

# LEAPFROGGING TOWARDS GREEN INFRASTRUCTURE — A CASE OF AFRICAN AVENUE

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## ABSTRACT

Green infrastructure supports urban areas by linking environmental, social and economic roles of other infrastructural developments, like connecting transport infrastructures with nature. Diverse street designs provide multiple benefits, such as carbon sequestration, flood management, reduced traffic accidents, wildlife habitat, neighbourhood beautification, improved air quality, noise pollution and more related to green infrastructure benefits. Thus, this article's first objective is to explore green infrastructure benefits and identify those related to transportation. Furthermore, allocate a category of multifunctionality for African avenue/Bole Street with experts' opinions. What green infrastructure benefits do the pavement, bioswales, planter boxes, trees and Bole/African avenue road altogether deliver? The second is to see the transportation planning of Addis Ababa, first by reviewing its environmental impact on the city and second by taking the case of African avenue/Bole street, which has gone in the process of widening. Since one benefit of GI is reducing traffic accidents, this road is built to reduce traffic accidents. We checked if it reduced traffic collisions occurring on African Avenue. Its direct accidental impact, injuries sustained in road traffic collisions are gathered and compared between the years before and after the widening of African avenue.

The GI value difference result indicates a considerable gap between the possible benefits the street could give and the current benefits. Transport impact on the city's environmental health is vast. Collisions on vehicles increased and the number of pedestrians affected increased; Thus, the papers suggest Addis Ababa needs to increase employed GI strategies and integrate new green infrastructure strategies to intensify multifunctionality. Moreover, the paper introduces the concept of Leapfrog and the possibility of shifting into green transportation.

*Keywords:* Addis Ababa, green infrastructure (GI), leapfrog, traffic accidents, GI benefits.

## 1 INTRODUCTION

Transport and green infrastructure have been attracted attention for ages. Interest in this subject has significantly increased since the 1970s. Many publications address the ecological effects of roads and traffic [1], Types of impact such as traffic accidents, emissions, noise, air cooling, stormwater.

It is crucial to establish green infrastructure to neutralize urban runoff, urban cooling, carbon sequestration and traffic accident impact of roads [2]. Since the transport sector has an immense impact on the environment, it can also reverse it if unified with green infrastructure [3]. It is more resilient, cost-effective and meets 21st century needs than grey infrastructures [4]. The research aims to find the benefits of green infrastructure in the transportation sector and use those benefits to evaluate African avenue.

GI provides a multifunctional infrastructure that is connected. Connecting a network of spaces and a more comprehensive range of functions demonstrates the benefits that GI can deliver [5]. The fundamental similarity between green infrastructure and transportation planning is creating connections and functioning networks, but the conflict seeks to connect in the same landscape and regions. According to Addis Ababa city Government plan commission [6], the city is losing its green coverage at a devastating speed. Climate change, flash floods, heatwaves and drought are significant environmental problems related to the city [7].

Recently, Addis Ababa's city is making efforts to recover the city's condition [8,9]. Given the significance, further study needs to show the value of GI and the degree of multifunctionality. Spaces and a more comprehensive range of functions demonstrate the benefits that GI can deliver [5]. The fundamental similarity between green infrastructure and transportation planning is to create connection and functioning networks, but the conflict is to create this connection in the same landscape and regions. According to Addis Ababa city Government plan commission [6], the city is losing its green coverage at a devastating speed. Climate change, flash floods, heatwaves and drought are significant environmental problems related to the city [7]. Recently, Addis Ababa's city is making efforts to recover the city's condition [8,9]. Given the significance, further studies need to show the value of GI, measure indicators and the degree of multifunctionality, which is the paper's primary objective.

## 2 METHODOLOGY

The first part of the research methodology searches and identifies the main benefits of green infrastructure and determines GI deliveries' services. With the GI benefits, a description and measure indicators are prepared that enables experts to assess the African avenue/Bole street context with the pavement, bioswales, planter boxes, trees, and the road as a general. Through academic expert's inputs, maps and data collected from concerned offices. The method [10,11] are adopted for the first part of the research. Green infrastructure benefits and their multifunctionality method [10] to produce a framework for multi-functional green infrastructure assets, and expert opinion [11] is adopted to identify linkages between green infrastructure and services using an expert opinion methodology. Academic experts identified, from available information of Ethiopian Institute of Architecture, Building Construction and City development department lists and networking with experts willing to cooperate, who already studied Addis Ababa's green issues and transportation.

