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Measuring the walkability of areas around Addis Ababa LRT stations by integrating Analytic Hierarchal Process (AHP) and GIS

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Abstract

Creating suitable walking conditions is the primary objective of sustainable urban models such as Transit Oriented Development (TOD). Walkable built up area benefit cities economically, environmentally, socially and improving public health. This can be utilized by creating suitable streets that enable people to access their daily needs walking without relying on private cars. Therefore in planning TOD, the existing walkability of the areas around transit station should be investigated taking factors that encourage walking into consideration. The objective of this research is find spatial method to measure the existing circumstances that encourage walking around Addis Ababa LRT stations by integrating the Analytic Hierarchy Process (AHP) and Geographical Information System (GIS). The results clustered areas with similar levels of walkability in group and represent them with different colors. The finding the study revealed that the majority of the study areas (approximately 72.35%) were classified as fairly walkable, 19.47% of the study area clustered as not walkable and only 8.15% clustered as walkable. This result is expected to offer valuable insights for urban planners and decision-makers to pass calculated decision to enhance walkability of the areas. As this method continues to advance with technologies it will play crucial role in planning TOD focusing on shaping the future of urban walkability and creating sustainable cities.

Keywords: Addis Ababa; Analytic hierarchy process (AHP); Geographical information system (GIS); Transit oriented development (TOD); Walkability; Weighted overlay analysis.

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1. Introduction

Easy access of people to their daily needs by walk within a built-up environment is essential criteria of sustainable urban development (Distefano et al., 2023; Moayedi et al., 2013; Rafiemanzelat et al., 2017; Talen & Ellis, 2002) and it is the right of all walks of life including people with disabilities (Erçetin, 2024). In the research aims to highlight the potential of insight in terms of integrated approach towards urban mobility and accessibility through the adoption of user-centered paradigm (Costa & Delponte, 2024) stated contemporary individual needs certainly require to shape mobility in order to assure universal access to facilities and opportunities. Many researches such as (Fang et al., 2023; Lamour et al., 2019; Toralles, 2023) have stressed that creating walkable environments is essential components of Transit Oriented Development (TOD) that promote sustainable urban development. TOD emphasizes high density, diverse land use, and pedestrian-friendly design around transit stations (Berawi et al., 2020; Cervero & Kockelman, 1997; Distefano et al., 2023; Ganning & Miller, 2020; Kumar et al., 2020; Mirmoghtadaee, 2016). Despite walking being the most common, cost-effective, environmentally friendly, and healthy mode of transport (ITDP, 2017; Loukaitou-Sideris, 2020; Schmeidler, 2014), recent urbanization trend focusing on motorized transport than walking. To address this issue, several sustainable urban development models have been proposed, including neo-traditional development, compact city, smart city, eco-city, and TOD (Jabareen, 2006; Rossetti et al., 2020). In all these sustainable development models, creating pedestrian friendly, walkable environment is considered crucial criteria. However this can be achieved through well-connected streets design, ensuring safety, promoting diverse land use, and increasing the number of commercial facades (Lamour et al., 2019) street amenities such as sitting areas and street lights along the walking street.

Walkable conditions benefits a city in various ways such as reducing traffic congestion, reduction in traffic casualties, reducing greenhouse gas emissions, increasing economic vibrancy along the street and increasing social cohesion (Khare et al., 2021a; T. Litman, 2017; T. A. Litman, 2003). Moreover it benefits personal health since it encourages physical activity, thereby promoting fitness, combating chronic diseases, such as obesity (Baobeid et al., 2021; Boarnet et al., 2008; Ewing & Cervero, 2010; Hossein Pour et al., 2018; Zapata-Diomedi et al., 2019). In planning to implement TOD, the existing walkability of areas to access transit stations and other important destination need to be investigated. This requires rigorous assessment that considers multiple variables (Baobeid et al., 2021; Ha et al., 2015; Knapskog et al., 2019; Naharudin et al., 2020). Researchers have used different methods and considered different variables to measure the walkability of an area, depending on the objectives, availability of important data and local conditions (Knapskog et al., 2019; Lu et al., 2018; Pilgram & West, 2023). Some studies have attempted to measure walkability at various scales, including citywide (Jeong et al., 2023; Kim et al., 2019; Telega & Telega, 2021), neighborhood (Ensari et al., 2023; Kim & Kim, 2020), and small areas around transit stations (Jeffrey et al., 2019; Naharudin et al., 2020; Pilgram & West, 2023; Shaaban et al., 2018). Regarding the type of data, some use subjective data, such as pedestrians' perception (Naharudin et al., 2020), whereas others use objective data. Spatial methods of measuring walkability of areas can provide valuable insights for urban planners and policymakers to identify which areas are suitable for walking or not. It would also help identify and prioritize the places that need intervention to improve walkability level. Therefore, the objective of this research is to find suitable spatial method to assess the walkability of an area, within an 800-meter radius around the Addis Ababa LRT stations by integrating the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS). AHP enables the analysis of multiple variables in a hierarchical manner, whereas GIS allows visualization and analysis of spatial data and produces a thematic map. The result displays areas with the same level of walkability in clusters and represented them in different colors. Therefore, this study is guided by three research questions:

1. What are the main variables (performance indicators) for walkability of area around transit stations in urban environment particularly Addis Ababa?

