Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Highway Engineering Stream

Estimation of Level of Service of Walkways Rehabilitation Projects of Addis Ababa City Roads Authority in Central Addis Ababa

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Highway Engineering

By:

Bahiru Lulie

November, 2019

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November, 2019

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis proposal entitled: "**Estimation of Level of Service of Walkways Rehabilitation Projects of Addis Ababa City Roads Authority in Central Addis Ababa"** is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for this thesis proposal have to be duly acknowledged.

Candidate:

Mr. Bahiru Lulie

______________________	25/11/2019
Signature	Date

As Master's Research Advisors, I hereby certify that I have read and evaluated this MSc Thesis proposal prepared under my guidance by Bahiru Lulie entitled: "**Estimation of Level of Service of Walkways Rehabilitation Projects of Addis Ababa City Roads Authority in Central Addis Ababa."**

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ABSTRACT

Every day, people are moving to perform their day to day activities and for different purpose such as for work, school, recreation and others. Currently, pedestrian walkway capacity is one of the problems in Addis Ababa. The walkway capacity and pedestrian crossing affects the socio-economic aspects of the city as a whole. Also, there are some problems occurred due to walkway problems in the city; traffic accident increases and pedestrian LOS decreases and others. The aim of this research is to estimate the LOS of walkway rehabilitation projects level of service of Addis Ababa city roads authority in central Addis Ababa and to establish measurable actions. This paper focused to assess the pedestrian level of service of the new walkway rehabilitation projects of Addis Ababa City Roads Authority at selected road sections of central Addis Ababa city. The study was based on three road sections. The selected sections were from 4 Kilo through Kidste Mariam to 6 Kilo, from Degol Square. to Kidste Mariam, from Meskel Square to Post Office. In this research, simple random probability sampling techniques was used. From 18,000 meters, only 3600 meters walkway sections are selected for assessment. The pedestrian and vehicle traffic volume on the selected sections and detail geometric data of the walkway are collected to evaluate its level of service. The traffic data was collected through manual counting. The details of geometric data and other important parameters of the walkways collected from the office of AACRA, and field measurement. The analysis performed using HCM 2010 methods, and International Road Assessment Program (iRAP) Software.

Results from HCM 2010 indicated that 80% of the pedestrian sidewalks surveyed are below LOS C and the results from International Road Assessment Programme (iRAP) methodology shows that poor performance of the pedestrian walkway and the average percentage decrease in iRAP score after all countermeasure was taken is 79%. Finally, most of the pedestrian walkways are in serious problems and need some improvements such as appoint school zone supervisors at school start and finish times, provide pedestrian fencing, provide pedestrian refuge at pedestrian crossings, apply speed management techniques (traffic calming) and reduce the operating vehicle speed.

Keywords: *Pedestrian walkways, Pedestrian accidents, Level of Service, Rehabilitation, Measurable actions, Geometric data, Capacity.*

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ACRONYMS

AACRA	Addis Ababa City Road Authority
CDB	Central Business District
HCM	Highway Capacity Manual
iRAP	International Road Assessment Program
LOS	Level of Service
ROW	Right of Way
Sq.	Square
TMA	Traffic Management Agency
TPMO	Transport Programming Management Office
V/C	Volume Capacity Ratio
WHO	World Health Organization
4 Kilo	Arat Kilo (Arat is The Amharic meaning of Number 4)
6 Kilo	Sidist Kilo (Sidist is The Amharic meaning of Number 6)

CHAPTER ONE

INTRODUCTION

1.1 Background

Most of the intra-CDB (Central Business District) trips of people are done by non-motorized modes, especially walking. Walking is an environmentally friendly mode of transport for short trips. Walking makes people healthy, since it burns calories, or does not emit greenhouse gases. Further, walking is the ideal means of transportation within urban city centers since it does not demand for parking. (Wickramasinghe, V., Dissanayake, S., 2017). In Addis Ababa it is also the highly used mode of transportation because of different reasons; lack of transport service, low economic level, for health purpose.

Pedestrians are the most vulnerable road users and are known for their wide choice of freedom while choosing a particular walking trend which makes them far more different from motorized users. Sidewalks and walkways (as per Highway Capacity Manual 2010) are pedestrian facilities which are separated from motor vehicle traffic and are not designed for bicycles or other non-pedestrian users. These facilities accommodate the highest volumes of pedestrians and provide the best levels of service as pedestrians do not share the facilities with other modes traveling at higher speeds. Sidewalks are located in proximity and parallel to roadways while the walkways (even though similar in construction to sidewalks) are located well away from the influence of automobile traffic and may be used to connect sidewalks. Similarly, pedestrian walkways are also used to connect portions of transit stations and terminals. (Banerjeea, A., Kumar, A.M., 2016).

Addis Ababa City Roads Authority (AACRA) is starting drainage and walkway rehabilitation project at different places in the city since September 2017.Therefore, LOS estimation of the walkway rehabilitation project is very important since it is directly related to traffic accident and environmental issues. Therefore, road authorities and other concerned bodies need to conduct a comprehensive study so that they can come up with a solution for the LOS, accidents and environmental issues.

1.2 Statement of the problem

More than 1.2 million people die each year on the world's roads, making road traffic injuries a leading cause of death globally. Most of these deaths are in low- and middle-income countries where rapid economic growth has been accompanied by increased motorization and road traffic injuries. As well as being a public health problem, road traffic injuries are a development issue: low- and middle-income countries lose approximately 3% of GDP as a result of road traffic crashes. Almost half of all deaths on the world's roads are among those with the least protection – motorcyclists, cyclists1 and pedestrians (World Health Organization (WHO), 2015).

The global rate of road traffic death is 18.2 per 100,000 population, there is significant variation across the world's regions, where the rate of death ranges from 9.3 to 26.6 per 100,000 population. Regional rates of road traffic deaths in Africa and South-East Asia are highest at 26.6 and 20.7 deaths per 100,000 population respectively. Vulnerable road users – pedestrians, cyclists and motorcyclists – represent more than half of all global deaths. Africa has the highest proportion of pedestrian and cyclist mortalities with 44% of deaths (Global status report on road safety, WHO, 2018).

Road traffic accident in Ethiopia is a cause of significant losses of human and economic resources. In 2007/8 Ethiopian fiscal year, police reported 15,086 accidents which caused the losses of 2,161 lives and over ETB 82 million equivalents to US$7.3 million. On average, about 56 per cent of the road traffic accident fatalities are pedestrians, 36 per cent are passengers, and only 8 per cent are drivers. The figure of pedestrian fatalities rises in built-up areas. For example, in the city of Addis Ababa, pedestrian fatalities are about 90 per cent of the total road accident fatalities in the city. These figures are indicators of the poor safety behavior of road users and lack of pedestrian facilities and respect for them (United Nations Economic Commission for Africa, 2009).

Since 1887, the foundation of Addis Ababa city, the population growth of the city is increasing rapidly. In addition to the driving road, those peoples need adequate and safe walk way to transport. In the city the pedestrian traffic accident is recorded in different places. It is logical to think that the pedestrian problem is solved by accommodating sufficient and safe walkway and providing well designed pedestrian passes. Hence, the

AACRA is rehabilitating walkways since September 2017 to solve the problem and the value is assessed in this paper.

1.3 Research Questions

The research questions that this study would like to seek for an answer are as follows:

1. What are the pedestrian's characteristics as to their age group, space requirements and walking speeds within the study area?

2. What are the factors affecting the pedestrian movements in relation to the geometric layout of walkways in the study area?

3. What is the level of service (LOS) of the rehabilitated walkway?

4. What are the possible measures to correct the problems and deficiencies for pedestrian walkways?

1.4 Objective of the Study

1.4.1 General Objective

The general objective of the study is to estimate the level of service of walkways rehabilitation projects of Addis Ababa city roads authority in central Addis Ababa and to establish measurable actions.

1.4.2 Specific Objective

- ✓ To identify the pedestrian characteristics as to their age group, space requirements and walking speeds within the study area.
- ✓ To determine the factors affecting the pedestrian movements in relation to the geometric layout of walkways in the study area.
- ✓ To analyze the capacity and level of service of the walkways.
- ✓ To put possible measures to correct deficiencies for pedestrian walkways.

1.5 Significance of the Study

The research has the following significance:

- ✓ The research will be used as a material for the government office, for other researchers and also will be used for other concerned individuals or organizations.
- ✓ Rates the selected walkways based on international road assessment program rating system and standard.
- ✓ Put some measurable actions used to minimize pedestrian accidents occurred due to walkway facility problems.

1.6 Scope of the Study

It is necessary to define the scope of the research topic since walkway assessment touches a lot of areas and wide. The untreated topics could be left for other researchers. Accordingly, the scope of this study was limited to the walkway rehabilitation projects of Addis Ababa City Roads Authority (AACRA). Hence, it focused mainly on at grade walkway facilities the overpass elements were not discussed. Also due to broadness of the topic the intersection and roundabout capacity evaluations were not analyzed in detail in this study. Finally, after the remedial measures were applied the star rating was reanalyzed by iRAP software only because of the result from the two methodologies in the first stage was similar and due to time limitation.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

There are various studies conducted to determine the level of service (LOS) of walkway and sidewalks as well as to assess the pedestrian flow characteristics.

Oeding (1963) conducted a study on a footpath in Germany and measured fundamental flow parameters. A study on the movement of pedestrians on footways in shopping streets in England was conducted by Older (1968) and he concluded that more efficient use was made by pedestrians of the narrow gateway than on the wider ones. Polus et al. (1983) analyzed properties and characteristics of pedestrian flow on sidewalks, in Haifa, Israel and observed that gender and density played a pivotal part in defining walking speed of pedestrians. A study on walkways was conducted by Tanaboriboon et al. (1986) to examine the characteristics of pedestrians in Singapore and concluded that Singaporeans have a slower walking rate than their American counterparts. Lam et al. (1995) through a study on walkways tried to find out the pedestrian flow characteristics in Hong Kong and saw that the speed-flow-density models developed in Hong Kong were similar to those developed in Singapore for similar facilities (Banerjeea, A., Kumar, A.M., 2016).

Rastogi et al. (2011) had worked on the design implications of walking speed for different types of pedestrian facilities on the basis of function and width, and found out that mean speed on sidewalks and wide-sidewalks were more than that on precincts. Analysis of the pedestrian walking characteristics at nineteen locations in five cities of India was conducted by Rastogi et al. (2013) and it was concluded that different flow characteristics need to be adopted for facilities under varying widths and operating under varying conditions. A study on the movement of pedestrians on the walkway in Bangladesh was done by Nazir et al. (2014) and it could be observed that age and gender significantly affected walking speed. Das et al. (2015) observed relationships of field data considering conventional and soft computing approach for sidewalk in India. Information on the Level of Service based on pedestrian space, flow rate and speed are developed by the Guidelines for Pedestrian Facilities IRC: 103-2012 and Highway Capacity Manual HCM 2000 and 2010 (Banerjeea, A., Kumar, A.M., 2016).

Estimation of pedestrian level of service (LOS) is the most common approach to assess quality of operations of pedestrian facilities. Pedestrian LOS is an overall measure of walking conditions on a route, path, or facility (Singh K., Jain, P.K., 2011).

2.2 Methods of evaluating pedestrian level of service

The current practices for evaluating pedestrian facilities can be grouped into two types

(i) Capacity Based Methods- HCM Method

(ii) Roadway Characteristics Based Methods Pedestrian Environment Factors

Capacity based methods use the principles of highway capacity which have been suitably adjusted to evaluate pedestrian facilities. They are helpful in planning pedestrian facilities but provide little information regarding acceptability by pedestrians.

Roadway Characteristics Based Methods are based on the characteristics of the walkways or pedestrian facilities. These methods use pedestrian perceptions and attempt to quantify the comfort level of pedestrians while encountering certain roadway characteristics (Singh K., Jain, P.K., 2011).

2.2.1 HCM 2010 method of pedestrian LOS

The HCM's methods for analyzing pedestrian LOS are based on the measurement of pedestrian flow rate and sidewalk space. The pedestrian flow rate incorporates pedestrian speed, density, and volume, which is equivalent to vehicular flow.

For the purpose of analysis, urban streets are separated into individual elements; point, link, segment and Facility, that are physically adjacent and operate as a single entity in serving travelers. A point represents the boundary between links and is represented by an intersection or ramp terminal. A link represents a length of roadway between two points. A link and its boundary points are referred to as a segment. Multiple contiguous segments can be combined into a single facility. (HCM 2010)

For this study the capacity evaluation is based on street segment and the HCM segment level of service calculation is described below.

Points and Segments

The link and its boundary points must be evaluated together to provide an accurate indication of overall segment performance. For a given direction of travel along the segment, link and downstream point performance measures are combined to determine overall segment performance.

If the subject segment is within a coordinated signal system, then the following rules apply when the segment boundaries are identified: A signalized intersection (or ramp terminal) is always used to define a segment boundary or only intersections (or ramp terminals) at which the segment through movement is uncontrolled (e.g., a two-way STOP-controlled intersection) can exist along the segment between the boundaries.

If the subject segment is not within a coordinated signal system, then the following rules apply when the segment boundaries are identified: An intersection (or ramp terminal) having a type of control that can impose on the segment through movement a legal requirement to stop or yield must always be used to define a segment boundary or an intersection (or ramp terminal) at which the segment through movement is uncontrolled (e.g., a two-way STOP-controlled intersection) may be used to define a segment boundary, but it is typically not done.

A midsegment traffic control signal provided for the exclusive use of pedestrians should not be used to define a segment boundary. This restriction reflects the fact that the methodologies described here were derived for, and calibrated with data from, street segments bounded by an intersection. An access point intersection is an unsignalized intersection with one or two access point approaches to the segment. The approach can be a driveway or a public street. The through movements on the segment are uncontrolled at an access point intersection.

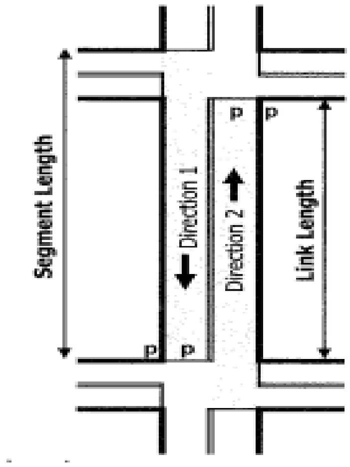


Figure 2-1 Figure Point link and Segment

Where P is point performance measure.

Historically, the HCM has used a single performance measure as the basis for defining LOS. However, researches in Quality and Level-of-Service indicates that travelers consider a wide variety of factors when they assess the quality of service provided to them. Some of these factors can be described as performance measures (e.g., speed), and others can be described as basic descriptors of the urban street character (e.g., sidewalk width). The methodology for evaluating each mode provides a procedure for mathematically combining these factors into a score. This score is then used to determine the LOS that is provided for a given direction of travel along a segment.

The LOS for this particular mode is determined by consideration of both the LOS score and the average pedestrian space on the sidewalk. The applicable LOS for an evaluation is determined from the table by finding the intersection of the row corresponding to the computed score value and the column corresponding to the computed space value.

Table 2-1 Segment LOS for the pedestrian travel mode(HCM 2010)

Pedestrian LOS Score	LOS by Average Pedestrian Space (ft2/ped.)					
	>60	>40-60	>24-40	>15-24	>8-15	≤ 8
≤ 2	A	B	C	D	E	F
>2.00 - 2.75	B	B	C	D	E	F
>2.75 - 3.50	C	C	C	D	E	F
>3.50 - 4.25	D	D	D	D	E	F
>4.25 - 5.00	E	E	E	E	E	F
>5.00	F	F	F	F	F	F

Note:in cross-flow situations, the LOS E/F threshold is $13ft^2/p$

The association between LOS score and LOS is based on traveler perception research. Travelers were asked to rate the quality of service associated with a specific trip along an urban street. The letter "A" was used to represent the "best" quality of service, and the letter "F" was used to represent the "worst" quality of service. "Best" and "worst" were left undefined, allowing the respondents to identify the best and worst conditions on the basis of their traveling experience and perception of service quality.

Urban street segment performance from a pedestrian perspective is separately evaluated for each side of the street.

Step 1: Determine Free-Flow Walking Speed

The average free-flow pedestrian walking speed S_{pf} is needed for the evaluation of urban street segment performance from a pedestrian perspective. Research indicates that walking speed is influenced by pedestrian age and sidewalk grade. If 0% to 20% of pedestrians traveling along the subject segment are elderly (i.e., 65 years of age or older), an average free-flow walking speed of 4.4 ft/s is recommended for segment evaluation. If more than 20% of pedestrians are elderly, an average free-flow walking speed of 3.3 ft/s is recommended. In addition, an upgrade of 10% or greater reduces walking speed by 0.3 ft/s.
Step 2: Determine Average Pedestrian Space

Pedestrians are sensitive to the amount of space separating them from other pedestrians and obstacles as they walk along a sidewalk. Average pedestrian space is an indicator of segment performance for travel in a sidewalk. It depends on the effective sidewalk width, pedestrian flow rate, and walking speed.

A. Compute Effective Sidewalk Width

   The effective sidewalk width equals the total walkway width less the effective width of fixed objects located on the sidewalk and less any shy distance associated with the adjacent street or a vertical obstruction. Fixed objects can be continuous (e.g., a fence or a building face) or discontinuous (e.g., trees, poles, or benches).

   The effective sidewalk width is an average value for the length of the link. It is computed by

$$W_E = W_T - W_{O,i} - W_{O,o} - W_{s,i} - W_{s,o} \geq 0.0$$

With $W_{s,i}=\max(W_{buf}, 1.5)$

$$W_{s,o}= 3.0P_{window}+2.0\ P_{buiding}+1.5\ P_{fence}$$

$$W_{O,i} = w_{O,i}-W_{s,i} \geq 0.0$$

$$W_{O,o} = w_{O,o}-W_{s,o} \geq 0.0$$

Where

W_E = effective sidewalk width (ft),

W_T = total walkway width (ft),

$W_{O,i}$ = adjusted fixed-object effective width on inside of sidewalk (ft),

$W_{O,o}$ = adjusted fixed-object effective width on outside of sidewalk (ft),

$W_{s,i}$ = shy distance on inside (curb side) of sidewalk (ft),

$W_{s,o}$ = shy distance on outside of sidewalk (ft),

W_{buf} = buffer width between roadway and sidewalk (ft),

P_{window} = Proportion of sidewalk length adjacent to a window display (decimal),

$P_{buiding}$ = proportion of sidewalk length adjacent to a building face (decimal),

P_{fence} = proportion of sidewalk length adjacent to a fence or low wall (decimal),

$w_{O,i}$ = effective width of fixed objects on inside of sidewalk (ft), and

$w_{O,o}$ = effective width of fixed objects on outside of sidewalk (ft).

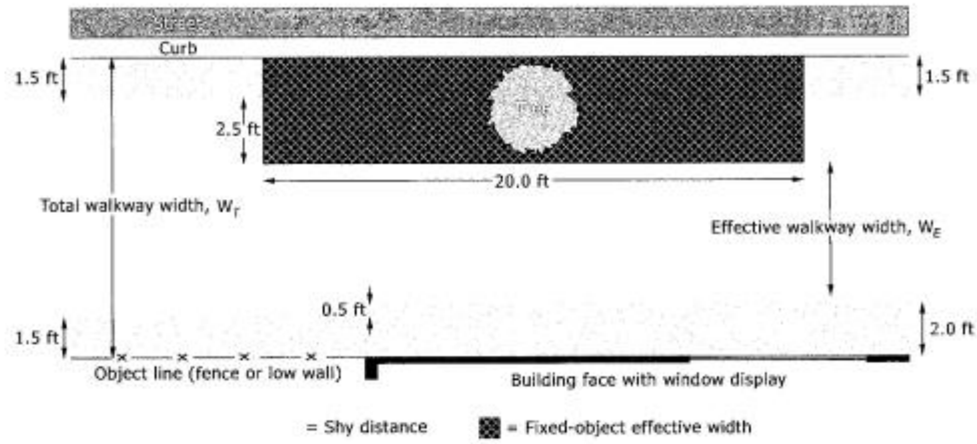


Figure 2-2 Width Adjustments for Fixed Objects

Shy distance on the inside (curb side) of the sidewalk is measured from the outside edge of the paved roadway (or face of curb, if present). It is generally considered to equal 1.5 ft. Shy distance on the outside of the sidewalk is 1.5 ft if a fence or a low wall is present, 2.0 ft if a building is present, 3.0 ft if window display is present, and 0.0 ft otherwise.

B. Compute Pedestrian Flow Rate per Unit Width

The pedestrian flow per unit width of sidewalk is computed by

$$V_p = \frac{V_{ped}}{60W_E}$$

Where

V_p = pedestrian flow per unit width (p/ft/min),

V_{ped}= pedestrian flow rate in the subject sidewalk (walking in both directions) (p/h), and

W_E = effective sidewalk width (ft)

C. Compute Average Walking Speed

The average walking speed S_p is computed by

$$S_p = (1 - 0.00078\ v_p^2)\, S_{pf} \quad \geq 0.5\, S_{pf}$$

where S_p = pedestrian walking speed (ft/s), S_{pf}- free-flow pedestrian walking speed (ft/s), and v_p = pedestrian flow per unit width (p/ft/min).

D. Compute Pedestrian Space

The average pedestrian space is calculated as

$V_p = 60\frac{S_p}{V_p}$ where Ap is the pedestrian space (ft^2/p) and other variables are as previously defined.

Step 3: Determine Pedestrian Delay at Intersection

The first delay variable represents the delay incurred by pedestrians who travel through the boundary intersection along a path that is parallel to the segment centerline d_{pp}. The second delay variable represents the delay incurred by pedestrians who cross the segment at the nearest signal-controlled crossing d_{pc}. The third delay variable represents the delay incurred by pedestrians waiting for a gap to cross the segment at an uncontrolled location d_{pw}.

Step 4: Determine Pedestrian Travel Speed

Pedestrian travel speed represents an aggregate measure of speed along the segment. It combines the delay incurred at the downstream boundary intersection plus the time required to walk the length of the segment. As such, itis typically slower than the average walking speed. The pedestrian travel speed is computed by

$$S_{Tp,seg} = \frac{L}{\frac{L}{Sp} + d_{pp}}$$

where

$S_{Tp,seg}$ = travel speed of through pedestrians for the segment (ft/s),

L = segment length (ft),

S_p = pedestrian walking speed (ft/s), and d_{pp} = pedestrian delay when walking parallel to the segment(s/p).

In general, a travel speed of 4.0 ft/s or more is considered desirable and a speed of 2.0 ft/s or less is considered undesirable.

Step 5: Determine Pedestrian LOS Score for Intersection

The pedestrian LOS score for the boundary intersection $I_{p,int}$ is determined in this step. If the boundary intersection is signalized, then the pedestrian methodology is used. If the boundary intersection is two-way STOP controlled, then the score is equal to 0.0.

Step 6: Determine Pedestrian LOS Score for Link

The pedestrian LOS score for the link $I_{p,link}$ is calculated by

$$I_{p,link} = 6.0468 + F_w + F_v + F_S$$

$$F_w = -1.2276 \ln(W_v + 0.5\,W_1 + 50\,p_{pk} + W_{buf}\,f_b + W_{aA}\,f_{sw})$$

$$F_v = 0.0091 \frac{v_m}{4\,N_{th}}$$

$$F_s = 4\left(\frac{S_R}{100}\right)^2$$

Where

$I_{p,link}$ = pedestrian LOS score for link,

F_w = cross-section adjustment factor,

F_v = motorized vehicle volume adjustment factor,

F_s = motorized vehicle speed adjustment factor, ln(x) = natural logarithm of x,

N_{th} = number of through lanes on the segment in the subject direction of travel (In);

W_v = effective total width of outside through lane, bicycle lane, and shoulder as a function of traffic volume (ft);

W_1= effective width of combined bicycle lane and shoulder (ft);

p_{pk} = proportion of on-street parking occupied (decimal);

W_{buf} = buffer width between roadway and available sidewalk (= 0.0 if sidewalk does not exist) (ft);

f_b = buffer area coefficient = 5.37 for any continuous barrier at least 3 ft high that is located between the sidewalk and the outside edge of roadway; otherwise use 1.0;

W_A = available sidewalk width = 0.0 if sidewalk does not exist or W_T- W_{buf} if sidewalk exists (ft);

W_{aA} = adjusted available sidewalk width = min(W_A, 10) (ft);

f_{sw} = sidewalk width coefficient = 6.0 - 0.3 W_{aA};

v_m = midsegment demand flow rate (direction nearest to the subject sidewalk) (veh/h);

S_R = motorized vehicle running speed = (3,600 L)/ (5,280 t_R) (mi/h).

Table 2-2 Variables for Pedestrian LOS Score for Link (HCM 2010)

Condition	Variable When Condition Is satisfied	Variable When Condition Is Not Satisfied
P_{pk} =0.0	W_t =W_{ol}+W_{bl}+W_{os}*	W_t =W_{ol}+W_{bl}
V_m >160 veh/h or street is divided	W_v =W_t	W_v =W_t (2-0.005 V_m)
P_{pk} < 0.25 or parking is striped	W_1 =W_{bl} +W_{os}*	W_1 =10

Notes: W_t = total width of the outside through lane, bicycle lane, and paved shoulder (ft);
W_{ol} = width of the outside through lane (ft);
W_{os}* = adjusted width of paved outside shoulder;if curb is present W_{os}* = W_{os} -1.5 >= 0.0, otherwise W_{os}* = W_{os} (ft);
W_{os} = width of paved outside shoulder (ft); and
W_{bl} = width of the bicycle lane = 0.0 if bicycle lane not provided (ft).

Step 7: Determine Link LOS

The pedestrian LOS for the link is determined by using the pedestrian LOS score from Step 6 and the average pedestrian space from Step 2.

Step 8: Determine Roadway Crossing Difficulty Factor

The pedestrian roadway crossing difficulty factor measures the difficulty of crossing the street between boundary intersections. Segment performance from a pedestrian perspective is reduced if the crossing is perceived to be difficult. The roadway crossing difficulty factor is based on the delay incurred by a pedestrian who crosses the subject segment. One crossing option the pedestrian may consider is to alter his or her travel path by diverting to the nearest signal-controlled crossing. This crossing location may be a midsegment signalized crosswalk or it may be a signalized intersection. A second crossing option is to continue on the original travel path by completing a midsegment crossing at an uncontrolled location. If this type of crossing is legal along the subject segment, then the pedestrian crosses when there is an acceptable gap in the motorized vehicle stream.

A. Compute Diversion Delay

   The delay incurred as a consequence of diverting to the nearest signal-controlled crossing is computed first. It includes the delay involved in walking to and from the midsegment crossing point to the nearest signal-controlled crossing and the delay waiting to cross at the signal. Hence, calculation of this delay requires knowledge of the distance to the nearest signalized crossing and its signal timing.

   The distance to the nearest crossing location Dc is based on one of two approaches. The first approach is used if there is an identifiable pedestrian path (a) that intersects the segment and continues on beyond the segment and (b) on which most crossing pedestrians travel. The location of this path is shown for two cases in figure below. Figure (a) illustrates the distance Dc when the pedestrian diverts to the nearest signalized intersection. This distance is measured from the crossing location to the signalized intersection.