Furthermore, four transport Police officers who witnessed the change of African avenue worked on that segment before and after redevelopment, with experience of more than six years, were selected from bole sub-city traffic police station—a total of 14 experts involved. With a list of GI benefits, a description, and measure indicators, the experts give value, and the value difference calculated, which is the difference between the asset's possible GI benefits (PGIB) with the asset's current GI benefits (CGIB). We used a relative percentage differences calculator to determine the GI value relative percentage difference, which converts the GI value difference to a percentage. The higher the relative Percentage difference is, the higher the asset needs attention [12].

$$GI \text{ value relative Percentage difference} = \left( \frac{[PGIB - CGIB]}{(PGIB)} \right) \times 100$$

The second part of the methodology helps to see, environmental and traffic accidental impact of Addis Ababa transport planning in the city. Traffic accidents in African avenue/Bole, located in the two most accident-prone sub-cities and one of the busiest roads with traffic flows, is selected to show the trend solution in the city.

The selected site allows the research to compare the pros and cons of the redevelopment—traffic collision data collected before the renewal of the road and after construction. Our data source was traffic collisions in African Avenue/Bole Road, collected by Addis Ababa bole sub-city police commission, traffic control and inspection office. Concerning the data's

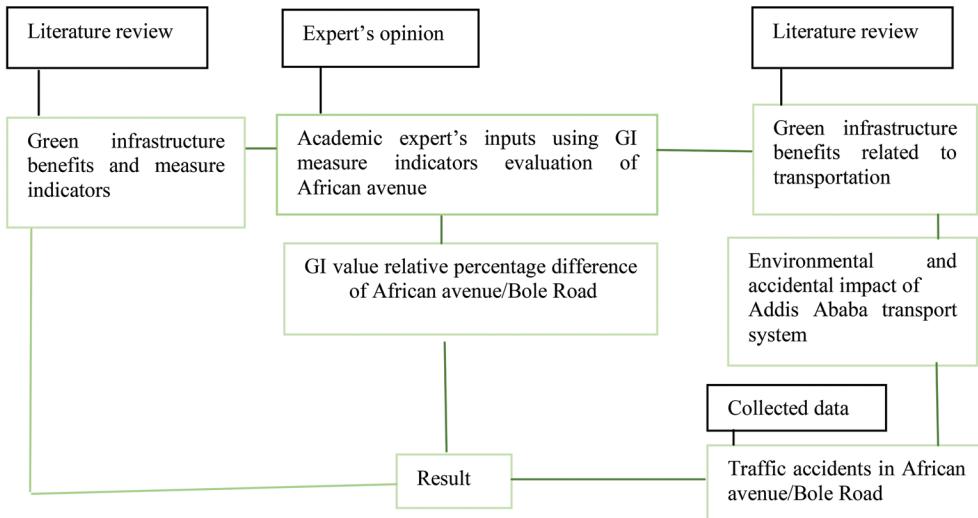


Figure 1: Method outline.

quality and validity, we checked every single report done by the traffic officers when the collisions occurred and counted it from the stored source file. Since they do not have separated data for each street, we separated the African avenue/Bole road reports from the other streets. Observations and collection of relevant photos and illustrative diagrams used to explain scenarios and situations under discussion.

## 2.1 Green infrastructure benefits

Connecting green infrastructure assets to a broader network of spaces increases their benefits [12].

### 2.1.1 List of GI benefits and measure indicators

This section demonstrates review findings on the summaries of benefits that GI can deliver [12]. The benefits of GI and measure indicators examine Bole Road context with the pavement, bioswales, planter boxes, trees, footpath and car path altogether deliver.

The expert's opinion on the chosen site is summarized, to determine the GI value difference multifunctionality level.