2. What is the significance of these performance indicators compared to each another?
3. How the walkability level of areas around of Addis Ababa LRT stations could be spatial evaluated?

To address these research questions, the study has the following specific objectives:

- Identify the main performance indicators (variables) of walkability in the context of Addis Ababa;
- Weight the significance of these variables among each other to impact walkability using the AHP;
- Find suitable way to integrate AHP and GIS to measure the walkability level of the area around four Addis Ababa LRT stations.

The remains of this paper are organized as follows: The next section provides a literature review on walkability, the main variables of walkability, methods used to measure walkability, and the integration of AHP with GIS. Section 3 describes the methodology employed in this research, focusing on weighting the significance of identified variables and the integration of AHP results in GIS through Weighted Overlay Analysis. Section 4 presents the results and finally section 5 summarizes the research, provides conclusions, and suggests future research areas.

2. Literature review

Walkable environment around transit station is the main prerequisite for TOD (Higgins & Kanaroglou, 2016; Jeffrey et al., 2019; Md. Kamruzzaman et al., 2014). In the research by (Pongprasert & Kubota, 2019) highlighted the significance of walkability by investigating the attitudes of TOD residents towards walking to transit stations. Measuring the walkability of the areas around transit stations is an important step (Khare et al., 2021a; Pilgram & West, 2023; Telega et al., 2021; van Nes, 2021) in advance of implementing TOD. Developing a method to measure walkability of urban areas for the purpose of improving its suitability to walk is utmost crucial (Hossein Pour et al., 2018).

2.1 The benefit of walkability in TOD

Walkable condition in TOD area reduce reliance on private cars, reduce traffic congestion, stimulate economic development, improve health outcomes, fostering a sense of community, and promoting environmental sustainability (Baobeid et al., 2021; Iamtrakul et al., 2021; Khare et al., 2021b; Wey & Chiu, 2013). Since benefits of walkability are multifaceted the focus of researchers varies based on perspectives and objectives the research. For example, a study by (Wey & Chiu, 2013) highlights the significance of pedestrian-friendly design in reducing automobile use, while (Lamour et al., 2019) focuses on the safety and security. Another study by (Lu et al., 2018) underscores the importance of walkability in sustainable planning strategies, and (Pongprasert & Kubota, 2019) emphasizes its benefits in terms of convenience, safety, and environmental concerns. Improving accessibility to important destinations and supporting strategic economic and sustainable urban development is considered by (Schlossberg & Brown, 2004). It also fosters social cohesion by encouraging interaction among individuals and encourages buying daily needs from local store, thereby support the local economy and strengthen the sense of community. Economically, walkability increases transit ridership, reduces transportation costs, facilitates business growth, and lowers infrastructure expenses and reduce housing problem (Gerardo et al., 2019). Environmentally, walkability yield positive outcomes in terms of low-carbon emissions, which is crucial for climate change adaptation (Baobeid et al., 2021; Ewing & Cervero, 2010). Generally, walkability is the core component of contemporary sustainable urban development models'.

2.2 Influencing variables (performance indicators) of walkability

In order for pedestrians to choose walking for their daily trips, certain encouraging conditions should be in place. Various studies have proposed different criteria for walkability based on objectives, perceptions, and the availability of important data for analysis. The most critical components of walkability are activities within the neighborhood, accessibility, structuring street network, safety, attractiveness and users density of streets (Batman et al., 2024). The Victoria Transport Planning Institute (VTPI, 2011) identifies pedestrian facilities, walkway condition, land use patterns, community support, security, and comfort as the main indicators (Rohana, 2015). The London Planning Advisory Committee takes a different approach and emphasizes connectivity, convenience, comfort, conviviality, and conspicuousness, calling them the '5C' features (Moura et al., 2017). Later on two more features such as coexistence and commitment, were added, making a total of '7C'. These seven features were measured using a set of 17 key indicators known as the Indicators of Accessibility and Attractiveness of Pedestrian Environment (IAAPE). In a research technique to quantitatively analyze walkability (Schlossberg, 2006) presented street network classification, pedestrian catchment areas and intersection density as the influencing variables. In the development of a conceptual framework to assess walkability in Malaysia, comfort, connectivity, convenience, conviviality, and conspicuousness were identified as the main indicators, endorsing the approach taken by Transport for London (Naharudin et al., 2020) . In another research by (Frank et al., 2005) identified building density, land use mix, and connectivity level. All the above literatures suggest different criteria that encourage walking within urban environment, however it is firm believer of the authors that it also depend on existing local condition of the city.