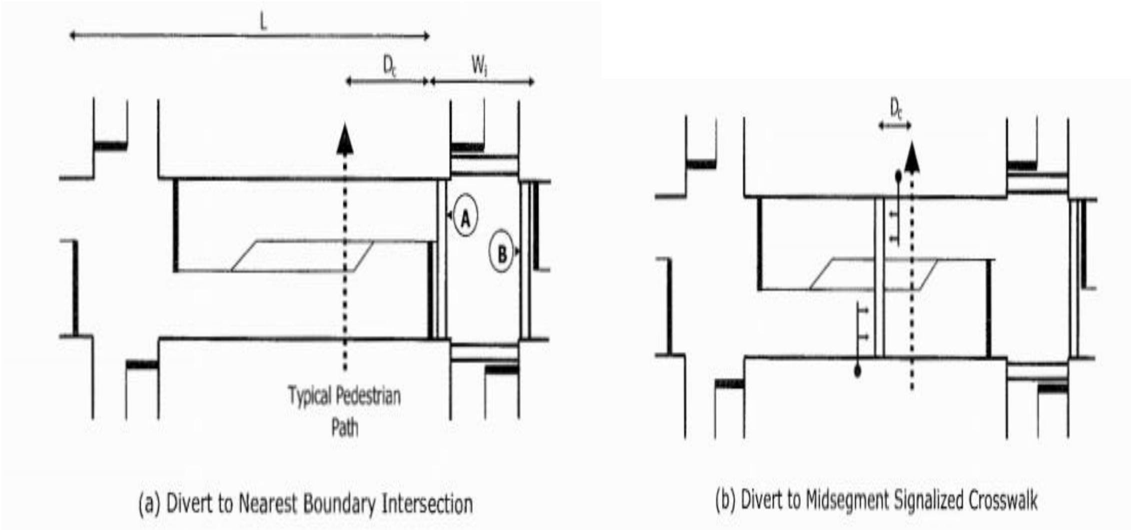


Figure 2-3 Diversion Distance Components

Figure 2.3 (b) illustrates the distance D_c when a signalized crosswalk is provided at a midsegment location. Inthis situation, the distance is measured from the pedestrian crossing location to the location of the signalized crosswalk.

Ineither case, the distance D_c is an input value providedby the analyst. The second approach is used if crossings occur somewhat uniformly along the length of the segment. Inthis situation the distance Dc canbe assumed to equal one-third of the distance between the nearest signal-controlled crossings that bracket the subject segment.

The diversion distance to the nearest crossing is computed by

$$D_d = 2D_c$$

Where D_d = diversion distance (ft), and D_c = distance to nearest signal-controlled crossing (ft).
If the nearest crossing location is at the signalized intersection and the crossing is at Location A in Figure 2.3 (a), then the above equation applies directly.

If the nearest crossing location is at the signalized intersection but the crossing is at Location B, then the distance obtained from the equation should be increased by adding two increments of the intersection width W_i.

The delay incurred due to diversion is calculated by using

$$d_{pd} = \frac{D_d}{S_p} + d_{pc}$$

where

d_{pd} = pedestrian diversion delay (s/p),

D_d = diversion distance (ft),

S_p = pedestrian walking speed (ft/s), and

d_{pc} = pedestrian delay when crossing the segment at the nearest signal controlled crossing (s/p).

The pedestrian delay incurred when crossing at the nearest signal-controlled crossing was determined in Step 3.

B. Compute Roadway Crossing Difficulty Factor

The roadway crossing difficulty factor is computed by using

$$\mathrm{F}_{cd} = 1.0 + \frac{0.10 d_{px} - (0.318\, I_{p,link} + 0.220\, I_{p,int} + 1.606)}{7.5}$$

where

F_{cd} = roadway crossing difficulty factor,

d_{px} = crossing delay = min(d_{pd},d_{pw}, 60) (s/p),

d_{pd} = pedestrian diversion delay (s/p),

d_{pw} = pedestrian waiting delay (s/p),

$I_{p,link}$ = pedestrian LOS score for link, and

$I_{p,int}$ = pedestrian LOS score for intersection.

If the factor obtained from Equation 17-37is less than 0.80, then it is set equal to 0.80. If the factor is greater than 1.20, then it is set equal to 1.20.

The pedestrian waiting delay was determined in step 3. If a midsegment crossing is illegal, then the crossing delay determination does not include consideration of the pedestrian waiting delay d_{pw}, [i.e., d_{px} = min (d_{pd}, 60)].

Step 9: Determine Pedestrian LOS Score for Segment

The pedestrian LOS score for the segment is computed by using

$$I_{p,seg} = F_{cd}(0.318\, I_{p,link} + 0.220\, I_{p,int} + 1.606)$$

where $I_{p,seg}$ is the pedestrian LOS score for the segment and other variables are as previously defined.

Step 10: Determine Segment LOS

The pedestrian LOS for the segment is determined by using the pedestrian LOS score from Step 9 and the average pedestrian space from Step 2.

2.2.2 International Road Assessment Program (iRAP) Evaluation

The International Road Assessment Programme (iRAP) is a registered charity dedicated to saving lives through safer roads. They provide tools and training to help countries make roads safe. Their activities include:

a) inspecting high-risk roads and developing Star Ratings and Safer Roads Investment Plans.
b) providing training, technology and support that will build and sustain national, regional and local capability
c) A tracking road safety performance so that funding agencies can assess the benefits of their investments.

The iRAP Protocols

1. Risk Maps use detailed crash data to illustrate the actual number of deaths and injuries on a road network.
2. Star Ratings provide a simple and objective measure of the level of safety provided by a road's design.
3. Performance Tracking enables the use of Star Ratings and Risk Maps to track road safety performance and establish policy positions.
4. Safer Roads Investment Plans draw on approximately 70 proven road improvement options to generate affordable and economically sound infrastructure options for saving lives

Star Ratings overview

Star Ratings are an objective measure of the likelihood of a road crash occurring and its severity. The focus is on identifying and recording the road attributes which influence the most common and severe types of crash, based on scientific evidence-based research. In this way, the level of road user risk on a particular network can be defined without the need for detailed crash data, which is often the case in low- and middle-income countries where data quality is poor. Research shows that a person's risk of death and serious injury is highest on a one-star road and lowest on a five-star road.

To assess if an inspection system meets the criteria for becoming an accredited iRAP Star Rating inspection system, an agreed demonstration Star Rating dataset will be provided to the iRAP core team together with the coding software. The demonstration Star Rating dataset will be a minimum of 10km in length and will include all data associated data (video, location, and coding data file).

The demonstration Star Rating data set is required to contain the minimum following set of iRAP Star Rating attributes provided in 100-meter segments:

i) Road name
ii) Latitude and Longitude
iii) Running Distance
iv) Segment Length
v) Lane width
vi) Curvature
vii) Sidewalk Provision – left
viii) Roadside Severity – right
ix) Intersection type

The star rating use five level from star 1 up to star 5 with color codes. 5-star roads are colored Green 4-star yellow, 3-star orange, 2-star red and 1-star black. 5-star roads have excellent performance where as the 1- star roads have poor performance. The star rating scores is different for different road user types and the detail is shown in the following chart.

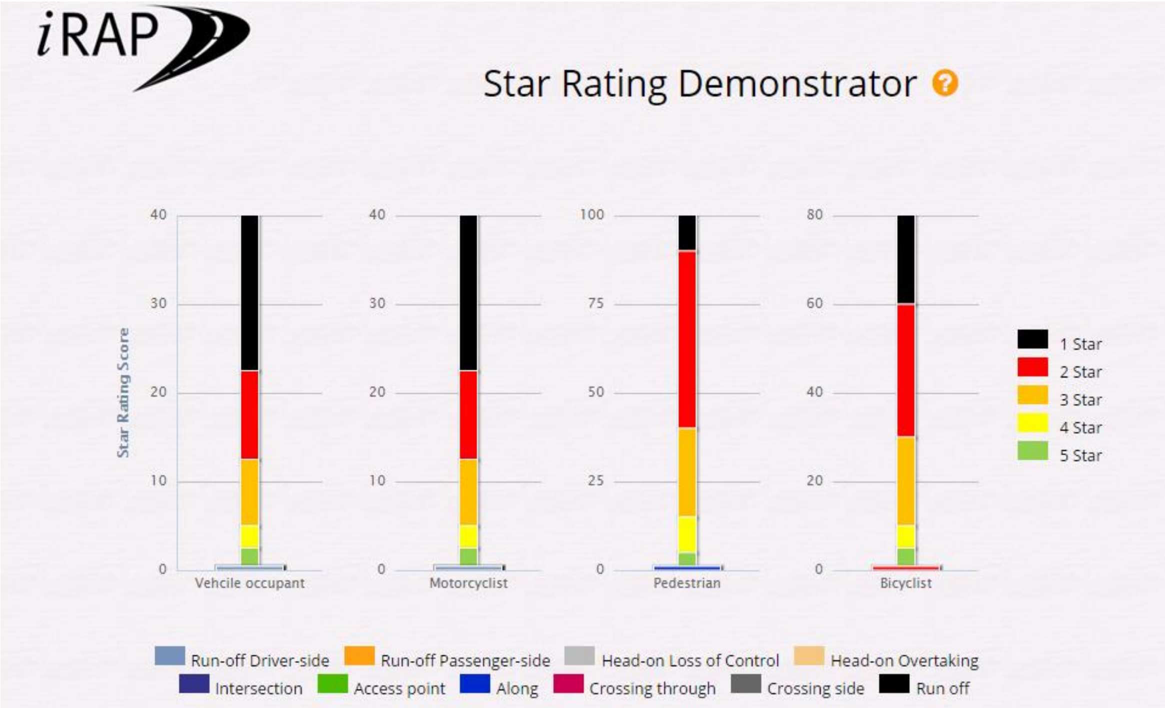


Figure 2-4 Star rating chart with scores and colors

2.3 Design Principles

In order to avoid common problems related to sidewalks and to achieve safety procedures, establishing a design to sidewalk should take place with a number of characteristics. In addition, this will assure fulfilling of the link and the place characteristics of the sidewalk. There are five major features are identified through various literature reviews and studies (Kang et al, 2012) (Yang, 1981), these are mobility, place, safety, sociability and amenity. Each design principle has a number of indicators that were derived from the main design term in order to be more appropriate (Osman, D. A. M., 2016).

1. Mobility**: -** This term means the ability for pedestrians to move from one place to another. The specific term indicators include continuity, functionality, efficiency, accessibility, affordability, consistency and connectivity. The continuity is for the pedestrian activities, the functionality according to the density of pedestrians in the street space, the efficiency of pedestrian facilities in terms of the efficient use of urban space in the restoration of the unique features of pedestrian facilities maintenance or preservation. Accessibility should occur to reach a particular place or facility with easily accessible properties. The sidewalk space should afford well-

formed walking environment, pleasant area with the activation of the surrounding activities. The consistency enables pedestrians to read the direction of the destination, consistency in space through composition, color, light, smell, and the slope of the ground, textures features also naturally perceived characteristics. In addition to connectivity, where pedestrians can move to any destination interconnected by walking, public transport, car and bicycle parking and any building that can be connected efficiently.

2. Place**: -** This helps pedestrian to recognize and remember features that distinguishes a particular space and other space properties. It could be achieved through a number of indicators such as symbolism, diversity, identity, unity, tradition, spirit of the time and elements of art. For example, Landmarks have symbolic significance as an important recognition of the destination. Through diversity pedestrians can enjoy a variety of experience and of the space through physical and non-physical environmental factors. Identity is achieved through unchanging of the components that have unique characteristics in the pedestrian space. Unity is clear when pedestrian street space full of various components is identified as one, multiple elements properly integrated into one organic system to accommodate the diversity. The tradition is handed down from the past and the spirit of the times characterizes the space by the configuration of culture of a definite era. Finally, elements of art make up the pedestrian space as an artistic activity, acts of culture and art exhibitions, concerts, festival take place and culture of the city reflected in the space characteristics.
3. Safety**: -** refers to all the ways and elements needed to minimize the possibility of occurrence of the risk arising from the existence of a traffic accident or a society crime while walking. The indicators include buffer and crime prevention plans. Buffer exists to avoid a direct conflict between transportation and pedestrian space. Physical separation takes place between the street space for vehicles and the sidewalk. Facilities and plans installed to prevent crimes.
4. Sociability: - The term sociability means that people would meet each other to share the areas of social interaction and to create a sense of community interaction. The term indicators include the presence of play, relax, share and equity. The sidewalk space can be a space to relax through benches, resting in the shade of

trees and meeting up. Also, it can be an area to play if width permits. Sharing external space takes place and equity as well through providing the chance for all types of people to use the path; children, elderly, people with disabilities.

5. Amenity**: -** brings comfort and provides convenience to pedestrians; people will feel refreshing during walking by a good composition of the surrounded environment of the sidewalk space. The indicators include landscape, aesthetic elements, natural elements, convenience and sense of openness. Landscape elements can be introduced to the sidewalk space that helps to provide amenity to the space. Aesthetic elements include colors, studied street furniture units and signage design help together with other natural elements in strengthening the design element. It is important to provide convenience through the presence of various facilities required to encourage the flow of pedestrian and ease walking without discomfort. The sense of openness depends on the parallel frontage to the sidewalks, the visual corridor of the building setback and the horizontal configuration of the pattern share in achieving this sense.

2.4 Roadway Design Manual recommendations

2.4.1 Sidewalk Location

For pedestrian comfort, especially adjacent to high speed traffic, it is desirable to provide a buffer space between the traveled way and the sidewalk. For curb and gutter sections, a buffer space of 3 ft [915 mm] or greater between the back of the curb and the sidewalk is desirable. For rural sections without curb and gutter, sidewalks should be placed between the ditch and the right of way line if practical.

2.4.2 Sidewalk Width

Sidewalks should be wide enough to accommodate the volume and type of pedestrian traffic expected in the area. The minimum clear sidewalk width is 5 ft [1525 mm]. Where a sidewalk is placed immediately adjacent to the curb, a side- walk width of 6 ft [1830 mm] is desirable to allow additional space for street and highway hardware and allow for the proximity of moving traffic. Sidewalk widths of 8 ft [2440 mm] or more may be appropriate in commercial areas, along school routes, and other areas with concentrated pedestrian traffic. Where necessary to cross a driveway while maintaining the maximum 2 percent cross slope, the sidewalk width may be reduced to 4 ft [1220 mm] if insufficient space is available to locate street fixtures (elements such as sign supports, signal poles, fire hydrants, manhole covers, and controller cabinets that are not intended for public use) outside the 5 ft [1525 mm] minimum clear width. The width may be reduced to 4 ft [1220 mm] for a length of 2 ft [610 mm] maximum, provided that reduced width segments are separated by at least 5 ft [1525 mm] in length.

2.4.3 Street Crossings

Intersections can present formidable barriers to pedestrian travel. Intersection designs which incorporate properly placed curb ramps, sidewalks, crosswalks, pedestrian signal heads and pedestrian refuge islands can provide a pedestrian-friendly environment. Desirably, drainage inlets should be located on the upstream side of crosswalks and sidewalk ramps. Refuge islands enhance pedestrian comfort by reducing effective walking distances and pedestrian exposure to traffic. Islands should be a minimum of 5 ft [1525 mm] wide to afford refuge to people in wheelchairs. A minimum 5 ft [1525 mm] width should be cut through the island for pedestrian passage, or curb ramps with a minimum 5 ft x 5 ft [1525 mm x 1525 mm] landing provided in the island.

2.4.4 Curb Ramps and Landings

A sidewalk curb ramp and level landing will be provided wherever a public sidewalk crosses a curb or other change in level. The maximum grade for curb ramps is 8.3 percent. The maximum cross slope for curb ramps is 2 percent. Flatter grades and slopes should be used where possible and to allow for construction tolerances. The minimum width of curb ramps is 4 ft [1220 mm], exclusive of flared sides. Where a side of a curb ramp is contiguous with a public sidewalk or walking surface, it will be flared with a slope of 10 percent maximum. Where a perpendicular or diagonal curb ramp is provided, a landing must be provided at the top of the ramp run. The slope of the landing will not exceed 2 percent in any direction. The landing should have a minimum clear dimension of 5 ft x 5 ft [1525 mm x 1525 mm] square or a 5 ft [1525 mm] diameter circle and will connect to the continuous passage in each direction of travel. Landings may overlap with other landings. Where a parallel curb ramp or driveway crossing is provided (i.e., the sidewalk ramps down to a landing at street level), the designer is encouraged to use a slope of 5 percent or less to avoid the need for detectable warnings or handrails on the sloped portions of the sidewalk. A minimum 5 ft x 5 ft [1525 mm x 1525 mm] landing should be provided at the entrance to the street for parallel curb ramps. At marked crossings, the bottom of a curb ramp run should be wholly contained within the markings of the crosswalk. Beyond the curb line, there should be a minimum 4 ft x 4 ft [1220 mm x 1220 mm] maneuvering space wholly contained within the crosswalk (marked or unmarked) and outside the path of parallel vehicular traffic. Manhole covers, grates, and obstructions should not be located within the curb ramp, maneuvering area, or landing.

2.4.5 Cross Slope

Sidewalk cross slope will not exceed 1:50 (2 percent). Due to construction tolerances, it is recommended that sidewalk cross slopes be shown in the plans at 1.5 percent to avoid exceeding the 2 percent limit when complete. Cross slope requirements also apply to the continuation of the pedestrian route through the cross walk.

2.4.6 Street Furniture

Special consideration should be given to the location of street furniture (items intended for use by the public such as benches, public telephones, bike racks, and parking meters). A clear ground space at least 2.5 ft x 4 ft [760 mm x 1220 mm] with a maximum slope of 2 percent must be provided and positioned to allow for either forward or parallel approach to the element in compliance with ADAAG/TAS. The clear ground space must have an accessible connection to the sidewalk and must not encroach into the 5 ft [1525 mm] minimum sidewalk width by more than 2 ft [610 mm].

Although a number of researches are conducted on walkway and pedestrian related topics in other countries, there are no enough researches conducted in Ethiopia which is a basic study needed especially in Addis Ababa.

CHAPTER THREE

RESEARCH METHODOLOGY

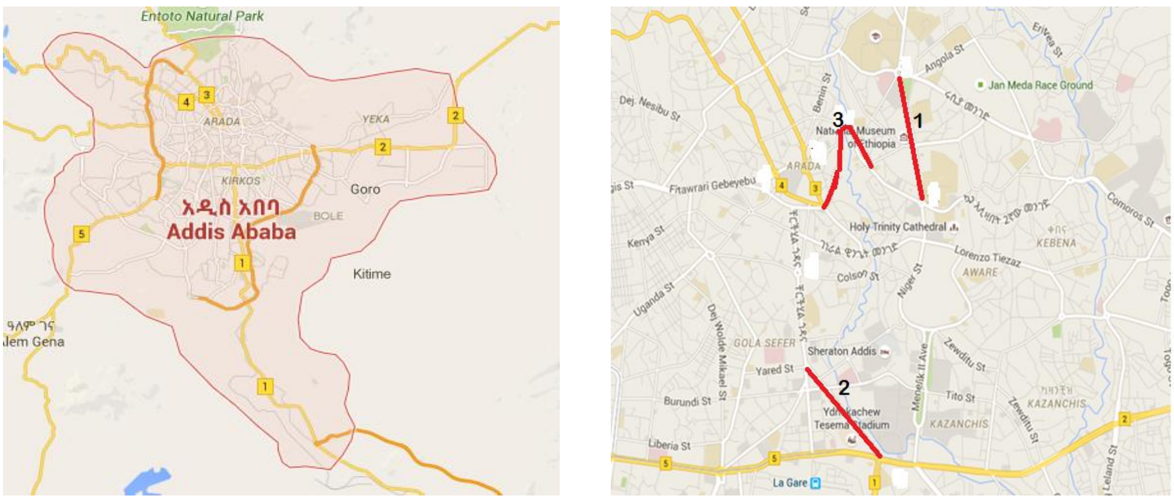
3.1 Introduction

In this research numerical calculations using simplified templates of the highway capacity manual (HCM 2010) and online software developed by international road assessment programs (iRAP) is used to determine the pedestrian level of service of the selected road sections.

3.2 Study Area

The research was conducted in the central part of Addis Ababa city; Which is the capital city of Ethiopia, at selected road sections. Based on Addis Ababa City Roads Authority (AACRA) area classification central Addis Ababa includes three sub cities; Arada, Lideta and Kirkos. The selected sections of road for this paper are from Arat kilo to Sidist Kilo, from Meskel Square to Post Office and from Degol Square to Ras Mekonnen Bridge**.**

The following figures show map of Addis Ababa city and the selected sections.



Map of Addis Ababa city (Source: Google Map 2018)

Selected road sections-Addis Ababa

1. Arat (4) kilo to Sidist (6) Kilo
2. Meskel Square to Post Office
3. Degol Square to Ras Mekonnen bridge

Figure 3-1 Map of the Study Area

Arat kilo to sidist kilo walkway

Meskel sq. to the post office walkway

Degol Sq. to Ras Mekonnen bridge walkway

Meskel sq. to the post office walkway

Figure 3 2 Pictures of the Study Area

3.3 Study design

Multi-stage design was followed for the completion of this research. In the first stage the functionality of the study was announced to the concerned local authorities and also, the road sections (routes) were selected.

In the second stage, for the selected routes data were collected by video recording, manual counting, and field measurement. Then, the road sections (routes) were evaluated against the rehabilitated capacity, quality and safety based on the International Road Assessment Program (IRAP) road ranking software for the pedestrian and the pedestrian LOS was determined using highway capacity manual.

On the third stage, the rank of the selected routes by IRAP software and the pedestrian LOS result from HCM was compared, analyzed and summarized.

On the next stage, the remedial measures to be applied were stated based on the summarized research study and ranking of the selected new rehabilitated walkway routes.

Finally, the routes rank (star rating) was analyzed by IRAP software again, compared with the previous rank if the remedial measures stated are applied and put the final conclusion and recommendation.

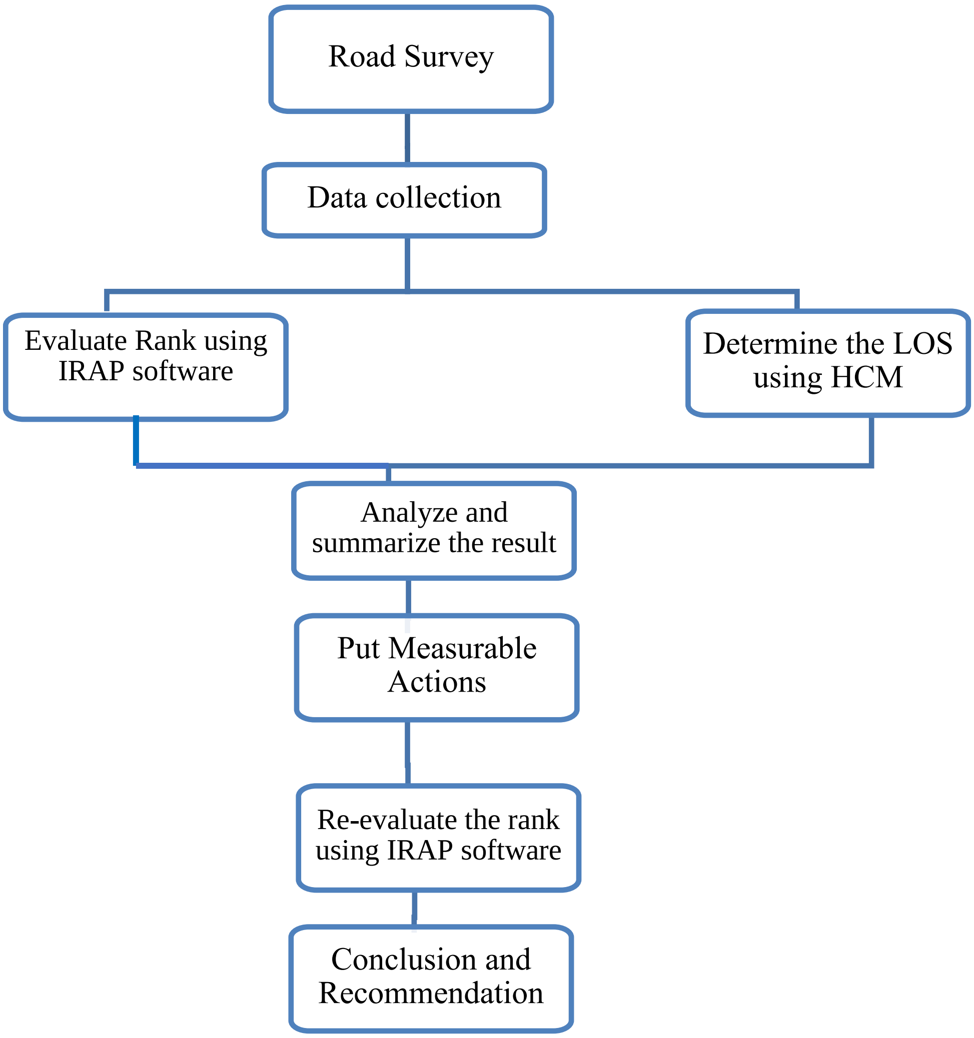


Figure 3-2 Study Design flow chart

3.4 Population

In this study, the walkway route length rehabilitates by Addis Ababa City Roads Authority in central Addis Ababa; Arada, Kirkos and Lideta Sub cities, which is 18,000 m, pedestrian volume, vehicle volume and iRAP and HCM software were served as the population of the study.

3.5 Sample Size and Selection

This study used the following formulae for sample size analysis. The formula is used in most statistics textbooks and researches, especially descriptive statistics dealing with probability. (Israel, Glenn D. 1992)

Sampling Technique and Procedure

For this research simple random probability sampling techniques are used.

1. Sample size – infinite population (where the population is greater than 50,000)

$$SS = Z^2 \times (p) \times (1-p) / C^2$$

SS = Sample Size

Z = Z-value (e.g., 1.96 for a 95 percent confidence level)
P = Percentage of population picking a choice, expressed as decimal
C = Confidence interval, expressed as decimal (e.g., .04 = +/- 4 percentage points)

2. Sample size – finite population (where the population is less than 50,000)

$$\text{New SS} = SS / (1 + (SS - 1)/ Pop)$$

Now, in my case the number of populations was finite (14 sites) which is less than 50,000 with 18,000 m length. Therefore, first the sample size was calculated using infinite population and then next the finite population formula was used.

$$SS = Z^2 \times (p) \times (1-p) / C^2$$

Use 95 percent confidence level, Z=1.96, C=0.04, P=0.5

Substitute the value and we get SS= 4

Then, New SS = SS / (1 + (SS - 1)/ Pop)

Where, SS= 4, Pop= 14

Substitute the value and we get New SS= 3

So, for this study three routes around 3600m length sample which was about 20% of the population selected.

3.6 Study variable

Two variables were taken into consideration; the dependent variable and independent variables.

Independent Variables

The independent variables which were determined during data collection include:

- ✓ Walkway width and segment length
- ✓ Traffic volume (pedestrian and vehicle)

- ✓ Availability of obstacles
- ✓ Availability of parking
- ✓ Intersection type
- ✓ Proportion of nearby structures (Buildings, Fences)
- ✓ Type and width of Medians

Dependent Variable

The dependent variable was:

- ✓ The Pedestrian LOS.

3.7 Software's and Instruments

In order to conduct this research camera was used for capturing pictures and recording videos. For the analysis part HCM 2010 excel templated and the online software from international road assessment program was used.

3.8 Data collection process

The first stage in data collection were obtained consent from AACRA, local governments, individuals and communities of Addis Ababa city.

The data for the purpose of this research were conducted through primary and secondary sources. For the primary data collections internationally reputable and recommended techniques of traffic data collections were used. The primary data, which are the traffic flow and travel time, were collected using:

- ✓ Video recording.
- ✓ Manual traffic flow counts.

The secondary data were obtained every 100 m or less to determine the geometric features of walkway for capacity analysis. These included the width of walkway section, segment length, spacing of pedestrian crossings, grade, slope, surface type, curb ramp and other walkway related features. The data recorded by AACRA were used as a source of secondary data.

2.2.1 Traffic Volume Data

Traffic volume of pedestrians and vehicles are important parameters for capacity analysis of HCM and IRAP software. Because of this, vehicle and pedestrian volume data were collected at peak hours with their direction of movements. A 1-hour study period and divides it into four 0.25-hour (15 Minutes) analysis periods is used. This approach accounts for systematic flow rate variation among analysis periods. It also accounts for queues that carry over to the next analysis period and produces a more accurate representation of the delay. The vehicles and pedestrians counted are summarized as shown in Table 3-1. The detail information on the movement of vehicles is put in Appendix A.