## 2.2 Addis Ababa transport impact

In today's cities like Addis Ababa, transport impact on most people falls outside the scope of the calculations. At the same time, the benefits of increased vehicle traffic volumes and speeds are recognized. However, environmental impact and reductions in walkability are often overlooked. The negative environmental impact of mobility-based transport planning has become undeniable and critical [46]. Such planning practices can reduce travel options, increase traffic collisions and encourage sprawl [47].

Additionally, it has a consequence on the environment. "Currently, transportation represents 68% of the city's greenhouse gas (GHG) scope 1 emissions" [48]. Furthermore, Fine

**Table 1: GI benefits and measure indicators.**

A. Safe & attractive links between community facilities. [12],[13],[14],[15]	B. Offer Social interaction [12],[16],[17],[18],[19]	C. Improve physical activity and health. [17],[20],[21],[22],[23],[24],[25]	D. Improves Mental health [12],[15],[17],[22],[26],[27],[28]
✓Easily reachable by everyone they're intended to serve ✓How adequately serve all the people that want or need to use them? ✓Do they discourage crime? ✓How well are they maintained? ✓Well-designed for their intended uses? ✓How safe are they? ✓Are they beautiful, exciting, and functional? ✓Physically accessible for all ✓Are they clean and well maintained? ✓Are the Facilities as flexible as possible?	✓How involved are the local community? ✓Provides residents with a sense of ownership ✓Does it improve community cohesion? ✓Does it increase physical activity and social engagement? ✓It includes walking, cycling, having a barbecue, or a meeting place ✓Have sufficient of urban furniture ✓How well is the aesthetic appeal of urban furniture? ✓Space to play for children	✓Is it easily accessible? ✓Creates opportunities to exercise ✓Encourages active travel, jogging, walking, and cycling ✓Does it help to improve air, water, and soil quality ✓Can it promote healthy lifestyles? ✓Optimize opportunities for working, learning and development. ✓Space to play for children	✓Does it feel comfortable and at ease? ✓Is it easily accessible for the communities? ✓Increasing social interaction, reduce isolation and stress. ✓Green and safe place ✓Reducing noise pollution ✓Considers older people ✓Pleasant View ✓Space to exercise ✓Restorative, uplifting and healing
E. Appealing places for living [12],[15],[29]	F. Appealing place for working/studying [12],[20],[30]	G. Appealing places & routes for recreation [12],[15],[31],[32]	H. Appealing places for increasing land/property values & demand [12],[15],[20],[22],[33]
✓A place with unique and lasting appeal ✓A place where people feel at home ✓Resource efficiency ✓A place that allows green mobility ✓It makes the area clean and healthy ✓Plays a role to make green and pleasant place ✓Well-managed and democratic	✓Protect the distinctiveness and character of the district and its settlements. ✓Cultural heritage and appreciation of sense of place. ✓Improve recreational links ✓Footpath to encourage walking in the area. ✓Connectivity and permeability of routes ✓Green and pleasant	✓Play facilities are available ✓Cycling and walking facilities provided ✓Enhance an area's image ✓Visual appearance and attractive ✓Recreational opportunities ✓Creates a chance to travel through natural ecosystems	✓Safe to live, to walk ✓Accessible for all age group ✓Attract visitors ✓Offers variety of opportunities ✓Retail and leisure spending ✓Well-maintained green space ✓Pleasant view
I. Decrease urban run-off. [12],[15],[20],[34],[35],[36],[37],[38]	J. Urban cooling [5],[12],[20],[36],[37]	K. Enhance air quality [5],[12],[20],[22],[36],[37]	L. Offers an Attractive setting for landscape /cultural heritage assets: [12],[20],[33]
✓flood alleviation ✓Reduce water velocity ✓Change water direction ✓Temporary holding before release ✓Increased vegetated land cover	✓Temperature reductions ✓Larger area of trees ✓Direct shading ✓Comfort for walking and cycling ✓Maximizing cooling via shading. ✓Minimizing the exposed surface to great amounts of sun radiation ✓Minimizing heat generation in environment	✓Shield the city from penetrating pollutant air or dust storms ✓Promotes non-motorized transport (by green structure) ✓Regulating temperature through shade and wind and humidifies the air ✓Trapping of dust	✓Produces green link/corridor ✓Good green/tree boundaries ✓Create a clear sense of place. ✓Conserve and create links to existing urban area ✓Preserve site and setting ✓Appropriate viewing opportunities and interpretation ✓Conserve existing historic field
M. Provide environmental resource for education & skills development [11], [12],[39]	N. Provide attractive places for tourism:[12],[22],[30],[40]	O. Carbon sequestration [12],[22],[34],[37]	P. Provide habitat/habitat for fish, wildlife species:[12],[15],[5],[22]

