limited to 50 km/h or less (Sheet, n.d.).

Before designing and installing cycle lanes one should consider certain points. According to NACTO (*Bikeway Design Guide*, 2011), the selection of an appropriate bikeway should be based on the following variables, road function (arterial, local), traffic volume, speed, traffic mix (e.g., truck percentage), expected users (e.g., is one type of user expected to dominate, such as children bicycling to school), road conditions (lane widths, total roadway width, conditions at intersections, and parking demand), driveways or access points, topography, existing and proposed adjacent land uses, and cost.

To distinguish the bike lane from the motor vehicle travel lanes, a strong white lane line marking shall be used. When located adjacent to parking, a strong white line marking of 4-inch widths should be used between the parking lane and the bike lane to prevent parked cars from encroaching on the bike lane.

To avoid door zone conflicts, bike lane striping and parking boundary markings should be separated if there is enough space. Color can be used to make a bike lane more visible.

The following are the ten guiding concepts that were developed by NACTO (*Bikeway Design Guide*, 2011).

- Cycling is an important mode of transportation;
- Land-use planning should make cycling easier, especially for short trips
- To boost cycling levels, each of the following strategies will need to be used: engineering, education, enforcement, and encouragement.
- Follow the five-step approach to find the most effective measure to improve the land transportation system for cyclists:
    1. Reduce the amount of traffic.
    2. Slow down traffic.
    3. Traffic management and intersection treatment

    5. Specific cycle facilities 4. Reallocation of road space
- All cycling, both 'cycle-only routes' and those that connect with other modes such as urban buses, coaches, trains, aircraft, and ferries, must be accommodated.
- Because cyclists can use the entire road network, area-based treatments are just as vital to them as site or route-based treatments.
- Cyclists with diverse degrees of experience and confidence have different demands when it comes to non-roading corridors (e.g. alleyways, parks and reserves, shared pathways, rail corridors, closed roads).
- A variety of policies and programs (e.g., land use planning, public health programs, travel demand management, parking management, secure cycle parking, or tourism promotion) should be employed to promote cycling.

These principles present a collection of values that can be used to help position cycling's function in the overall transportation system. Cycling may be given the attention it deserves by presenting its role in this way.

2.2.5. Evaluation of the Bicycle Friendly Community Metric.

The League of American Bicyclists (LAB) program puts five E's as a root for the bicycle friendly community metric. These are Engineering, Education, Encouragement, and Evaluation & Planning. If any of these characteristics are missing, the case for bicycle friendliness will be weak (Hughes & Advisor, 2015). These principles guide the evaluation of each entity.

Engineering consists of comfortable infrastructure that connects to public transportation destination. People's willingness to get on a bike and ride is influenced by their physical surroundings. The availability of infrastructure that invites and encourages bicycling is the most visible and arguably most tangible indication of a great place for biking (James, 2021). Education focuses on teaching the public about safe riding and traffic habits. Building wonderful environments for bicycling requires a variety of methods for people to get the skills and confidence to ride. Encouragement inquires about community advocacy groups developing a vibrant bike culture that embraces and celebrates bicycling (Hughes & Advisor, 2015). Encouraging individuals to ride by providing them with a variety of possibilities and incentives to cycle and preparing celebrations of national bike month increases the number of bike users. To protect bicycles, enforcement looks at policy strengths and how well enforcement law can respond to the demands of road users. Evaluation & Planning asks about the data collection required for good policy recommendations. A successful plan focuses on establishing a seamless cycling network that promotes short trip distances and multi-modal excursions, and is supplemented by encouragement, education, and enforcement programs to increase usage.

2.2.6. Bicycle Compatibility Index and Bicycle Level of Service

Numerous methods to measure bicycle compatibility index and bicycle level of service have been created in the past by various researchers. All methods are revised in the table below to measure BCI and BLOS based on the attributes and variables needed.

Table 2. 1 BCI and BLOS Measuring Methods

Methods	References
Bicycle Level of Service	Botma (1995); Dixon (1996); Jensen (2007); Petritsch et al, (2007); The highway capacity manual (2011)
Bicycle Compatibility Index	Harkey & Reinfurt, 2012; The highway capacity manual (2011)

2.2.6.1. Bicycle compatibility Index – BCI

The BCI model was created for urban and suburban streets (i.e., midblock sites outside of major intersections) and incorporated criteria that bikers use to evaluate a road's "bicycle friendliness" (e.g., curb lane width, traffic volume, and vehicle speeds) (Harkey & Reinfurt, 2012). The BCI model developed by Harkey (2012), as well as the accompanying level of service (LOS) designations, enable practitioners to: evaluate their routes for compatibility with shared-use operations by cars and bikers, as well as plan for and create routes that are compatible with bicycles. The BCI model can be utilized for the following purposes in particular:

Using physical and operational features such as lane widths, speed, and volume, the bicycle compatibility index (BCI) allows practitioners to assess the ability of a range of roads to accommodate both vehicles and bicyclists (Harkey & Reinfurt, 2012). It can be used in three different ways, making it extremely versatile: Existing roads can be assessed for their efficiency. New highways or highways that are being redesigned may be assessed. & Planning: forecasts can be used to assess future roadway bicycle compatibility (Eshetu, 2015). In this study this model will be applied to assess an existing road for its efficiency in accommodating both motorists and bicyclists.

Table 2.2 Recommended truck percentages by functional classification for streets where such information is not available

Functional Classification (Type of street)	Recommended truck percentage (HV)
Principal Arterial (Non-Freeway)	3.5 %
Minor Arterial	2 %
Collector Street	1.5 %
Local Street	0 %

Source: (FHWA, 2012).

The BCI model's data requirements are low and, for the most part, comprise information that has traditionally been collected by governments and municipalities for other purposes.

However, there will always be regions where certain data will be unavailable. In such instances, the practitioner must make decisions about the values to use inside the BCI model. It's also possible that the accessible data aren't in a format that can be immediately entered into the model (FHWA, 2012). In that situation, specific computations must be performed in order to convert the data into the proper format.

The Index**:** BCI = 3.67 - 0.966BL - 0.410BLW - 0.498CLW +0.002CLV + 0.0004OLV + 0.022SPD + 0.506PKG - 0.264AREA + AF

The table below shows the variables, their definitions, the data requirements needed to conduct the BCI measurement for roads.

Table 2. 3 Bicycle compatibility Index model - variables definition

BL= presence of bicycle lane or paved shoulder >= 0.9m (No= 0 Yes=1)	PKG= presence of parking lane with more than 30 percent occupancy (No=0 Yes=1)
BLW= bicycle lane (paved shoulder) width m to the nearest tenth	Area= type of roadside development residential = 1 other type= 0
CLW= curb lane width m to the nearest tenth	AF= ft + fp + frt where ft= adjustment factor for track volumes fp= adjustment factor for parking turn over frt= adjustment factor for right-turn volumes
CLV= curb lane volume vph in one direction OLV= other lane volume- same direction vph	SPD= 85th speed percentile speed of traffic km/h

Three additional factors describing specific operating conditions were also investigated in addition to the primary variables included in the BCI model. These additional variables, presence of large trucks or buses, vehicles turning right into driveways and vehicles pulling into or out of on-street parking, have a potential impact on the comfort level of bicyclists (FHWA, 2012).

Table 2. 4 BCI level service grades

LOS	BCI Range	Compatibility Level
A	<1.50	Extremely High
B	1.51 - 2.30	Very High
C	2.31 - 3.40	Moderately High
D	3.41 - 4.40	Moderately Low
E	4.41 - 5.30	Very Low
F	> 5.30	Extremely Low

Source: (Harkey 2012)

2.2.6.2. Bicycle level of service (BLOS) model.

This method of measurement was developed by an American consulting engineering firm under the "Highway Capacity Manual" to measure on-road bicyclist comfort level using road's geometry and traffic conditions. According to HCM (Barker et al., 2010), it was developed to be conducted for segments, intersections and links. Link BLOS is calculated based on ten variables: width of bike lane, width of paved shoulder, on-street parking occupancy, width of curb lane, vehicle speed, vehicle traffic volume, heavy vehicles percentage, pavement condition, presence of curb, and number of through lanes (Eshetu, 2015). The ten attributes combining to form the calculation is as follows:

$$\text{BLOS score} = 0.760 + Fw + Fv + Fs + Fp$$

Where, Fw – width adjustment factor, Fv – vehicle volume adjustment factor, Fs – Vehicle speed adjustment factor and Fp - pavement condition adjustment factors.

Some values may not be easily accessible, hard to find from the governmental offices or there may be absence of data. In this case, the models have put default values to be used as identified below.

Table 2. 5 Summary of default values used in BCI and BLOS

Variable	Default value
85th percentile speed	Posted Speed limit plus 15 km/hr
K- factor	0.10
D- factor	0.55 or 1.0 A
F- factor	0.8 or 1.0 B

BLOS = $0.760 + 0.507 \ln(VOL15/L)+0.199SP_t (1 + 10.38HV)^2 + 7.066(1/PR5)^2$-0.005(WE

Table 2. 6 BLOS service of extending from excellent (A) to worst (F)

BLOS score	BLOS grade
< 2.00	BLOS “A”
2.00 – 2.75	BLOS “B”
2.75 – 3.50	BLOS “C”
3.50 – 4.25	BLOS “D”
4.25 – 5.00	BLOS “E”
>5.00	BLOS “F”

Source: (highway capacity manual, America 2011)

2.2.7. Bicycle Lane and the impact on the users

Cycle Lanes have various impacts on its users mainly according to its safety. Crash statistics involving cyclists, like those involving motor vehicles, suffer from under-reporting or non-reporting, particularly non-injury and minor injury crashes (Officer et al., n.d.). Different types of bi-cycle lanes can be installed in relation to the type of the street. Common infrastructure types include shared-use lane markings or “sharrows”; on-street painted bike lanes and buffered bike lanes which provide extra segregation from traffic (Boettge et al., 2017).

Figure 2. 1 types of bike lanes

Source: (National Association of City Transportation Officials, 2014).

Shared lane marking or “Sharrow”: It is made up of a bicycle sign and a double chevron arrow above it. They are not exclusive bike lanes, but, as the name suggest, a “shared lane marking.” They are a “share the road sign,” but painted on the street (National Association of City Transportation Officials, 2014).

Striped Bike lane: The lane is fairly straightforward, consisting of two lines with a bicycle marking in the center, creating a dedicated bicycle-only travel lane. These lanes are usually painted white and are positioned on the far right side of the road. They could be painted a different color to attract more attention (Jsoulliere, 2017).

Buffered bike lanes: According to Bikeway Design Guide (2011), these types of lanes have multiple uses. It provides greater shy distance between motor vehicles and bicyclists, Provides space for bicyclists to pass another bicyclist without encroaching into the adjacent motor vehicle travel lane, encourages bicyclists to ride outside of the door zone when the buffer is between parked cars and bike lanes, provides a greater space for bicycling without making the bike lane appear so wide that it might be mistaken for a travel lane or a parking lane, appeals to a wider cross-section of bicycle users. Encourages bicycling by contributing to the perception of safety among users of the bicycle network.

Protected Bike lanes: effectively designate bike space on the road and prohibit autos from invading it. Physical barriers, such as plastic bollards on-street parking or even planters, provide excellent protection for those riding bikes in on-street bike lanes (Jsoulliere, 2017).

Many studies have looked specifically at bicycle lanes and wide curb lanes separately to examine how they impact bicycles and cars to determine if bicycle facilities are beneficial at enhancing traffic operations (Torrance et al., 2009). When installed on an existing vehicular road access bicycle lanes may pose some problems if it is not well located. Traffic flow will likely increase if added on a narrow sized road. This in return will cause traffic congestion, lack of available parking space, lack of drop off spots, reduced vehicular street width and crashes of bicycles. Furthermore, the added bicycle lane should bring about an attractive environment to cycle and walk. Safety and comfort are amongst the aspects to be considered. Therefore, it is necessary to follow the bicycle guidelines when allocating cycling corridors so as to bring about a positive impact on its surroundings.

This literature review shows the assessment of the intuition between bikes and vehicles within the intersections in urban regions (Pu et al., 2017). The issue of urban cycle lanes can be framed within the broader context of sustainable mobility, though it deserves more specific attention, particularly given its links to the goals of sustainable and resilient cities (Fistola et al., 2020). According to (*Bikeway Design Guide*, 2011), Those prior studies, however, did not seek to evaluate and anticipate the vehicle delay caused by bicycles in various traffic scenarios, which is still a crucial issue that has not been adequately addressed (Pu et al., 2017). Bicycle paths are ordinarily on the right side of the road, between the adjoining travel path and curb, street edge, or parking path. Bicycle lanes can constitute a share of the road on the vehicular ways in urban areas. Bicycling as a mode of transportation is becoming increasingly common in the western world. Although further research and studies into how bicycles influence traffic flow on mixed roads are needed (Schaefer et al., 2020). “Cyclist safety has drawn a great interest from researchers; nevertheless, most of the previous work that evaluated the bicycle–vehicle conflicts was for the intersection areas” (Chen et al., 2018).

Cycle lanes are distinguished from the vehicle traffic by marking on the road. The vertical aspect distinguishes separated bike lanes from regular and buffered bike lanes. Their closer proximity to the adjacent highway and the fact that they are bike-only facilities distinguish them from shared-use paths (and side paths). Bike lanes that are separated are also known as cycle paths or safe bike lanes (*SEPARATED BIKE LANE*, 2015).

The design of a bike lane necessitates careful consideration of current traffic levels and activities, as well as sufficient protection buffers to protect bicyclists from parked and moving automobiles, as well as compliance to prevent encroachment and double-parking. Color, lane markers, signs, and intersection treatments can all be used to identify bike lanes (*Bikeway Design Guide*, 2011). This review consists of the definitions, principles, types, design guidelines, and evolution of bicycle planning.

2.3. Empirical Review

A case study from Philadelphia's experience, the Mayor (Kenney) installed a mile-long protected bike lane on Chestnut Street, from 45th Street to 33rd Street. This new lane is critical to the network because it links West Philadelphia to University City and Center City, as well as other bike lanes such as 40th, 38th, and 34th avenues. The researchers chose this segment of the lane for their treatment because of its critical connections, the street's width, which allows for feasible installation, and its designation as a high crash corridor due to high speeds (Berman et al., 2017).

This street has introduced crashes per mile compared to other streets. One of the primary goals of creating this lane was to reduce crashes and improve overall safety on this stretch of Chestnut Street (Berman et al., 2017).