2.3 Methods of measuring walkability

There are numerous studies that have presented different methods for measuring the walkability of an area. The methods vary based on the objectives, perception, and scale of the study area. Additionally, the approaches used for analysis can differ depending on the type of data being used (subjective or objective). For measuring the walkability of an urban area (Telega et al., 2021), categorized the methods into four groups: (i) subjective methods based on surveys, interviews, and questionnaires; (ii) subjective methods using direct audit tools or stock-taking; (iii) objective methods utilizing GIS tools; and (iv) mixed methods. This approach they integrated open source spatial data and utilized the Kernel Density and Line Density tools in ArcGIS software to measure the walkability in Krakow, Poland. In measuring the walkability of a pedestrian street (Naharudin et al., 2020) combined ANP and GIS and integrated subjective and objective data. In a study conducted in Melbourne, Australia by (Cowie et al., 2016) , the walkability of areas around 230 train stations was measured using road density to identify "sweet-spots" (high walkability-low weighted road density) and "sour-spots" (low walkability-high weighted road density). A study in assessing the most suitable walkable path in Shiraz city, Iran (Schlossberg, 2006), integrated GIS, remote sensing, and multi-criteria evaluation (MCE). An objective walkability index was developed by (Frank et al., 2004) considering parameters related to people's health using GIS, which consisted of the sum of residential density, intersection density, and land use mix as indicators. In recent research aimed at promoting the environmental benefits of walkability (Jeong et al., 2023), combined a walkability index and transit accessibility index to create a walkable, transit-friendly metropolis. The potential of integrating AHP with GIS to measure walkability has been highlighted by studies such as (Gervasi et al., 2018; Lee et al., 2013; Rossetti et al., 2020; Schlossberg, 2006). AHP allows for assigning weights to each factor based on their relative importance, while the weighted overlay tool in GIS can calculate the walkability of areas. This index can then be used to identify areas with higher or lower walkability and prioritize interventions to improve walkability.

3. Methodology and data used

The methodology entails identifying key factors that contribute to a pedestrian-friendly environment, gathering data to analyze each variable, prioritizing the variables based on their influence, and evaluating the walkability of areas surrounding the stations. The research establishes six performance indicators, namely street network density, intersection density, land use diversity, business activities along the route, safety and security features, and comfort of street. AHP is then employed to determine the significance of these indicators. The walkability level of the areas around the four Addis Ababa LRT stations is finally measured by integrating the result of AHP into GIS using the weighted overlay tool. Spatial data for the areas around four selected stations is extracted from a geospatial database of the study areas. The vector layer is converted into a raster layer and reclassified to ensure easy integration into GIS. The weighted overlay analysis tool is utilized to combine the AHP results with the reclassified raster layer in the GIS software. Each indicator's percentage score from AHP is multiplied by the corresponding cell value in the reclassified raster layer. The sum of these results for each grid cell provides an overall value for the walkability level of the areas. The final outcome is then plotted on a spatial map. The methodology is illustrated in Fig.1.