**Table 1: (Continued)**

<ul style="list-style-type: none"> <li>✓ Educational potential</li> <li>✓ Help to progress understanding of sustainability matters</li> <li>✓ Provide opportunities for residents to interact with urban nature</li> <li>✓ Inspire citizens to take actions to improve the environment in cities.</li> <li>✓ Benefit residents through conservation and enhancement of ecosystem services</li> <li>✓ Offer nature-based opportunities for place based environmental education</li> <li>✓ Use educational spaces that may not be seening as educational (e.g. Mechanical places of green buildings, waste-management amenities and bioswales)</li> </ul>	<p><b>Q. Provide attractive places for securing inward investment:</b> [12],[20],[33]</p> <ul style="list-style-type: none"> <li>✓ Ability to perform several functions</li> <li>✓ Attractive and accessible places for people</li> <li>✓ Act as a tourism site</li> <li>✓ Deliver landscape character enhancement</li> <li>✓ Sufficient close-by facilities</li> </ul>	<p><b>Q. Provide attractive places for securing inward investment:</b> [12],[31]</p> <ul style="list-style-type: none"> <li>✓ Vegetation strips of roadside and fence line</li> <li>✓ Includes wetland and shore habitats</li> <li>✓ Fauna moving through disperse pollen and seed</li> <li>✓ Patches of native vegetation</li> <li>✓ There exist Movements of species</li> <li>✓ Provide food and shelter for wildlife.</li> <li>✓ Providing landscape connections between areas of habitat</li> </ul>	<p><b>R. Provide wildlife corridors</b></p> <ul style="list-style-type: none"> <li>✓ Provides walking, picnicking and taking photographs place</li> </ul>	<p><b>S. Provide local food &amp; energy production</b></p> <ul style="list-style-type: none"> <li>✓ Presence of long rooted crops</li> <li>✓ Soil management practice</li> <li>✓ Practices of carbon farming</li> <li>✓ Trees in the equation as well.</li> <li>✓ Availability of allotment areas</li> <li>✓ Localizing and improving food production</li> <li>✓ Embrace biodiversity</li> <li>✓ Use natural energy or renewable energy source</li> </ul>	<p><b>T. Economic benefits</b></p> <ul style="list-style-type: none"> <li>[12],[20],[42]</li> </ul>
<p><b>U. Reduce traffic accidents</b></p> <ul style="list-style-type: none"> <li>[1],[12],[36],[43]</li> </ul>	<p><b>V. Buffered against drought</b></p> <ul style="list-style-type: none"> <li>[12],[44]</li> </ul>	<p><b>W. Sound pollution</b></p> <ul style="list-style-type: none"> <li>[1],[12],[45]</li> </ul>	<p><b>X. watersheds/water resources</b></p> <ul style="list-style-type: none"> <li>[12],[15],[38]</li> </ul>		
			<ul style="list-style-type: none"> <li>✓ Driver comfort by giving relief from the sun and wind</li> <li>✓ Visual comedy landscape</li> <li>✓ Presence of trees, vegetation barriers</li> <li>✓ Permeable surface</li> <li>✓ Supports non-motorized movements</li> </ul>	<ul style="list-style-type: none"> <li>✓ Restock groundwater reserves</li> <li>✓ Availability trees and green roofs</li> <li>✓ Water quality protection</li> <li>✓ Flood mitigation</li> <li>✓ Permeable/Pervious/Porous pavement</li> <li>✓ Limit and reduce the effects of change on the local environment</li> <li>✓ Availability of bioretention cells, stormwater planters, tree pits, and rain gardens,</li> </ul>	

Table 2: Sample to illustrate expert's opinion table. The experts listed from 1 to 14 evaluated the benefits listed in 2.1 from A to X in Bole road.