Another case study on the development of a method to assist in evaluating the "best" cycling route integrated into public transportation in Mussurunga Station, Salvador, Bahia, Brazil is taken as exemplary literature for this study. The use of the focal group technique and content analysis to know the perception of cyclists interviewed about the main criteria for the choice of routes, used in its offsets as the division of 3 distinct groups of cyclists (students, workers, and activists cyclists) were satisfactory as allowed for the debate and the exchange of knowledge between these groups (Ana et al., 2014).

(Bicalho et al., 2019) used the Potential for Cycling Assessment Method (PCAM) to map the population's aptitude for cycling in the city of Oporto (PT). The authors demonstrated that propensity may be represented using a three-dimensional approach that takes into account three indicators: Cycling's Target Population (TP), Target Areas (TA), and Political Commitment (PCC).

Some cities around the world with the best cycling practices are listed below in the table.

Table 2. 7 Best cycling cities in the world

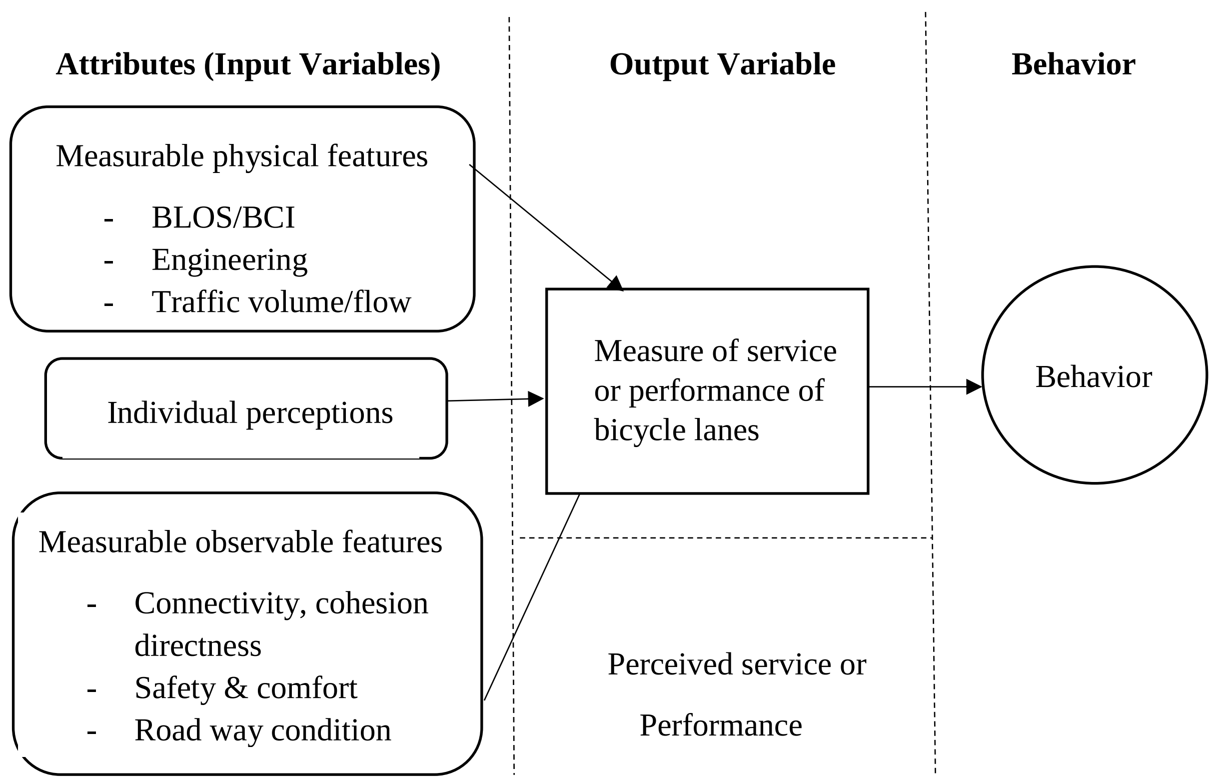
No.	Cities	
1	Utrecht, Netherlands	- 250 miles of committed bike lanes. - Cycling takes 50% of commutes
2	Sevilles, Spain	- 50 miles of cycle lanes in a year - A municipal bike rental plan called Sevici
3	Montreal, Canada	- 400 miles of bike lanes. - Cycling takes 2% of commutes
4	Copenhagen, Denmark	- 650,000 bike population (slightly more bike than the local 20anish people)
5	Berlin, Germany	- 13% of all trips in the city are made by bike - Hugely wide roads after second world war
6	Portland, Oregon	- 175 miles of bike lanes - 18% of citizens using bikes

Despite increased interest, cycling in Ethiopian cities has yet to garner widespread acceptance. It has a small part of the city's modal transportation for a variety of reasons; Local officials prioritized the construction of a roadway for motorized traffic rather than non-motorized traffic (Tulu et al., 2019). Although the local government has made some efforts to improve the Non-Motorized Transportation (NMT) environment, biking and bicycle facilities have received absolutely little attention (Eshetu, 2015). Lebu-Jemmo cycling corridor is the first cycle lane that has ever been built in the city of Addis Abeba. In reality, city bicycle lanes are typically judged solely on their length, regardless of the network's total quality or usefulness. Geometrical (width, slope, etc.) and construction (type of pavement) characteristics, as well as functional (reserved for bicycles or cycle-pedestrian), safety (visibility, signage, etc.), and connection (continuous network vs. isolated and separated cycle lanes) characteristics, all have a significant impact on the perception of the cycle network and the likelihood of using bicycles (Fistola et al., 2020).

Furthermore, planners and users are undoubtedly resistant to cycling as a means of transportation due to individuals' beliefs, attitudes, and intentions. Persuasion approaches used in various behavioral science studies to change people's attitudes and behaviors include psychological strategies, creating awareness, educational methods, scientific understanding, lowering barriers, increasing advantages, or designing an action plan (Bicalho et al., 2019).

Another thing they noticed was that the protected bike lane made some signs even more difficult for drivers to notice (Berman et al., 2017). The researchers recommended that spaces where conflicts between cyclists and vehicles should receive extra attention from safety improvements. In these cases, the NACTO Urban Bikeway Design Guide recommends colored—usually green in the United States—road markings can increase cyclists' visibility and raise users' awareness of the conflict.

2.4. Conceptual Framework



2.5. Lesson Drawn from Literature Review

A key takeaway from this Literature review is that bicycle facilities should not be an afterthought, and care requirements that have been adapted for cyclists may not be the best fit for their needs. According to (*Bikeway Design Guide*, 2011), bike lanes should be designed in consideration of guidelines and standards for the effectiveness and efficient use of the bike lane. Bicyclists' experiences, including interactions with current infrastructure and other road users, must be considered in the design of potential cycling infrastructure to ensure that it is as secure and useful as possible. The chestnut street for bikeway can be an example for the assessment of this research's study route (Lebu-Jemmo) corridor. It has brought clarity and focus to the research problem intended to be covered; Research methodologies to consider, broadening knowledge on bicycle planning. The use of different methodologies such as bicycle friendliness community metric, bicycle compatibility and bicycle level of service: had both benefits and challenges used on intersections, segments and public streets.

In the previous studies, the importance of NMT, design guidance and standards of bike lanes, its function, and type has been studied well whilst the evaluation of bikeway performance is often a neglected issue related to the level of quality, friendliness and effectiveness of the infrastructure. The same is true in the Ethiopian context. Many researchers including (Tulu et al., 2019) and (Eshetu, 2015) have studied about the use of bicycles for tacking climate change while there are fewer studies about bicycle infrastructure and its effectiveness. Moreover, the existence of national planning and design criteria as well as a local strategy is no assurance that they will be applied or understood properly. As a result, specialist training of practitioners on how to implement the principles included in the literature review is the final piece in achieving best practice. Therefore this study aims to evaluate the effectiveness of the Lebu-Jemo bicycle lane and its impacts on other road network users and businesses by the use of various methods developed before.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This study follows a theoretical stance of pragmatism philosophy which uses the combination of both single and multiple realities to examine using the best tools. This study used different ways of interpreting the matter and undertakes the research in broader views. Supportive concepts from multiple realities are to be considered instead of relying on a single point of view. The assessment of bicycle lane includes the consideration of multiple individuals' perceptions, beliefs, attitudes, and intentions towards the matter. The objectives of this study are achieved through a deductive approach that begins from an expected pattern and examines all the possibilities to reach the general conclusion.

3.1.1. Description of the Study Area

The study area is located in the Nifas Silk Lafto sub-city in Addis Abeba, Ethiopia. The site is selected because it is the first bikeway installed as a kick start to the plan in the city. The specific location of this bicycle lane is installed on the corridor from Lebu to Jemmo 1. The bicycle lane is a bi-directional way with a length of 3 km.

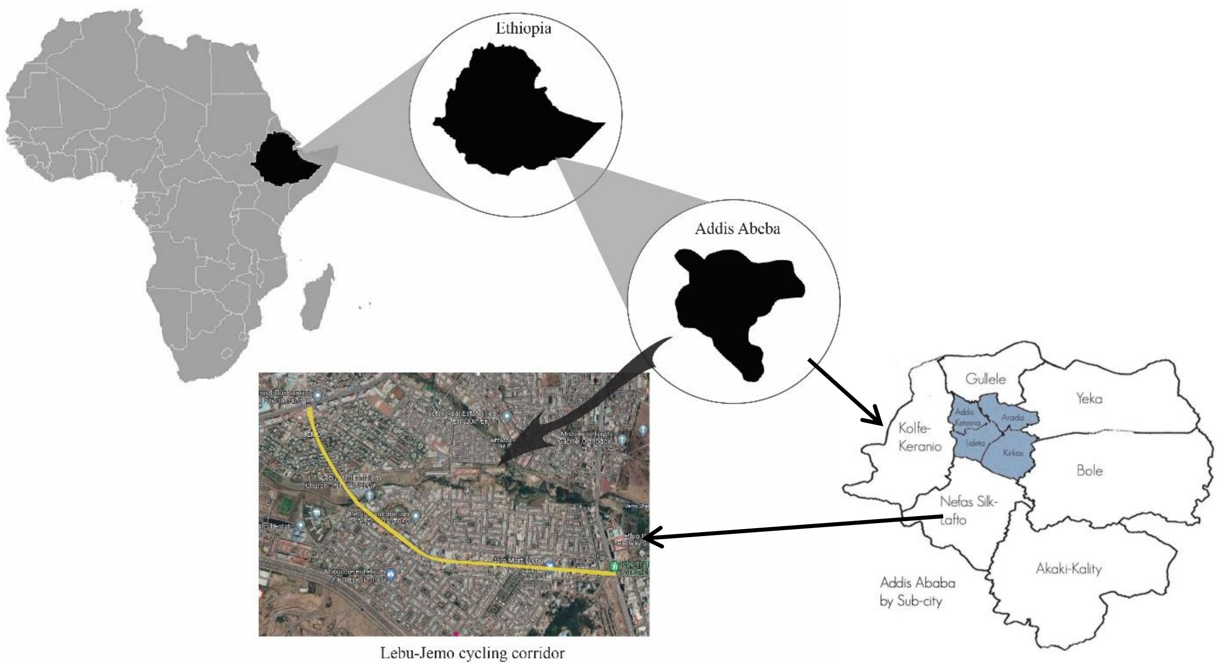


Figure 3. 1 location map of the study area

3.2. Measurement of bicycle lane effectiveness

3.2.1. Materials used.

During observation of the site, pictures of the area are taken using a smartphone. Secondary data sources like reports, pictures, documents, previous studies and maps are used from local offices in Addis Abeba and from the internet.

3.2.2. Methods used.

One of the best methods for obtaining data about the performance of on-street bicycling corridor is through observation of what is going on in the actual space. For this analysis, continuous site visits/ observation is used according to the five fundamental conditions identified by (LTSA, 2004) and (RTA, 2003). The other method conducted was a through study from previous literature. Previous studies on the measure of bicycle lanes have been conducted to come with methods of bicycle lane performance measurement.

3.3. Level of bicycle lane users

The objective two aims to assess whether the number of bicycle lane users increased or decreased after the installation of the bicycle and to compare with the number of cyclists before its installation.

3.3.1. Materials used.

The materials used for the site analysis with Bicycle Friendliness Community Assessment include pictures of the area are taken using a smartphone during site observation. Furthermore, for ease and quality of the counting cyclists' video is recorded using a smartphone besides the manual count done by data collectors. Necessary information, records, and points are written on A4-sized papers. Google Maps, Google Earth, and Arcgis 10.8 are used to locate and generate street network maps of the study area during the site analysis stage.

For the bicycle traffic count an extensive data collection made by Addis Abeba Transport Bureau to gather information about the number of cycle users in the specified region before the installation of the bike lane was collected. The count of cyclists along the corridor is recorded manually on paper and encoded in Microsoft Excel afterward to generate results of the average number of cyclists per hour.

3.3.2. Methods used.

One of the best methods for obtaining data about urban spaces is through observation of what is going on in the actual space. For this analysis, continuous site visits/ observation and questionnaires for commuters in that particular route are used according to the five variables (refer to section 2.2.2) of the bicycle-friendly community (BFC) assessment. Questionnaires help to collect primary data from the users of the route to record their perceptions. In addition to these methods, multiple site photos are taken to fill in some missing observations. Satellite images from Google earth are taken to prepare the location, land use, and street pattern of the study area.

For assessing the number of cyclists accessing the bike lane, the manual bicycle traffic count method has been used. The number of cyclists is counted at three different times of the day i.e. in the morning from 12 am to 1 am, in the daytime from 6 pm to 7 pm, and in the evening from 12 pm to 1 pm for five days. The recorded data from these rounds are then calculated into the average number of cyclists per hour and prepared in tabular and graphical forms. This result is then compared to the number of cyclists before the installment of the bicycle lane to reach results.

3.4. Impacts of the bicycle lane on other road network users and businesses

This objective aims to answer the question which impacts affect the road users of the Lebu-Jemo bicycle corridor, both motorized and non-motorized transport users, and business corridors adjacent to the bike lane.