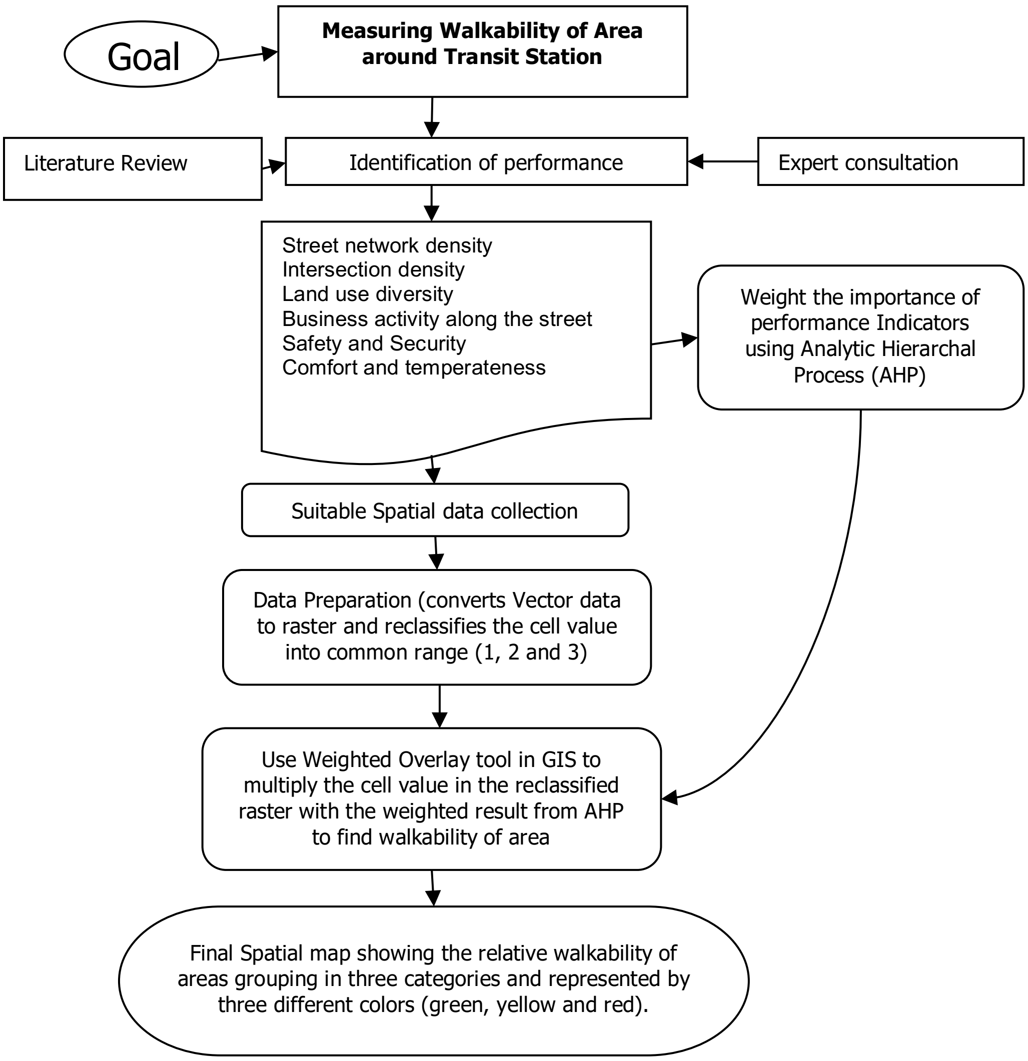

Fig.1 Schematic representation of methodology

3.1 Study area

Addis Ababa is the economic, political and diplomatic capital of Ethiopia with political boundary of 572 square kilometers and located at the central core of Ethiopia at an average elevation of 2,400 meters above mean sea level. The population and housing census which has been scheduled for 2017 delayed due to domestic security concern to 2020. The delayed 2020 census was rescheduled again in response to COVID-

19. Therefore according to 2007 population and housing census the population of Addis Ababa is more than 2.7 million with an annual growth rate of 3.8% per year.

The city has experienced unprecedented horizontal expansion and informal settlements that has caused political instability due to encroachment of surrounding farmland. It is also the main reason that has exacerbated the ousting of the central government from power in 2018. With the purpose to analyze the physical extent and proportion of population living in formal and informal settlements in Addis Ababa (Berhanu; et al., 2024) find out that informal area constituted 61% and 59% of the residential land use in 2011 and 2022, respectively.

To address long standing transportation problems in the city, the Federal Government, in collaboration with the Addis Ababa city administration, implemented the Light Rail Transit (LRT), connecting the four corners of the city to the central Business District (CBD). Ever since LRT's commencement in September 2015, is has played a significant role in easing transportation problems. However LRT itself faced has faced financial challenges that would jeopardize its sustainability. In addition, the LRT system intended to resolve mitigate traffic congestion, air pollution and GHG emission the system's impact on the environment is criticized due to lack of enough crossing points for cars to cross from one side to the other. TOD is considered as one of the remedial measures to address the financial shortage.