Table 3-1 Summarized Peak hour Pedestrian and Vehicle traffic volume

Road Name	Segment No.	Direction	Peak Hr pedestrian volume	Peak Hr Vehicle volume(PCU
From 4 Killo to 6 killo	1	Left	2109	1060
	1	Right	1976	999
	2	Left	1556	935
	2	Right	1418	847
From Meskel Sq to Post office	1	Left	1359	936
	1	Right	1273	997
	2	Left	1024	817
	2	Right	933	654
From Degol Sq to Ras Mekonen Bridge	1	Left	1551	862
	1	Right	1482	735

3.8.2 Geometric Data

Table 3-2 Geometric Data

Road Name	Segment No.	Direction	Length(ft)	Average Walkway width(ft)	Median width(ft)
From 4 Kilo to 6 Kilo	1	Left	1683	27.8	3.3
	1	Right	1899.6	16.2	3.3
	2	Left	2132.5	18.3	3.3
	2	Right	2152.3	21.3	3.3
From Meskel Sq. to Post office	1	Left	2739.5	16.7	4.9
	1	Right	2926.5	18.4	4.9
	2	Left	987.5	15.7	4.9
	2	Right	1161.4	21.5	4.9
From Degol Sq. to Ras Mekonnen Bridge	1	Left	3047.9	12.8	-
	1	Right	3064.3	11.7	-

3.9 Data processing and analysis

After the data was collected according to the previous section, then walkway rank was assessed using international road assessment online software by the help of international road assessment and star rating and Investment Plan Coding Manual and the pedestrian level of service was determined by the High way capacity manual (HCM ,2010) using excel templates.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

The analysis was made based on the gathered quantitative and qualitative data to assess the pedestrian LOS and the star ratings for pedestrians. The pedestrian level of service for the identified segments was analyzed using HCM 2010 and the star ratings for pedestrians were estimated by International Road Assessment Programme (iRAP) online software. Before the results of these two methodologies some important parameters are discussed below.

4.1 Pedestrian characteristics

4.1.1 Pedestrian age distribution

According to the age group 54% of the pedestrians are adults (age from 15 to 64 years old),35% elderly (> 64 years old) and the rest 11 % are Children (< 15 years old).

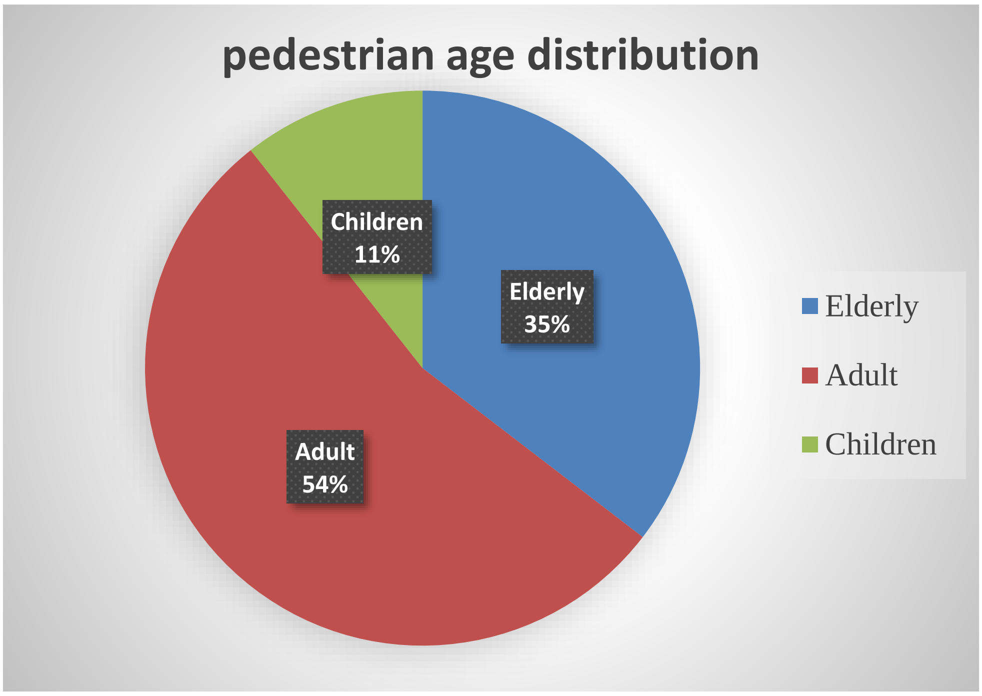


Figure 4-1 pedestrian age distributions

4.1.2 Pedestrian Speed

As per HCM 2010 walking speed is influenced by pedestrian age and sidewalk grade. If 0% to 20% of pedestrians traveling along the subject segment are elderly (i.e., 65 years of age or older), an average free-flow walking speed of 4.4 ft/s is recommended for segment evaluation. If more than 20% of pedestrians are elderly, an average free-flow walking speed of 3.3 ft/s is recommended. In addition, an upgrade of 10% or greater reduces walking speed of 0.3 ft/s. Therefore, for this study, the percentage of elderly pedestrians are 35 %, which is greater than 20 % the average free-flow walking speed is 3.0 ft/s.

4.1.3 Pedestrian and Vehicle Peak flow

Based on observed actual field conditions at peak hours the pedestrian volume is high at the location from Arat Kilo to Kidste Mariyam junction and low at sections from Ambassador to Post office, whereas vehicle volume is high at locations from Arat Kilo to Kidste Mariyam junction and from Meskel Square to Ambassador and low at sections from Ambassador to Post office.

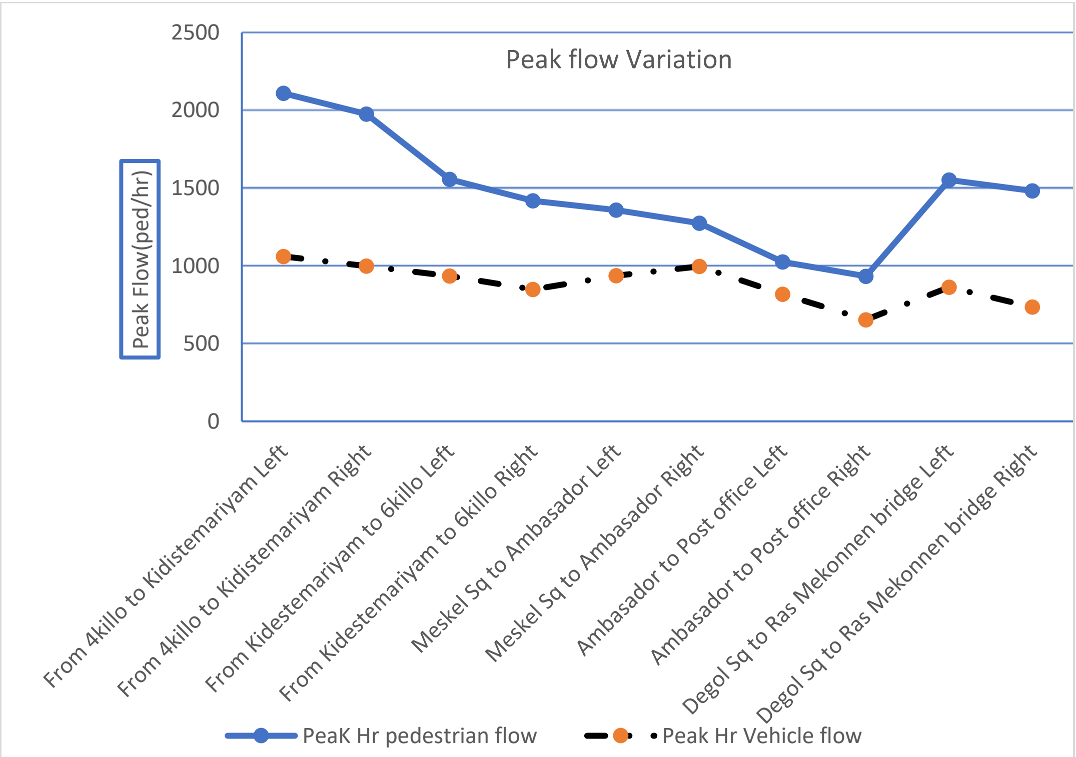


Figure 4-2 Pedestrian and Vehicle Peak flow Variation

4.2 Factors Affecting Pedestrian Movements

4.2.1 Sidewalk width

The average sidewalk width for walkway sections from Degol square to Ras Mekonnen bridge is smaller than that of Meskel square to post office and 4 killo to 6 killo whereas the average sidewalk width of road section from 4 killo to Kidistemariyam left side is the best one from the others which is 27.8ft.

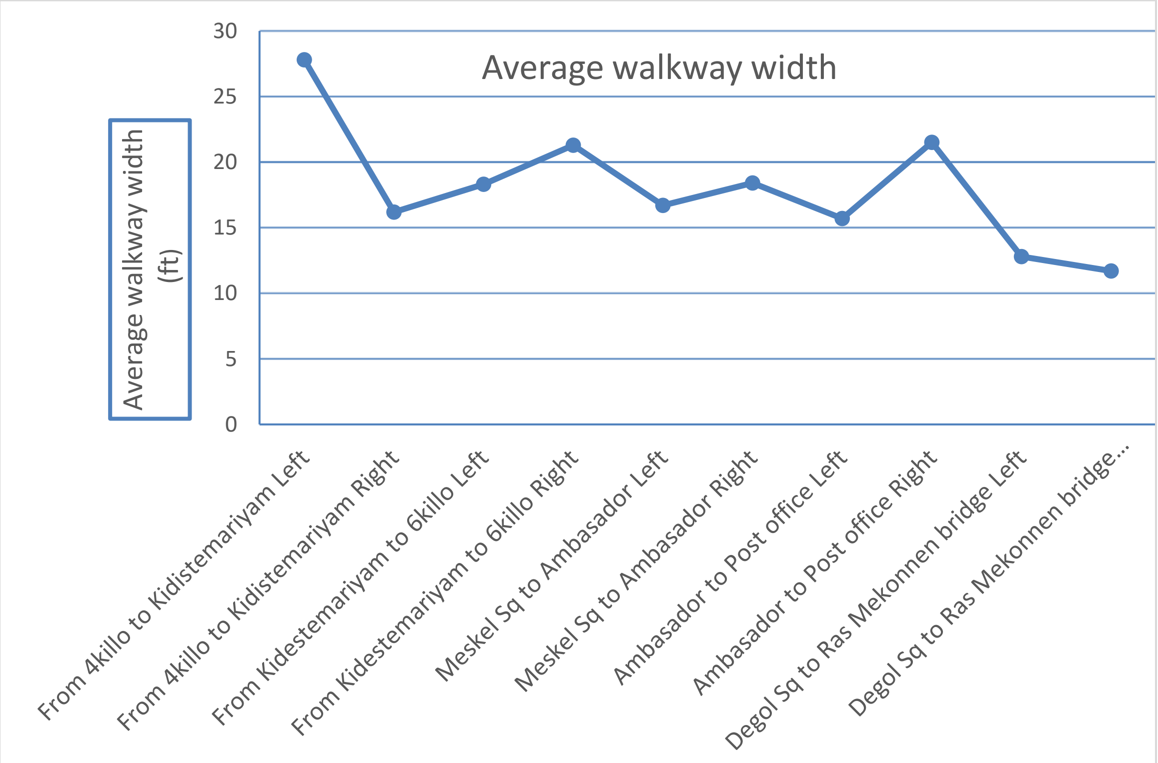


Figure 4-3 Average sidewalk width

4.2.2 Median Width

There is no median width totally for road segment from Degol Square to Ras Mekonnen bridge whereas section from Meskel square to post office has good median width that the rest which is 4.9 ft.

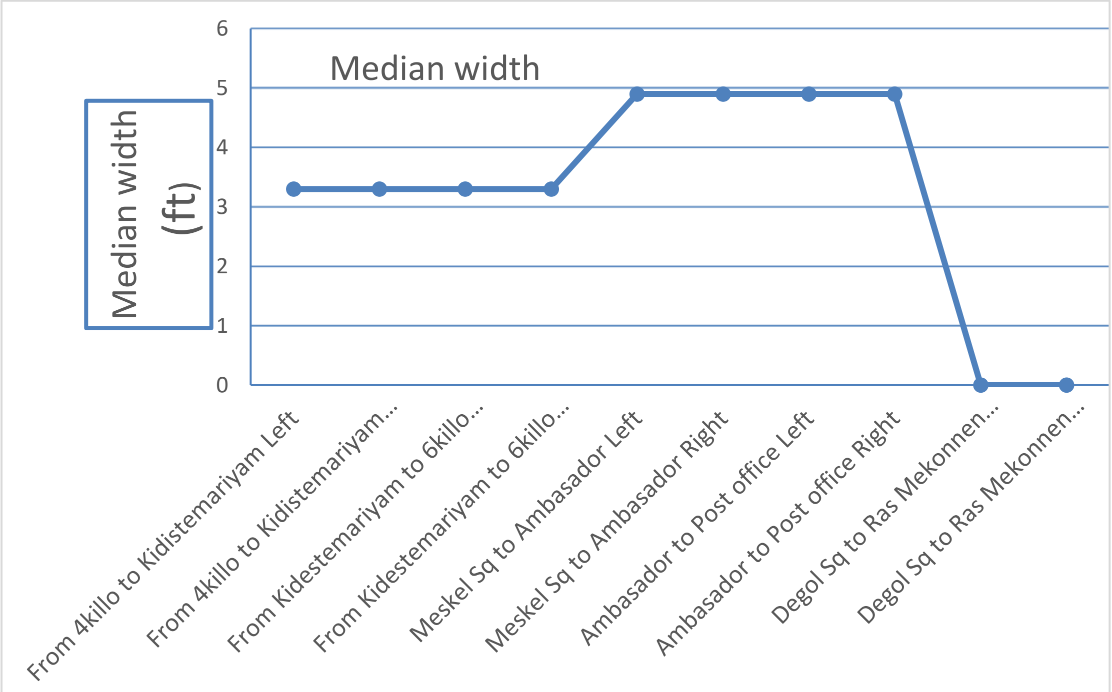


Figure 4-4 Median Width

4.2.3 Fixed objects on the walkway

Availability of fixed object on the walkway highly affect the pedestrian movement. These objects include street light poles, traffic sign poles, advertisement poles, trees, guard houses and other objects put permanently on the sidewalk. All sections have fixed object on the walkway right of way width and it is not suitable for disabled persons as well as for all users without disability.

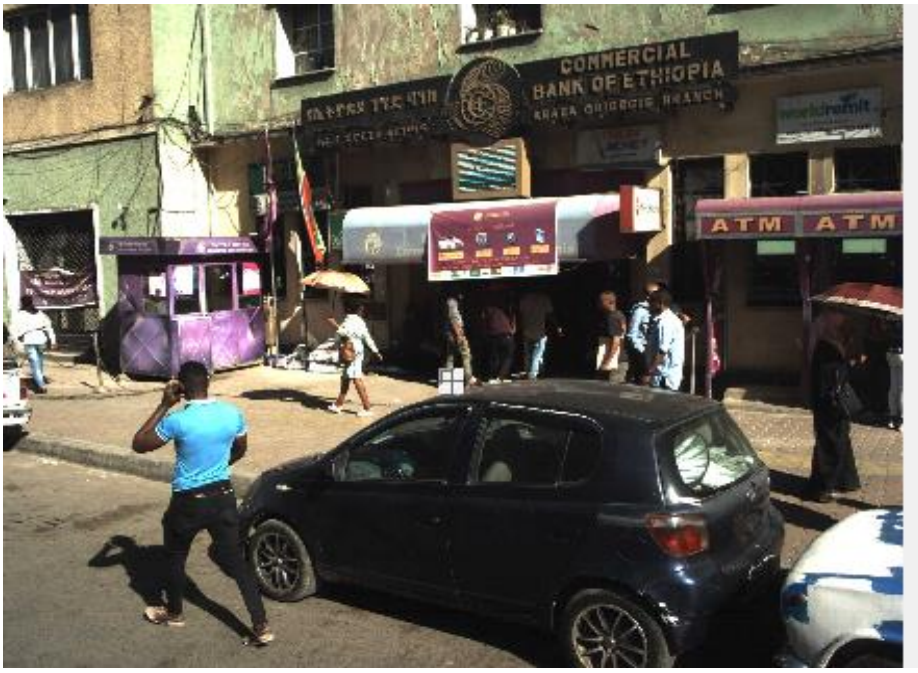


Figure 4-5 Degol Sq. to Ras Mekonnen bridge (ATM machines, Guard house)

Figure 4-6 Degol Sq. to Ras Mekonnen bridge walkway (trade on walkway)

4.2.4 Non fixed objects on the walkway

Non fixed objects put on the walkway have also a great effect on the movement of pedestrians. These includes illegal trade on the walkway, waste materials and construction materials on the walkway.

Figure 4-7 Non-Fixed Object on Walkway

4.3 Pedestrian LOS Result using HCM 2010

The pedestrian LOS was calculated by LOS+ spreadsheet which is created by Fehr & Peers. This spreadsheet was created to assist in the computation of the link-based Multi Modal Level of Service (MMLOS) for urban streets under existing, field measured conditions.

Sample calculations for road section from 4 killo to 6 killo right side

Step 1: Input parameters of the segment
The parameters used first are pedestrian walking speed, pedestrian flow rate, vehicle flow rate, speed limit, segment length and green cycle for through lane.

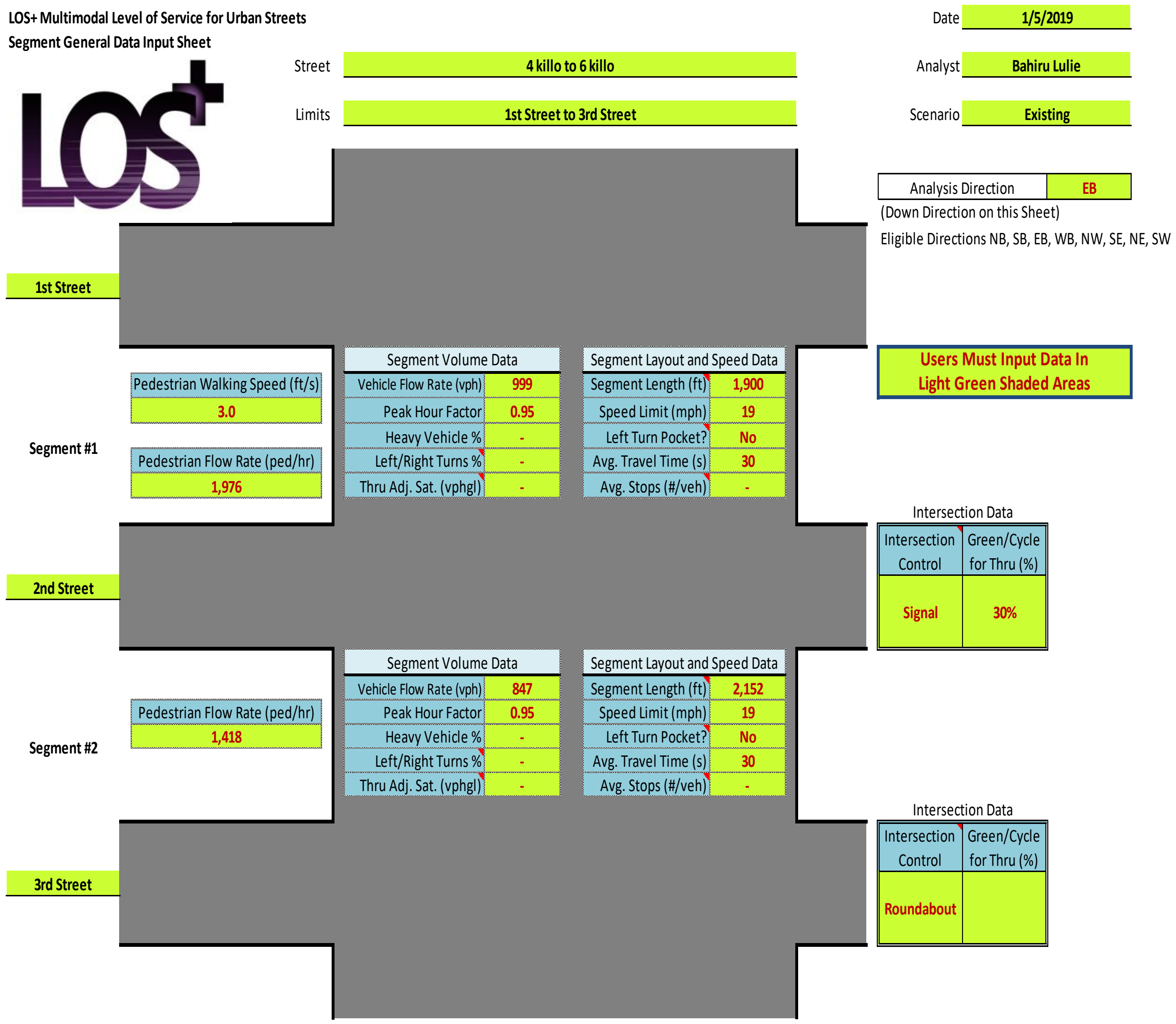


Figure 4-8 Segment data

Step 2: Geometrical data

Secondly, the geometrical data necessary for LOS calculation is filled. These includes sidewalk width, Buffer, shoulder width, bike lane, travel lane, median width and parking. Additionally, the proportion of adjacent object to the sidewalk is used.

LOS+ Multimodal Level of Service for Urban Streets
Street Cross-Section Input Data Sheet Street 4 killo to 6 killo Limits 1st Street to 6th Street

Segment #1 General guidance on input parameters is provided at the bottom of this sheet. Analyst Bahiru Lulie Date 1/5/2019

From 1st Street To 2nd Street

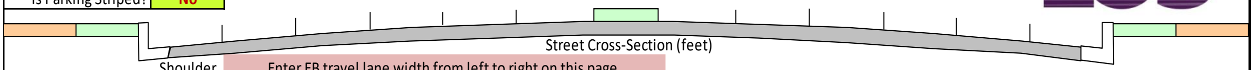
1

Fixed Object Width (ft)	Parking Occupancy %
1.2	14%

Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	2
Pavement Condition	4.0

EB WB



Street Cross-Section (feet)
Shoulder
Enter EB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
16.2	0.5	12.0	0.0	12.0				3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.00	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.86	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
Yes	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Segment #2
From 2nd Street To 3rd Street

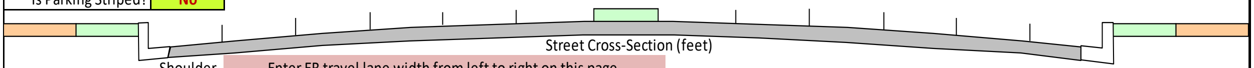
2

Fixed Object Width (ft)	Parking Occupancy %
3.2	17%

Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	2
Pavement Condition	4.0

EB WB



Street Cross-Section (feet)
Shoulder
Enter EB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
21.3	0.0	12.0	0.0	12.0				3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.00	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.63	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Figure 4-9 Geometrical data

Step 3: LOS Computation

All calculation steps and the formulas used for this template is discussed under 2.2.1 section of the literature review part of this research. The calculation using simplified templates of HCM 2010 based on the data recorded in step one and two is shown below.

Compute Pedestrian LOS

Street: **4 killo to 6 killo**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	from
1	16.7	0.9	1.5	1.20	0.50	13.14	Input_XSection
2	21.3	0.6	1.5	3.20	0.00	15.99	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	from
1	3.0	1,976	2.51	2.99	71.47	Input_SegData, Input_XSection
2	3.0	1,418	1.48	2.99	121.58	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_v (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor	from	Median Type
1	12.0	12.0	10.5	0.14	5.37	10.0	3.0	-4.9618	Input_XSection	D
2	12.0	12.0	10.5	0.17	1.00	10.0	3.0	-4.9360	Input_XSection	D

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	from
1	2.2727	0.7456	4.1032	Input_SegData, Input_XSection
2	1.9269	0.9571	3.9948	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	D
2	D

LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

Figure 4-10 Pedestrian LOS calculation

Step 4: Result

Finally, the pedestrian space, pedestrian LOS score and the total level of service is determined as below. According to the result, on a sidewalk or walkway with LOS A, pedestrians move freely without altering their speed in response to other pedestrians or to a decrease in the sidewalk width. On the other hand, on a sidewalk or walkway with LOS F, all walking speeds are severely restricted.

LOS+ Multimodal Level of Service for Urban Streets
Results Summary

LOS+

Street	4 killo to 6 killo	Direction	EB	Date	1/5/2019
Limits	1st Street to 3rd Street	Scenario	Existing	Analyst	Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode: Ped Space[1]	LOS Score	LOS
1	4 killo to kidistemaryam	1st Street	2nd Street	71.47	4.10	D
2	Kidistemaryam to 6 Killo	2nd Street	3rd Street	121.58	3.99	D

Figure 4-11 Pedestrian LOS Result

4.3.1 Pedestrian LOS Score

The pedestrian LOS score for the link is depending on cross-section of the walkway and carriageway, cross-section of the shoulder and buffer, motorized vehicle volume, number of lanes and motorized vehicle running speed. The larger the score indicates that poor performance and the smaller one is better. Therefore, based on these parameters the pedestrian LOS score for a section from Ambassador to the post office is the best and for section of Degol Square to Ras Mekonnen Bridge is the worst.

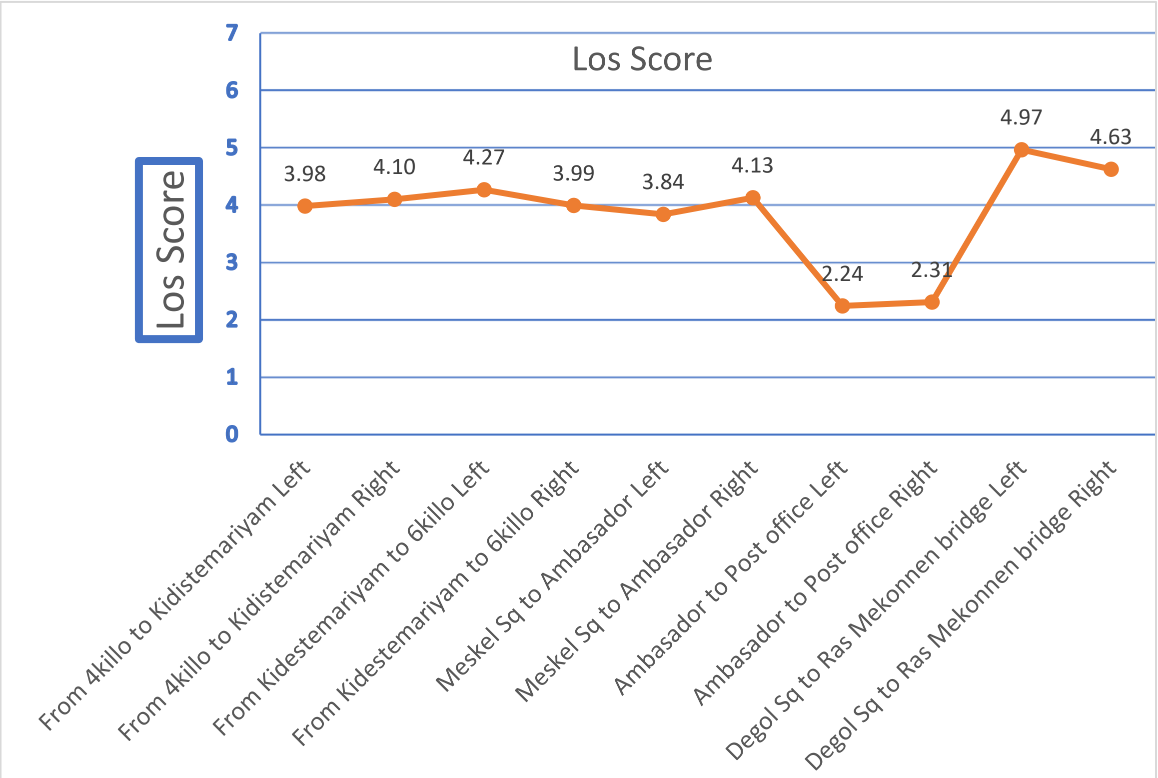


Figure 4-12 Pedestrian LOS Score

4.3.2 Pedestrian space

The pedestrian space is depending on the effective walkway width, average pedestrian walking speed and the pedestrian volume. For the selected samples the pedestrian space is sufficient (>=60 ft^2/ ped) except the Degol square to Ras Mekonnen bridge right side segment. The analysis is shown in section 4.3 step 3.