3.4.1. Materials used.

To determine the impact of the bicycle lane on road users and businesses, a strategy of surveying is used in this study to collect information from a pre-defined group about a particular topic to reflect people's perceptions. The questionnaire is a type of survey filled by the respondent itself while interviews are filled by the interviewer using verbal responses from the respondent. A standardized interview is conducted to record the key informants' reflections on the topic. It necessitates the survey of an open-minded opinion of users on the bicycle lane without leading to any preconceived thoughts or ideas. Questionnaires are printed out with A4 size paper. Notebooks are used to record interview responses. It involves reformulating the stories given by people based on their experiences and in different contexts. It has used software like SPSS to record and analyze quantitative data. For the assessment of BCI and BLOS, secondary data from different offices have been used.

3.4.2. Methods used.

Assessment of the impact of bicycle lanes is done using surveys and interviews with different road users who access the vehicular road either by private cars or public transportations (taxi, bus, or bajaj). Other users who are influenced by the bicycle lane like pedestrians and businesses (restaurants, shops, banks, and gas stations) that are situated adjacent to the bicycle lane are included in the survey. Users' perception of their feelings towards the cycle lane concerning safety and comfort with the environment is collected through surveys and interviews which are both qualitative methods.

Another method is the use of the Bicycle Compatibility Index (BCI) assessment and Bicycle Level of Service (BLOS) analysis method by Harkey (1998) to evaluate the capability of the Lebu-Jemo road to accommodate both motorists and bicyclists and to measure on-road bicyclist comfort level. Both analyses are made using the calculations by gathering the important variables from concerned bodies. Below are the tables used to calculate BCI and BLOS assessments sourced from (Hughes & Advisor, 2015).

Table 3. 1 BCI data entry worksheet

Location	Geometric and road side data						Traffic operations data				Parking data		
Lebu-Jemo	No. of Lanes (one direction)	Curb Lane Width (m)	Bicycle Lane Width (m)	Paved Shoulder Width (m)	Residential Development (y/n)	Speed Limit (km/h)	85th %tile Speed (km/h)	AADT	Large Truck % (HV)	Right Turn % (R)	Parking Lane (y/)	Occupancy (%)	Time Limit (minutes

Table 3. 2 BCI Intermediate calculations worksheet

Location	Peak hour computations							Adjustment factors				
Middle block identified	Peak Hour Factor (K-factor)	Directional Split (D-factor)	Curb Lane %	Curb Lane Truck % (T-factor)	Peak Hour Volume (PHV)	Peak Hr Curb Lane Volume (CLV)	Peak Hr Other Lane(s) Vol (OLV)	Peak Hr Curb Lane Truck Vol (CLTV)	Large Truck Adjustment Factor (Ft)	Peak Hr Right Turn Volume	Right Turn Adjustment Factor (Frt)	Parking Adjustment Factor (Fp)

Table 3. 3 Bicycle Compatibility Index and Level of Service Computations worksheet

Location	BCI model variables										Results	
Midblock identifier	BL	BLW	CLW	CLV	OLV	SPD	PKG	AREA	AF	BCI	Level of Service	Bicycle Compatibility level

Table 3. 4 BLOS data entry & calculations worksheet

Route name	Vol_{15}	L	SPp	SPt	HV	PR_5	W_e	Wt	%OSP	Wl	Wps	Wv	AADT

Table 3. 5 BLOS score and level of service calculations worksheet

Route name	Vol_{15}	L	SPt	HV	PR5	We	BLOS score	letter grade	Level of service

3.5. Sampling

The study used different types of sampling techniques for various method of data collection. The questionnaire survey used simple random probability sampling technique for collecting responses from respondents. This technique was chosen because categorizing a diverse mix of road users passing by this route at various hours, with differing numbers and purposes is very challenging. Furthermore for the key informant survey, purposive/judgmental non-probability sampling was conveyed to choose the most knowledgeable sources from the business sectors that are adjacent to the bike lane.

The population reaching or crossing over this site is too many which leads to the calculation sample size using Corhan’s formula for unknown population.

$$N = [Z^2*P\ (1-P)] / E^2$$

E= margin of error, Z= Z-score, P= population proportion, N= population size

Table 3. 6 Sample Size

Population proportion	50%
Given Z value (Z-score)	1.96
Confidential Level	95%
Margin of Error	5

Detail calculation of sample size:

- Population type: any person can enter through the site at anytime from anywhere so it is difficult to bound the population size and sample frame.
- Sample Size = $[Z^2 * P\ (1-P)]\ /\ E^2$

$$= [(1.96)^2 * 0.5(1-0.5)] / (0.05)^2$$

$$= 384.16$$

Thus, for this case, a sample size of at least 384 people would be necessary. Among this sample size 15 business owners are interviewed as key informants while the rest 369 (both motorists & non-motorists) are contacted through questionnaires.

3.6. Data Type and Collection

The major data type used in this research is observational data which was obtained through human observations, manual counts, record information and open-ended inspection. This data type was used to partly answer the first research question. The second data type used is derived/compiled data type that involves using of existing data from concerned bodies to create a new data through transformation. Bicycle traffic count, bicycle friendliness community, bicycle compatibility index and bicycle level of service used secondary data from secondary source.

Evaluating data using the qualitative and quantitative data analysis or mixed-based approach is used in this research data. Counting of bicycles and BCI/BLOS analysis to assess the effectiveness of the use of bicycle lane is quantitative data analysis method. While the analysis of population perception through questionnaires and interviews are data obtained through qualitative analysis. Data obtained through the qualitative data analysis method consists of words, pictures, maps, descriptions, and observations. Primary data is collected for addressing the problem at hand while secondary data is collected for purposes other than the problem at hand (Ajayi, 2017).

Table 3. 7 Data Collection

Objectives	Primary Data Collection	Secondary Data Collection
To assess the number of cyclists using the bicycle lane.	Cycle count, video recording, observation, questionnaire	Reports and data from Addis Abeba Transport Bureau.
To demonstrate the impacts of the bicycle lane on other road network users and businesses.	Survey questionnaire, Key informant Interview and BCI/BLOS analysis	Reports and data from Addis Abeba Transport Bureau.

3.7. Data Analysis Techniques

In this study, qualitative and quantitative data analysis will be performed to evaluate the data. Qualitative analysis will be used to answer the questions why, what, and how while quantitative analysis deals with statistics and numbers. This type of study refers to the procedures and processes that are utilized for the analysis of knowledge to supply some level of understanding, explanation, or interpretation. Some of the most commonly used methods are:

The use of Narrative Analysis for conducting study under objective two will be used. It involves analyzing data that comes from a variety of sources including field notes, surveys, interviews, and other written forms. It involves reformulating the stories given by people based on their experiences and in different contexts. It may use software like SPSS to record quantitative data. Descriptive analysis techniques are employed to analyze the collected data.

Table 3. 8 Data Analysis Method

No.	Objectives	Data Analysis Method
1	To identify ways of measuring the effectiveness of the bicycle lane.	Qualitative Analysis
2	To assess the number of cyclists using the bicycle lane.	Qualitative and Quantitative Analysis
3	To demonstrate the impacts of the bicycle lane on other road network users and businesses.	Narrative Analysis, Quantitative Analysis

Table 3. 9 Variables of the Study

No.	Objectives	Variables
1	To identify ways of measuring the effectiveness of the bicycle lane.	Bikeway performance
2	To assess the number of cyclists using the bicycle lane.	Bike lane performance, roadway condition, location, infrastructure, number of bicycles assessed
3	To demonstrate the impacts of the bicycle lane on other road network users and businesses.	Traffic volume/flow, safety/protection of bike lane, cycling culture

3.8. Ethical Consideration

The ethical aspect of the research will take place to protect the rights and welfare of research participants, as well as to reduce the risk of physical and psychological discomfort, damage, and/or treatment occurring as a result of the research procedure, to protect the rights of the researchers to conduct lawful research, and to protect the reputation of the university implementing or supporting research, and to reduce the probability of claims for negligence against specific researchers, universities, and all cooperating persons or organizations.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The analysis for the two objectives is based on perceptual and quantitative data analysis. The practice from the 1998 Federal Highway Administration National Strategic Plan Implementation manual was adapted to satisfy the second objective of this research, which is to measure bicycle compatibility and level of service based on indices from best experience. The index presents the appropriate measurement indexes. Bicycle tracking from consistent manual bicycle count data related to bicycle lanes and number of cyclists and site analysis based on the League of American Bicyclists evaluation of bicycle friendliness community is the basis for analyzing objective one.

4.1. Measurement of bicycle lane effectiveness

The Lebu-Jemo cycling corridor is the city of Addis Abeba's first bicycle lane to be installed. The Addis Abeba city administration's Road and Transport Bureau, Non-Motorized Transport Strategy, inaugurated this cycling lane in February 2020. The cycling lane was created as a pilot initiative to encourage Addis Ababa to invest in safer, more sustainable transportation.

The bikeway is installed from Lebu to Jemmo corridor on one side of the street which is 3km long. The three-lane street in either direction was redesigned to accommodate a curbside bi-directional cycle facility on one side, limiting on-street parking to the other side. The wide travel lanes on this street allowed for plenty of existing space to create this dedicated cycling facility.

Figure 4. 1 lebu-jemo cycling corridor

Figure 4.1 shows the study area and its interaction with other sub-arterial and local streets. Lebu-Jemo bike lane is stretched on one side of the route with a length of 3 km as shown on figure 4.2 on 2D view.

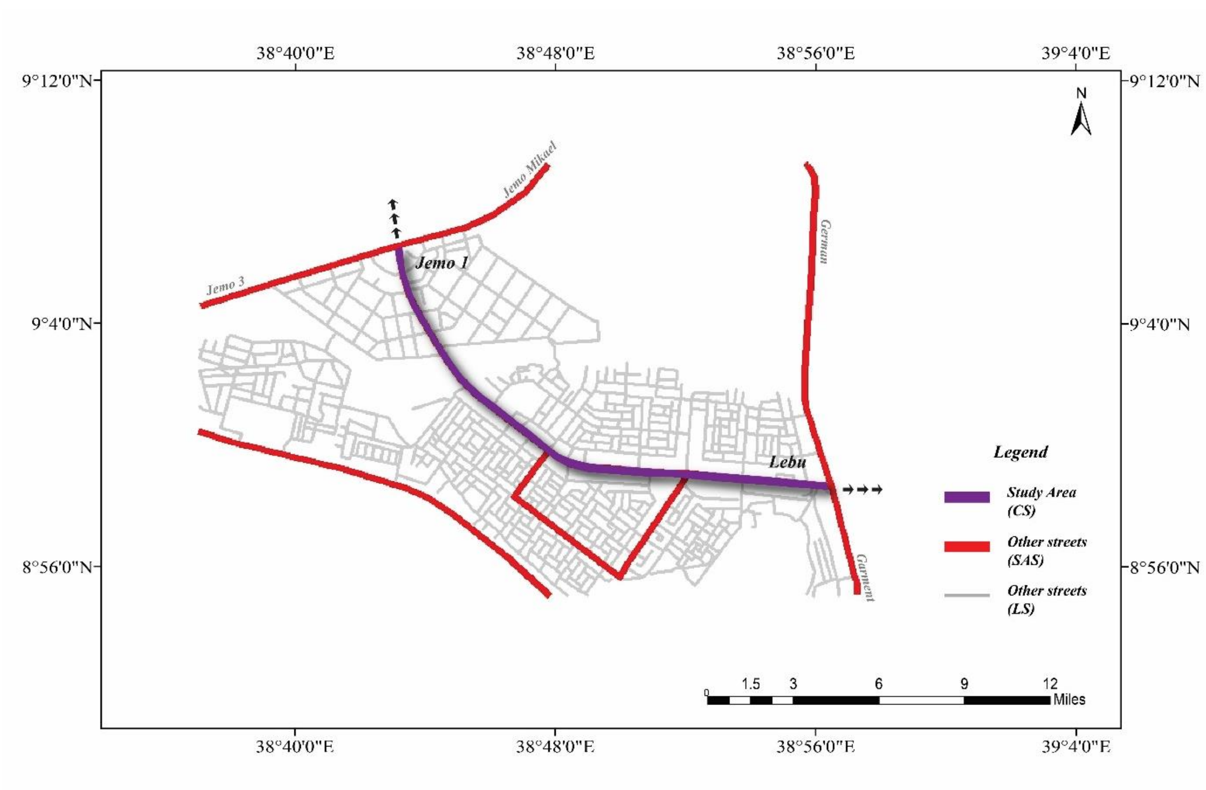


Figure 4. 2 study area

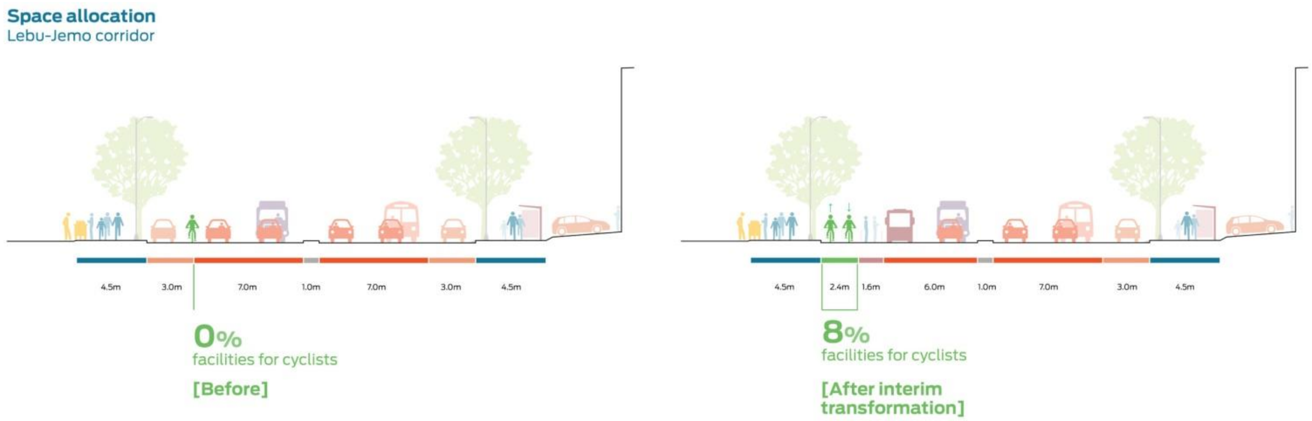


Figure 4. 3 sectional view of study area before and after installation bike way

The sectional view sourced from (Addis TV, 2020) in the figure above shows the difference between before and after installation. A bicycle lane of width 2.4 m has been provided taking an 8% of the exacting vehicular access.