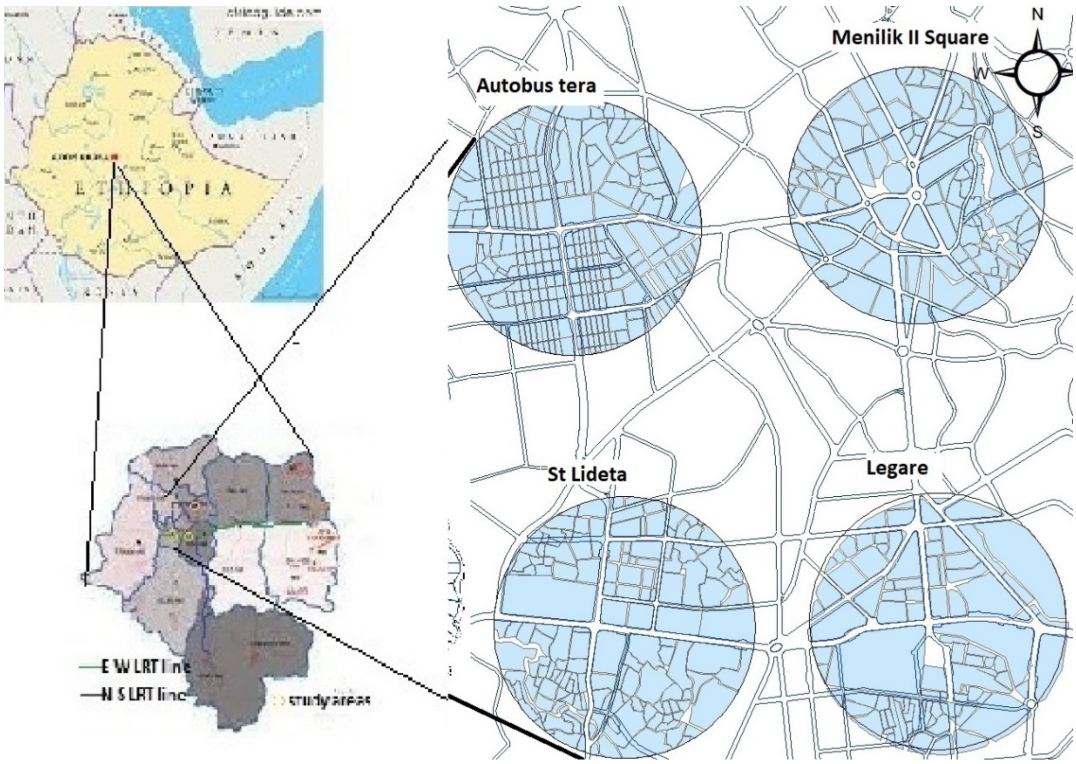

Fig.2 Detail map of the study area

Ethiopian Railways Corporation (ERC), in charge of LRT together with the Addis Ababa City Administration established a steering committee (Tekolla et al., 2021) to oversee the planning and implementation of TOD. The feasibility study has been conducted along the LRT route, focusing on 10 stations, and a detailed bankable feasibility study also been undertaken on four stations mainly located in the central Business District (CBD). These stations are Legare station, St. Lideta station, Autobus Tera station, and Menelik 2nd square station as shown in Fig.2. In order to understand if TOD would be a real solution for the problem, a rigorous investigations need to be performed. One of these investigations is measuring the existing walkability of built-up area around the transit station. Walkability is defined as a measure of how friendly an area is for walking (Westaby, 2019).

3.2 Identification of the indicators, data collection and preparation for the analysis

The variables of walkability identified in this research are street network density; intersection density; land use diversity; safety of walkways and crossings; business activity and vibrancy along the streets and comfort and temperateness of the street. To analyze the variables primary and secondary data used. The primary data have been collected interviewing experts in the relevant field to weight the significance of multiple influencing variables using AHP. Secondary data is a spatial data extracted from Geospatial Database of the study area. The vector layer converted to raster layer and reclassified to fit for the analysis as shown in Fig.3.

Street network density (SND)

Presence of enough street networks invites pedestrian to walk than taking private car. Thus street network density considered as an influencing factor in most research regarding the assessment of walkability (Frank et al., 2005; Schlossberg, 2006). The data used to analyze street density extracted from Geospatial data of the study area. Vector layer of road network was converted to a raster using the line density tool in GIS and reclassified to the common range of (3, 2, and 1) representing higher, moderate and low street density respectively as shown in Fig.3A.

Intersection density (ID)

Road crossing provides shortcuts for pedestrians to overcome network barriers. Higher intersection density increases connectivity, accessibility and interconnected street network. To analyze intersection density point data was extracted from the geospatial data of the study area. The vector layer was converted to a raster layer using the point density tool in GIS software and reclassified common range 3, 2 and 1 representing higher moderate and low intersection density respectively as shown in Fig.3B.

Land use diversity (LUD)

Land use diversity determines access to various important destinations such as retail shops, public services, and recreational areas (Suminar & Kusumaningrum, 2022). However the interaction of transport and land use are complex and not widely analyzed (Carpentieri et al., 2019) and suggested new governance tools to support territorial transformations for sustainable use of land resources. In this research to analyze land use diversity, data was extracted from the Geospatial data of the study area in vector format and then converted into a raster layer. The raster layer reclassified to a common range (3, 2, and 1), as shown in Fig.3C.

Safety and Security of the Streets

Safety and security play a significant role in the walkability of an area. The streets and crossings must provide encouraging environment for pedestrians, avoiding crime, robbery and traffic fatality (Jamal, 2017). For the analysis of safety and security, the study areas have been tessellated into a 400 by 400 meter vector map. Each cell has been filled with a value based on relative safety and security. If the area is believed to be safe and secure, the cell value is 3; if the area is fairly safe, the cell value would be 2; and if the area is not safe, the cell value would be 1. The vector file was converted to a raster with three cell values (3, 2, and 1) as shown in Fig.3D.

Business activity and vibrancy of the streets

The presence of business activity along the streets enhance walkability as it provides convenient access to a variety of retail shops (Knapskog et al., 2019; Batman et al., 2024). Walking in a city provides ample time to experience everything the ground floors have to offer (Singh, 2016). To evaluate the presence of business activity on the streets, the study area has been divided into 400 by 400 meters grid cells and assigned cell values of 3, 2, and 1 based on the relative number of business on the streets. If business activities good, assign a cell value of 3; if there is a fair amount of business activities, assign a cell value of 2; and if there are less business activities along the streets, assign a cell value of 1. The vector layer then converted to a raster layer to common range 3, 2, and 1, as shown in Fig.3E.

Comfort and temperateness of street

Pleasant and comfortable streets encourage people to walk for more than just commuting such as for recreation. Elements such as street furniture, plantings, overhead lighting, and improved landscaping enhance the appeal of walking (Jamal, 2017). To assess the comfort and suitability of the streets, we divided the study area into grid cells measuring 400 by 400 meters. Each cell was assigned with cell value of 3, 2 and 1 based on the comfort and temperateness of the cell. A value of 3 indicates a comfortable walking area, 2 indicate a fairly comfortable area, and 1 indicates an area that is not comfortable for walking. Then vector layer was converted to a raster layer with values (3, 2, and 1) as shown in Fig.3F.