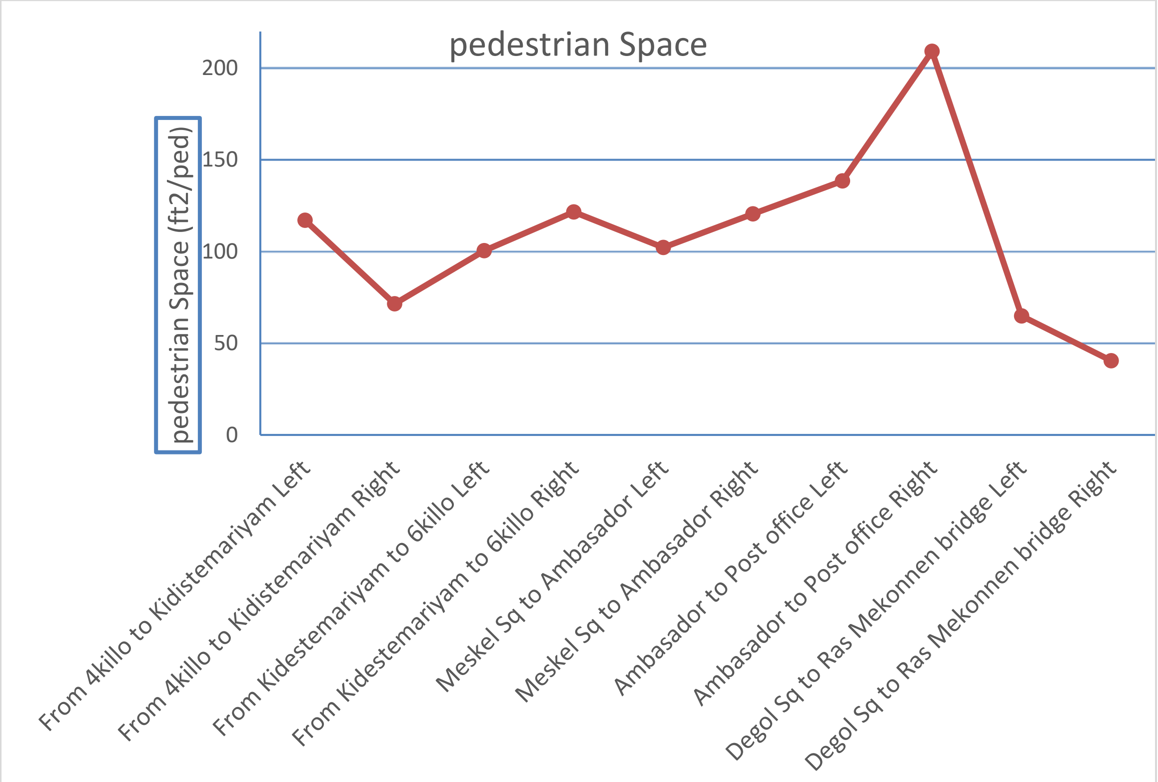


Figure 4-13 Pedestrian spaces

4.3.3 Pedestrian LOS result

The pedestrian LOS is determined by combining the two performance measures which are the pedestrian space and Pedestrian Los score. The analysis is shown in section 4.3 step 3and 4. From the ten surveyed segments eight of them have level of service D and E which is 80 % from the sample and only 20% of the sample is ranked LOS B.

Table 4-1 Pedestrian LOS Result

Road Name	Segment No.	Direction	pedestrian Space (ft2/ped)	Los Score	Pedestrian LOS
From 4 Killo to 6 killo	1	Left	117.10	3.98	D
	1	Right	71.47	4.10	D
	2	Left	100.53	4.27	E
	2	Right	121.58	3.99	D
From Meskel Sq to Post office	1	Left	102.19	3.84	D
	1	Right	120.60	4.13	D
	2	Left	138.51	2.24	B
	2	Right	209.17	2.31	B
From Degol Sq to Ras Mekonen Bridge	1	Left	64.93	4.97	E
	1	Right	40.49	4.63	E

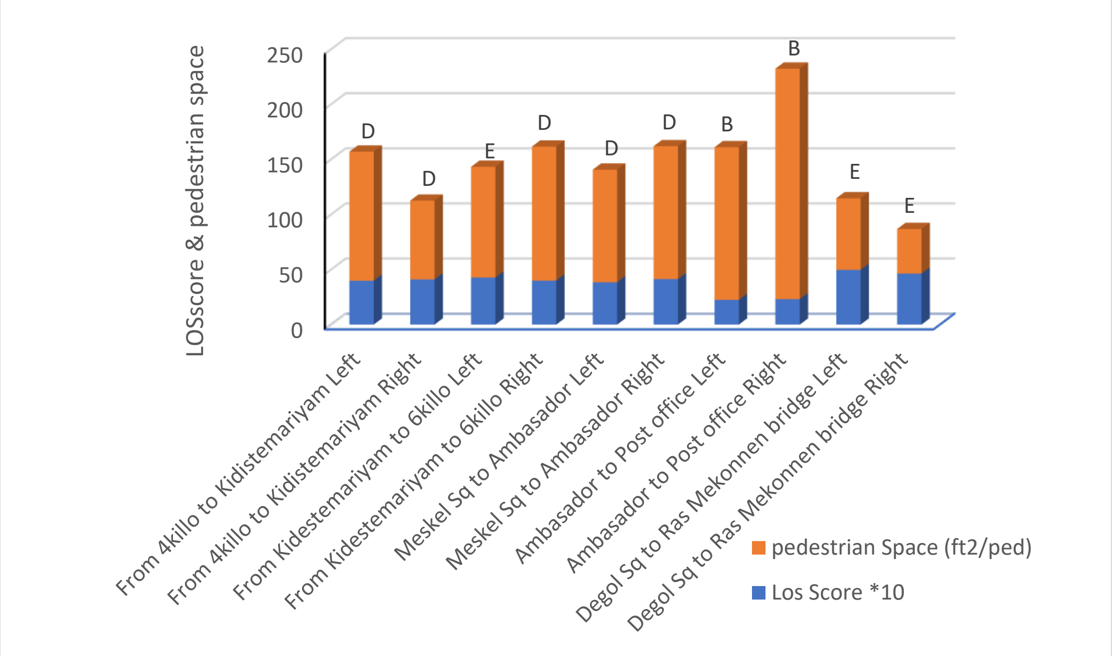


Figure 4-14 Pedestrian LOS result

4.4 iRAP Star Rating Results for Pedestrian Mode and countermeasures

Based on the coded and supporting data, the ViDA online software produces star rating of the network surveyed. After the star rating was analyzed different countermeasures were used in order to enhance the performance of the roads and the star rating was improved as shown below. Similar to the LOS score the larger the iRAP score indicates that poor performance and the smaller one, was better.

Sample analysis for road section from 4 killo to 6 killo

Step1: Select the road category

In order to determine the star rating rank of the road section using international road assessment programme online software star rating demonstrator the first step is select the road category that match with the inspected road from the selection.

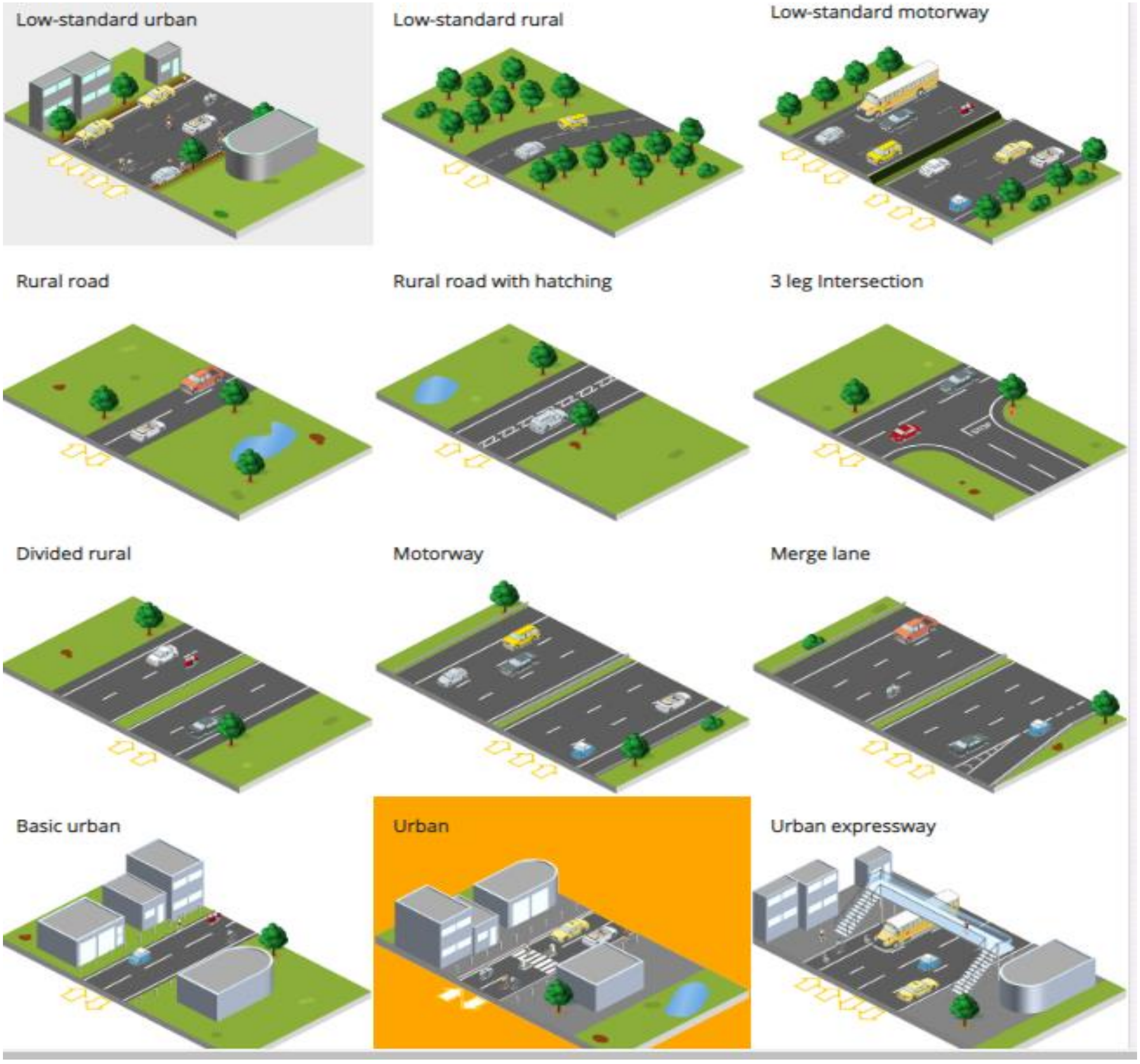


Figure 4-15 Road category

Step 2: Sidewalk and Carriageway total information

Next to road category all necessary information about the sidewalk and carriageway are filled to the software. These data are classified in six sections.

- ✓ Road side attributes
- ✓ Mid-block
- ✓ Flow data (all users)
- ✓ Vulnerable road user (VRU) facilities and Land use and
- ✓ speed

Figure 4-16 Sidewalka and Carriageway total informations

Step 3: See the result

After all the information are filled the software gives the result. The star rating use five level from star 1 up to star 5 with color codes. 5-star roads are colored Green 4-star yellow, 3-star orange, 2-star red and 1-star black. 5-star roads have excellent performance whereas the 1- star roads have poor performance. The star rating scores is different for different road user types

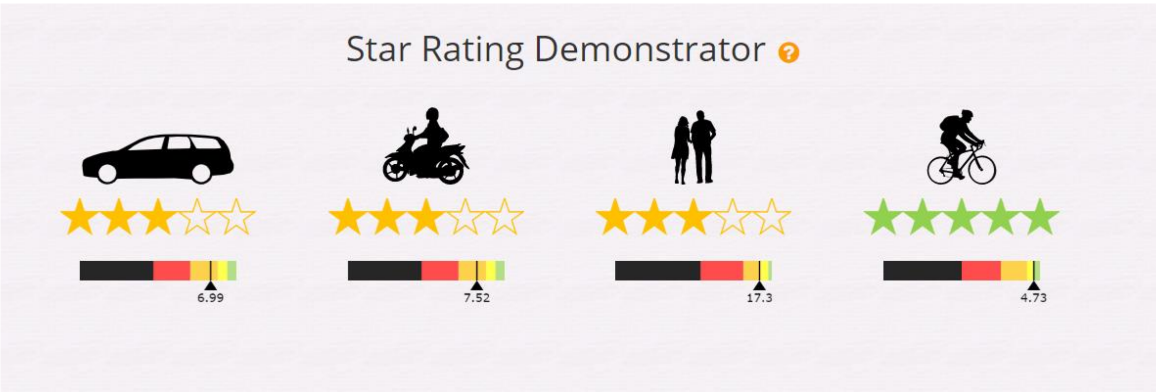


Figure 4-17 Star Rating Result

Step 4: Apply countermeasures

The pedestrian mode star rating rank is three stars as shown above. So, in order to improve the rank counter measures should be taken. For instance, for this road section two countermeasures are taken which are provide pedestrian fencing and appoint school zone supervisors at school start and finish times.

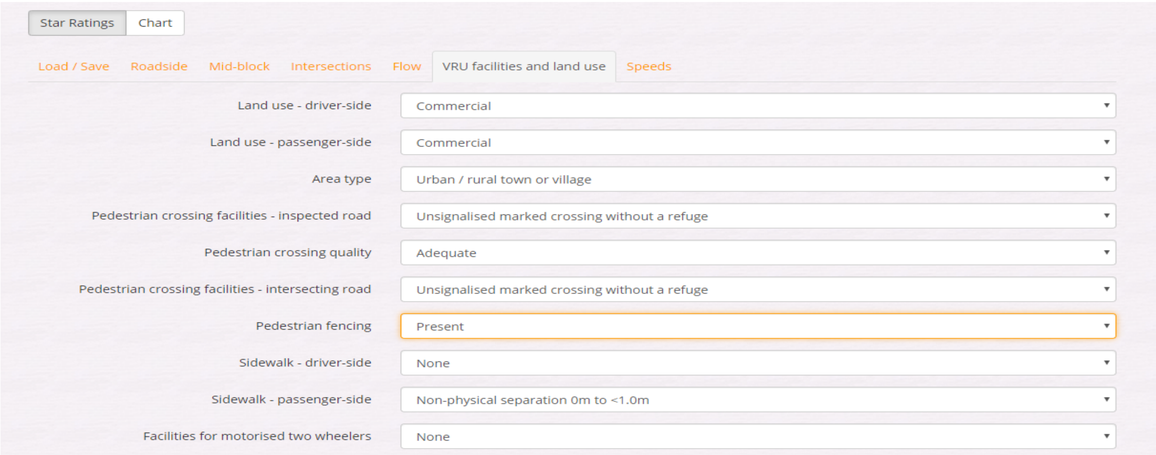


Figure 4-18 Countermeasures

Step 3: See the result a gain

Now, the pedestrian mode star rating rank becomes 5 Star and safe for pedestrians.

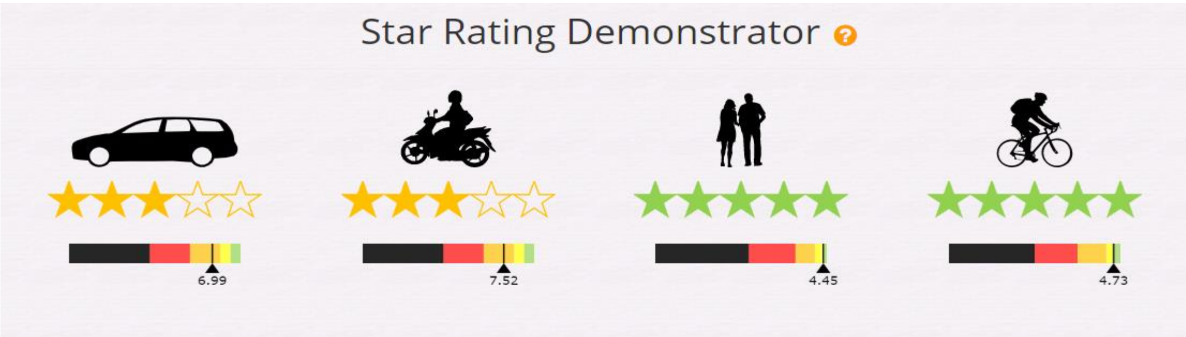


Figure 4-19 Modified star rating result

Table 4-2 summarized star rating results

Road Name	Before countermeasure		After countermeasure 1		After countermeasure 2	
	iRAP scorefor pedestrian mode	Star rating	iRAP scorefor pedestrian mode	Star rating	iRAP scorefor pedestrian mode	Star rating
From 4 Killo to 6 killo	17.30	3	5.29	4	4.45	5
From Meskel Sq to Post office	22.43	3	14.9	4	4.88	5
From Degol Sq to Ras Mekonnen Bridge	23.16	3	14.83	4	3.36	5

For road segment from 4 Kilo to 6Kilo the countermeasures are first appoint school zone supervisors at school start and finish times and second provide pedestrian fencing, for Degol Sq. to Ras Mekonnen bridge first provide pedestrian refuge at pedestrian crossings and provide pedestrian fencing and second apply speed management techniques(traffic calming) and reduce the operating vehicle speed, for Meskel Sq. to Post office section first provide pedestrian fencing and apply speed management techniques(traffic calming) and then reduce the operating vehicle speed.

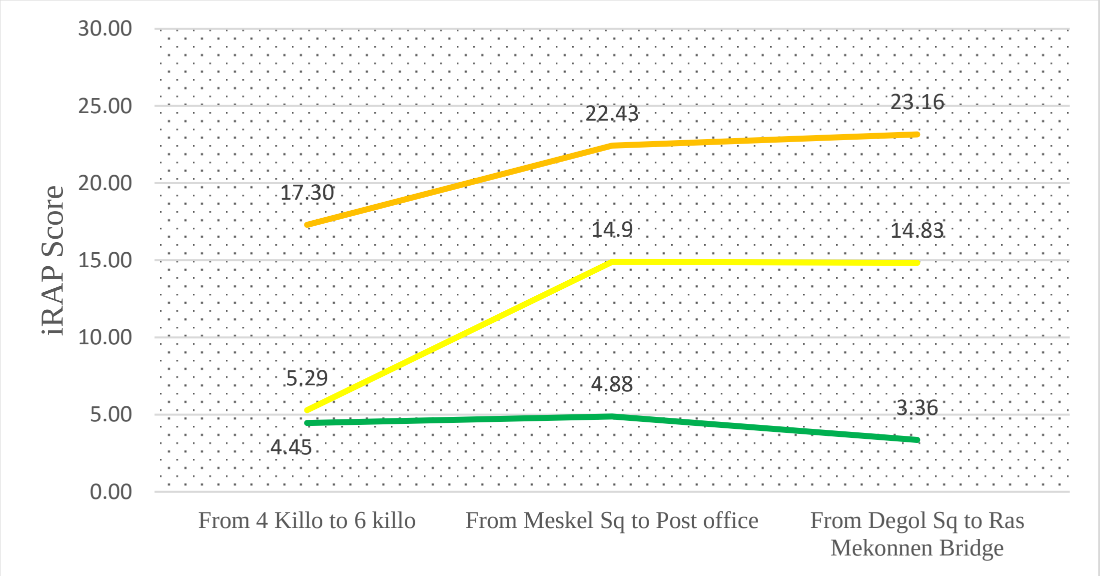


Figure 4-20 iRAP Score

Based on iRAP standard the larger the iRAP score indicates that poor performance and the smaller one is better. The above graph shows the iRAP score of the selected routes before countermeasure was taken, after countermeasure 1 and after countermeasure 2.As a result after the second countermeasure taken the iRAP score for road section from 4Killo to 6Killo becomes 4.45,for road section from Meskel Sq. to Post office becomes 4.88 and for section from Degol Sq. to Ras Mekonnen bridge becomes

3.36.The average percentage decrease in iRAP score after all countermeasure is 79% and it is shown in the table below.

Table 4-3 iRAP score percentage decrease after all countermeasure

Road Name	Before countermeasure	After all countermeasure	
	iRAP score for pedestrian mode	iRAP score for pedestrian mode	Percentage decrease in iRAP score
From 4 Killo to 6 killo	17.30	4.45	74
From Meskel Sq. to Post office	22.43	4.88	78
From Degol Sq. to Ras Mekonnen Bridge	23.16	3.36	85
		Average	79

Finally, after the countermeasure all road sections become star 5 and the summarization of the iRAP score and the star rating is shown below.

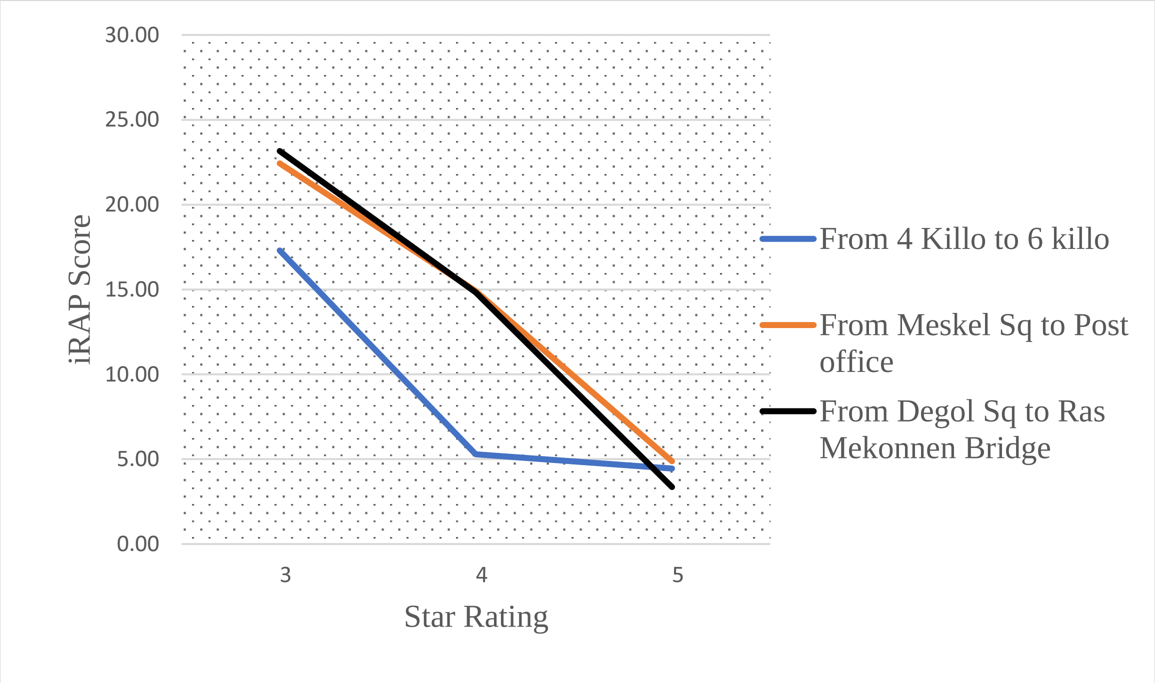


Figure 4-21 iRAP Star rating

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The results of the selected pedestrian walkways capacity analysis using the Highway capacity manual (HCM 2010) pedestrian LOS analysis methodology and the International Road Assessment Programme (iRAP) methodology shows that most of the pedestrian walkways are in serious problems.

The Highway capacity manual (HCM 2010) pedestrian LOS analysis basically depends on the two performance measures which are the pedestrian space and Pedestrian Los score. For the selected samples the pedestrian space is sufficient (>=60 ft^2/ ped, Ability to move in desired path, no need to alter movements) except the Degol square to Ras Mekonnen bridge right side segment. The problem for the segment from Degol square of Ras Mekonnen bridge right side is it has larger fixed objects along the pedestrian walkway. The pedestrian LOS score is not good for the selected samples except for the segment from Ambassador to Post office. Due to the combining effects of the two performance measure the pedestrian LOS is poor (LOS D & E) except for the segment from Ambassador to Post office (LOS B).

For the segment from Ambassador to Post office (LOS B) there is sufficient area for pedestrians to select walking speeds freely to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians, and to response to their presence when electing a walking path.

The result from the International Road Assessment Programme (iRAP) online software also shows that poor performance of the pedestrian walkway. But after some countermeasures are applied the performance is increased and the star rating becomes five star which is the indicator of the best performance. The countermeasures include appoint school zone supervisors at school start and finish times, provide pedestrian fencing, provide pedestrian refuge at pedestrian crossings, apply speed management techniques (traffic calming) and reduce the operating vehicle speed.

5.2 RECOMMENDATIONS

The pedestrian LOS from the HCM 2010 methodology is reduced due to the pedestrian LOS score. The pedestrian LOS score is sensitive to the separation between pedestrians and moving vehicles; it is also sensitive to the speed and volume of these vehicles. Physical barriers and parked cars between moving vehicles and pedestrians effectively increase the separation distance and the perceived quality of service. Higher vehicle speeds or volumes lower the perceived quality of service.

The important parameters for Pedestrian LOS score are also the same as the countermeasure taken in the iRAP methodology. Therefore, from the research study and analysis result the following recommendation are made in order to enhance the pedestrian walkway performance.

i) It is better to provide pedestrian fencing along the section of the segment in both directions.
ii) provide pedestrian refuge at pedestrian crossings.
iii) Remove the unnecessary obstacles from the walkway area.
iv) apply speed management techniques (traffic calming).
v) In some sections especially for segment from Degol to Ras Mekonnen bridge increase the walkway width.
vi) Protect the right of way (ROW) from illegal actions like trade on the walkway. (see Appendix D)
vii) Make suitable all ramps for assisted pedestrians
viii) for blinds the yellow lines should be free from any obstacles and the tack tile should be placed where change of directions happens.

Finally, Since the collected data for the analysis was limited, especially regarding peak hour traffic, further study is recommended with more data collection in order to make any improvement of the walkway.