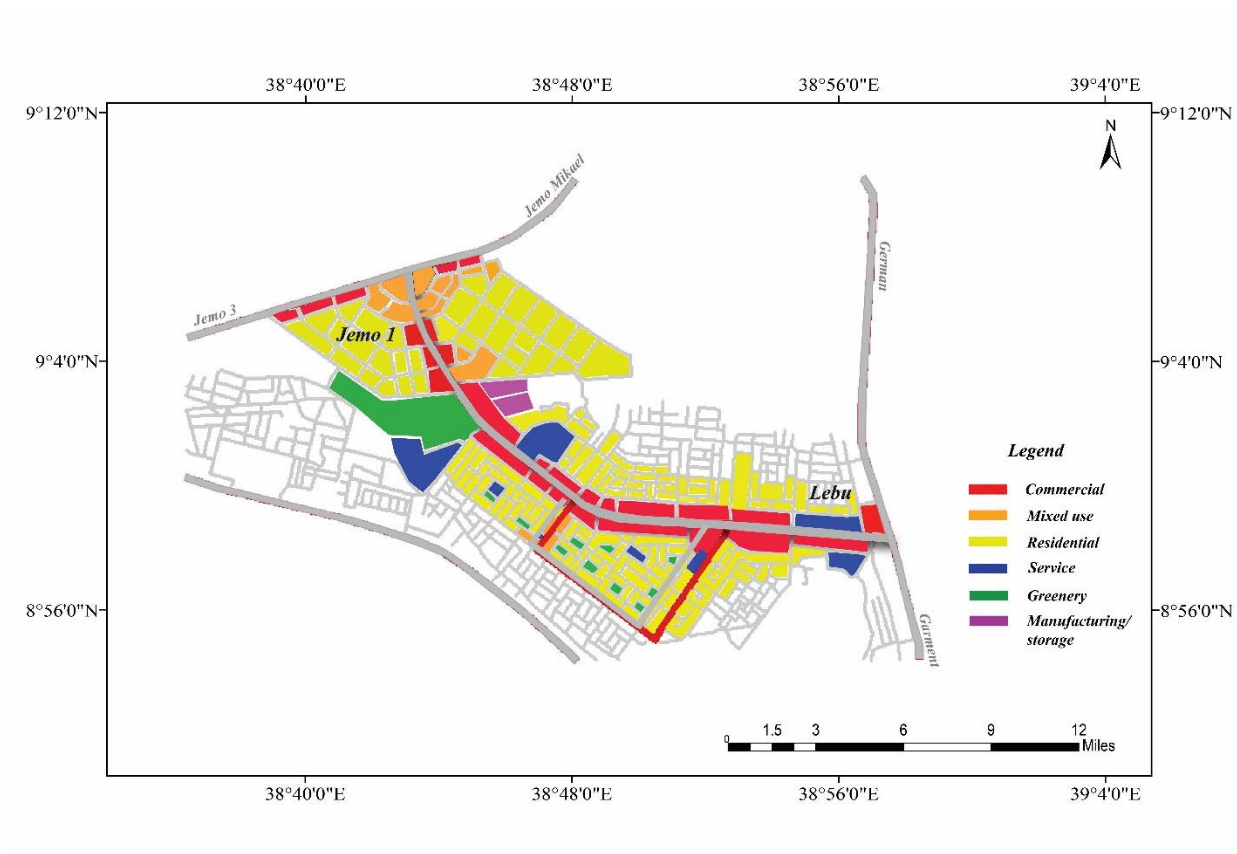


Figure 4. 4 land use activity

The above figure shows the study area, is a mixed-use area with a lot of commercial activity along the Lebu-Jemo corridor. Different businesses are embedded in the area such as supermarkets, shops, restaurants, boutiques, gas stations, and street markets. As clearly shown in the figure, the majority of land use is covered by residential development of condominiums, real estate, and private and social housing. This variable shows a mixed activity which in general, indicates greater access to services and facilities can be easily covered by cycling. Furthermore, residents with a higher land use mix are said to engage in more social and outdoor activities. This has increased the demand for short-distance travel, which in turn has increased bicycle usage. These characteristics indicate that the Lebu to Jemo bicycle lane corridor has good bikeability.

4.1.1. Cohesion.

It is the extent to which a bicycle network joins up with origins and destinations - with all sites of departure and arrival (refer section 2.2.1). From the continuous site observation made and the maps shown in figure 4.2, it was studied that the bike way connects major destinations of public transport station in both ways, Jemo 1 and Lebu which are the major terminals of transportation that take to different parts of the city. However, network continuity of the lane on both ends and its linkage to major land use and activity in the city was unplanned. The bike way takes nowhere to the city; it is only bounded in the study area which is a major turn off for the bicycle users.

4.1.2. Directness.

Directness refers to minimizing the amount of time spent waiting at intersections. The number of times cyclists have to stop or do not have right of way should be as near to zero as practicable on all types of cycle routes, though this will, likely be difficult to achieve in practice.

A bike lane with many intersections is thought to have low connectivity and directness, while one with fewer intersections is thought to have high connectivity. The bicycle lane from Lebu to Jemo has only one roundabout (varnero) and three intersections without traffic lights, indicating that a bike rider can easily use the lane without stopping. This measurement indicates that the lane is simple to understand by all users. Furthermore, the intersections are not properly laid out to allow for safe bicycle crossings and other road users.

However the poor physical condition of the site which lacks proper maintenance and illegal encroachment of the bike lane by other road users has made it difficult for the cyclists to use the bike way without stopping.

4.1.3. Safety.

Safety is a treatment aimed at avoiding confrontations; in terms of crossing vehicles, speeds, and separation from vehicle kinds, in a uniform manner. People must have safe access to stations with well-designed crossings that allow pedestrians to cross busy streets safely and conveniently, and they must meet standards such as a raised crosswalk that is elevated to the level of the adjacent footpath considering the speed of the motor vehicle, at unsignalized crossings, a walker should not have to cross more than two lanes of traffic before reaching a walker refuge, and speed bumps that are designed to reduce the speed of the motor vehicle.

In relation to accidents related to bicycles, two minor accidents have been recorded as data collected from Addis Abeba Traffic Management Agency. One is a cyclist lightly being hit by a car while riding outside of the bike lane resulting in no injury. The second one happened on a major intersection (musica bet) when pedestrians get hit by a cyclist when trying to cross the road.

4.1.4. Comfort.

Comfort is about prevention of inconvenience for all users by eliminating the need to stop, providing smooth surfaces, and minimizing obstacles from other cars. It is clear that the environment is a variable because it has an impact on comfort and attractiveness. There are four popular indicators for measuring this variable: bicycle lanes along water, bicycle lanes along beauty, bicycle lanes along built-up region, and bicycle lanes along green space. Because it is erected in a built-up region, the Lebu to Jemo bicycle lane only meets one of the measurements. The bicycle lane received no shadow impact from the built-up area because it was erected in a west-to-east direction, exposing the bike rider to the sun all of the time during the hot season. During field observation, the researcher discovered that the majority of the buildings created opposite the bicycle lane are low rise buildings, exposing the bike lane to south west sun light radiation, which is the most hazardous radiation generated and can affect the comfort of bicycle rider.

4.1.5. Personal Security.

Personal security, feeling of safety, and the attractiveness of the environment are all examples of attraction. According to the researcher's observations in the field, the bicycle lane is being used by pedestrians as a walking side corridor, which makes cyclists feel restricted when riding; for safety reasons, the authority separates the bicycle lane from the traffic lane with thermoplastic delineators and Bullard's, but the thermoplastic delineators are mostly damaged, and the Bullard's are mostly damaged which minimized the safety of the cyclists.

4.1.6. Discussion.

According to the study made by AACRA, the role of the biking lane project was to explore the possibilities of urban riding and cycle sharing in Addis Ababa by focusing on air quality and public health issues. However according to (LTSA, 2004) and RTA (2003), the five fundamental conditions must be met for an appealing cycling network that strive to meet in order to be effective cycle routes. The Lebu to Jemo bicycle lane project ran into a number of obstacles when it came to improving mobility along that area. The first issue is that the lane is blocked by other motor vehicles for parking, laying by on the bicycle lane to pick up passengers, and using it as a transportation station, forcing bicyclists to utilize the motor vehicle traffic lanes to avoid them, jeopardizing user safety. The lack of pedestrian awareness about the bike lane is the second safety issue in this bike lane, since most of the time they push the walking area inside the bike lane space. Aside from this issue, the lane lacks a shade effect that could persuade pedestrians to choose bicycles as a form of transportation.

The connectivity of the bike lane is considered high because it has fewer intersections with just one roundabout (Varnero) and three intersections without traffic lights, indicating that a bike rider can simply use the lane without stopping. This value implies that the lane is easy to comprehend for all users.

4.2. Assessment of the number of cyclists using the bicycle lane.

To address the first objective of this research, detailed observation of the study area by using the five E’s from the BFC metric (from section 2.2.2), taking pictures and recording videos, cycle count method of analysis, and conducting a survey through questionnaires for motorized and non-motorized transport users were applied to come up with the results.

4.2.1. Site Analysis Result per BFC Metric.

The site analysis was made using a method of evaluation by the LAB program i.e. Bicycle Friendliness Community metric's five variables. (Refer to section 2.2.2)

4.2.1.1. Engineering.

The bicycle infrastructure was assessed in detail from the start of the bike lane to the end with the use of photographs and recordings. From the researcher's observation, the following results were noted. Thermoplastic lane markings along the entire length were complemented with green markings at all intersections, and curb cuts to indicate where there were conflict zones. On-ground and curb-side signs were painted and installed to inform the citizens about the new infrastructure on their streets. Nevertheless, the current condition of the lane has made it harder for its users to easily ride on. Through time, green concrete blocks have been replaced because the thermoplastic lane markings were out of use. Currently, the green concrete markings are misplaced leading the lane unsafe to cycle on. The figure below shows the comparison of the before and after effects.

The Figure 4.5 on the left sourced from (Addis TV, 2020) shows the bike lane right after it was added when the buffer was thermoplastic whilst the right shows the current condition of the cycle lane with misplaced markings causing uncomfortable cycling environment.

Figure 4. 5 before and after site physical condition

4.2.1.2 Education.

Education focuses on teaching the public about safe riding and traffic habits to get skills and confidence to ride. From the observation on study area, cars are continuously seen parked on the bicycle lane because of lack of space to park and use in the business places allocated adjacent to the lane. Other two/three-wheeled motorized transports like motorcycles and bajaj's pass by through the bicycle lane to travel faster whenever there is traffic congestion. Consequently, this makes the bicycle users unsafe and uncomfortable to ride freely.

It is also observed that most of the cyclists are tracked cycling out of the bicycle lane together with vehicles on the vehicular road access. Pedestrians are mostly seen walking in the bike lane especially during the night time while street vendors occupy the area during weekends and holidays.

The images below show the transition of the bike lane through time after installation. The ‘After’ effect shows the current condition of the cycle lane while the ‘before’ shows what the bike lane looked like right after it was launched. The figures under ‘before’ are taken from (Addis TV, 2020).

Before	After
	
	

Figure 4. 6 motorized transport interfering the bike lane

4.2.1.3 Encouragement.

One of the encouraging programs that are being held on Sunday mornings at the end of every month has been planned by stakeholders and a task force, led by the Traffic Management Agency in partnership with district heads, the health bureau, sports, and youth associations, and local NGOs, rebranded the initiative “Menged Le Sew” – meaning “Streets for People” in Amharic. Lebu-Jemo road is one of the areas where this initiative is undertaken. Even though most citizens do not have the financial means to own a bicycle, the availability of car-free days and bicycles deployed by the Ministry of Health encourages the use of bicycle riding. A lot of children, youngsters, elders, athletes, and families are seen enjoying themselves on the roads. Below is the picture was taken on April 3, 2022 “Menged Le Sew” event.

Figure 4. 7 car free day event

4.2.1.4 Enforcement.

Despite the best efforts of city agencies, there has not been enough consistent enforcement to prevent cars from illegally encroaching on cycle lanes, which are very frequently parked for extended periods of time. Three-wheeled motors using the cycle lane to pass by quick from the traffic. The Traffic Police and the TMA have been enlisted to educate and deploy more enforcement personnel in order to better combat this type of driving conduct at all points along the route. However, people are still seen commit illegal activities such as parking, street vending and driving in the bike lane.

4.2.1.5 Evaluation and Planning.

The creation of a bicycle network is hampered by poor land use planning. The city master plan has shown to construct a compact and connected metropolis in theory; yet, unplanned horizontal growth of the city poses an issue in infrastructure provision. Houses and buildings have been built without considering the future requirement for transportation infrastructure. This could provide a problem to the city's present and future bicycle network expansion.

4.2.2. Bicycle Tracking Result.

Much data was gathered prior to the analysis via observation as well as the collection of secondary data from offices like Addis Abeba Transport Bureau and Addis Ababa City Roads Authority (AACRA). Since then, data has been collected on the number of bicycles along the corridor at three different times of the day for five rounds. A report made on this particular bike lane by Non-Motorized Transport (NMT) Strategy for Addis Ababa, AARTB was used to compare the bicycle count results from three years back.

In the table below, the data from these five rounds have been combined into averages. Table 4.1 clearly shows the recorded manual bicycle count data during three times of the day for five days. These data are then calculated into average number of cyclists per hour in the study area.

In addition, hundreds of user questionnaire responses by people who use the corridor frequently have also provided qualitative input in addition to the quantitative data.

Table 4. 1 Cycle count record

Bicycle count days	Period of time	Duration counts for 1 hour (LT)	No. of Bikers
Day 1	Morning	12am-1am	11
	Day time	7pm-8pm	9
	Evening	12pm-1pm	12
Day 2	Morning	12am-1am	9
	Day time	7pm-8pm	8
	Evening	12pm-1pm	18
Day 3	Morning	1am-2am	12
	Day time	7pm-8pm	10
	Evening	12pm-1pm	13
Day 4	Morning	1am-2am	10
	Day time	7pm-8pm	9
	Evening	12pm-1pm	15
Day 5	Morning	1am-2am	9
	Day time	7pm-8pm	8
	Evening	12pm-1pm	16

From the manual count, it is observed that there are higher numbers of cyclists during weekend evenings. This indicates that most people are bicycling for enjoyment and refreshments more than commuting to places as a mode of transport.