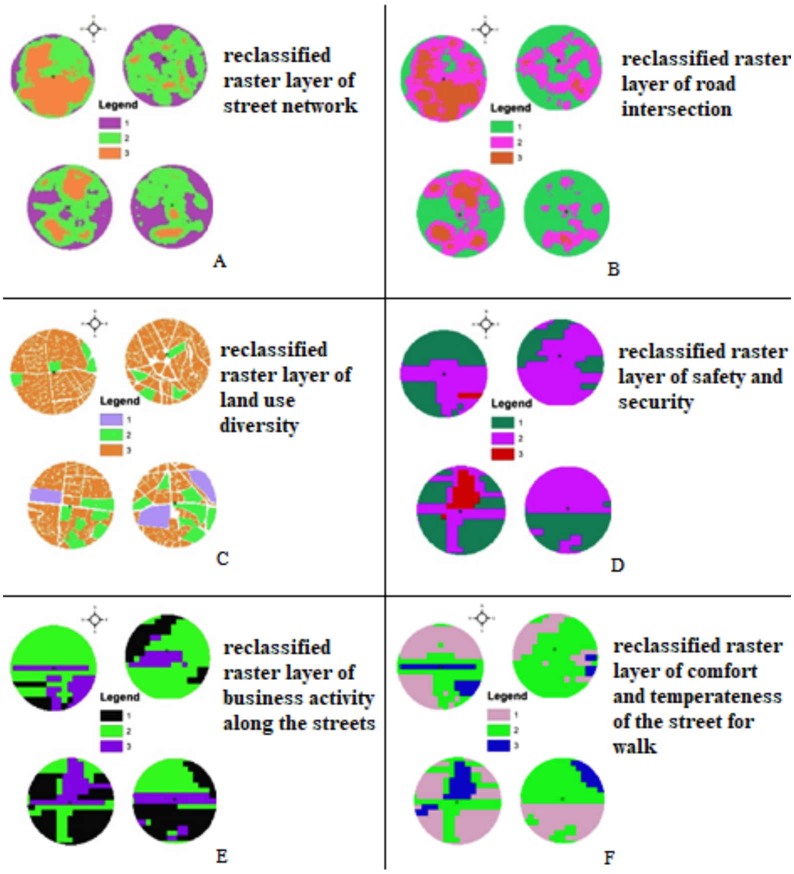

Fig.3 The reclassified data of the indicators

3.3 Weighting significance of walkability indicators

Analytic Hierarchy Process (AHP) technique has been utilized to weight the influence of variables according to their significance. A questionnaire survey was conducted among 30 experts in the relevant field. The experts are asked to rate the significance of the identified variables to influence walkability of areas. The expert judgments were then summarized into a single score, which was then used to create a pair-wise matrix.

The critical steps in AHP are building hierarchy, establishing comparative pair-wise matrix, calculate the significance, and finally check the consistence of judgments.

Step 1: Building hierarchy from the main goal to influencing variable: in the first step hierarchy is built from the intended goal to the main variables as shown in the Fig.4 below.

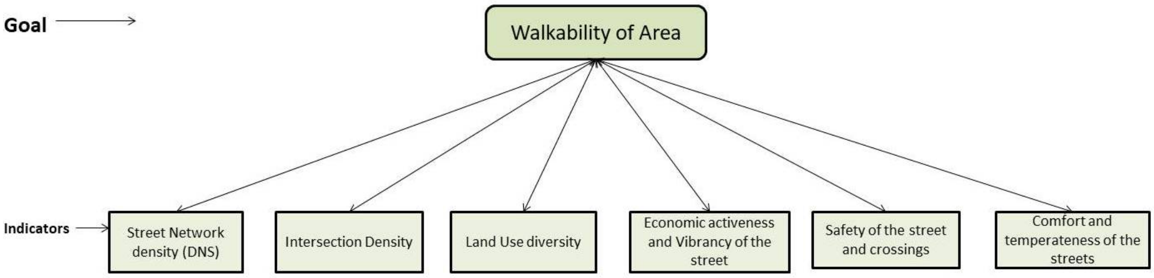

Fig.4 Hierarchal arrangement of goal and criteria

Step 2: By consulting 30 experts in relevant field, we established the comparative pair-wise matrix. Analytical Hierarchal process (AHP) adopts the 1 to 9 ranking methods.

	SND	AV	TC	SCA	ID	LUD
SND	1	1	2	2	3	1
AV	1	1	0.5	3	3	2
TC	0.5	2	1	1	1	1
SCA	0.5	0.33	1	1	1	1
ID	0.33	0.33	1	1	1	1
LUD	1	0.5	1	1	1	1

SND=street network density
AV= Economic Activity and vibrancy of street
TC= Comfort and temperateness of the street
SCA= Safety of street and crossing
ID= Intersection density
LUD=Land use diversity

Tab.1 Pair-wise matrix of indicators for walkability

Step 3: Calculate the significance of each indicator. Calculate Eigen value or Lambda

$$W = \frac{Egi}{\sum_{i=1}^{n} Egi} \quad (1)$$

Where

$$Egi = \sqrt[n]{(a11\ x\ a12\ x\ a13 \ldots \ldots ann)} \quad (2)$$

$$\lambda max = \sum_{j=1}^{n} [wj * \sum_{i=1}^{m} aij] \quad (3)$$

Step 4: Check the consistency of judgments.