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APPENDICES

APPENDIX -A

SUMMERIZED TRAFFIC DATA

Pedestrian traffic volume for 4 Kilo to 6 Kilo

Pedestrian Traffic Count											
Road Name				From 4 Killo to 6 killo							
segment	Time	Left side Pedestrian count				AverageTotal	Right side Pedestrian count				Average Total
		Tuesday	Wednesday	Thursday	Saturday		Tuesday	Wednesday	Thursday	Saturday	
Segment 1	7:00-7:15AM	533	536	465	283	2109	489	540	467	282	1976
	7:15-7:30AM	548	686	604	368		572	628	546	332	
	7:30-7:45AM	633	736	637	396		619	676	592	369	
	7:45-8:00AM	475	630	548	359		465	547	473	309	
	5:00-5:15PM	349	561	490	312	1820	356	574	501	318	1770
	5:15-5:30PM	450	672	584	368		431	557	487	308	
	5:30-5:45PM	465	594	521	324		474	535	471	294	
	5:45-6:00PM	328	528	456	277		421	565	489	298	
Segment 2	7:00-7:15AM	389	397	344	208	1556	357	383	351	208	1418
	7:15-7:30AM	402	511	439	276		425	441	415	239	
	7:30-7:45AM	456	545	471	288		452	480	347	269	
	7:45-8:00AM	347	469	413	269		331	393	359	222	
	5:00-5:15PM	255	415	363	234	1345	256	408	381	221	1284
	5:15-5:30PM	336	499	425	282		315	395	370	222	
	5:30-5:45PM	339	439	386	243		341	379	358	212	
	5:45-6:00PM	241	384	337	203		302	401	367	210	

Pedestrian traffic volume From Meskel Sq. to Post office

Pedestrian Traffic Count											
Road Name				From Meskel Sq to Post office							
segment	Time	Left side Pedestrian count				AverageTotal	Right side Pedestrian count				Average Total
		Tuesday	Wednesd	Thursday	Saturday		Tuesday	Wednesd	Thursday	Saturday	
Segment 1	7:00-7:15AM	336	338	293	178	1359	308	340	294	178	1273
	7:15-7:30AM	345	432	381	232		360	396	344	209	
	7:30-7:45AM	430	501	433	269		421	460	402	251	
	7:45-8:00AM	299	397	345	226		293	344	298	194	
	5:00-5:15PM	220	353	309	196	1177	224	362	316	200	1142
	5:15-5:30PM	311	464	403	254		297	384	336	213	
	5:30-5:45PM	293	374	328	204		299	337	297	185	
	5:45-6:00PM	207	333	287	174		265	356	308	188	
Segment 2	7:00-7:15AM	253	258	224	135	1024	232	249	228	135	933
	7:15-7:30AM	273	347	299	188		289	300	282	162	
	7:30-7:45AM	296	354	306	187		294	312	226	175	
	7:45-8:00AM	225	305	268	175		215	255	234	144	
	5:00-5:15PM	158	257	225	145	865	159	253	236	137	825
	5:15-5:30PM	218	324	276	183		205	257	241	144	
	5:30-5:45PM	221	286	251	158		222	246	233	138	
	5:45-6:00PM	157	250	219	132		196	261	239	137	

Pedestrian traffic volume From Degol Sq. to Ras Mekonnen Bridge

Pedestrian Traffic Count											
Road Name		From Degol Sq to Ras Mekonen Bridge									
segment	Time	Left side Pedestrian count				AverageTotal	Right side Pedestrian count				Average Total
		Tuesday	Wednesd	Thursday	Saturday		Tuesday	Wednesd	Thursday	Saturday	
Segment 1	**7:00-7:15AM**	389	391	339	207	1551	357	394	341	206	1453
	7:15-7:30AM	411	515	453	276		429	471	409	249	
	7:30-7:45AM	462	537	465	289		452	494	432	269	
	7:45-8:00AM	347	460	400	262		339	399	345	225	
	5:00-5:15PM	304	488	426	271	1532	310	499	436	276	1482
	5:15-5:30PM	419	625	543	342		401	518	453	287	
	5:30-5:45PM	367	469	412	256		374	423	372	232	
	5:45-6:00PM	249	401	347	210		320	429	372	227	

Peak hour Vehicle traffic volume

Vehicle Types	4killo to 6 killo				meskel sq to post office				Degol sq to RM bridge	
	Segment 1		Segment 2		Segment 1		Segment 2		Segment 1	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Car	327	316	301	287	323	365	292	234	302	287
Land Rover	152	238	178	125	213	187	169	135	85	68
Small Bus	184	138	147	143	138	167	134	107	198	158
Medium Bus	42	34	27	28	22	18	14	11	9	7
Large Bus & Truck	24	19	21	17	14	11	9	7	6	4
Total Hourly	729	745	674	600	710	748	618	494	600	525
Total (PCU) hourly	1060	999	935	847	936	997	817	654	862	735

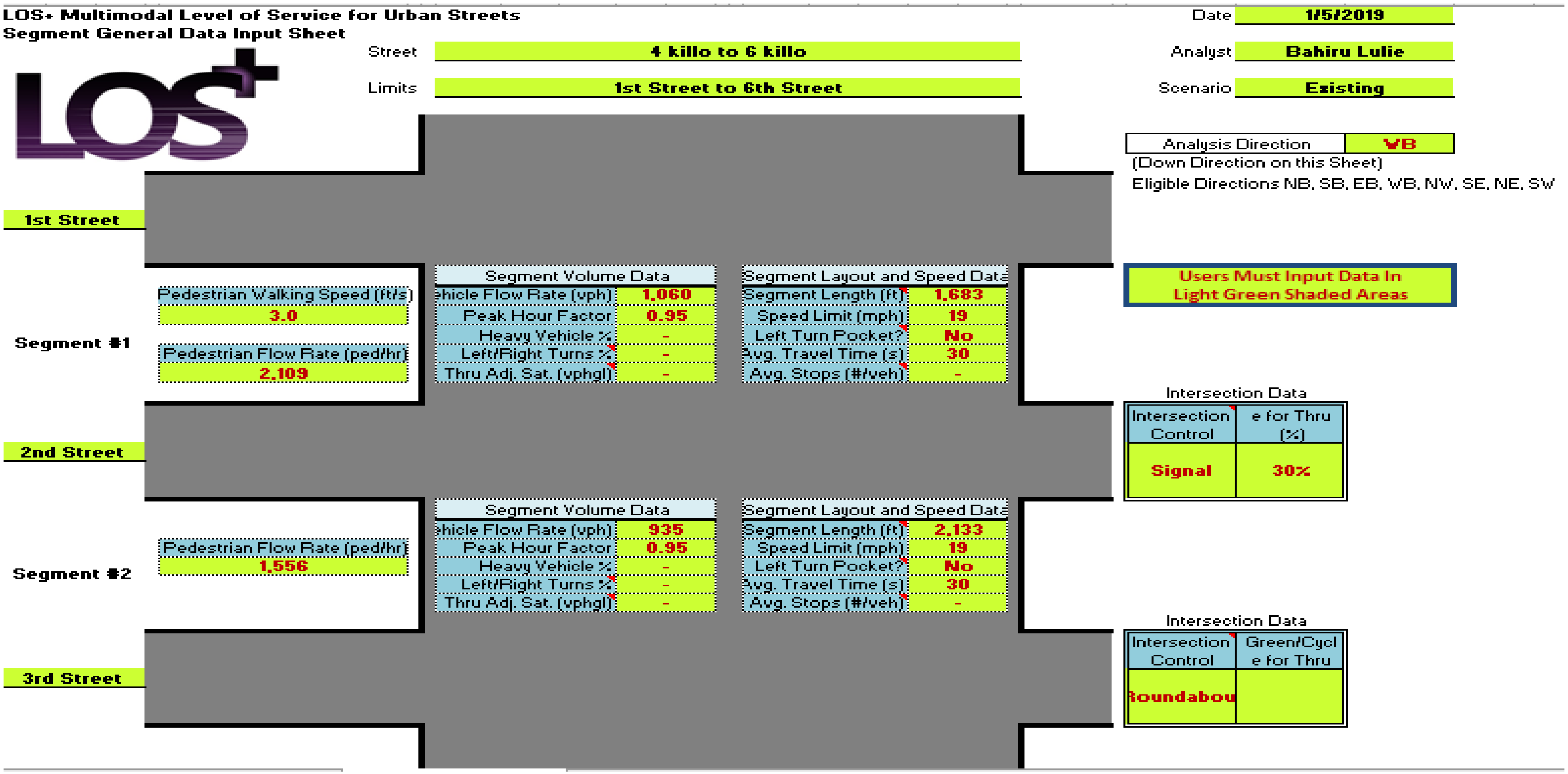
Pedestrian traffic volume Count format

Pedestrian Traffic Count														
General information				Road name				4 Killo to Kidestemariyam						
				Segment No.				1						
				Direction/side				Left						
Date	Time	Unassisted						Assisted(skalers,wheelchairs...)						Sum
		Male			Female			Male			Female			
		Older	Adult	Child	Older	Adult	Child	Older	Adult	Child	Older	Adult	Child	
Tuesday	7:00-:7:15AM	136	177	26	65	93	31	2	3					533
	7:15-7:30AM	187	161	44	34	79	42		1					548
	7:30-7:45AM	87	201	103	51	133	54	1	2			1		633
	7:45-8:00AM	84	169	23	37	146	15		1					475
	5:00-:5:15PM	79	142	18	30	63	17							349
	5:15-5:30PM	93	184	9	29	127	7					1		450
	5:30-5:45PM	132	113	4	86	125	3		2					465
	5:45-6:00PM	74	144	6	25	71	4	1	3					328
	Sub total	872	1291	233	357	837	173	4	12	0	0	2	0	Total
	Total	3763						18						3781
Wednesday	7:00-:7:15AM	153	161	20	56	112	29	2	3					536
	7:15-7:30AM	140	154	66	126	139	59	1	1					686
	7:30-7:45AM	96	221	113	67	155	79		3		1	1		736
	7:45-8:00AM	101	203	28	91	183	25		1					630
	5:00-:5:15PM	103	170	22	92	153	19	1						561
	5:15-5:30PM	121	221	11	109	199	10		1			1		672
	5:30-5:45PM	172	136	5	154	122	4				1			594
	5:45-6:00PM	96	173	7	87	156	6	1	2					528
	Sub total	981	1439	271	782	1218	233	5	11	0	2	2	0	Total
	Total	4923						20						4943
Thursday	7:00-:7:15AM	138	129	18	50	101	26	2	1					465
	7:15-7:30AM	126	123	59	113	125	53	2	1			1		604
	7:30-7:45AM	86	177	102	60	139	71	1						637
	7:45-8:00AM	91	162	25	82	164	22		1		1			548
	5:00-:5:15PM	92	136	19	83	138	17	3						490
	5:15-5:30PM	109	177	10	98	179	9		1		2			584
	5:30-5:45PM	154	108	4	139	110	4	1						521
	5:45-6:00PM	87	138	6	78	140	6	1						456
	Sub total	883	1151	244	704	1096	209	10	4	0	3	1	0	Total
	Total	4287						18						4305
Saturday	7:00-:7:15AM	83	77	13	30	60	16	4						283
	7:15-7:30AM	76	74	42	68	75	32		2					368
	7:30-7:45AM	52	106	71	36	84	43	1	2			1		396
	7:45-8:00AM	54	97	17	57	115	16				2			359
	5:00-:5:15PM	55	82	14	50	97	10	3				1		312
	5:15-5:30PM	65	106	7	59	125	5				1			368
	5:30-5:45PM	93	65	3	83	77	2		1					324
	5:45-6:00PM	52	83	5	47	84	3	1	2					277
	Sub total	530	690	171	430	717	128	9	7	0	3	2	0	Total
	Total	2666						21						2687

APPENDIX -B

PEDESTRIAN LOS ANALYSIS USING LOS+ SPREED SHEET

From Arat Kilo to Sidist Kilo Left Side Pedestrian LOS analysis



LOS+ Multimodal Level of Service for Urban Streets
Street Cross-Section Input Data Sheet Street 4 killo to 6 killo Limits 1st Street to 6th Street

Segment #1 General guidance on input parameters is provided at the bottom of this Analyst Bahiru Lulie Date 1/5/2019
From 1st Street To 2nd Street

1

Fixed Object Width (ft)	Parking Occupancy %
3.6	18%

Is Curb Present? Yes
Is Parking Striped? No

WB | EB

Median Type (0-3)	2
Pavement Conditio	4.0

Street Cross-Section (feet)
Shoulder Enter WB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
27.8	1.0	12.0	0.0	12.0	0.0			3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.28	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.25	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
Yes	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Segment #2
From 2nd Street To 3rd Street

2

Fixed Object Width (ft)	Parking Occupancy %
2.0	9%

Is Curb Present? Yes
Is Parking Striped? No

WB | EB

Median Type (0-3)	2
Pavement Conditio	4.0

Street Cross-Section (feet)
Shoulder Enter WB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
18.3	0.0	12.0	0.0	12.0				3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.02	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.24	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

General Notes
Analysis is for "oncoming traffic" i.e. on the left
Fixed object width should be entered if the fixed objects are outside the buffer area but within the sidewalk
Median = 0 if None, 1 if One-way, 2 if Painted or TWLTL, 3 if Raised

Explanation of Pavement Rating Numbers
FHWA HPMS Pavement Rating System
Source: Exhibit 17-7, Capter 17, Highway Capacity Manual 2010.

Rating	Description
4.0-5.0	New or nearly new superior pavement. Free of cracks and patches.
3.0-4.0	Flexible pavements may begin to show evidence of rutting and fine cracks. Rigid pavements may begin to show evidence of minor cracking.
2.0-3.0	Flxible pavements may show rutting and extensive patching. Rigid pavements may have a few joint fractures, faulting, or cracking.
1.0-2.0	Distress occurs over 50% or more of the surface. Flexible pavement may have large potholes and deep cracks. Rigid pavement distress includes joint spalling, patching, and cracking
0.0-1.0	Distress occurs over 75% or more of the surface. Large potholes and deep cracks exist.
Notes	
1	If pavement is of uneven quality, these ratings apply to portion of street where most bikes would be (right most lane, bike lane, shoulder).
2	Rigid pavements are portland cement concrete pavements. Flexible pavements are asphalt pavements.

Compute Pedestrian LOS

Street: **4 killo to 6 killo**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	from
1	28.8	0.8	1.5	3.60	1.00	22.91	Input_XSection
2	18.3	0.3	1.5	2.00	0.00	14.52	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	from
1	3.0	2,109	1.53	2.99	117.10	Input_SegData, Input_XSection
2	3.0	1,556	1.79	2.99	100.53	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor	from	Median Type
1	12.0	12.0	10.5	0.18	5.37	10.0	3.0	-5.0589	Input_XSection	D
2	12.0	12.0	10.5	0.09	1.00	10.0	3.0	-4.8446	Input_XSection	D
									D	Divided

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	from
1	2.4115	0.5852	3.9846	Input_SegData, Input_XSection
2	2.1271	0.9396	4.2689	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	D
2	E

LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

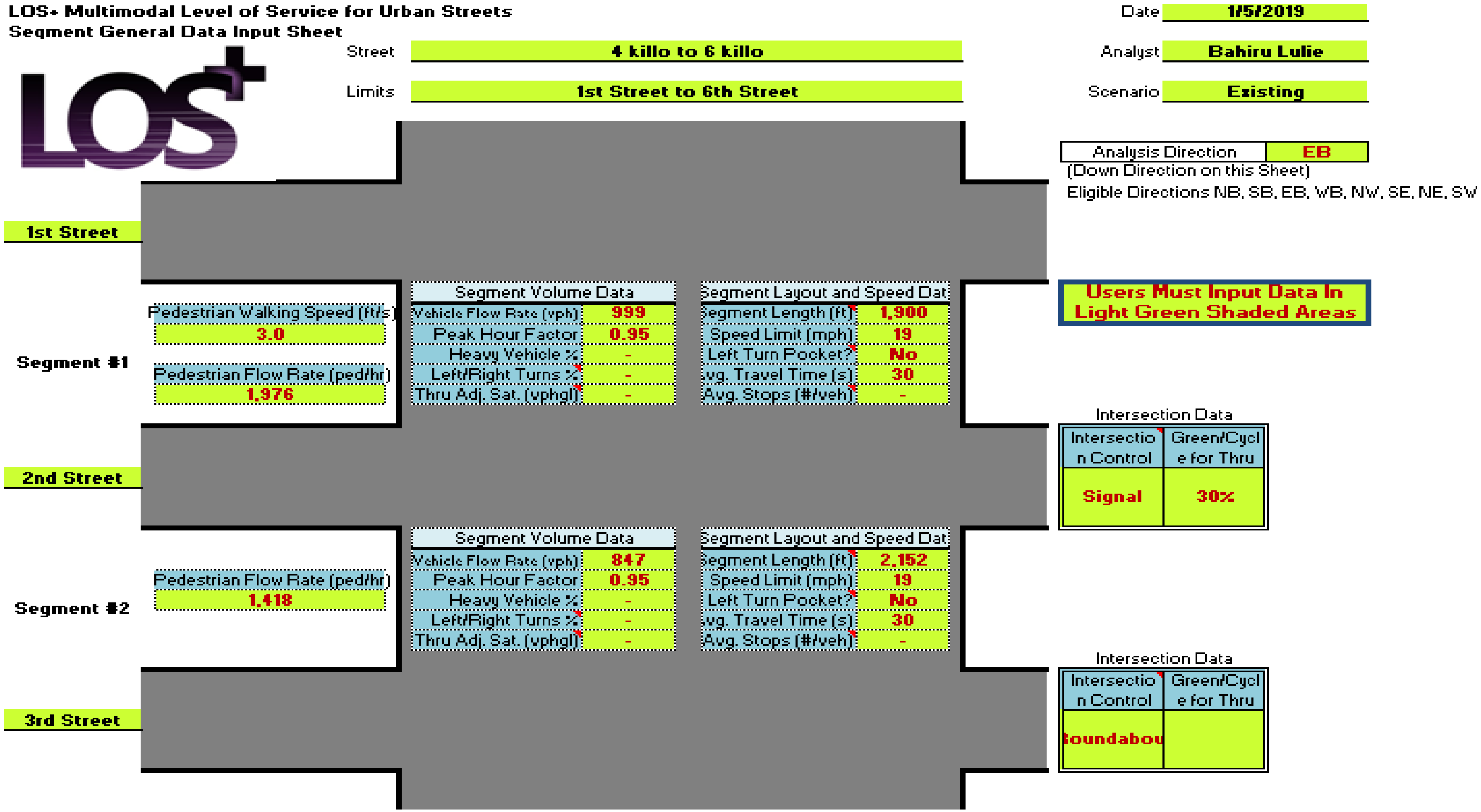
LOS+ Multimodal Level of Service for Urban Streets
Results Summary

Street ____________ Direction WB Date 1/5/2019

Limits 4 killo to 6 killo Scenario Existing Analyst Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	From 4killo to Kidistemariyam	1st Street	2nd Street	117.10	3.98	D
2	From Kidestemariyam to 6killo	2nd Street	3rd Street	100.53	4.27	E

From Arat Kilo to Sidist Kilo Right Side Pedestrian LOS analysis



LOS+ Multimodal Level of Service for Urban Streets

Street Cross-Section Input Data Sheet Street 4 killo to 6 killo Limits 1st Street to 6th Street

Segment #1 General guidance on input parameters is provided at the bottom of this sheet. Analyst Bahiru Lulie Date 1/5/2019

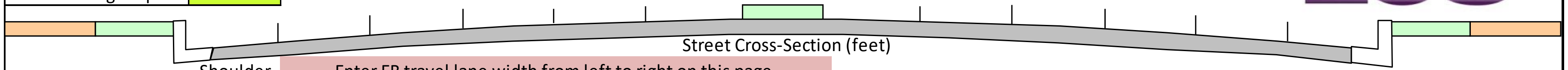
From 1st Street To 2nd Street

1

Fixed Object Width (ft)	Parking Occupancy %
1.2	14%
Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	2
Pavement Condition	4.0

EB WB



Enter EB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
16.2	0.5	12.0	0.0	12.0				3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.00	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.86	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
Yes	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Segment #2

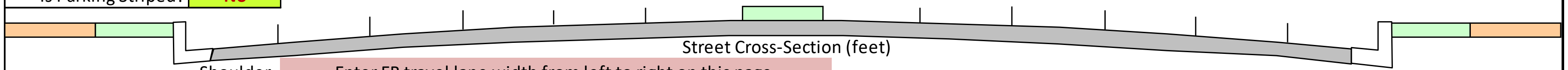
From 2nd Street To 3rd Street

2

Fixed Object Width (ft)	Parking Occupancy %
3.2	17%
Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	2
Pavement Condition	4.0

EB WB



Enter EB travel lane width from left to right on this page.

Sidewalk	Buffer	Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
21.3	0.0	12.0	0.0	12.0				3.3

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.00	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.63	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Compute Pedestrian LOS

Street: **4 killo to 6 killo**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	from
1	16.7	0.9	1.5	1.20	0.50	13.14	Input_XSection
2	21.3	0.6	1.5	3.20	0.00	15.99	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	from
1	3.0	1,976	2.51	2.99	71.47	Input_SegData, Input_XSection
2	3.0	1,418	1.48	2.99	121.58	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor	from	Median Type
1	12.0	12.0	10.5	0.14	5.37	10.0	3.0	-4.9618	Input_XSection	D
2	12.0	12.0	10.5	0.17	1.00	10.0	3.0	-4.9360	Input_XSection	D

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	from
1	2.2727	0.7456	4.1032	Input_SegData, Input_XSection
2	1.9269	0.9571	3.9948	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	D
2	D

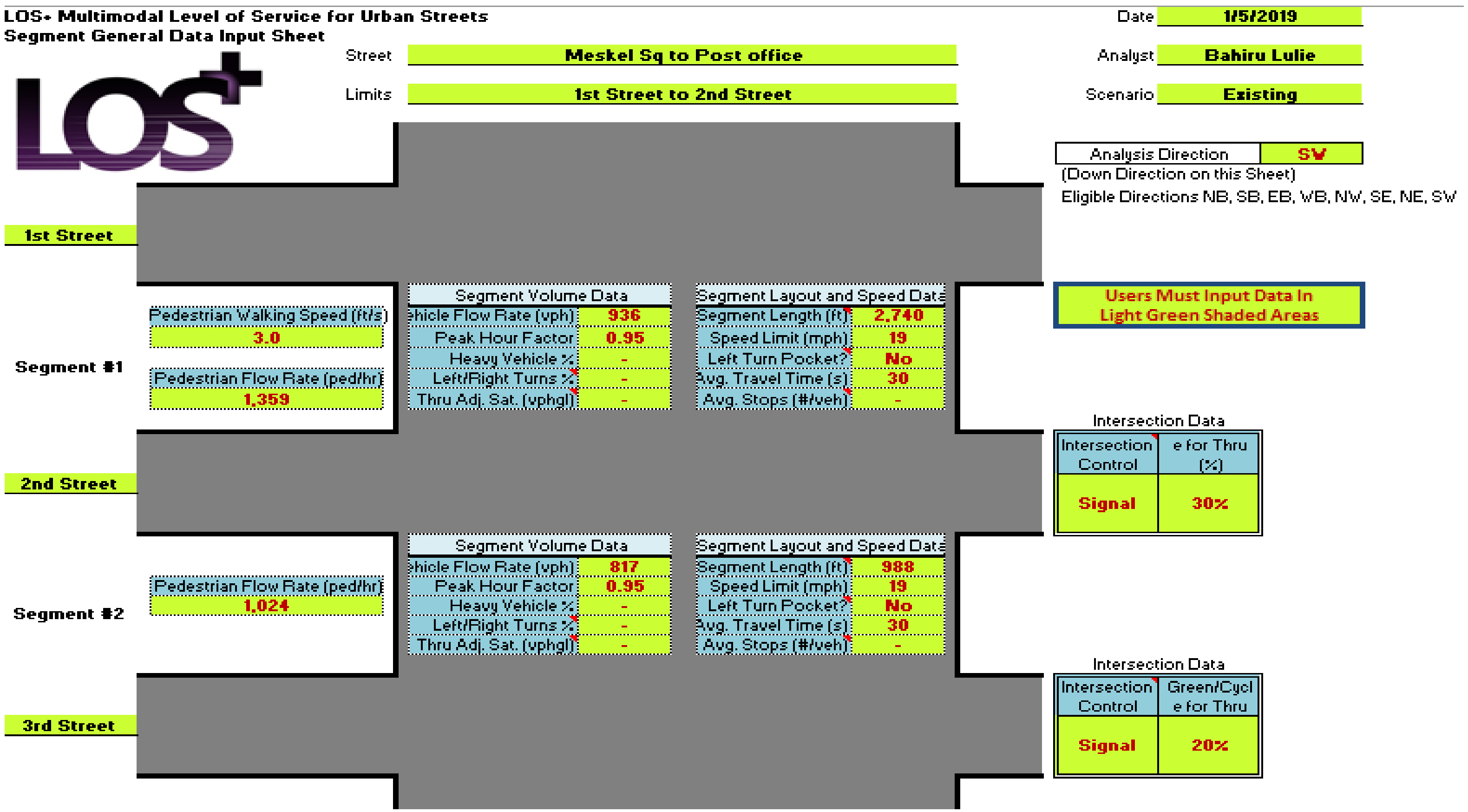
LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

LOS+ Multimodal Level of Service for Urban Streets
Results Summary

Street	4 killo to 6 killo	Direction	EB	Date	1/5/2019
Limits	1st Street to 3rd Street	Scenario	Existing	Analyst	Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	4 killo to kidistemaryam	1st Street	2nd Street	71.47	4.10	D
2	Kidistemaryam to 6 Killo	2nd Street	3rd Street	121.58	3.99	D

Meskel Sq. to Post office Left Side Pedestrian LOS analysis



LOS+ Multimodal Level of Service for Urban Streets

Street Cross-Section Input Data Sheet Street: Meskel Sq to Post office Limits: 1st Street to 2nd Street

General guidance on input parameters is provided at the bottom of this sheet.