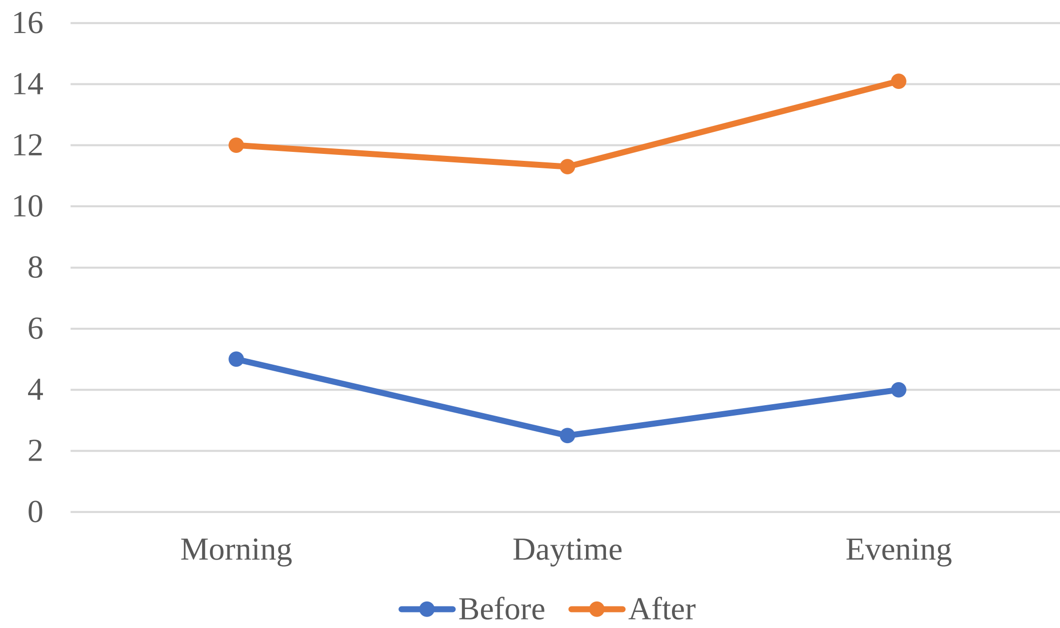


Figure 4. 8 average bicycle users before and after

The graph indicates before and after relationships about the number of users at different times of the day. Before and after the installation of the bike lane the average number of cyclists per hour during the evening shows a higher increment than the other times of the day. The data labeled as "before" were collected from various data sets and provided by the Addis Ababa Road Transport Bureau (AARTB). In contrast to the bike count data between three years back (7.5 times) and now (8.6 times) shows a very slow increment of cyclists.

4.2.3. Survey results.

This study has gained 312 responses returned out of 359 distributed questionnaires 15 being the key informant interviews. The questionnaire has been filled by those above the age of 18.

Table 4. 2 Bicycle owners

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	103	33.0	33.2	33.2
	No	207	66.3	66.8	100.0
	Total	310	99.4	100.0	
Missing	System	2	.6		
Total		312	100.0		

From the total number of respondents asked, only 33% of them state they do have bicycle and 66.3% of them do not have bicycle whereas the rest 0.6% of them haven't responded to the question.

Table 4. 3 Number of cyclists

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	155	49.7	49.7	49.7
	No	157	50.3	50.3	100.0
	Total	312	100.0	100.0	

Table 4.4 as illustrated above, from the total returned responses, 49.7% of the responses show that the participants do cycle while the remaining do not cycle due to many reasons.

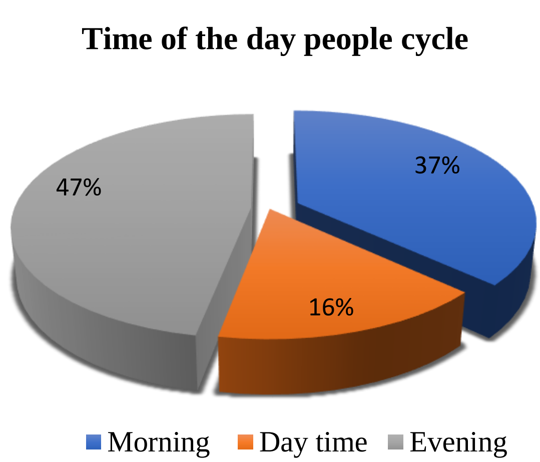


Figure 4. 9 time of the day people cycle

As shown in the figure above, both motorized and non-motorized transport users who said they bicycles were asked at which time of the day they frequently ride a bicycle. According to the pie chart, the majority of cyclists ride during the evening next to that, 37% of the respondents ride at the morning while the rest cycle during the daytime.

Table 4. 4 Bike lane users

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	96	30.8	36.8	36.8
	No	165	52.9	63.2	100.0
	Total	261	83.7	100.0	
Missing	System	51	16.3		
Total		312	100.0		

From the total valid responses collected about how many of them were using the bike lane effectively, the majority of participants which is about 63.2% from the above table do not use the bike lane, 36.8% of them use the installed bike lane and the rest from the total participants haven’t filled the question.

Table 4. 5 Functionality of bike lane

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	71	22.8	28.1	28.1
	No	156	50.0	61.7	89.7
	I don't know	26	8.3	10.3	100.0
	Total	253	81.1	100.0	
Missing	System	59	18.9		
Total		312	100.0		

In table 4.6, from 253 active respondents, 28.1% of the respondents think the bike lane is functional and being effectively used by its users while 61.7% of respondents said the bike lane is giving less function than its intended to give and the rest 10.3% do not know if it’s giving function or not.

Of the total respondents who completed the questionnaire, the majority of them indicated that the main reason that hindered them from riding bikes was the fact that cycling is not a trend/culture in the city or the people are not initiated in using bicycles. As illustrated in the graph below, the other causes commented by 18.2% of the respondents' were that many people do not own bicycles and 15 % of them said people have lack safety to bicycle on the provided bike lane. Lack of maintenance which leads to uncomfortability has been recorded as one of the reasons many people are not cycling. 6.4% of the participants said what kept them from bike riding is because the bike lane is not connected to other bike ways or that it is short and lacks continuous network.

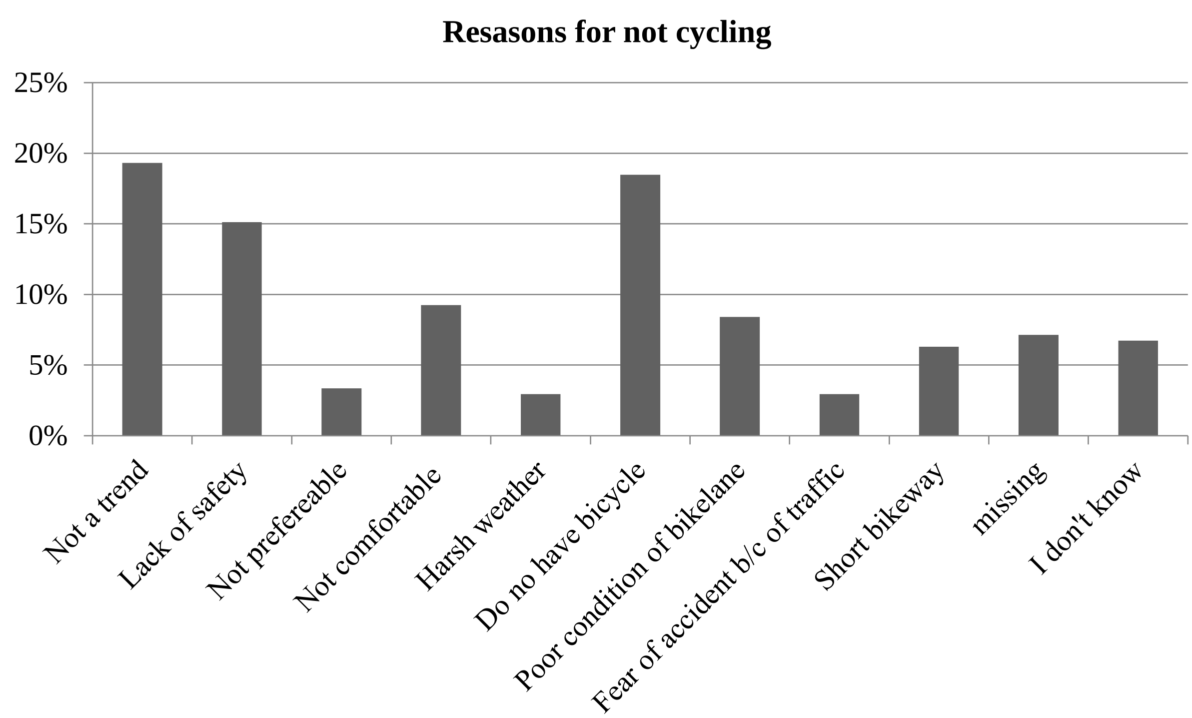


Figure 4. 10 causes for not cycling

4.2.4. Discussion.

To answer the first research question, how effectively do cyclists use the bicycle lane; three methods of analysis have been used. The first method, observation of the study area using LAB's evaluation metric, was used to evaluate the Lebu-Jemo bicycle corridor according to the five key variables which will guide how the variables play an important role in the rate of Lebu-Jemo bike lane users. The site observation according to the five E's analysis, Engineering and Education analysis of the bike lane needs an improvement while the rest are evaluated as good. For people to bicycle with comfort and safety, according to (LTSA, 2004) and RTA (2003), an appealing cycling network facility must strive cohesion, directness, safety, comfort, and personal security to meet to be effective cycle routes (refer to section 2.2.1). From the observation, it is clear that the current condition of the Lebu-Jemo bicycle infrastructure needs maintenance. From the findings, it has been mentioned that car-free day events are held each month by AATM which is a good way to encourage people in using NMT. Moreover, education and enforcement in the community should be strengthened to guide those people parking in the bike lane, vending on the bike lane space, and motor vehicle drivers who are violating traffic management agency regulations in using the bike lane properly.

The second and key method to attain objective one, bicycle count analysis, has been applied to compare the before and after relationship between the number of cyclists after the installation of the bike lane. Following the bicycle tacking analysis made, the result shows an increase in the number of cyclists after the interim bi-directional cycling infrastructure was installed on the corridor with 8.6 times the number of cyclists before installation. This indicates the installation of the bicycle infrastructure initiated the community to use bicycles as one mode of transport to commute to places. During site observation, it has been noticed that there are many bicycle rental services in the study area following the installation of this infrastructure. This directly affects the number of cyclists to rise because of easy access to bicycles. In contrast to the results of previous studies, the number of cyclists increased very slowly.

The last method, the collection of people's perceptions, has been obtained to figure out the thoughts and bike lane usage habits directly from the community. The responses from the questionnaire survey show only 33% of the respondents own bicycles. This indicates lower ownership of bicycles by the users. Despite the low ownership, almost half of the respondents – 49.7% of the cycle.

This indicates that the people have initiatives to cycle using rental bicycles and other methods no matter the reasons that hinder them to own a bicycle. As some of the respondents mentioned the reason for the low ownership rate was that the price of bicycles was unaffordable and highly expensive. Due to a lack of local bicycle manufacturers and high import charges, bicycles are out of reach for the general public in the city.

Furthermore, from the question on how many people were using the provided bike lane, the analysis identifies that the majority of the participants – 63.2% of them do not use the bike lane due to many reasons. From observations and information from respondents, they tend to cycle outside the bike lane together with vehicles, and some of them prefer cycling in less active areas designed with a wider and more comfortable bike lane while others prefer to ride on local roads with fewer cars interfering. As stated in the responses most of them think the bike lane is not effectively being used by cyclists because of several reasons. One of the major causes that impeded the participants to use the bikeway is the absence of a cycling culture in the city, the behavior of private car drivers imposing a lack of safety on bicycle users, and the fact that the bikeway is not continuously networked to other bikeways and major areas led bicycles to not be used as an alternative mode of transport in the city.

In general, the results from both qualitative and quantitative data indicate that the number of cyclists has increased slowly following the installation of the bicycle lane in the corridor according to the quantitative analysis. However, from the qualitative data result, despite the slow increment in the number of cyclists in the area the majority of them do not use the provided bike lane due to lack of safety, maintenance, and un connectedness of the bikeway.

4.3. Impact of the bicycle lane on other road network users and businesses.

4.2.1 Population perception analysis.

Table 4. 6 Value of bike lane

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	206	66.0	74.1	74.1
	No	72	23.1	25.9	100.0
	Total	278	89.1	100.0	
Missing	System	34	10.9		
Total		312	100.0		

Here the table shows how the respondents think about the value of the bike lane among the community. From the collected data, 66% of the total respondents said that the bike lane adds value to the community through different means as such initiation to promote healthy and friendly environment, 72 of them from the total 312 respondents think the bike lane has no value to the community while the left respondents haven't given any response to the question.

In response to the above question, the following data has been recorded from those who think the bike lane has value to the community.

Table 4. 7 Advantages that the bike lane provided to the community

		Frequency	Percent
Valid	Safety and comfort	28	8.9
	Created awareness and initiation to using more bicycles	16	5.1
	Promoted the use of NMT (non-motorized transport)	12	3.8
	Ease of movement	10	3.2
	Environmentally friendly	12	3.8
	Money saving	10	3.2
	Promotes Health	22	7.0
Total		110	35.0

The question, "If yes, which advantages has this bike lane provided?" was raised for the respondents who felt positive about the bike lane adding value to the community in table 4.7. Among those, the majority of the respondents who gave answers to this item in table 4.8 thought that the bike lane has majorly provided safety and comfort after the installation of bike lane for cyclists.

Of the mentioned advantages, 8.9% of the respondents are happy about the bike lane because it promotes health and sporting activity of the community. 5.1% of the respondents indicated that the installation of the bike lane has initiated the people to using more bicycle out in the public, 3.8 % of them said the bike lane promoted the use of NMT, 3.8% of them replied it is environmental friendly and the rest think that it is a money saving method and it helps for an ease of movement.

Table 4. 8 Drawbacks or discouraging reasons to use this bike lane

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Traffic congestion	19	6.1	20.7	20.7
	Narrowed vehicular access	17	5.4	18.5	39.1
	Lack of car parking and drop offs	19	6.1	20.7	59.8
	Increased accidents and bike crashes	13	4.1	14.1	73.9
	Unattractive environment	11	3.5	12.0	85.9
	Lack of safety because of cars	13	4.1	14.1	100.0
	Total	92	29.3	100.0	
Missing	System	222	70.7		
Total		314	100.0		

As table 4.9 in the above, only 92 respondents gave answers to the question, “. If No, What do you think are the drawbacks this bike lane has brought. Among them, 19 of them said it causes traffic congestion; nineteen of them think it brought lack of car parking and drop off space; seventeen of the respondents complained the bike lane is causing the existing vehicular access to be narrowed. From a total of 92 valid responses, 14.1% of them think the bike lane increased accidents and bike crashes; 14.1% of others felt lack of safety because of motorized transports interference in the space left for cyclists while the rest thought that it has created unpleasant environment.