To calculate the consistency index CI of judgment matrix (Eq.4), and get the consistency ratio CR using the following (Eq.5).

$$CI = \frac{(\lambda max - n)}{n - 1} \quad (4)$$

Where λ_{max} is Eigen value or Lambda

n is the number of indicators

$$CR = \frac{CI}{RI} \tag{5}$$

Where CR is consistency ratio and RI is the random index

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.46

Tab.2 Saaty's random ratio for different value of n

Eigen value (Lambda max) is calculated to be 6.42, consistency index equals to 0.07 and consistency ratio equals to 0.068 which is 6.8%. Since the consistency ratio is less than 10% threshold the pair wise comparison is consistent.

Indicators and Description	Symbol	Priority
Street Network Density	SND	0.24
Economic Activity and vibrancy of street	AV	0.23
Comfort and temperateness of the street	TC	0.16
Safety of street and crossing	SCA	0.12
Intersection density	ID	0.11
Land use diversity	LUD	0.14

Tab.3 The weight of indicators to alter walkability of area around transit station

3.4 Walkability using weighted overlay tool in GIS

Weighted overlay analysis technique integrates AHP with GIS to create a consolidated result displayed on spatial map. It involves combining the result of AHP with reclassified raster data of influencing variables such as street network density, intersection density, land use diversity, safety and security, business activity along the street, and comfort and temperateness of the street for walking.

Weighted overlay follows steps for the analysis:

- Find suitable data for each indicator to analyze;
- Vector layer have to be converted to raster layer and reclassified to suitable common scale;
- New raster layer is generated multiplying each raster layer cell's value with their corresponding weight resulted from AHP using *equation 6 and* totaling to derive walkability.

$$Walkability = \sum_{i-1}^{n} Wi * Xi \tag{6}$$

Where: Wi is weight assigned for each performance indicator, X_i is the cell value in raster file of spatial data. The spatial data used includes street network density, intersection density, land use diversity; safety and security of streets, business activities along the streets and comfort and temperateness of the streets. All spatial data extracted from Geospatial database of the study area, converted to raster data and reclassified to normalized common scale 3, 2 and 1.

GIS model builder enabled the automation of workflow, making the process quick and repeated with appropriate data for other area by only change location of data as shown in Fig.5.

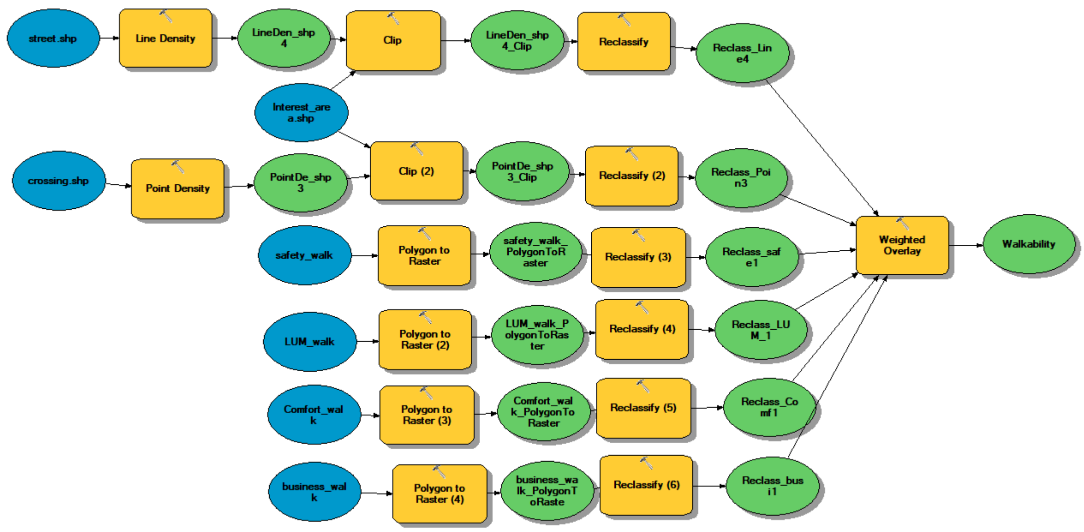

Fig.5 GIS model of the workflow of measuring walkability of area

4. Findings

The objective of this research was to find spatial method to measure the relative walkability level of areas around the Addis Ababa LRT stations by integrating the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS). This integration allowed benefiting from the multiple criteria analysis power of AHP and the power of GIS in spatial data analysis. This approach helped to come up with comprehensive results that can be illustrated on thematic map. The method involves three main steps: identifying main performance indicators, weighting the significance of the indicators based on their influence to create a walkable environment in context of Addis Ababa combine the AHP and GIS to measuring walkability. The identified indicators include road network density, intersection density, land-use mix, safety and security of the streets, business activity along the streets, and the comfort and appeal of the streets.

Since all performance indicators would not have equal impact, indicators were weighted according to their significance to influence the walkability of the area using AHP. The analysis results reveal that the road network density has the highest influence rate with 24%, Economic activity along the street ranked second with 23%, Comfort and temperateness of the street ranked third with 16%, Land use diversity ranked fourth with 14%, safety of street and crossing rated fifth 12% and Intersection density ranked last with 11% priority. The above result clearly displays the significance of street network density and business activity along the street in Addis Ababa Context taking up almost 47% priority compared to other four performance indicators. It also revealed that intersection density and safety of the street have less significance to encourage people to walk.