GI benefits	A-X														
Experts	1-14														
Experts opinion (1-14) 	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Green infrastructure benefits(A-X)															
A.Provide safe & attractive links to / between community facilities	L	L	L	L	L	L	M	M	L	L	L	VL	L	L	
B.provide social interaction	L	H	L	L	L	L	L	L	L	L	L	L	M	L	
C.provide opportunity for physical activity and health	VL	M	L	M	L	L	L	L	M	L	L	VL	M	L	
D.provide opportunities for improving mental health	VL	L	L	M	L	L	L	L	M	L	M	L	L	L	

particulate matter (PM2.5) annual average concentration is twice the World Health Organization guidelines, which raises serious health concerns for the city citizens [49]. Indifferent from the history of the developed world transport system, Addis Ababa transport planning is trying its best to make the city suitable for motorization. Conversely, 70% of the population is pedestrian [50]. Even though Addis Ababa has a low road network density and vehicle ownership, cited as the worst example of traffic accidents. Considering the trend of road crashes in Addis Ababa, Ethiopia, ultimately, the opposite is evident; Addis Ababa and the country face a high rate of traffic collisions despite low car ownership. The death rate by traffic collisions reaches at least 114 per 10,000 vehicles per year, while in the UK and Ireland, only 10 and 60 [51]. According to the review, Addis Ababa, Ethiopia's capital city shares more than 60% of the traffic collisions in the country; pedestrians were the most affected, taking 79% of the total injuries.

According to the Addis Ababa police commission report, 391 people lose their lives on Addis Ababa streets each year. Even it might be bigger than that, according to [52] referencing the world health organization, the actual number is six times the reported number. If history has been taught as right, automobile-oriented development has caused many misshapes to society.

### 2.2.1 African avenue/bole road

It is located at the west of bole sub-city and south of the kirkos sub-city. It is the main road that connects Addis Ababa international airport and Meskel square. According to the traffic officers, the road is called VIP street since most international guests use the road as an entrance and exit from the city. So it has a considerable value in showing the city image. The width of the road increased to eliminate traffic collisions and traffic congestion. The data collected in this road segment helps evaluate the strategy to increase roads' width if it helps eliminate traffic collisions. The research tried to seek if road construction helped reduce traffic jams and traffic collisions as intended? Furthermore, seek if it has created multifunctionality in green infrastructure.

The study tries to show an overview of the recent road infrastructure development in Addis Ababa but primarily focusing on the road from Meskel Square to Bole AirPort, African Avenue/Bole Road. The premises for the selection of this specific site are

- African Avenue's recent construction provides the research with conditions that best represent the current transport planning and delivery system. Addis Ababa city road authority (AACRA) has launched a road development program to upgrade, rehabilitate and expand the city road network. AACRA considers the African avenue project as exemplary for the development program.