Below is the graph that clearly shows the variation in between the responses of the people. The majority of negative impacts raised by the respondents was traffic congestion, lack of car parking space and narrowed vehicular access.

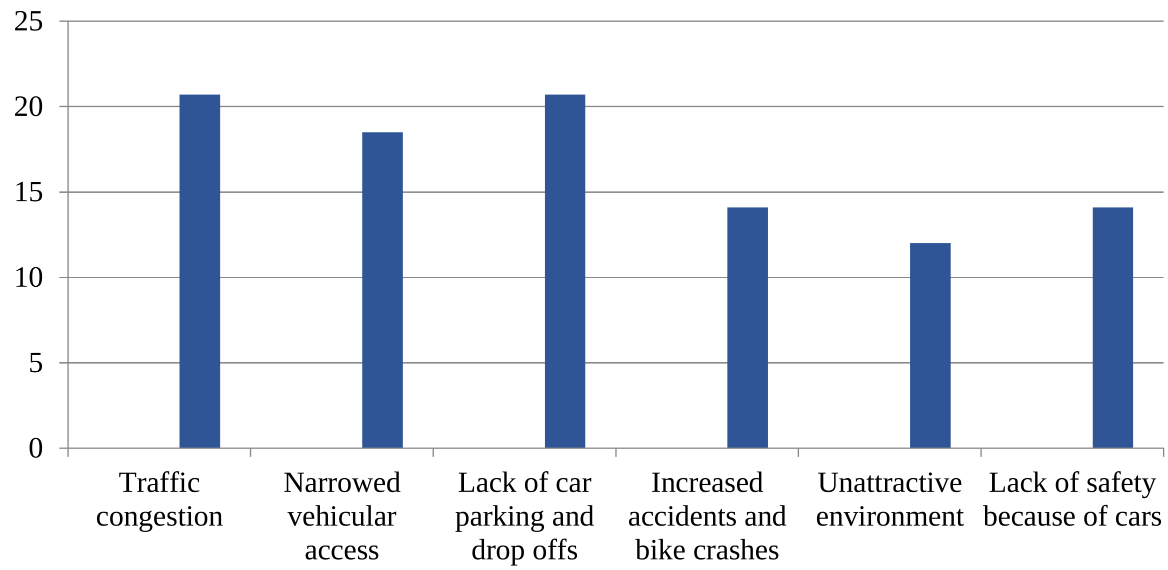


Figure 4. 11 negative impacts of the bike lane

Table 4. 9 Necessity of the bike lane according to location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	150	48.1	52.1	90.6
	No	111	35.6	38.5	38.5
	I don't know	27	8.7	9.4	100.0
	Total	288	92.3	100.0	
Missing	System	24	7.7		
Total		312	100.0		

In here, the above table shows collected respondents' opinion on the relevance of the bike lane in the particular study area. 111 of the respondents from the total valid responses which is about 38.5% of them do not think it is necessary to have a bike lane installed in that location, 52.1% of them think the bike lane is relevant in that location while the rest said they do not know whether it is relevant or not.

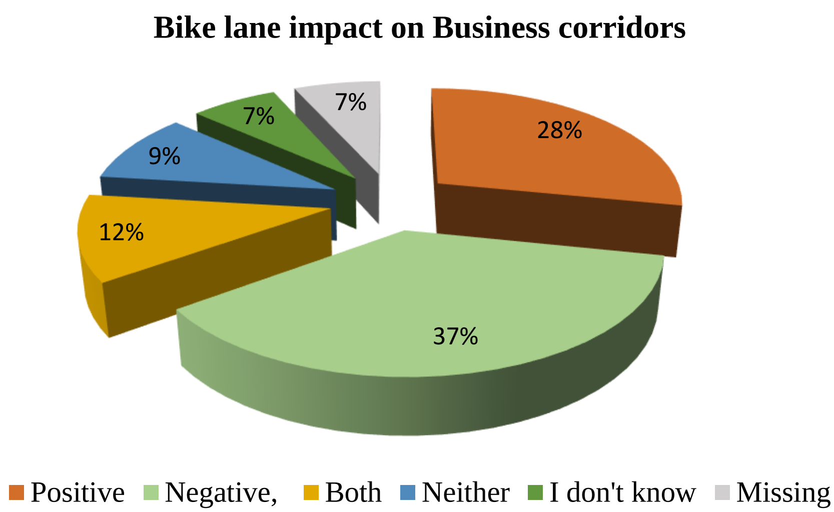


Figure 4. 12 bike lane impact on business corridor

The pie chart above is the response of the people who filled to the question “Does the bike lane have a positive or negative impact on businesses located adjacent to the bicycle lane. 37% of them said the bicycle lane has a negative impact on the business corridors; 28% of them are positive about the bike lane; some of them think it has both negative and positive impact.

Some of the people (7%) indicated that they do not know what impact it has and the rest returned the questionnaire without responding to this question.

Table 4. 10 Positive impacts of bike lane on business corridors

		Frequency	Percent
Valid	Creates safe environment	22	21
	Attracts more businesses	17	16
	Economically friendly	16	15
	Facilitates transportation	15	14
	Time saving	15	14
	Employment opportunities	13	12
	Develops cycling trend	9	8
Total		107	100

In table 4.11, among those who responded positively about the impact on business corridors in the above question (see figure 4.12), 21% of the participants are happy that the bikeway has crated safe environment; 16% think that the existence of the bike lane attracts more business and customers to the market; it develops cycling trend throughout the city; 15% are happy about the lane because it is economical friendly. Moreover, 12% of respondents reported it creates employment opportunities to the youth while the other respondents mentioned time saving and facilitation of transport as positive impacts of the Lebu-Jemo bike lane on business corridors adjacent to the lane.

Similarly, from figure 4.12, 37% of the respondents think the Lebu-Jemo cycling corridor has negative impacts on marketers adjacent to the corridor. The table below shows that 38% of the participants responded the existence of the bicycle infrastructure has caused lack of parking space for customers to drop by into the shops or for the customers to unload packages. The other 30% said it caused traffic jam, 15% of them said it slows productivity in the market and the rest it affects government tax policy.

Table 4. 11 Negative impacts of Lebu-Jemo bike lane on business corridors

		Frequency	Percent
Valid	Lack of parking space	48	38
	Slows productivity in the market	41	30
	Traffic jam	31	9
	Affects government tax policy	14	15
Total		139	100

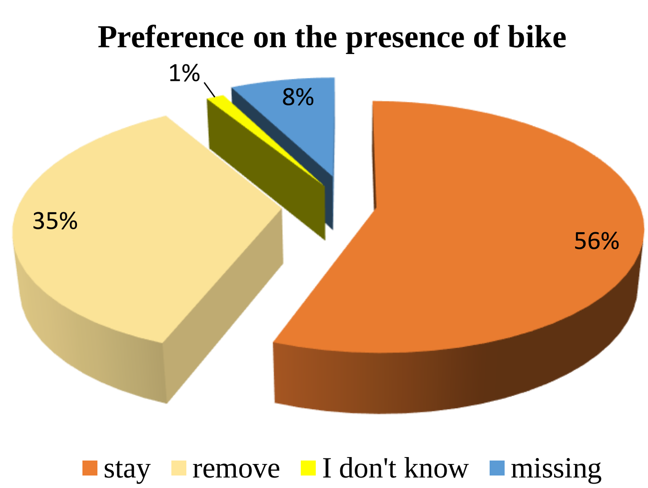


Figure 4. 13 preference on the presence of bike lane

In the figure above when asked whether the bike lane to stay or removed, 56% of respondents reported that the bike lane should stay, 35% of them believe it should be removed and 1% do not know if they want it to stay or removed. The rest 8% has not responded to the question provided.

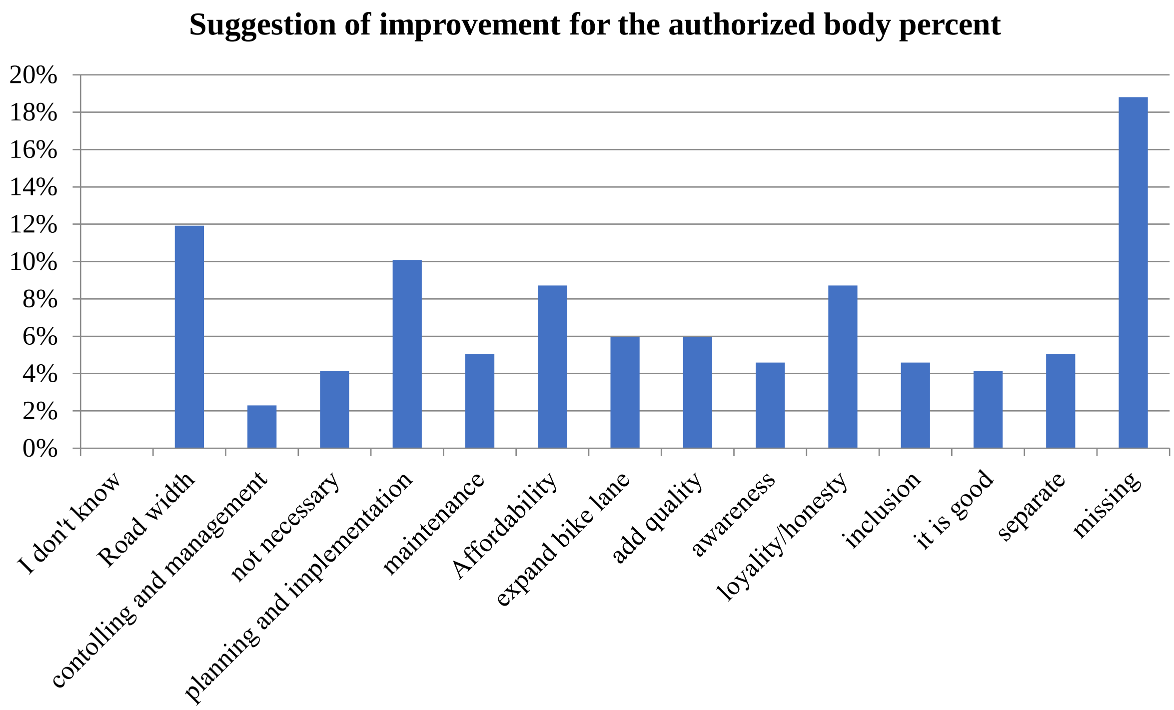


Figure 4. 14 improvement suggestion

Figure 4.14 presents responses when the participants were asked which improvements would initiate the to use the bicycle lane for cycling and to suggest the authorized body for an improvement, the majority commented that, the bike lane should be installed in wider vehicular access roads or that it needs to be designed together with the road from the beginning. 10% of the respondents are concerned about the planning and implementation. Many of them suggested the concerned body to make researches before implementations. In addition to this, 9% of the participants commented that loyalty and honesty during implementation should be underlined for a better result while the other 9% suggest the price of bicycles or affordability issues to be improved.

Table 4. 12 Rate of overall effectiveness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very poor	43	13.7	14.8	14.8
	Poor	73	23.2	25.1	39.9
	Medium	95	30.3	32.6	72.5
	Good	47	15.0	16.2	88.7
	Very good	33	10.5	11.3	100.0
	Total	291	92.7	100.0	
Missing	System	21	7.3		
Total		312	100.0		

The last question raised for the respondents to fill was to rate the overall effectiveness of the bike lane. Majority of the people rated the bike lane as medially effective which is about 32.6%, 25.1% of them rated the bike lane as poorly effective and not being used effectively for its intended purpose. 43 of the respondents from the total valid responses rated very poor effectiveness, 16.2% of them think the lane is somehow good in giving function while the rest of them from those that give their valid answers rated very good.

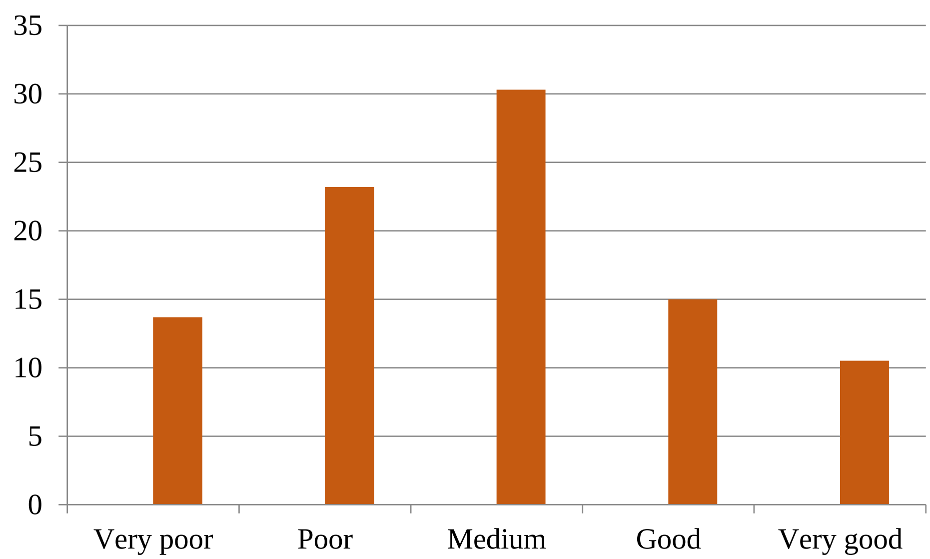


Figure 4. 15 rate of overall effectiveness

On the figure above, the bar graph illustrates the above table well by showing a clear difference between the rates of the respondents. Medium rate has been given by the majority of the respondents while the least rating has been given to ‘very good’ effectiveness.

4.2.2 Bicycle Compatibility Index (BCI) and Level of Service (LOS) Analysis.

This analysis was made by using the variables mentioned on 2.3.1 Section in this paper by using secondary data collected from Addis Abeba Transport Bureau, Addis Abeba traffic management office and Addis Abeba City Road Authority.

a) Bicycle Compatibility Index (BCI).