Analyst: Bahiru Lulie Date: 1/5/2019

Segment #1

From 1st Street To 2nd Street

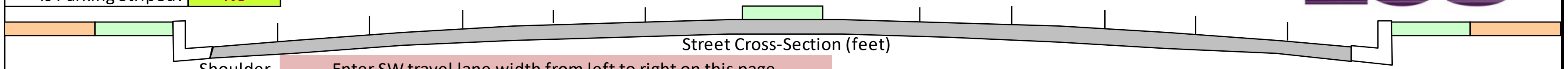
1

Fixed Object Width (ft)	Parking Occupancy %
1.3	7%

Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	3
Pavement Condition	4.0

SW NE



Enter SW travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
16.7	0.0	12.0	0.0	12.0	12.0			4.9

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.27	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.47	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Segment #2

From 2nd Street To 3rd Street

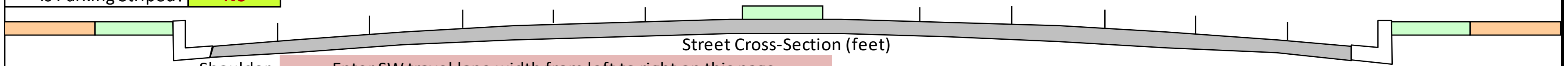
2

Fixed Object Width (ft)	Parking Occupancy %
2.0	1%

Is Curb Present?	Yes
Is Parking Striped?	No

Median Type (0-3)	2
Pavement Condition	4.0

SW NE



Enter SW travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
15.7	1.7	10.0	0.0	12.0	12.0			4.9

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.21	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.13	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
Yes	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Compute Pedestrian LOS

Street: **Meskel Sq to Post office**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	from
1	16.7	1.0	1.5	1.30	0.00	12.89	Input_XSection
2	17.4	0.6	1.7	2.00	1.65	13.15	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	from
1	3.0	1,359	1.76	2.99	102.19	Input_SegData, Input_XSection
2	3.0	1,024	1.30	3.00	138.51	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor	from	Median Type
1	12.0	12.0	10.5	0.07	1.00	10.0	3.0	-4.8207	Input_XSection	D
2	12.0	12.0	8.5	0.01	5.37	10.0	3.0	-4.9330	Input_XSection	D

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	from
1	1.0647	1.5506	3.8414	Input_SegData, Input_XSection
2	0.9293	0.2015	2.2447	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	D
2	B

LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

LOS+ Multimodal Level of Service for Urban Streets

Results Summary

Street	Meskel Sq to Post office	Direction	SW	Date	1/5/2019
Limits	1st Street to 2nd Street	Scenario	Existing	Analyst	Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	Meskel Sq to Ambasador	1st Street	2nd Street	102.19	3.84	D
2	Ambasador to Post office	2nd Street	3rd Street	138.51	2.24	B

Meskel Sq. to Post-office Right-Side Pedestrian LOS analysis

LOS+ Multimodal Level of Service for Urban Streets
Segment General Data Input Sheet

Street	**Meskel Sq to Post office**	Date	**1/5/2019**
Limits	**1st Street to 3rd Street**	Analyst	**Bahiru Lulie**
		Scenario	**Existing**

Analysis Direction	**NE**

(Down Direction on this Sheet)
Eligible Directions NB, SB, EB, WB, NW, SE, NE, SW

Users Must Input Data In Light Green Shaded Areas

1st Street

Segment #1

Pedestrian Walking Speed (ft/s)	**3.0**
Pedestrian Flow Rate (ped/hr)	**1,273**

Segment Volume Data		Segment Layout and Speed Data	
hicle Flow Rate (vph)	**997**	Segment Length (ft)	**2,927**
Peak Hour Factor	**0.95**	Speed Limit (mph)	**19**
Heavy Vehicle %	**-**	Left Turn Pocket?	**No**
Left/Right Turns %	**-**	Avg. Travel Time (s)	**30**
Thru Adj. Sat. (vphgl)	**-**	Avg. Stops (#/veh)	**-**

Intersection Data

Intersection Control	e for Thru (%)
Signal	**30%**

2nd Street

Segment #2

Pedestrian Flow Rate (ped/hr)	**933**

Segment Volume Data		Segment Layout and Speed Data	
hicle Flow Rate (vph)	**654**	Segment Length (ft)	**1,161**
Peak Hour Factor	**0.95**	Speed Limit (mph)	**19**
Heavy Vehicle %	**-**	Left Turn Pocket?	**No**
Left/Right Turns %	**-**	Avg. Travel Time (s)	**30**
Thru Adj. Sat. (vphgl)	**-**	Avg. Stops (#/veh)	**-**

Intersection Data

Intersection Control	Green/Cycle for Thru
Signal	**20%**

3rd Street

LOS+ Multimodal Level of Service for Urban Streets

Street Cross-Section Input Data Sheet Street: Meskel Sq to Post office Limits: 1st Street to 3rd Street

Segment #1 General guidance on input parameters is provided at the bottom of this sheet. Analyst: Bahiru Lulie Date: 1/5/2019

From: 1st Street To: 2nd Street

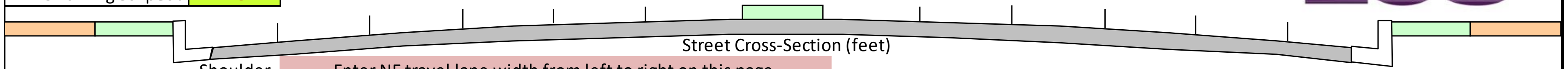
1

Fixed Object Width (ft)	Parking Occupancy %
1.3	7%

Median Type (0-3)	3
Pavement Condition	4.0

NE SW

Is Curb Present?	Yes
Is Parking Striped?	No



Enter NE travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
18.4	0.0	12.0	0.0	12.0	12.0			4.9

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.46	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.44	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Segment #2

From: 2nd Street To: 3rd Street

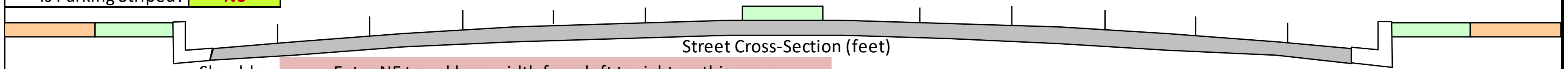
2

Fixed Object Width (ft)	Parking Occupancy %
1.4	2%

Median Type (0-3)	3
Pavement Condition	4.0

NE SW

Is Curb Present?	Yes
Is Parking Striped?	No



Enter NE travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
21.5	0.0	12.0	0.0	12.0	12.0			4.9

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.19	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.14	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Compute Pedestrian LOS

Street: **Meskel Sq to Post office**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	from
1	18.4	1.4	1.5	1.30	0.00	14.24	Input_XSection
2	21.5	0.5	1.5	1.40	0.00	18.08	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	from
1	3.0	1,273	1.49	2.99	120.60	Input_SegData, Input_XSection
2	3.0	933	0.86	3.00	209.17	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor	from	Median Type
1	12.0	12.0	10.5	0.07	1.00	10.0	3.0	-4.8207	Input_XSection	D
2	12.0	12.0	10.5	0.02	1.00	10.0	3.0	-4.7587	Input_XSection	D

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	from
1	1.1341	1.7695	4.1297	Input_SegData, Input_XSection
2	0.7439	0.2787	2.3107	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	D
2	B

LOS by Average Pedestrian Space (ft^2/p)

LOS Score	60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

LOS+ Multimodal Level of Service for Urban Streets
Results Summary

Street: Meskel Sq to Post office | Direction: NE | Date: 1/5/2019

Limits: 1st Street to 3rd Street | Scenario: Existing | Analyst: Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	Meskel Sq to Ambasador	1st Street	2nd Street	120.60	4.13	D
2	Ambasador to Post office	2nd Street	3rd Street	209.17	2.31	B

Degol Sq. to Ras Mekonnen bridge Left-Side Pedestrian LOS analysis

LOS+ Multimodal Level of Service for Urban Streets

Segment General Data Input Sheet

Street	Degol Sq to Ras Mekonnen bridge
Limits	1st Street to 2nd Street
Date	1/5/2019
Analyst	Bahiru Lulie
Scenario	Existing
Analysis Direction	NB

(Down Direction on this Sheet)

Eligible Directions NB, SB, EB, WB, NW, SE, NE, SW

1st Street

Segment #1

Pedestrian Walking Speed (ft/s)	3.0
Pedestrian Flow Rate (ped/hr)	1,551

Segment Volume Data	
Vehicle Flow Rate (vph)	862
Peak Hour Factor	0.95
Heavy Vehicle %	2.0%
Left/Right Turns %	-
Thru Adj. Sat. (vphgl)	-

Segment Layout and Speed Data	
Segment Length (ft)	3,048
Speed Limit (mph)	19
Left Turn Pocket?	No
Avg. Travel Time (s)	30
Avg. Stops (#/veh)	-

Users Must Input Data In Light Green Shaded Areas

Intersection Data

Intersection Control
SSSC

Side-Street-Stop Controlled (SSSC)

2nd Street

LOS+ Multimodal Level of Service for Urban Streets
Street Cross-Section Input Data Sheet

Street: Degol Sq to Ras Mekonnen bridge
Limits: 1st Street to 2nd Street

Segment #1

General guidance on input parameters is provided at the bottom of this sheet.

Analyst: Bahiru Lulie
Date: 1/5/2019

From: 1st Street To: 2nd Street

1

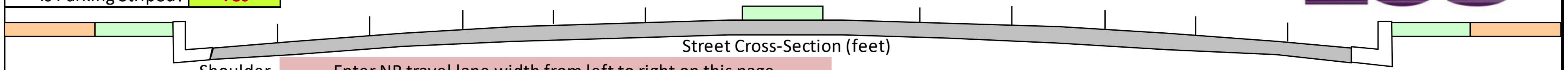
Fixed Object Width (ft)	Parking Occupancy %
0.5	19%

Is Curb Present?	Yes
Is Parking Striped?	Yes

Median Type (0-3)	0
Pavement Condition	3.5

NB

SB



Enter NB travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
12.8	0.0	12.0	0.0	12.0				0.0

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.54	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.34	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
No	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Compute Pedestrian LOS

Street: **Degol Sq to Ras Mekonnen bridge**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	
1	12.8	1.4	1.5	0.50	0.00	9.38	from Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	
1	3.0	1,551	2.76	2.98	64.93	from Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor		Median Type
1	12.0	12.0	10.5	0.19	1.00	10.0	3.0	-4.9579	from Input_XSection	UD

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	
1	1.9611	1.9194	4.9694	from Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	E

LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

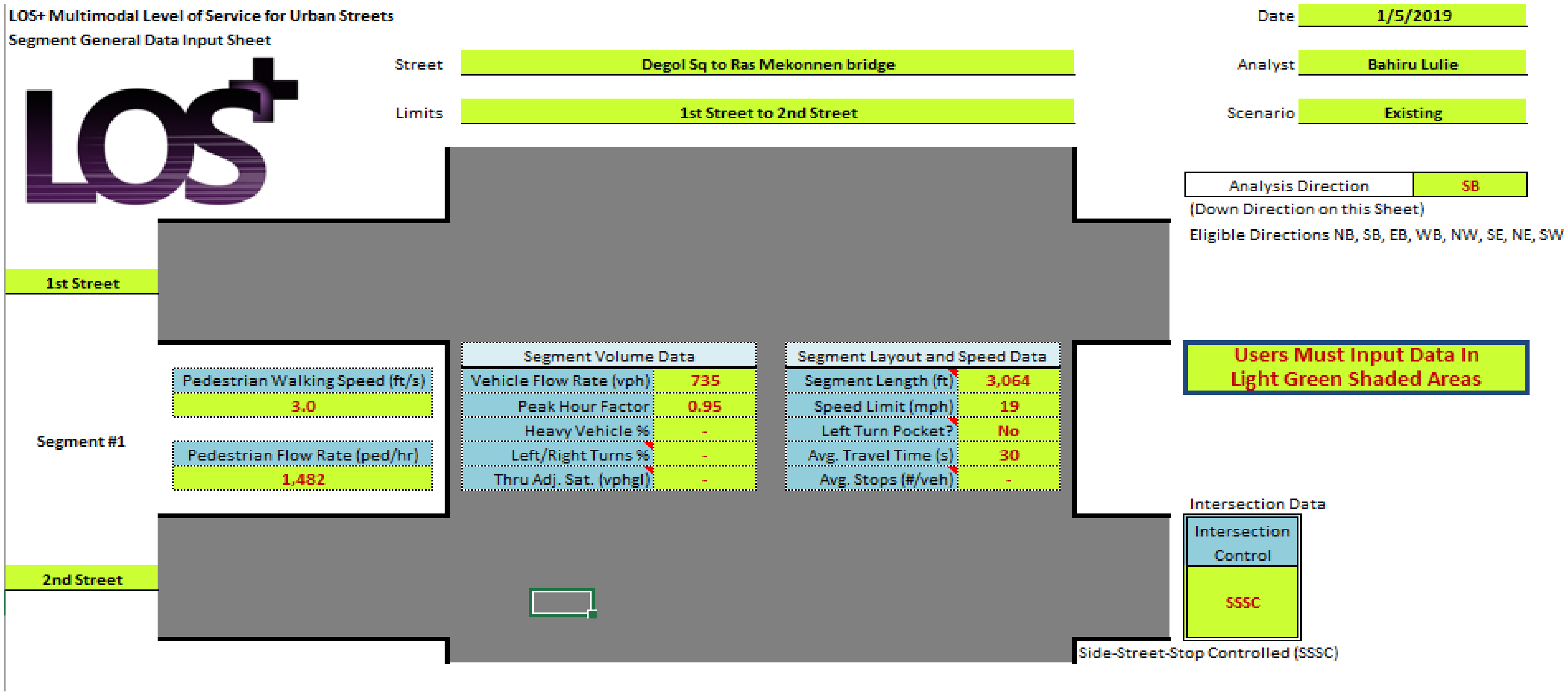
LOS+ Multimodal Level of Service for Urban Streets
Results Summary

Street ______ Direction NB Date 1/5/2019

Limits Degol Sq to Ras Mekonnen bridge Scenario Existing Analyst Bahiru Lulie

Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	Degol Sq to Ras Mekonnen bridge	1st Street	2nd Street	64.93	4.97	E

Degol Sq. to Ras Mekonnen bridge Right-Side Pedestrian LOS analysis



LOS+ Multimodal Level of Service for Urban Streets
Street Cross-Section Input Data Sheet

Street: Degol Sq to Ras Mekonnen bridge
Limits: 1st Street to 2nd Street

Segment #1

General guidance on input parameters is provided at the bottom of this sheet.

Analyst: Bahiru Lulie
Date: 1/5/2019

From: 1st Street   To: 2nd Street

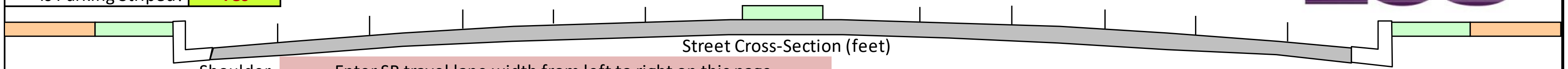
1

Fixed Object Width (ft)	Parking Occupancy %
3.3	28%

Is Curb Present?	Yes
Is Parking Striped?	Yes

Median Type (0-3)	0
Pavement Condition	3.5

SB   NB



Street Cross-Section (feet)

Enter SB travel lane width from left to right on this page.

Sidewalk	Buffer	Shoulder Parking	Bike Lane	Trav. Lane	Trav. Lane	Trav. Lane	Trav. Lane	Median
11.7	0.0	10.0	0.0	12.0				0.0

0.00	Proportion of Sidewalk Length Adjacent to a Window Display (decimal)
0.39	Proportion of Sidewalk Length Adjacent to a Building Face (decimal)
0.48	Proportion of Sidewalk Length Adjacent to a Fence or Low Wall (decimal)
Yes	Does buffer contain continous barrier at least 3 ft high and average spacing of 20 ft or less? (i.e., trees or bollards)

Compute Pedestrian LOS

Street: **Degol Sq to Ras Mekonnen bridge**

1. Compute Effective Sidewalk Width

Segment	Total Walkway Width (ft)	Shy Dist. Outside S/W (ft)	Shy Dist. Inside S/W (ft)	Effective Fixed Object Width (ft)	Buffer Width (ft)	Effective Sidewalk Width (ft)	
							from
1	11.7	1.3	1.5	3.30	0.00	5.64	Input_XSection

2. Compute Average Pedestrian Space

Segment	Avg. Free-Flow Ped. Walking Speed (ft/s)	Pedestrian Demand (ped/hr)	Ped. Flow Rate Per Unit Width (ped/ft/min)	Average Ped. Walking Speed (ft/s)	Average Pedestrian Space (ft^2/ped)	
						from
1	3.0	1,482	4.38	2.96	40.49	Input_SegData, Input_XSection

3. Cross-Section Adjustment Factor

Segment	Total Width W_T (ft)	Effective Width W_V (ft)	Effective Width W_1 (ft)	On-Street Parking Occ (decimal)	Buffer Area Coefficient	Adj. Available Sidewalk Width (ft)	Sidewalk Width Coefficient	Cross-Section Adjustment Factor		Median Type
									from	
1	12.0	12.0	8.5	0.28	5.37	10.0	3.0	-5.0313	Input_XSection	UD

4. Motorized Vehicle Volume and Speed Adjustment Factors, Pedestrian LOS Score for Link

Segment	Vehicle Volume Adjustment Factor	Vehicle Speed Adjustment Factor	Ped. Link LOS Score	
				from
1	1.6721	1.9401	4.6277	Input_SegData, Input_XSection

5. Determine Pedestrian LOS for Link

Seg.	Ped. Link LOS #
1	E

LOS Score	LOS by Average Pedestrian Space (ft^2/p) 60	40	24	15	8	0
-100	A	B	C	D	E	F
2.00001	B	B	C	D	E	F
2.75001	C	C	C	D	E	F
3.50001	D	D	D	D	E	F
4.25001	E	E	E	E	E	F
5.00001	F	F	F	F	F	F

LOS+ Multimodal Level of Service for Urban Streets
Results Summary

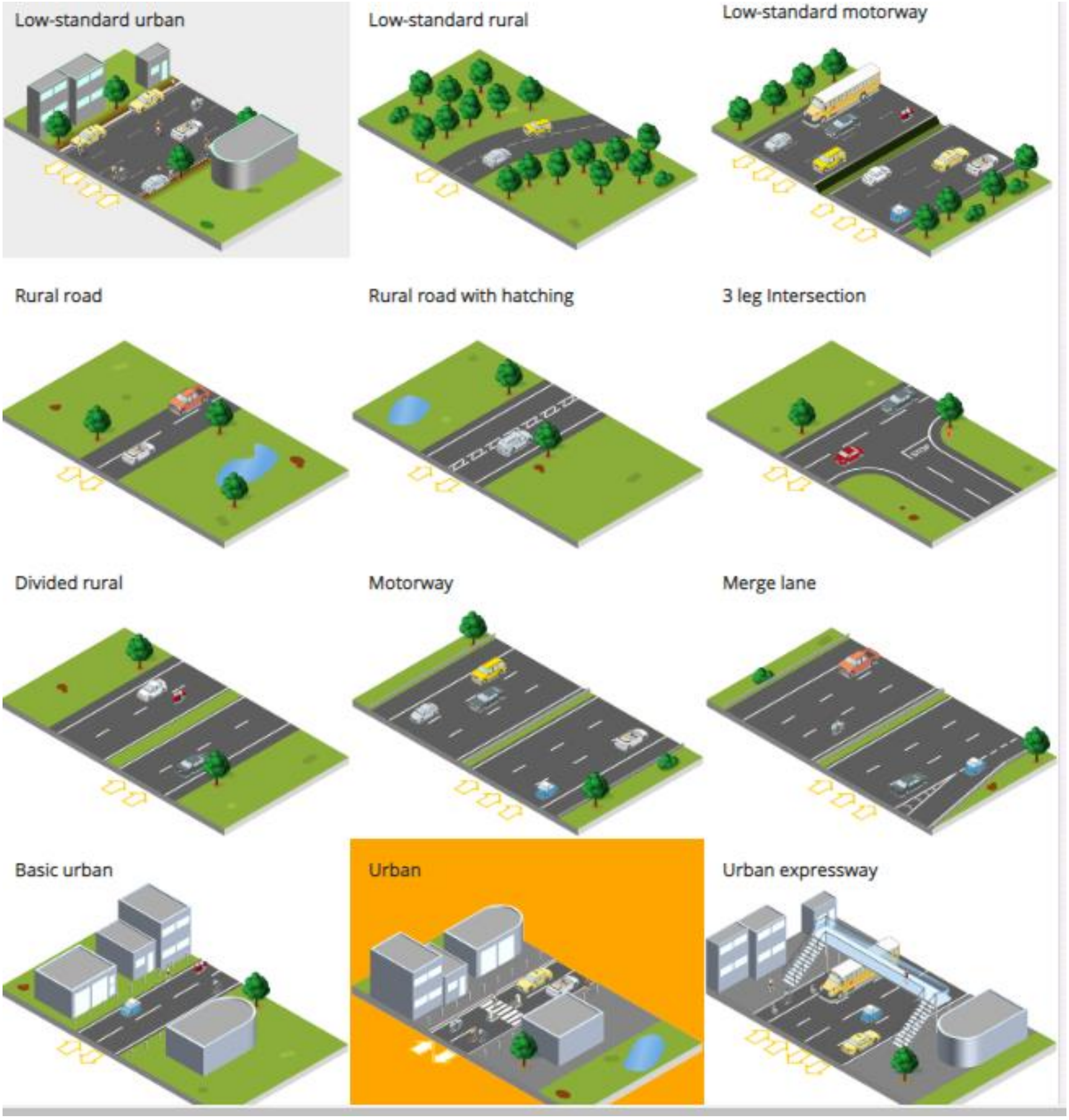
Street ______ Direction SB Date 1/5/2019

Limits Degol Sq to Ras Mekonnen bridge Scenario Existing Analyst Bahiru Lulie

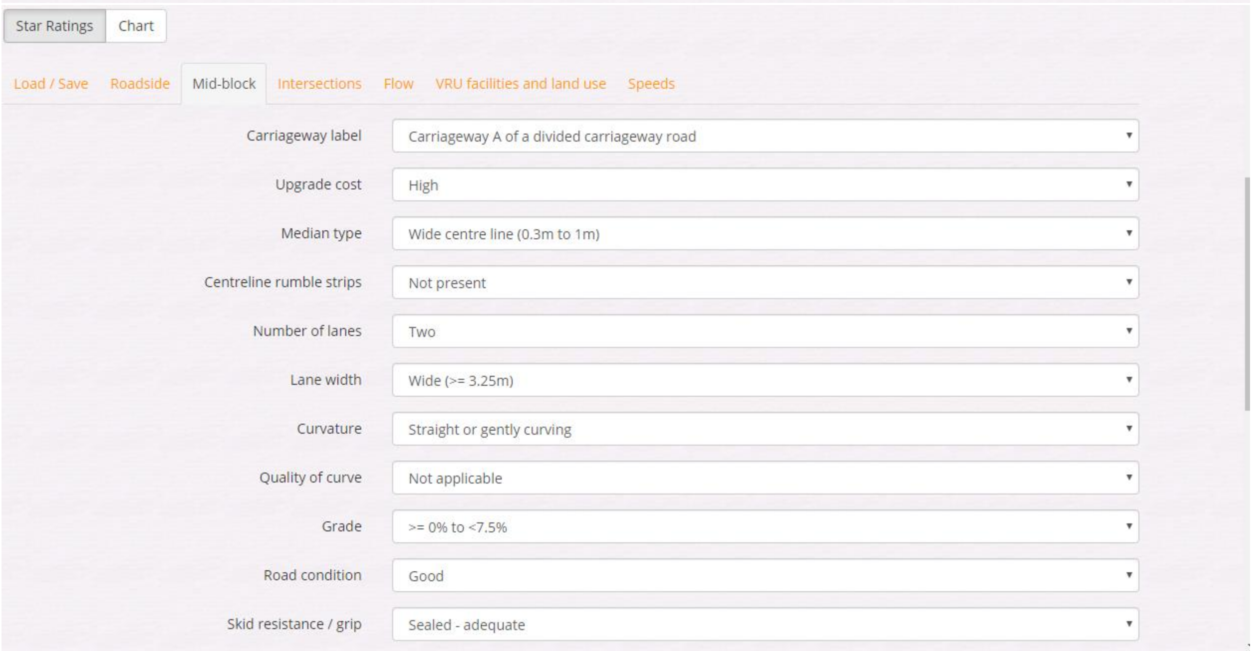
Segment	Street Name	From	To	Pedestrian Mode		
				Ped Space[1]	LOS Score	LOS
1	Degol Sq to Ras Mekonnen bridge	1st Street	2nd Street	40.49	4.63	E

APPENDIX -C

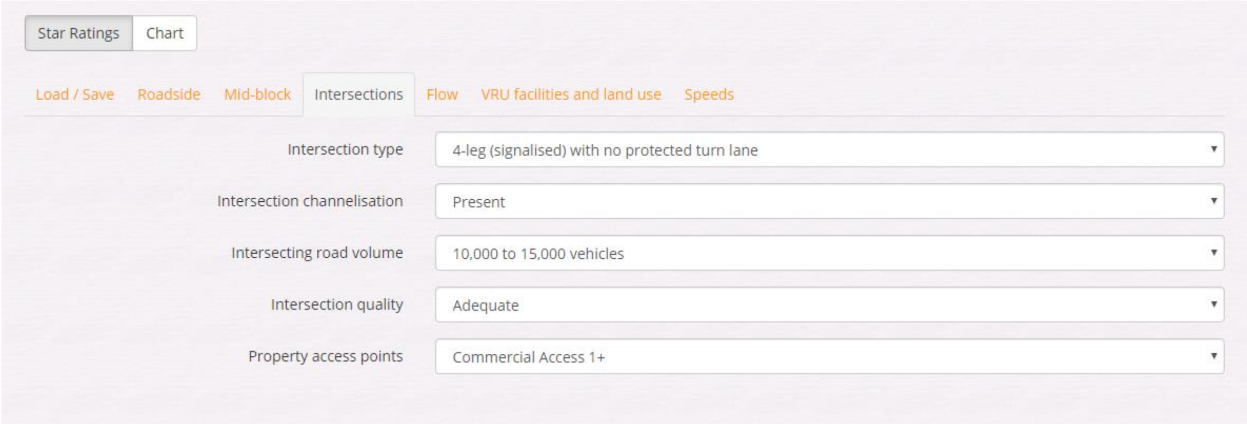
iRAP ONLINE SOFTWARE ANALYSIS

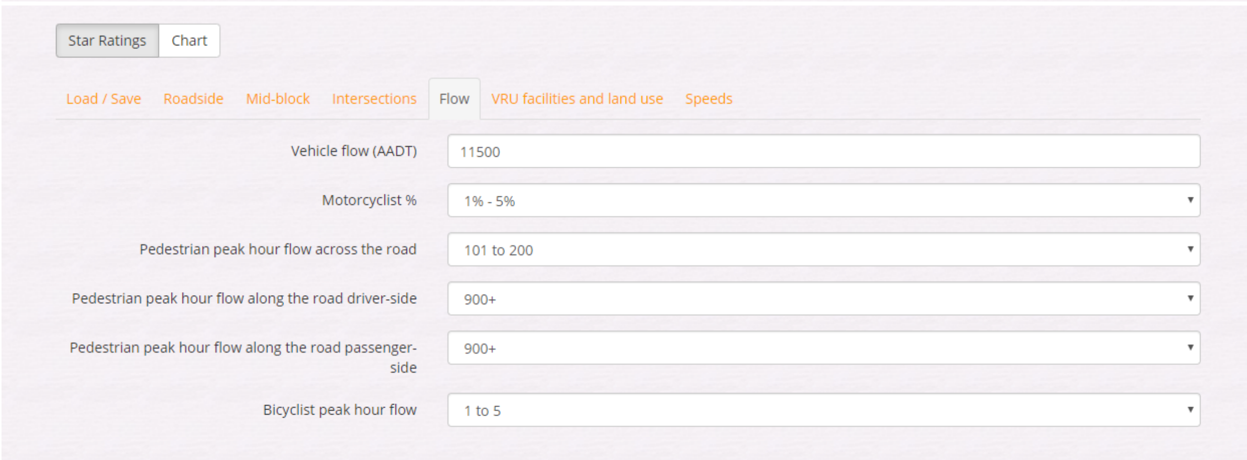

Low-standard urban
Low-standard rural
Low-standard motorway
Rural road
Rural road with hatching
3 leg Intersection
Divided rural
Motorway
Merge lane
Basic urban
Urban
Urban expressway