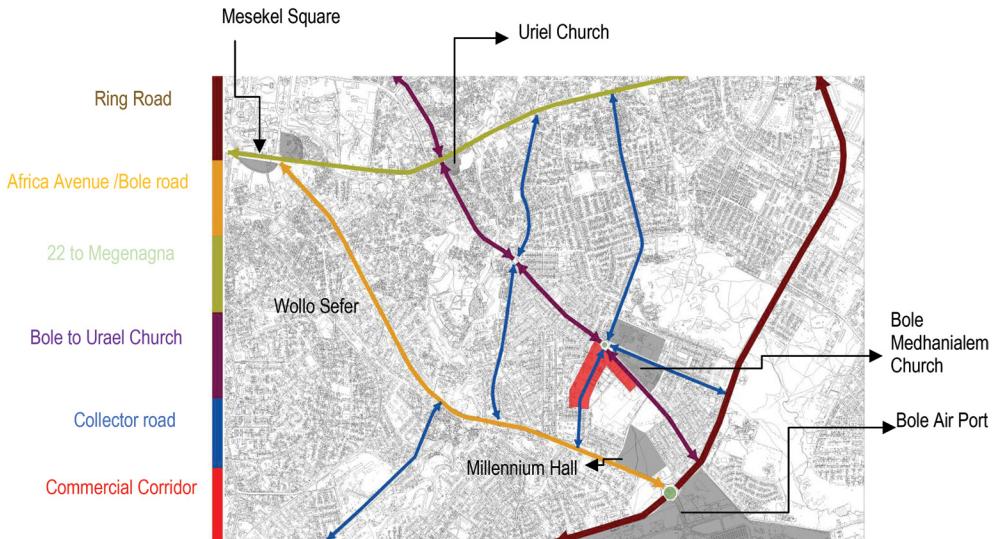


Figure 2: Location of African avenue/Bole road. Source: [6].

- The reason for constructing and updating African avenue gives a benchmark to compare it with its former condition.
- The symbolic importance of the path as it is the gateway to the city and main corridor of the city.
- It is found in the two top sub-cities experiencing the highest rate of car accidents involving pedestrians in Addis Ababa.

### 3 RESULTS

We explored the pavement, bioswales, planter boxes, trees and the road of Bole/African avenue altogether deliver with a possible 24 GI benefits to analyse the estimated value differences and categories of multifunctionality. Figure 3 shows the results of the model based on the expert's view. It uses the measurement of the category of multifunctionality (VL 4 and less, L 5-6, M 7-8, H 9-10, VH 11 and above). It is a very low category of multifunctionality; considering the possible benefits gained from the asset, the result indicates that attention is needed [12].

The relative percentage difference calculator indicates that the lower the current GI assets benefits are, the higher the difference is and vice versa [12]. The GI value percentage difference between Bole street's possible GI benefits and Bole's current GI benefits (PGIB and CGIB) is 69.23%, making the GI value difference gap high. The GI value difference results and categories of multifunctionality indicate a need for attention to GI strategies. Figure 4 shows the difference between the possible GI asset benefits and the current benefit that they are giving, indicating which GI benefit needs attention and can help the transport sector.

One of the benefits of green infrastructure is the reduction of traffic accidents. According to the expert's opinion and the data supported, Addis Ababa has a high traffic accident rate [53], and bole road follows the same trend.

Table 3: Identified current GI benefits in Addis Ababa ,through experts opinion.

Site	Identified current GI benefits(CGIB)	Identified Potential GI benefits(PGIB)
Bole/Afric an avenue	E,F,H,L (4)	A,B,C,G,I,J,K,O,P,R,S,U,W (13)

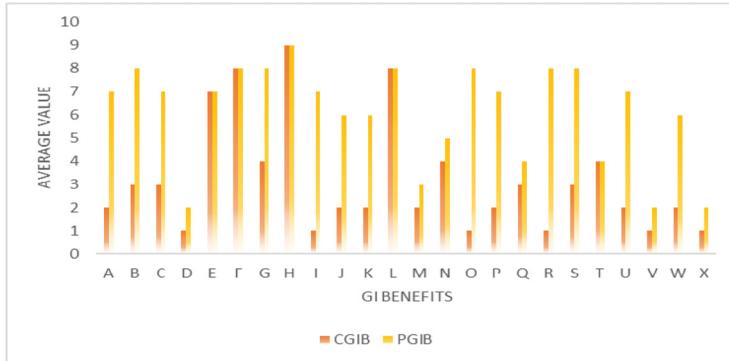


Figure 3: GI value difference.



Figure 4: Monthly report on the total collisions on vehicles and pedestrian before and after construction of the road.

### 3.1 Traffic accidents, in African avenue (bole taxi station up to Wollo sefer)

We collected this data from the bole sub-city traffic police's report. Since the office does not have specific data on every individual accident, we analysed every written statement of the traffic police officers in the period needed for the paper and dragged reports of every collision and injury in the sub-city from July 2011 to August 2012, from July 2013 up to August 2014.

September 2013, up to the end of June, the road was at construction and out of service. We chose this period to show the collisions and injury rate before and after the construction or the widening of the African avenue project.