Table 4. 13 BCI data entry worksheet

Location	Geometric and road side data					Traffic operations data					Parking data		
Mid-block identified	No. of Lanes (one direction)	Curb Lane Width (m)	Bicycle Lane Width (m)	Paved Shoulder Width (m)	Residential Development (y/n)	Speed Limit (km/h)	85th %tile Speed (km/h)	AADT	Large Truck % (HV)	Right Turn % (R)	Parking Lane (y/)	Occupancy (%)	Time Limit (minutes)
Lebu-Jemo	3	3.5	2.4	2.4	Y	30	45	7701	0.012	0.025	N	0	<15

The curb lane width of the road is 3.5m (11.67 ft). Bicycle lane width of lebu-jemo bikeway is 2.4m and paved shoulder is also 2.4m as referred from project report prepared by NMT strategy office (Addis TV, 2020). Since there is a residential development on the route corridor of Lebu-Jemo road, it is possible to say the residential development of the area as “yes‟. Condominiums around jemo, royal apartments around lebu muzica bet and varnero apartments around lebu mebrat hayl are some of the residence areas found at the route corridor.

According to the information collected from the relevant organizations (i.e. AATB), the posted speed limit of 30 km/h is generally observed in all Addis Ababa urban streets, with the exception of the ring road. The volume of traffic turning right during peak hours is unclear; however it is anticipated to be modest given the sort of development. The 85th percentile traffic speed is also unknown; hence, the program's default value is utilized, which simply adds 15 km/h to the speed limit, resulting in an assumed value of 70 km/h. Another unknown element for this particular street is the traffic mix. It is assumed that during peak hours, the percentage of trucks on this route is only 1.5 percent.

- (metric) 85th percentile speed = 30km/hr + 15km/hr = 45km/hr
- 85th percentile speed (mileage) = 17.5 miles per hour + 10 miles per hour = 27.5 miles per hour
- $AADT_{base}$ (Lebu-Jemo) = 2600

Large truck (HV %) = [15 heavy + 15 articulated] =30/2600
= 0.012%-from previous study

The current AADT amount as collected from concerned bodies is 7701. To take into account the percentages of heavy vehicles, the percentage of different vehicles on different road classifications is provided in the table below, according to the AACRA manual.

Table 4. 14 Typical values of Addis Ababa traffic

Road classification	AADT(Two ways)	Vehicle groups typical percentage				
		Car	Light	Medium	Heavy	Articulated
Arterial	10000	80	17	2	0	1
Sub arterial	9000	89	9	1	0	1
Collector	4000	91	8	1	0	0
Local	1500	97	3	0	0	0

Source: (AACRA manual, 2004)

The Lebu-Jemo bike lane is installed on a collected street. Therefore, taken from the table 4.14, the percentage of large trucks for Collector Street is 0 % (heavy + articulated).

Because no data on the right turn volume has been identified, a judgment should be made, as the model suggests when data is unavailable. As a result, the site's transportation route has no frequent driveways. Thus, if a right turn volume of 270 is achievable, say 200, right turn percentage (R percent) can be calculated by dividing this amount by the relevant AADTs.

- (R %) = 200/7701 = 2.59% = 2.6%

According to evidence gleaned from authorities concerned, there is no on-street parking allowed in Addis Ababa (the existing allowance is only temporary until enough off-street parking buildings are built), and since no parking lane has been built for this purpose, it is possible to consider/say parking lane as "No = "N," .

Because taxis frequently stop on the outer curb lane to load and unload passengers, and because the route and location of the bikeway are unclear, it is vital to set the parking time limit to "less than 15 minutes" to account for taxis and, to a lesser extent, buses.

Table 4. 15 Bicycle Compatibility Index and Level of Service Computations for Lebu-Jemo

Location	**BCI model variables**									**Results**		
Midblock identifier	BL	BLW	CLW	CLV	OLV	SPD	PKG	AREA	AF	BCI	Level of Service	Bicycle Compatibility level
Lebu-Jemo	1	2.5	3.5	141	228	45	0	1	0.6	1.635	B	Very high

- PHV (Peak hour volume) = AADT *K*D
  = $(PHV)_{L\text{-}J}$= 7701 *0.1*0.55 = 423.55
- Curb lane volume (CLV) = *PHV/N*, where N is No. of lane
  = $(CLV)_{L\text{-}J}$ = 424/3 = 141.33
- Other lane volume (OLV) = PHV- CLV $(OLV)_{L\text{-}J}$ = 423.55-141.33 = 282.22
- Peak hour curb lane truck volume (CLTV) = PHV * HV*T $(CLTV)_{L\text{-}J}$ = 424*0.01*0.8= 3.392

Large truck adjustment factors, since peak hour curb lane truck volumes are 4 and 5 which are less than 10 (4&5<10), the corresponding f_t (adjustment factor for truck volume) is 0.0 for both routes from adjustment factors table developed by the model.

- Peak hour right turn volume (PHRTV) = PHV *R%, where R% is right turn percentage $(PHRTV)_{L-J}$ = 424 *0.026 = 11

Adjustment factor for right turn volume has been already assumed to be less than 270, therefore, f_{rt} = 0.0 can be taken from adjustment factors table developed by the model.

BCI = 3.67 – 0.966BL – 0.410BLW – 0.498CLW + 0.002CLV + 0.0004OLV + 0.022SPD + 0.506PKG – 0.264AREA + AF

BCI = 3.67 – 0.966(1) – 0.410(2.4) – 0.498(3.5) + 0.002(141) + 0.0004(228) + 0.022(45) + 0.506(0) – 0.264(1) + 0.6 = 1.635 – **very high compatibility**.

b) Bicycle Level of Service (BLOS).

Table 4. 16 BLOS data entry & calculations from Lebu to Jemo

Route name	Vol_{15}	L	SPp	SPt	HV	PR_5	W_e	Wt	%OSP	Wl	Wps	Wv	AADT
Lebu-Jemo	105.89	3	22.5	1.83	0.012	5	11.67	11.67	0	0	0	11.67	7701

The above table shows data entered according to the above adjustments. Detail calculation is presented as follows:

Taken from BCI calculation, ADT and D the Volume of directional traffic in 15 minute time period (VOL 15) is calculated as: (VOL 15) = ADT*D*Kd/4*PHF, where ADT-average daily traffic, D-directional split, Kd-peak to daily factor and PHF- peak hour factor.

(VOL15) = 7701*0.55*0.1/4*1 = 105.89

Kd, peak to daily factor is taken as 0.1 from the model recommended default values if the value is unknown and PHF= peak hour factor as, 1 from the model recommended value if the value is unknown from previous studies.

Total number of directional through lane, L, is 3. According to Addis Abeba's traffic information, the posted speed limit (Spp) is 30km/hr but in this case since it brings an error while calculating we will use 35km/hr which equals to 22.5mi/hr.

- Effective speed limit (Spt) =1.1199ln (Spp-20) +0.8103. So, (Spt) =1.1199ln (22.5-20) +0.8103= 1.84
- Percentage of heavy vehicles can be taken from BCI analysis made on section 4.2.2.1 (HV) = 0.012%.
- PR5= five point surface condition rating can be considered as '4' since the route has some deterioration.

The total width of outside lane pavement equals to 3.5m from section 4.2.2.1 while calculating for BCI. Since the shoulders (walk ways) are not bike able as previously stated on BCI analysis (Wt) = 3.5m or 11.67 feet.

Effective width as a function of traffic volume = Wv = Wt since the AADT, 7701, is greater than (>) 4000veh/day & since the street is not striped as the model recommends, the value for the route is, 3.5m/11.67ft.

Width of paving, Wl, between the outside lane stripe and the edge of pavement equals 0 for this route.

Width of pavement striped, Wps, for on-street parking equals "0" for this route as there is no on-street parking allowed as previously stated on BCI analysis.

Average effective width of outside through lane:

We = Wr- (10ft*%OSPA) for the above wl & wps values i.e We= Wv – (10ft*%OSPA)

= 11.67 – (10*0), % OSPA=0

(Wl)= 11.67ft

Table 4. 17 BLOS score and level of service calculations for Lebu-Jemo route

Route name	Vol15	L	SPt	HV	PR5	We	BLOS score	letter grade	Level of service
Lebu-Jemo	127	3	1.83	0.016	4	11.67	2.756	C+	Moderately high

$BLOS = 0.760 + 0.507 \ln (VOL15/L) + 0.199SP_t (1 + 10.38HV)^2 + 7.066(1/PR5)^2 - 0.005(WE)^2$

(BLOS) A-C = 0.507ln (127/3) +0.199 (1.83) (1+10.38*0.016)2+7.066 (1/5)2 -0.005 (11.67)2+0.760

= 1.899 + 0.495+0.283 – 0.681 + 0.76 = 2.756 - **moderately high**

4.2.3. Discussion.

This section summarizes the findings and contributions made. From the result in section 4.2.1, according to most participants, the Lebu-Jemo bike lane has less benefit to the community while some of them responded it adds value to the community. As recorded from a key informant he states the bike lane is only being used by a limited amount of cyclists and many pedestrians referring that it is only taking space and has no benefit to him. This indicates the gap in creating awareness and building enforcement within the community. In comparison to the benefits and drawbacks of the Lebu-Jemo bike lane responses, 22.7% of them discussed the advantages they have gotten through the lane while 16% complained about the drawbacks the bike lane has caused them. From the discouraging causes, the bike lane brought many of the responses were traffic congestion caused by narrowed vehicular access and lack of parking lots. As one of the traders discussed, when people lack a parking area they tend to stop their car on the vehicular road which then causes traffic jams which then leads to some two/three-wheeled motorists using the bike lane to pass by the quickly from the congestion. Consequently, the safety and comfort of cyclists become lowered.

On the questionnaire, survey participants were asked whether the bike lane has a negative or positive impact on business corridors. According to their feedback, many of them discussed its negative impacts on the merchants near the bicycle infrastructure. As collected from the key informants from 15 business corridor merchants, many of them demonstrated that the bigger issue they are facing is concerning lack of parking spaces. One individual from a mart, named Desalegn, stated that ‘individuals remove the green concreted barriers at night when no one is seeing to have their cars parked’ and another commented ‘customers pass by because of lack of parking and this has affected my business in some percent’. Another retailer who opened his shop a year ago stated that the use of the bicycle lane was more of a disadvantage than a benefit. “Only some cyclists use it, but for us traders it’s closing the market.” The cycling corridor is often used by pedestrians. “Customers coming with cars want to buy things from me but because they lack parking lots they often pass me by.”

Similarly, according to a trader at a children’s toy and bicycle shop, it was found that only children buy a bicycle and an adult bicycle sells from 12,000 to 15,000 ETB which is unaffordable for the majority of the community. Bicycles are unaffordable for the city's masses due to a lack of local manufacturers and high import duties. According to the trader, the construction of the bike lane has created some job opportunities for her to sell bicycles. According to “Kaldis Coffee” the restaurant’s guard mentioned it has become difficult to let parked cars out in the existence of the bike lane but at the same time, he added that the infrastructure has brought many customers to the restaurant.

Nevertheless, most of the respondents wish the bike lane to stay than be removed but with some improvements made. From those who returned the questionnaire and gave valid responses, they want the concerned bodies to improve in planning and implementation, loyalty and honesty, and affordability of bicycle prices. In contrast, some of the participants chose the bike lane to be removed because it has less benefit and that it should be installed in better locations with wider roads like Hachalu Hundessa road. Finally, the respondents were asked to rate the overall effectiveness of the cycle lane, and the majority rated it as “medium” and the minority rated it “very good”. This indicates that the bike lane is more or less effective but it needs to be improved to achieve the goal of the NMT strategy in Addis Abeba.

A further novel finding of the quantitative analysis result is that the Lebu-Jemo road is highly compatible for cycling as a result of the BCI calculation made in the finding section and has a moderately high level of service from the BLOS calculation. These evaluation results demonstrated that the road is highly compatible which infers that the road is "bicycle friendliness" according to Harkey (1998)’s model. This result has proved that Lebu-Jemo existing road is efficient in accommodating both motorists and bicyclists. Nevertheless, one of the most difficult and intimidating aspects of bicycling is navigating an intersection, especially one with heavy traffic, dedicated turn lanes and many turning vehicles in which the BLOS and BCI measures are bounded to test because it requires multiple data sources that is not readily available. In contrast, the qualitative analysis finding denoted that the majority of the participants are positive about the bike lane while some have been negatively impacted by the existence of the bike lane. In addition to that, the result from the key informants shows that many of the businesses adjacent to the bike lane are negatively impacted by the existence of the cycling corridor.

4.4. Major Findings

The use of NMT and evaluation of bike lanes have been a marginalized issue for many years now in Africa. The same is true in the case of Addis Abeba's NMT systems. According to this study the effectiveness of the Lebu-Jemo road bike lane has presented the following key findings:

The study demonstrates that the Lebu to Jemo bicycle lane project ran into various obstacles in terms of safety and improving mobility along that area. Participants are impeded to use the bike way because of the absence of a cycling culture in the city, behavior of private car drivers imposing lack of safety on bicycle users and the fact that the bike way is not continuously networked to other bikeways and major areas led bicycles to not be used as an alternative mode of transport in the city. People parking cars and people parking on the street generated illegal sources of strangling in most places. Another problem studied was due to a lack of local bicycle manufacturers and high import charges, bicycles are out of reach for the general public in the city. Because of this reason the potential number of bike lane users has decreased. As the information collected from the interviews with key informants indicate, the business corridors are negatively impacted by the existence of the bike lane due to lack of available parking spaces for their customers.

Nevertheless, Lebu-Jemo bike way installation has given the community a chance to ride bicycles in public. The result from before and after relationship from the annual bicycle count data illustrated that the number of cyclists have increased very slowly following the installation of the bike lane. The quantitative analysis resulted from BCI and BLOS evaluation calculation shows that Lebu-Jemo route is moderately compatible and has good level of service.

The community highly values the bike lane but after sometime the effectiveness of the bike way has lowered due to safety, functionality, space, maintenance and enforcement problems. This indicates that the result from the quantitative data cannot give us a conclusion about the perceptions of the community and what is exactly going on, on the ground. It has been noted that if improvements like proper planning and implementation, controlling management, maintenance and affordability of bicycles were to be made, people would be encouraged to use the provided bike lane effectively.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

The main method used to evaluate the condition or effectiveness was bicycle count assessment. Furthermore, many methods have been used to assess the bikeability of bicycle lanes, and among the various bikeability measuring methods that have been reviewed and compiled, the researcher discovered that bicycle friendliness community, bicycle compatibility index and bicycle level of service methods are the best fit for evaluation because they are convenient methods that can show the condition of the Lebu to Jemo bicycle lane project.