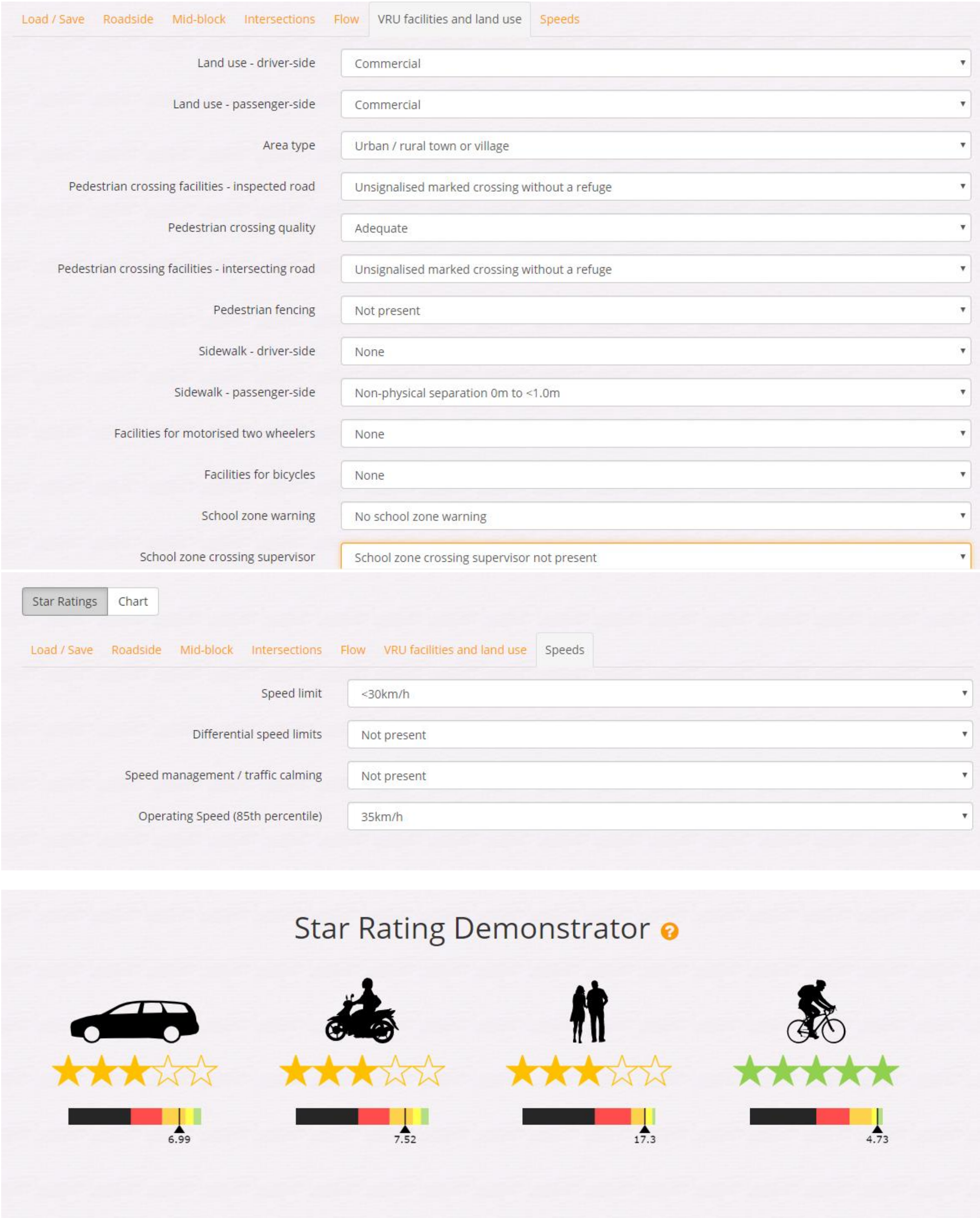
iRAP online Software Analysis from Arat Kilo to Sidist Kilo

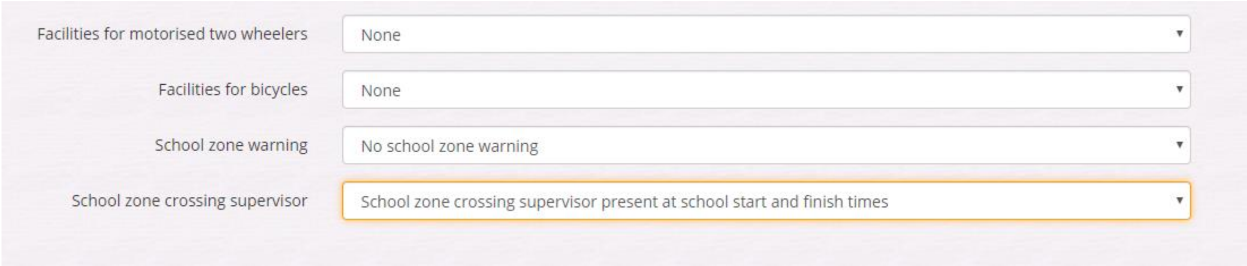



Delineation
Adequate
Street lighting
Present
Vehicle parking
Two sides
Service road
Not present
Roadworks
No road works
Sight distance
Adequate

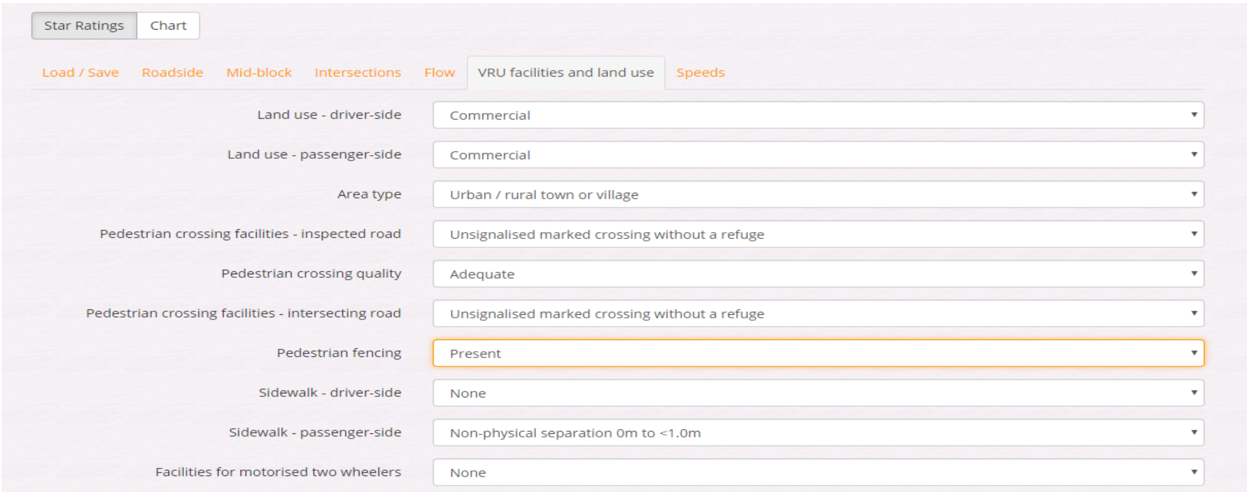

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Intersection type
4-leg (signalised) with no protected turn lane
Intersection channelisation
Present
Intersecting road volume
10,000 to 15,000 vehicles
Intersection quality
Adequate
Property access points
Commercial Access 1+


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Vehicle flow (AADT)
11500
Motorcyclist %
1% - 5%
Pedestrian peak hour flow across the road
101 to 200
Pedestrian peak hour flow along the road driver-side
900+
Pedestrian peak hour flow along the road passenger-side
900+
Bicyclist peak hour flow
1 to 5


Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Land use - driver-side
Commercial
Land use - passenger-side
Commercial
Area type
Urban / rural town or village
Pedestrian crossing facilities - inspected road
Unsignalised marked crossing without a refuge
Pedestrian crossing quality
Adequate
Pedestrian crossing facilities - intersecting road
Unsignalised marked crossing without a refuge
Pedestrian fencing
Not present
Sidewalk - driver-side
None
Sidewalk - passenger-side
Non-physical separation 0m to <1.0m
Facilities for motorised two wheelers
None
Facilities for bicycles
None
School zone warning
No school zone warning
School zone crossing supervisor
School zone crossing supervisor not present
Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Speed limit
<30km/h
Differential speed limits
Not present
Speed management / traffic calming
Not present
Operating Speed (85th percentile)
35km/h
Star Rating Demonstrator
6.99
7.52
17.3
4.73

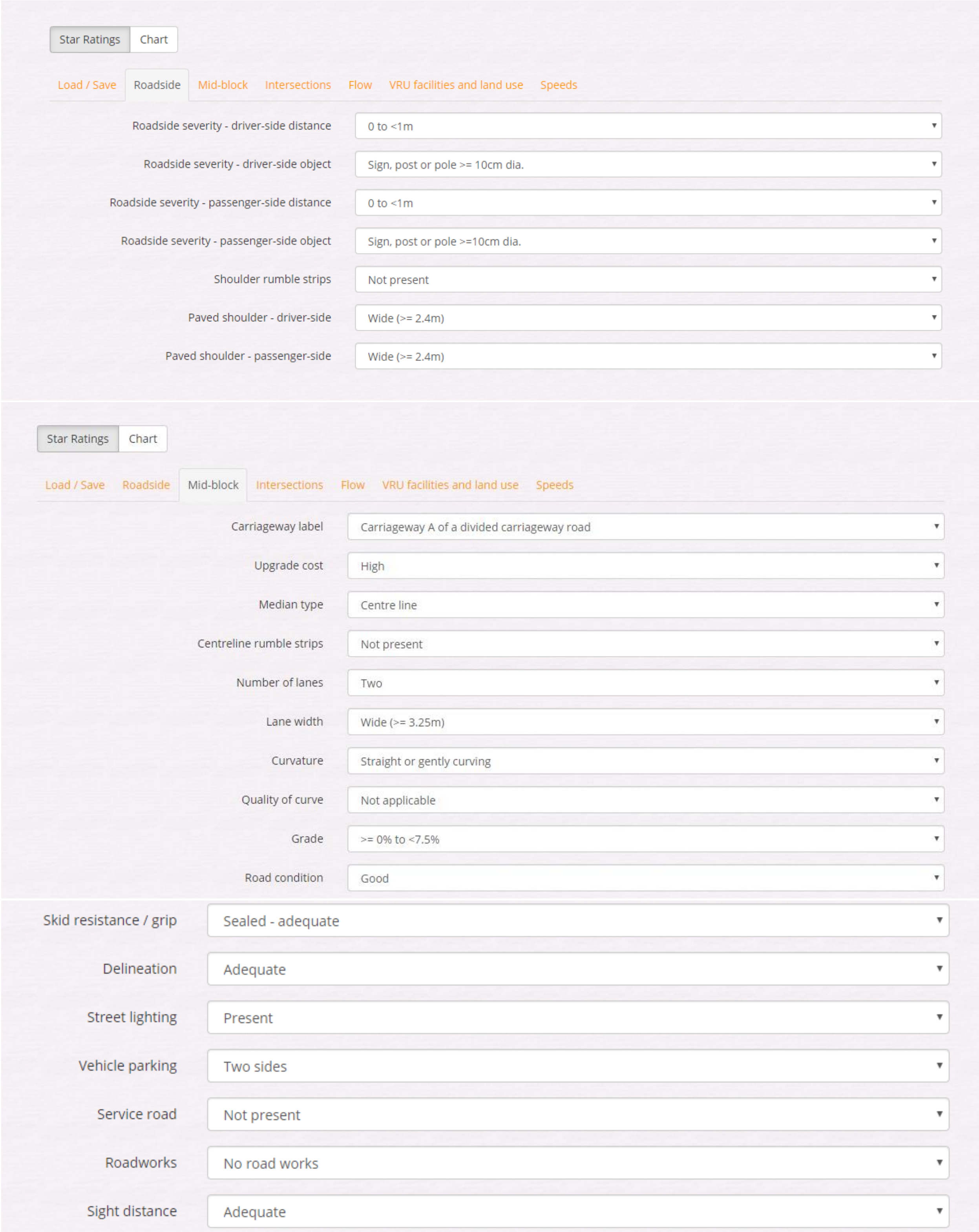


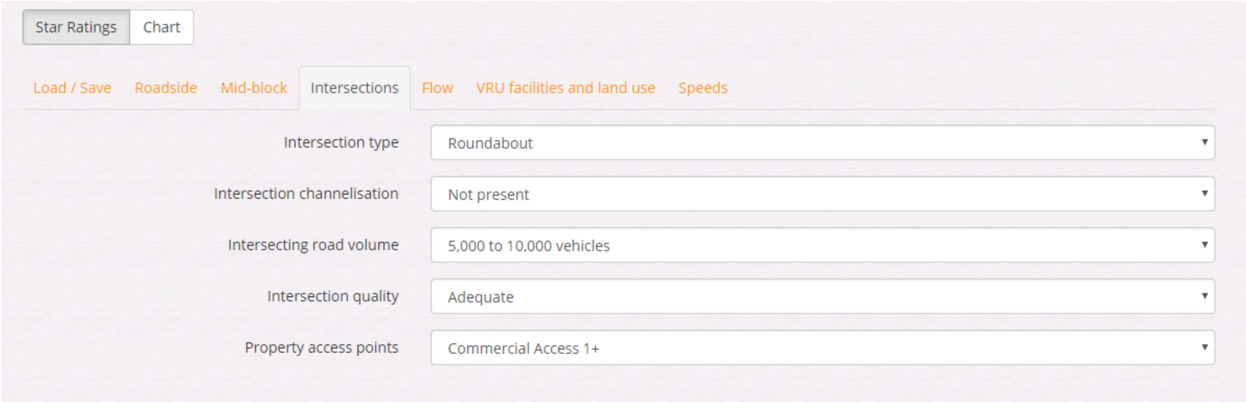
Rating after counter measure 1

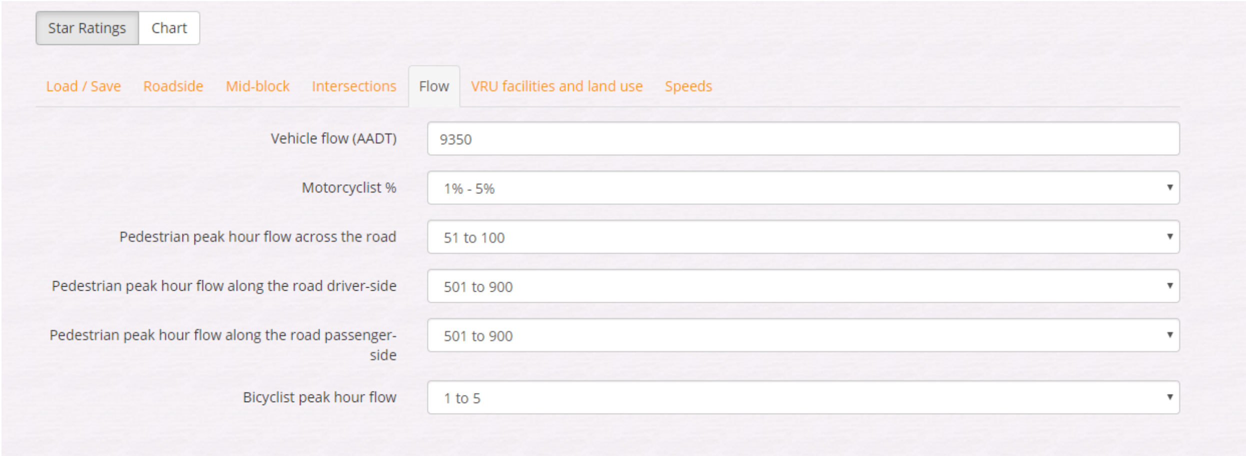


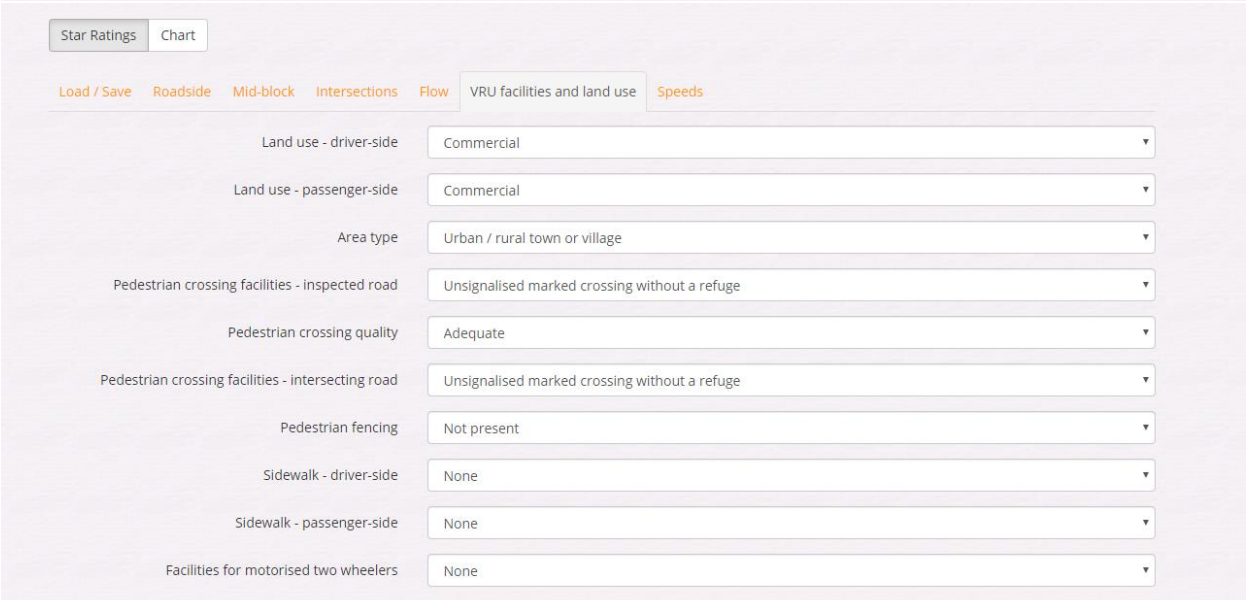
Rating after counter measure 2

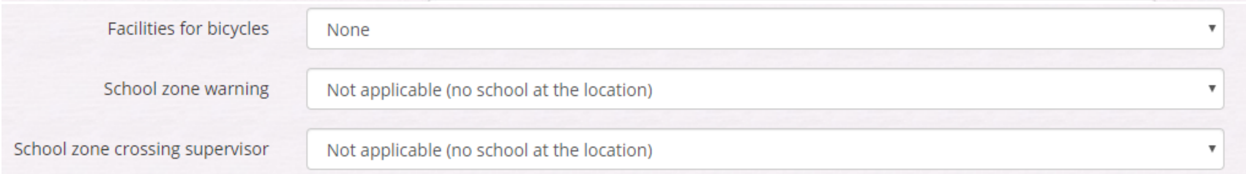
iRAP online Software Analysis From Degol Sq to Ras Mekonnen Bridge

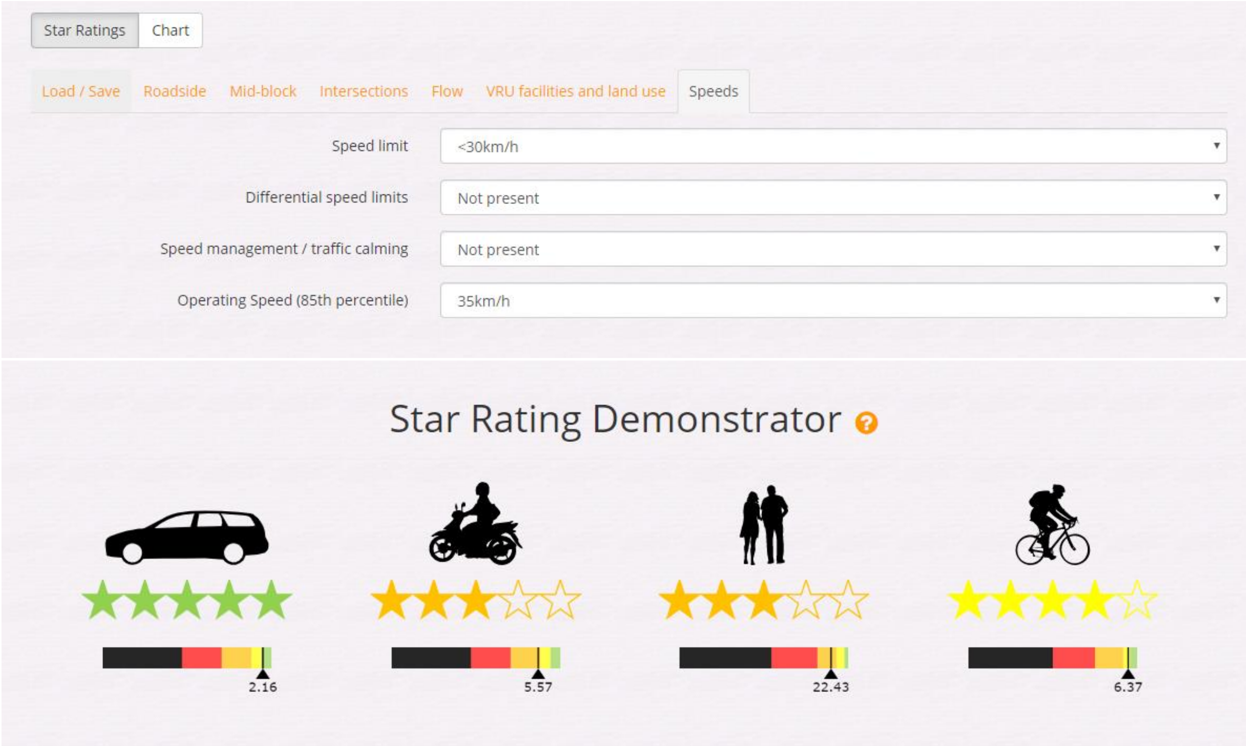


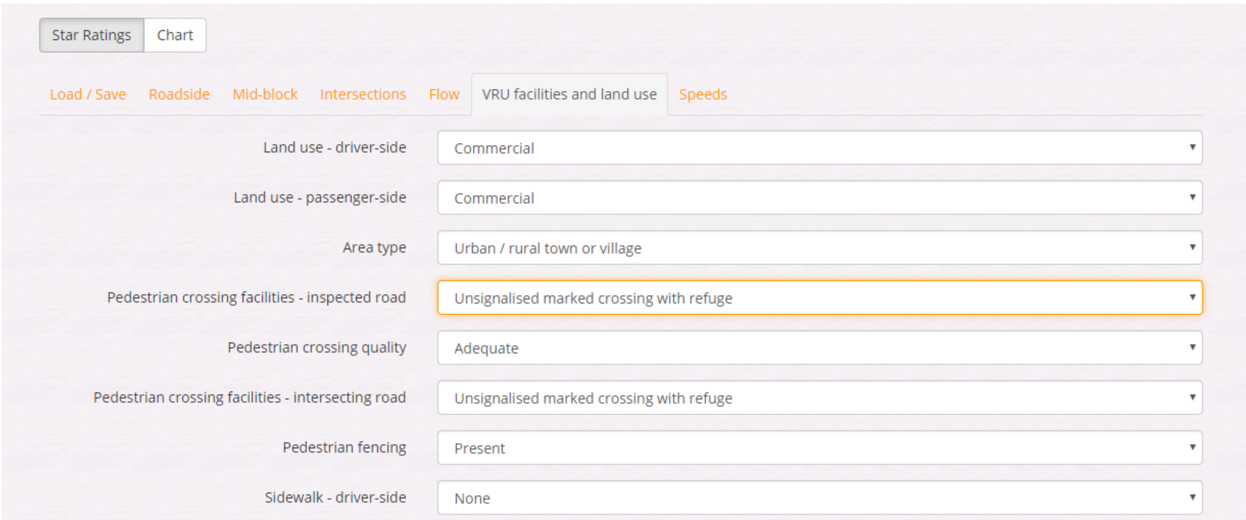

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Intersection type
Roundabout
Intersection channelisation
Not present
Intersecting road volume
5,000 to 10,000 vehicles
Intersection quality
Adequate
Property access points
Commercial Access 1+

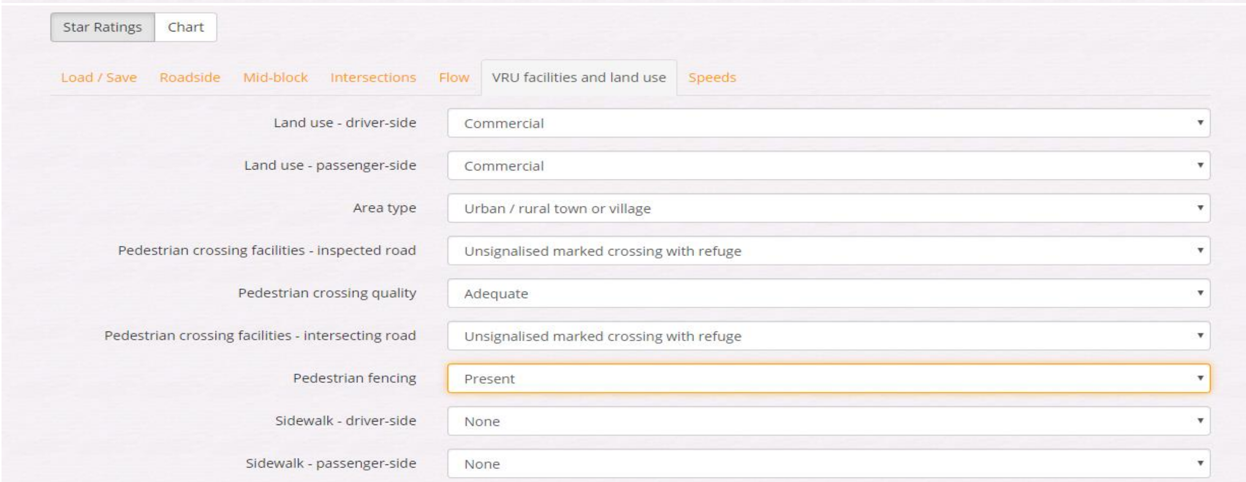

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Vehicle flow (AADT)
9350
Motorcyclist %
1% - 5%
Pedestrian peak hour flow across the road
51 to 100
Pedestrian peak hour flow along the road driver-side
501 to 900
Pedestrian peak hour flow along the road passenger-side
501 to 900
Bicyclist peak hour flow
1 to 5


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Land use - driver-side
Commercial
Land use - passenger-side
Commercial
Area type
Urban / rural town or village
Pedestrian crossing facilities - inspected road
Unsignalised marked crossing without a refuge
Pedestrian crossing quality
Adequate
Pedestrian crossing facilities - intersecting road
Unsignalised marked crossing without a refuge
Pedestrian fencing
Not present
Sidewalk - driver-side
None
Sidewalk - passenger-side
None
Facilities for motorised two wheelers
None

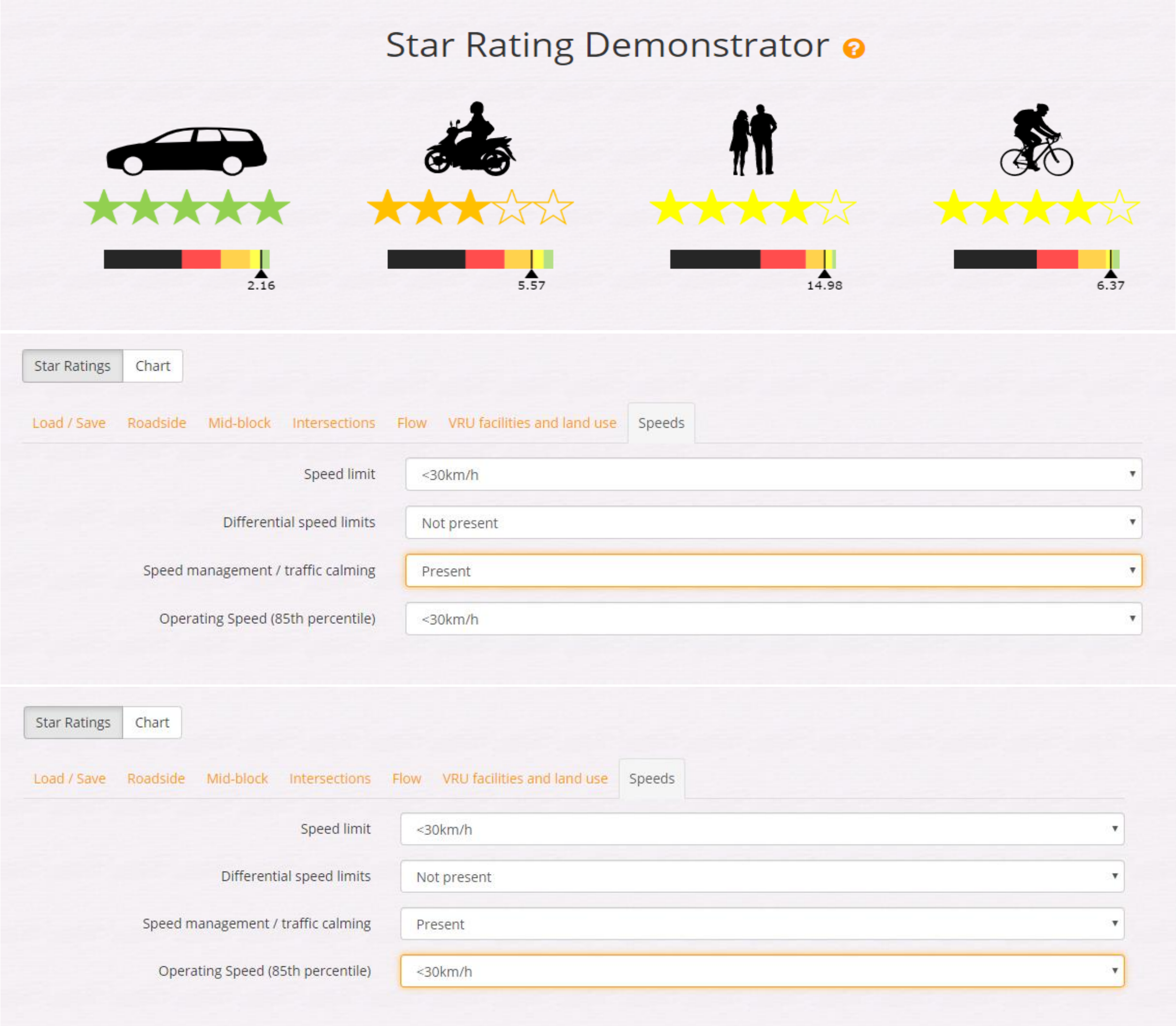

Facilities for bicycles
None
School zone warning
Not applicable (no school at the location)
School zone crossing supervisor
Not applicable (no school at the location)