Figure 5 shows the widening of the street did not reduce accidents, especially on pedestrians. The pedestrians impacted by the collision rate increase every month.

#### 4 DISCUSSIONS

After the experts explored transportation elements in African avenue and used GI benefits as an evaluator, the paper found road safety as a sensitive issue in the current trend of Addis Ababa transportation planning. The main reason African avenue was modified was to ensure road safety, lower environmental impact and decrease congestion. However, the existing transport system is characterized by high accident levels, high traffic congestion and negative environmental impacts; studies [51,56] support the same conclusion. All the questioned officers mentioned that widening the existing road attracted more traffic to the streets, which increased collisions. Experts also noted that an increase in the road width does not consider green elements and pedestrians, reveals the deaths and injuries in road accidents, greenhouse gas emissions, noise and environmental impacts of traffic congestion. The paper suggests green infrastructure benefits as a measuring tool to leapfrog from the current experience and adopt sustainable strategies.

##### 4.1 Leapfrog

The study's findings revealed that environmental impact and traffic accidents are increasing in Addis Ababa. On the other hand, the study shows how green infrastructure development has an immense benefit and can be used as a framework. A transportation scheme without undesirable impacts or minor impacts is not only wanted but also crucial. Luckily, it is technologically possible, but government strategies and social attitudes would need substantial changes and leapfrog from the current trend. Therefore, it is premised that leapfrog to green infrastructure should put technical methods in association with suitable economic strategies and management practices.

The concept of leapfrogging suggests that there is a potential for developing cities like Addis Ababa to learn from the developed world's paths. Learn from the mistakes they made and avoid them. Cities like Addis Ababa, which are at the early stage of infrastructure development, have options to take an efficient way. So why not leapfrog? "Technological leapfrogging refers to a process in which developing countries can bypass intermediate development steps and progress directly to more advanced technological options" [54]. Macmillan dictionary defines the word leapfrog as "to go straight from a job or position that was lower in status than someone is to one that is higher than theirs" [55]. According to Todd Litman, "in urban transport, this process could infer a move directly to more sustainable transport options rather than committing to a predominantly auto-based urban form" [57].

The hierarchy of urban transport through an evolutionary process has five stages. The lowermost stage is the time where trips are made by foot to access needs. Then follows where minibus vehicles support trips. Then comes in the middle, two-wheel vehicles; next comes, complete motorization stage (private cars and limited public transport); at the top of the pyramid comes green transportation with more sustainable options [56]. The question for a city like Addis Ababa is to see the possibility of leapfrogging and how? The city is in the paratransit dominant stage at the bottom of the pyramid. Minibusses (vans) provide most

public transport, so it is possible to leapfrog to the top of the pyramid before going through the remaining stages.

As [57] suggests, a city like Addis Ababa can move directly towards the top of the pyramid where green transport and not motorized infrastructures dominate since motorization levels are still relatively low. Curitiba has become a source of inspiration for other cities aspiring for smart status but low cost [58,59]. The case of Curitiba indicates a possibility for the developing world to take a chance and leap 40–70 years of transport planning experience that led to more construction of new roads and transport infrastructure. This loop of increased car, adding roads, increased congestion and accidents have led to a decrease in the quality of urban life.

## 5 CONCLUSIONS

The construction of new roads and maintaining the existing ones is increasing throughout the years; evaluating constructed roads through GI measurements indicates the need to leap current trend. GI delivers an adverse range of benefits—environmental, economic and social benefits to urban dwellers. The listed benefits and measure indicators in Table 1 can be adopted to measure infrastructure in green and grey developments and identify its multifunctionality. While the term GI has been around for a long time, it is still essential to promote GI benefits. The identified benefits of GI assets have room for further study even though this study tried to investigate numerous studies. A more accurate view of green infrastructure assets and their benefits helps local governments, professionals and communities decide where, when and to what extent green infrastructure practices should become part of future planning. This study shows the direction for further research and helps to evaluate and identify GI asset that needs attention. Furthermore, this study can be used as a checklist for the new ongoing projects in the city.

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