The study demonstrates that the Lebu to Jemo bicycle lane project ran into various obstacles in terms of safety and improving mobility along that area which has led to the failure of the project. The first issue is that the bicycle lane is blocked by other motor vehicles for parking; the second safety issue on this bike lane is a lack of pedestrian awareness of the bike lane, as they frequently push the walking zone into the bike lane space which causes bicyclists to utilize the motor vehicle traffic lanes to avoid them and puts their safety in jeopardy. The study discusses that there has been weak enforcement for people parking in the bike lane, vending on the bike lane space, and motor vehicle drivers who are violating traffic management agency regulations relating to the Lebu to Jemo cycling lane project.

From the bicycle count analysis data the number of cyclists has increased following the installation of the bicycle lane to the corridor. Whereas, the results found in the qualitative data, shows the majority of them do not use the provided bike lane due to lack of safety and maintenance. In addition, this finding demonstrates that the existing Lebu-Jemo road is capable of accommodating both automobiles and bikers. In contrast, the qualitative research revealed that the majority of participants are happy about the bike lane, although some have been negatively affected by its presence. Furthermore, the findings of the key informants reveal that the existence of the bicycle corridor has a detrimental influence on many of the businesses near to it.

5.2. RECOMMENDATIONS

1. Future studies should take into account that extensive research and analysis is prior to developing and installing the remaining bicycle corridors in a way that addresses the future flow of traffic, demand for parking space, location by taking notes from the issues faced in the previously established bike ways. One of the inaugurated bike way in 2014 is an exemplary design that solve most of the problems founded in this study-. The design of wollo-sefer to Ourael bike way design is incorporated in the road design that includes colorful parking spaces along the bike lane and center of the road, which helps prevent congestion caused by parking problems and encouraging NMT.
2. Creation of awareness in the community to use the bike lane only for bicycling activities which will increase the number of bicyclists by eliminating safety issues linked to pedestrians and strengthening enforcement in an appropriate manner related to motor vehicle lane users and bicycle lane users, which leads to bicyclists using the lane without fear of traffic accidents and collisions. Education on the importance of bike ways and NMT in general should be given to the community for the success of attaining the plan of attaining to promote bicycle as a mode of transport by Addis Abeba NMT Strategy safe cycling program.
3. Continuous maintenance and controlling of the protections/delineations of the bike way from vehicular access is necessary to improve the safety, comfort and beauty of the environment.
4. BCI (bicycle compatibility index) and BLOS (bicycle level of service) should be produced based on the city's and country's current conditions to aid in the analysis of roads for bikeway planning and design.
5. People parking cars and people parking on the street generated illegal sources of strangling in most places. It has been noted that the generated illegal sources of strangling in most places can be resolved by completing regulatory work and increasing the visibility of notices on the site.

Research Fund Acknowledgement

The research thesis is funded by Adama Science and Technology University under the grant number: ASTU/SM-R/438/22, Adama, Ethiopia.

REFERENCE

Abolhassani, L., Afghari, A. P., & Borzadaran, H. M. (2019). Public preferences towards bicycle sharing system in developing countries: The case of Mashhad, Iran. *Sustainable Cities and Society*, *44*(April 2018), 763–773. https://doi.org/10.1016/j.scs.2018.10.032

Ajayi, V. O. (2017). *Primary Sources of Data and Secondary Sources of Data*. *September*, 1–6. https://doi.org/10.13140/RG.2.2.24292.68481

Addis TV. (2020). *Lebu-Jemo Interim Cycling Corridor*. https://www.facebook.com/AAMMATV/videos/180911629833337/

Ana, S., Pinto, I., Ribeiro, D., & Delgado, J. (2014). Multicriteria Analysis for Evaluation of Bike Lane Routes Integrated to Public Transportation. *Procedia - Social and Behavioral Sciences*, *162*(Panam), 388–397. https://doi.org/10.1016/j.sbspro.2014.12.220

Barker, J. B., Allen D.Biehler, & Larry L.Brown, S. (2010). HCM2010 Highway Capacity Manual. In Transportation Research Board of The National Academies (Vol. 1). http://hcm.trb.org/?qr=1%0Ahttp://dx.doi.org/10.1016/j.ssci.2016.03.011

Berman, J., Finfer, R., Haney, T., Orgren, T., & Sauer, C. (2017). *Chestnut Street Bike Lane Evaluation*.

Bicalho, T., Silva, C., Cunha, I., Teixeira, J., & Proença, A. (2019). Planners' attitudes towards the cycling potential of their cities – Creating awareness for attitude change. *Travel Behaviour and Society*, *17*(August), 96–103. https://doi.org/10.1016/j.tbs.2019.08.002

Boettge, B., Hall, D. M., & Crawford, T. (2017). Assessing the bicycle network in St. Louis: A place-based user-centered approach. *Sustainability (Switzerland)*, *9*(2), 1–18. https://doi.org/10.3390/su9020241

Chen, J., Li, Z., Wang, W., & Jiang, H. (2018). Evaluating bicycle–vehicle conflicts and delays on urban streets with bike lane and on-street parking. *Transportation Letters*, *10*(1), 1–11. https://doi.org/10.1080/19427867.2016.1207365

Duthie, J., Brady, J. F., Mills, A. F., & Machemehl, R. B. (2010). Effects of on-street bicycle facility configuration on bicyclist and motorist behavior. *Transportation Research Record*, *2190*, 37–44. https://doi.org/10.3141/2190-05

Ekblad, H., Svensson, A., & Kongin, T. (2016). Bicycle planning in an urban context. *Literature Review*, *December*, 1–36. https://doi.org/10.13140/RG.2.2.36461.38889

Eshetu, G. (2015). *Bikeway Compatibility and Implementation Study on Selected Routes of Addis Ababa*. *December*.

Federal Highway Administration. (2015). *Separated bike lane planning and design guide: Appendix*. *May*.

FHWA. (1998). The Bicycle Compatibility Index : A Level of Service Concept , Implementation Manual. In *Design*. https://doi.org/No. FHWA-RD-98-072

Fistola, R., Gallo, M., Rocca, R. A. La, & Russo, F. (2020). The effectiveness of urban cycle lanes: From dyscrasias to potential solutions. *Sustainability (Switzerland)*, *12*(6), 1–23. https://doi.org/10.3390/su12062321

Glitz, B. (1997). The focus group technique in library research: An introduction. *Bulletin of the Medical Library Association*, *85*(4), 385–390.

Guide, B. D. (2019). *LET ' S RIDE JC Bikeway Design Guide*. *September*.

Harkey, D., & Reinfurt, D. (1998). The Bicycle Compatibility Index: implementation Manual. *Report FHWA-RD-98-905. Department of Transportation, U.S.*

Hughes, S. A., & Advisor, B. J. A. (2015). *BY*. *July*.

Jsoulliere. (2017). *Lanes and Sharrows and Buffers ... Oh My ! Four Types of Bike Lanes Explained* (pp. 1–8).

Koglin, T., & Rye, T. (2014). The marginalization of bicycling in Modernist urban transport planning. *Journal of Transport and Health*, *1*(4), 214–222. https://doi.org/10.1016/j.jth.2014.09.006

LTSA (2004). *Cycle Network & Route Planning Guide*. Land Transport Safety Authority, Wellington.

Morrison, C. N., Thompson, J., Kondo, M. C., & Beck, B. (2019). On-road bicycle lane types, roadway characteristics, and risks for bicycle crashes. *Accident Analysis and Prevention*, *123*(August 2018), 123–131. https://doi.org/10.1016/j.aap.2018.11.017

National Association of City Transportation Officials. (2014). Shared Lane Markings. *Urban Bikeway Design Guide*, *96*. https://nacto.org/publication/urban-bikeway-design-guide/bikeway-signing-marking/shared-lane-markings/

Officer, A. P., Council, C. C., Lecturer, S., & Engineering, N. R. (n.d.). *the Effect of Cycle Lanes on 1 Introduction 2 Research Context*. *Civil*.

Oosterhuis, H. (2016). Cycling, modernity and national culture. *Social History*, *41*(3), 233–248. https://doi.org/10.1080/03071022.2016.1180897

Pu, Z., Li, Z., Wang, Y., Ye, M., & Fan, W. (2017). Evaluating the Interference of Bicycle Traffic on Vehicle Operation on Urban Streets with Bike Lanes. *Journal of Advanced Transportation*, *2017*. https://doi.org/10.1155/2017/6973089

Pulugurtha, S. S., & Thakur, V. (2015). Evaluating the effectiveness of on-street bicycle lane and assessing risk to bicyclists in Charlotte, North Carolina. *Accident Analysis and Prevention*, *76*, 34–41. https://doi.org/10.1016/j.aap.2014.12.020

RTA (2003). *Bicycle Guidelines* (1.0 ed.). Roads and Traffic Authority of New South Wales, Sydney.

Schaefer, J. S., Figliozzi, M. A., & Unnikrishnan, A. (2020). Evidence from Urban Roads without Bicycle Lanes on the Impact of Bicycle Traffic on Passenger Car Travel Speeds. *Transportation Research Record*, *2674*(7), 87–98. https://doi.org/10.1177/0361198120920880

SEPARATED BIKE LANE. (2015). *May*.

Sheet, I. F. (n.d.). *Give Cycling a Push Implementation Fact Sheet Cycle lanes CYCLE LANES Overview Background and Objectives*. 2–7.

Shinkle, D., Teigen, A., & Pound, W. T. (2008). *Encouraging Bicycling and Walking The State Legislative Role*. www.ncsl.org

Smith, A., Zucker, S., Lladó-Farrulla, M., Friedman, J., Guidry, C., McGrew, P., Schroll, R., McGinness, C., & Duchesne, J. (2019). Bicycle lanes. *Journal of Trauma and Acute Care Surgery*, *87*(1), 76–81.

Tulu, G. S., Hadgu, M., & Tarekegn, A. G. (2019). Bicycling in Addis Ababa, Ethiopia: Opportunities and challenges. *Journal of Sustainable Development of Transport and Logistics*, *4*(2), 50–59. https://doi.org/10.14254/jsdtl.2019.4-2.5

Turner, S. M., Shafer, C. S., & Stewart, W. P. (1700). *BICYCLE SUITABILITY CRITERIA: LITERATURE REVIEW July 1997 AND STATE-OF-THE-PRACTICE SURVEY 6. Performing Organization Code 7. Author(s) 8. Performing Organization Report No. Title: Identify and Develop Criteria for Evaluating Roads to Determine Their Suit*. *7*(2), 8–72.

APPENDICES

Appendix A- Field Observation Checklist

Bicycle count Round	Period of time	Duration counts/ peak hour for 1 hour (LT)	No. of Bikers
Day-	Morning	12am-1am	
	Day time	7pm-8pm	
	Evening	12pm-1pm	

Appendix B- Field Observation calculation

Cycle tracking at different years	Time of the day	Average cycle count/hour
Before cycle lane installed	Morning	
	Day time	
	Evening	
After three years of installation	Morning	
	Day time	
	Evening	
Total		

Appendix C- Questionnaire

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

DEPARTMENT OF URBAN PLANNING AND DESIGN

MSC PROGRAM

Dear respondent, thank you in advance for your time.

This questionnaire is designed to gather data for research purposes to the fulfillment of MSc in the field of Urban Planning and Design on thesis topic "Effectiveness of Bicycle Lane: The case of Lebu-Jemmo in Addis Abeba, Ethiopia. Accordingly, your genuine responses are extremely important for this research, so please be free and respond to all the open-ended and closed questions.

Respondent Number ---------

1. What is your Sex?

   A. Male B. Female

2. What is your age group?

   18-25 B. 26-35 C. 36-50 D. 51-65 E. Over 65

3. Where do you live?

   Lebu- Musica sefer B. Lebu- Mebrat Hayl C. Lebu- Medhaniyalem

   D. Jemmo 1 E. other

4. Do you have a bicycle?

   A. Yes B. No

5. Do you cycle?

A. Yes B. No

6. If Yes, How often do you cycle?

A. Everyday B. Three days a week C. Only on weekends D. other

7. Do you bicycle on the cycle lane that is provided for bikers (Lebu-Jemmo)?

A. Yes B. No

8. Do you think the bike lane is functional? Are cyclists using it effectively?

A. Yes B. No C. I don't know

9. If Yes, Which time of the day do you see more cyclists?

A At morning B. Day time C. At night

10. Why do you think many people are not cycling?

11. In your opinion, Do you think the bike lane adds value to the community?

A. Yes B. No

12. If Yes, Which advantages has this bike lane provided?

A. Safety and comfort B. Created awareness and initiation to using more bicycles C. Promoted the use of NMT (non-motorized transport)

D. Ease of movement E. Environmentally friendly F. Money saving

G. Promotes Health

13. If No, What do you think are the drawbacks this bike lane has brought?

A. Traffic congestion B. Narrowed vehicular access

C. Lack of car parking and drop offs D. Increased accidents and bike crashes

E. Unattractive environment F. Lack of safety because of cars

14. Does the bike lane have a positive or negative impact on businesses located in front of the bicycle lane? How?

---

15. In your opinion, Do you think a bike lane is not necessary in this location?

A. Yes B. No C. I do not know

16. If Yes, Why?

---

17. Do you prefer the bike lanes to stay or not?

---

18. If not, what would you suggest for the authorized body to improve?

---

19. Please rate the overall effectiveness of the bike lane?

	1	2	3	4	5	
Very poor	○	○	○	○	○	Very good

20. At last, please state if there is anything you want to add on the topic.

Thank you for your time!

Appendix D- Key Informant Interview

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

DEPARTMENT OF URBAN PLANNING AND DESIGN

MSC PROGRAM

Dear interviewee, thank you in advance for your cooperation to answer the following questions. The aim of this interview is to gather data for research purposes to the fulfillment of MSc in the field of Urban Planning and Design on thesis topic "Effectiveness of Bicycle Lane: The case of Lebu-Jemmo in Addis Abeba, Ethiopia. Accordingly, the information's you provide are extremely important for this research, so please be free and I assure you that the information you provide me will be kept confidential.

1. Does your business require much vehicular movement like loading and unloading goods or more parking spaces?
2. Do you have any deliveries made to your place by using bicycles?
3. What is your opinion about the bicycle lane?
4. What obstacles have you encountered because of this bicycle lane?
5. Addis Abeba transport minister bureau has planned to install 200km bicycle lanes throughout the city to increase the use of non-motorized transport. What improvements should be made to install new bike lanes in other locations?
6. How do you think the negative impacts should be solved to enhance the existing bike lane?

Thank you for your time.