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Speed limit
<30km/h
Differential speed limits
Not present
Speed management / traffic calming
Not present
Operating Speed (85th percentile)
35km/h
Star Rating Demonstrator
2.16
5.57
22.43
6.37

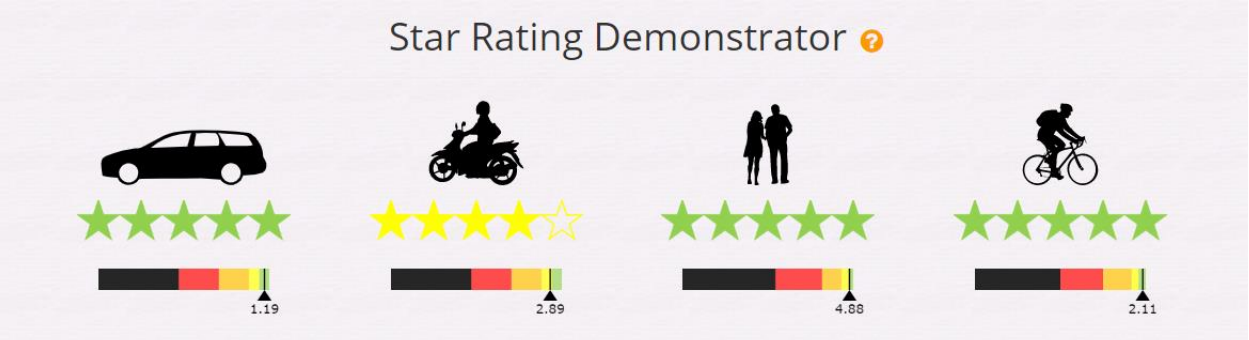

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Land use - driver-side
Commercial
Land use - passenger-side
Commercial
Area type
Urban / rural town or village
Pedestrian crossing facilities - inspected road
Unsignalised marked crossing with refuge
Pedestrian crossing quality
Adequate
Pedestrian crossing facilities - intersecting road
Unsignalised marked crossing with refuge
Pedestrian fencing
Present
Sidewalk - driver-side
None


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Land use - driver-side
Commercial
Land use - passenger-side
Commercial
Area type
Urban / rural town or village
Pedestrian crossing facilities - inspected road
Unsignalised marked crossing with refuge
Pedestrian crossing quality
Adequate
Pedestrian crossing facilities - intersecting road
Unsignalised marked crossing with refuge
Pedestrian fencing
Present
Sidewalk - driver-side
None
Sidewalk - passenger-side
None

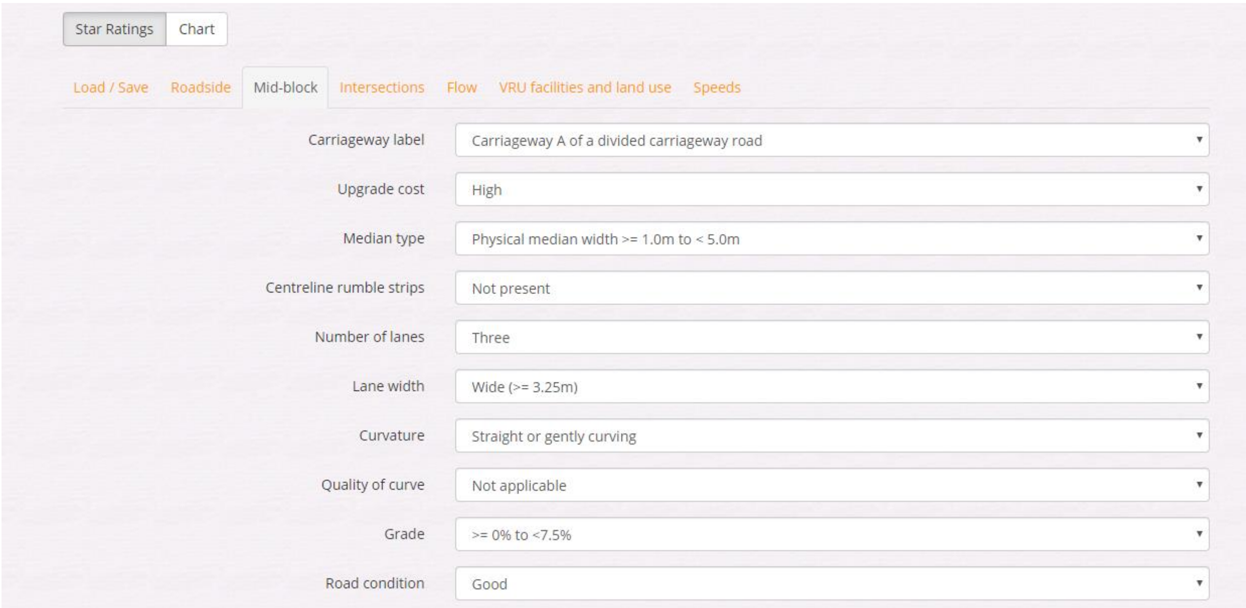
Rating after counter measure 1

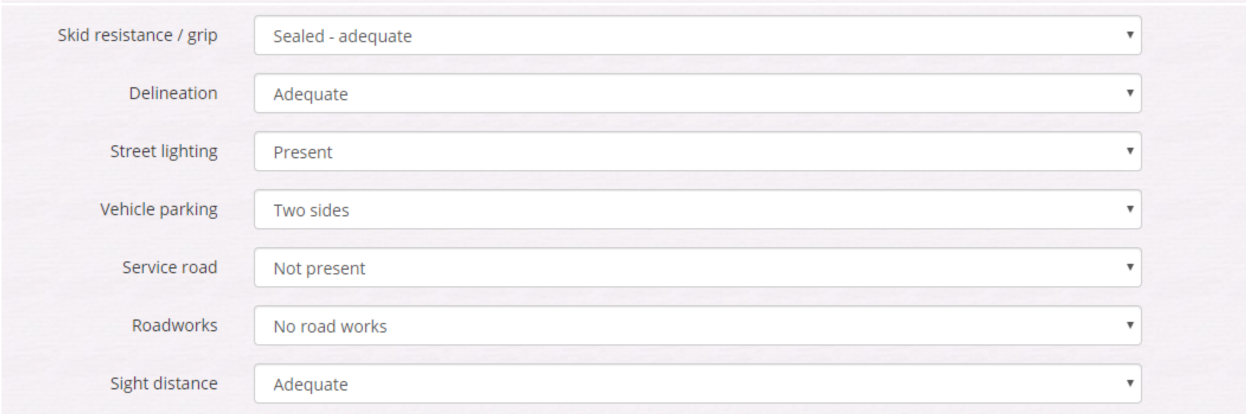


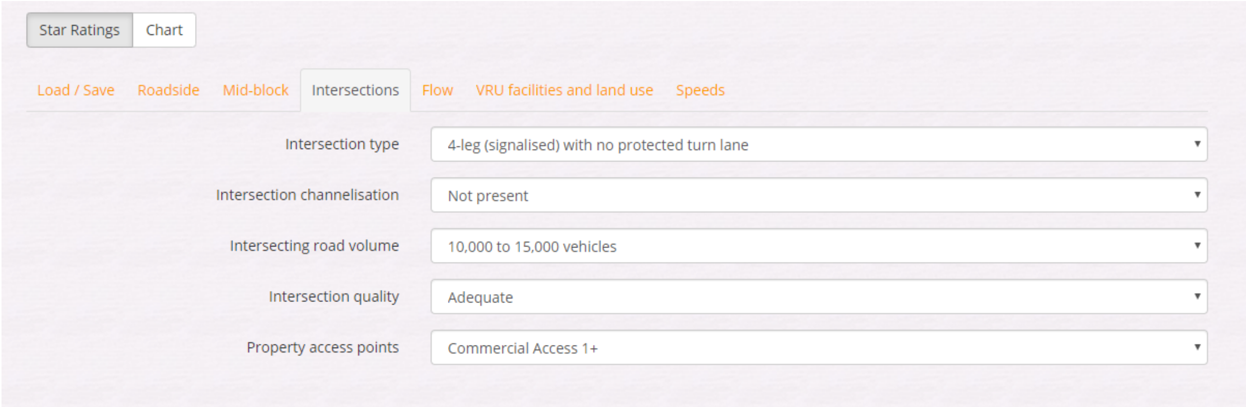
Rating after counter measure 2



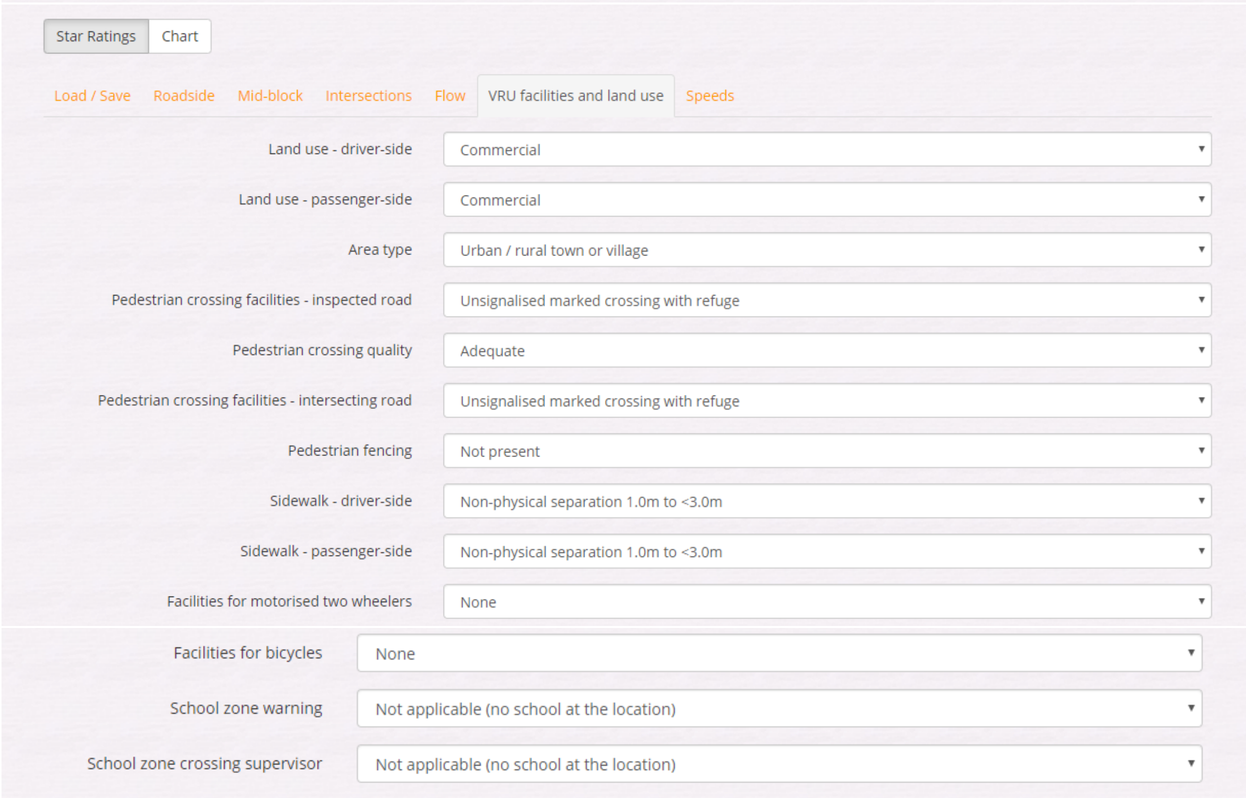
iRAP online Software Analysis from Meskel Sq. to Post office

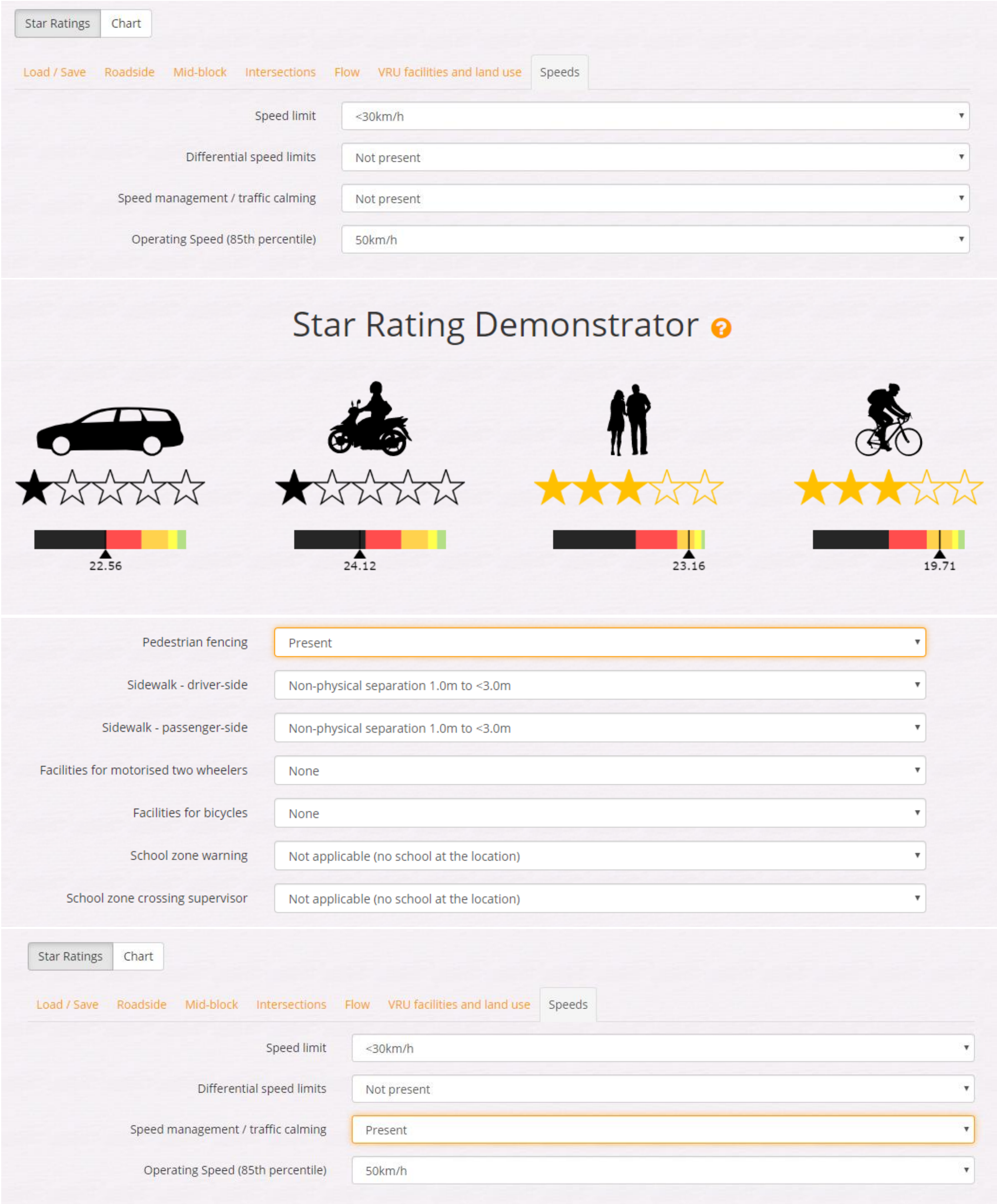




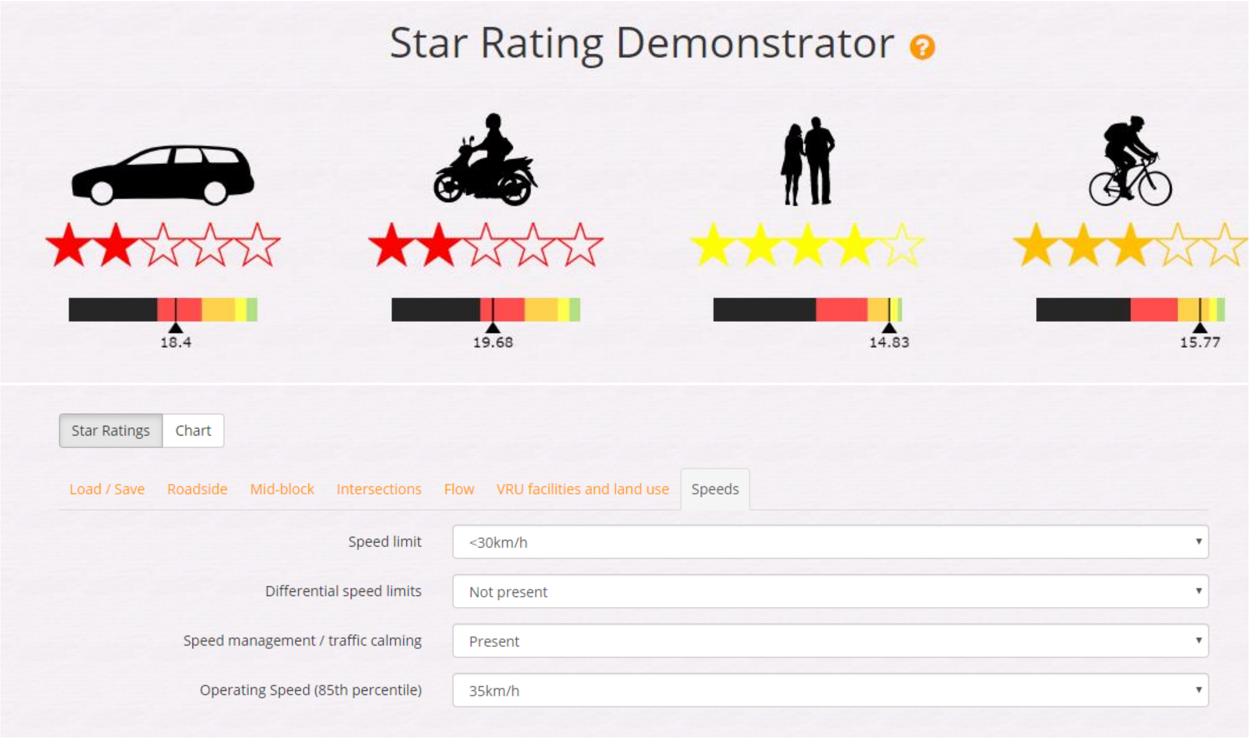

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Intersection type
4-leg (signalised) with no protected turn lane
Intersection channelisation
Not present
Intersecting road volume
10,000 to 15,000 vehicles
Intersection quality
Adequate
Property access points
Commercial Access 1+


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Vehicle flow (AADT)
10810
Motorcyclist %
1% - 5%
Pedestrian peak hour flow across the road
101 to 200
Pedestrian peak hour flow along the road driver-side
900+
Pedestrian peak hour flow along the road passenger-side
900+
Bicyclist peak hour flow
6 to 25

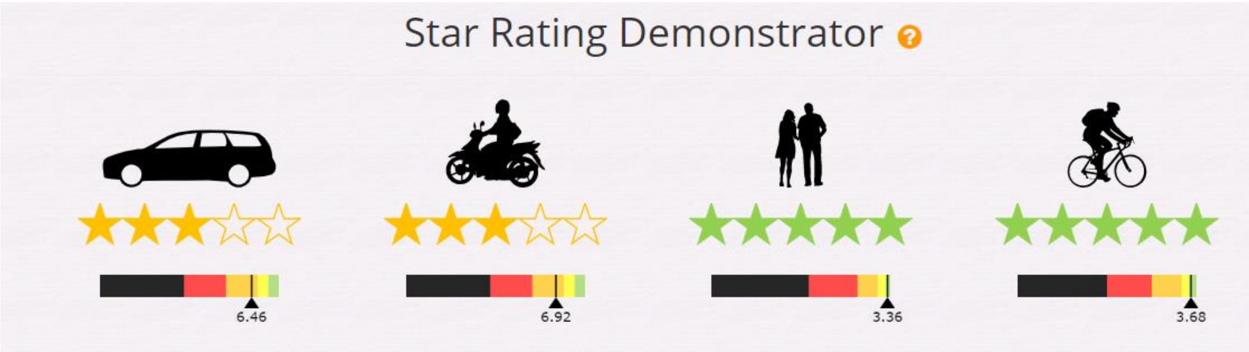

Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Land use - driver-side
Commercial
Land use - passenger-side
Commercial
Area type
Urban / rural town or village
Pedestrian crossing facilities - inspected road
Unsignalised marked crossing with refuge
Pedestrian crossing quality
Adequate
Pedestrian crossing facilities - intersecting road
Unsignalised marked crossing with refuge
Pedestrian fencing
Not present
Sidewalk - driver-side
Non-physical separation 1.0m to <3.0m
Sidewalk - passenger-side
Non-physical separation 1.0m to <3.0m
Facilities for motorised two wheelers
None
Facilities for bicycles
None
School zone warning
Not applicable (no school at the location)
School zone crossing supervisor
Not applicable (no school at the location)


Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Speed limit
<30km/h
Differential speed limits
Not present
Speed management / traffic calming
Not present
Operating Speed (85th percentile)
50km/h
Star Rating Demonstrator
22.56
24.12
23.16
19.71
Pedestrian fencing
Present
Sidewalk - driver-side
Non-physical separation 1.0m to <3.0m
Sidewalk - passenger-side
Non-physical separation 1.0m to <3.0m
Facilities for motorised two wheelers
None
Facilities for bicycles
None
School zone warning
Not applicable (no school at the location)
School zone crossing supervisor
Not applicable (no school at the location)
Star Ratings
Chart
Load / Save
Roadside
Mid-block
Intersections
Flow
VRU facilities and land use
Speeds
Speed limit
<30km/h
Differential speed limits
Not present
Speed management / traffic calming
Present
Operating Speed (85th percentile)
50km/h

Rating after counter measure 1

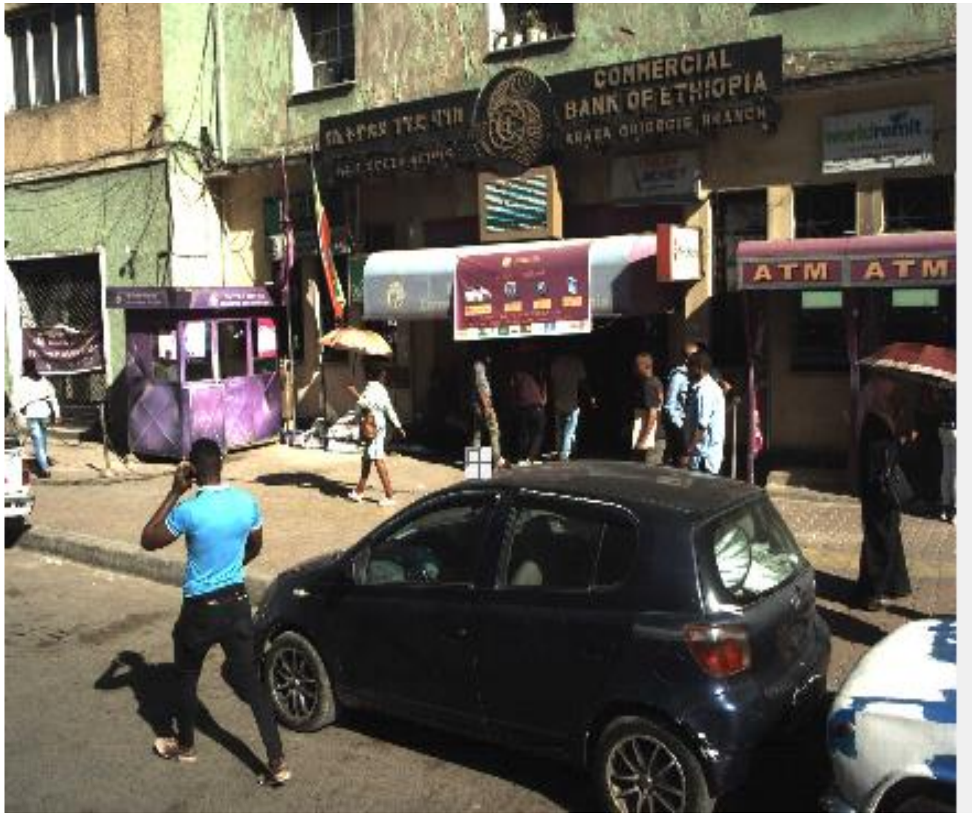


Rating after counter measure 2

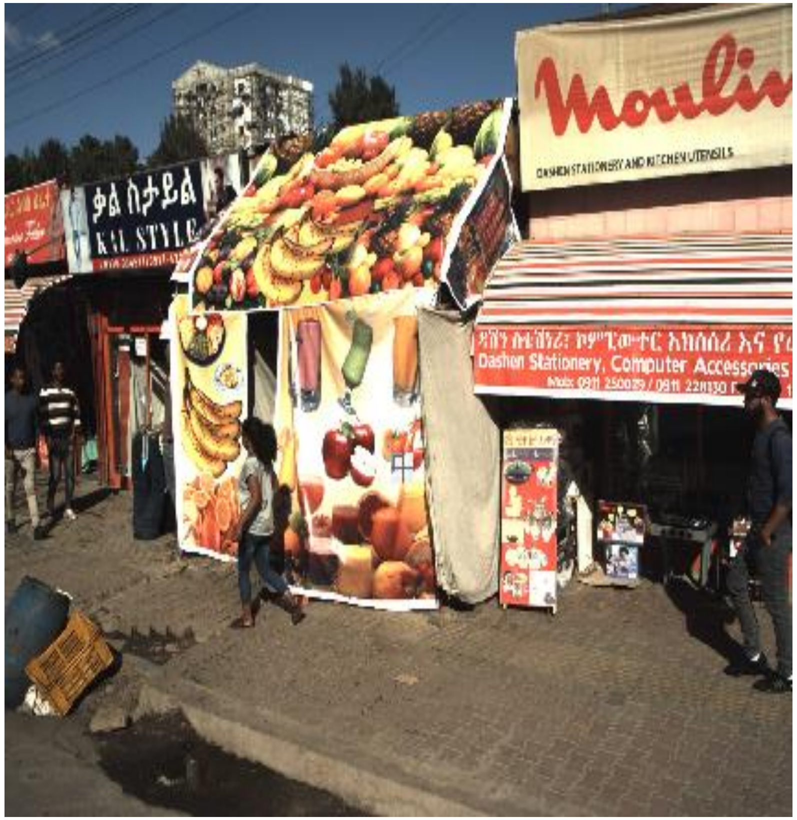


APPENDIX -D

RIGHT OF WAY PROBLEMS IN WALKWAY



Degol Sq. to Ras Mekonnen bridge walkway
(ATM machines, Guard house)



Degol Sq. to Ras Mekonnen bridge walkway
(trade on walkway)