The third step involves integrating the results of AHP into GIS software using the Weighted Overlay Analysis tool to measure walkability. The result clusters areas with similar levels of walkability into the same categories representing them with different colors; Green Yellow and Red represent high, moderate, and low walkability, respectively. The results revealed that the majority (about 72.35%) of the study areas were classified as moderately walkable, followed by lower walkability areas, making up 19.47% of the total, while walkable areas constituted about 8.16%.

4.1 Walkable areas

As it is shown in Fig.6, the walkability level varied among different stations in the study area. For example, the area surrounding the Autobus Tera station had a higher concentration of walkable areas. The area around this station has a well-organized street network, resulting in a more regular urban layout.

Additionally, the presence of Merkato, the largest marketplace in Addis Ababa, further enhanced the walkability of this area, as shown in Fig.6. Business activities increase walkability and thereby increase property value like real-estate (Carpentieri et al., 2019). Another LRT station that exhibits a relatively higher walkability is the area around St. Lideta station mainly located at the immediate north of the station. The main reason duet to the recent redevelopment of the area with mixed residential and commercial complexes. This particular area is characterized as a well-connected street, active business activities, presence public service within the area contributed to higher level of walkability. The walkable areas are mainly known for active business and vibrant nature.

4.2 Lower walkable areas

On the other hand, areas with lower walkability levels were mainly found around St. Lideta and Legare stations. These areas are characterized by larger block sizes, unplanned settlements (slums), and lower business activity. These areas are primarily occupied by industrial zones, warehouses, and government institutes surrounded by fences. Walking in an area is extremely difficult because lack of appropriate side walkways, lower land use mix, lesser comfort, lesser business activity etc. Any intervention to improve walkability of area should focus on those variables.

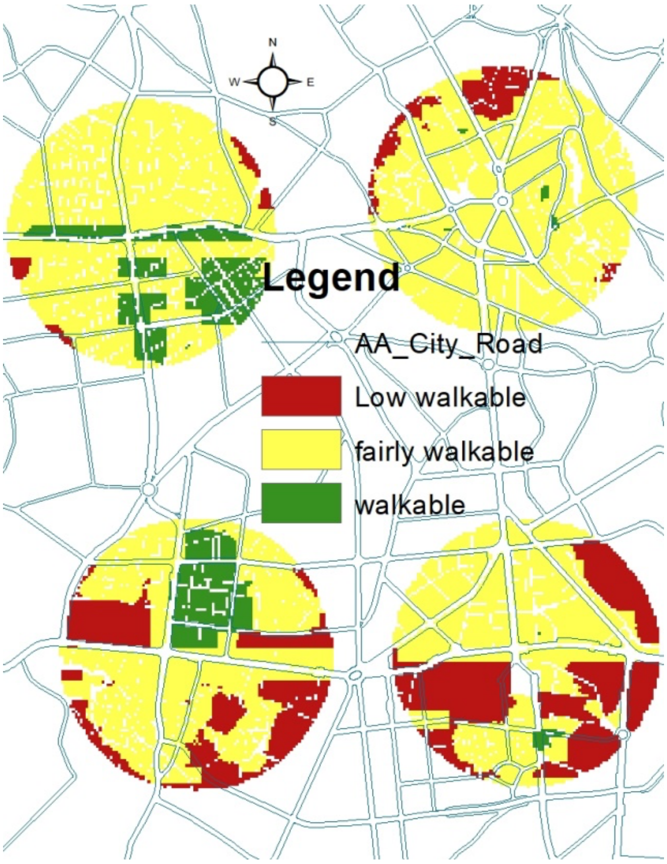

Fig.6 The areas with better walkability

5. Conclusion

Establishing walkable conditions around transit stations is crucial to the success of TOD projects. The process should also focus on the factors that would encourage people to choose walking over using private cars for short trips to access their daily needs. Measuring walkability of area is crucial steps in planning to implement TOD projects around transit nodes considering the entire factors that influence the suitability of the areas to walk. However, this is a complex and multi-dimensional process. It involves physical infrastructure, social concern, safety and security, environmental conditions, economic activity, and comfort. Thus, integrating AHP and GIS is a suitable method to analyze all in hierarchal manner. AHP allows the simultaneous analysis of multiple variables, whereas GIS enables the analysis and production of thematic maps that highlight walkable, fairly walkable, and non-walkable areas. The results revealed that the majority of the study areas (approximately 72.35%) fell under the fairly (moderately) walkable category (yellow), followed by non-walkable areas, accounting for 19.47% (red). The walkable area represents only 8.16% of the study area, represented in (green). As shown in Fig.6, walkable areas are concentrated at places where street networks are well connected, smaller block sizes, and vibrant business activities, such as the Autobus Tera station. On the contrary low walkable areas are concentrated at locations with bigger blocks size, less business activity, less safety, and uncomfortable walking conditions. This finding can assist urban planners and policymakers in locating walkable areas and identifying priority areas for intervention to improve walkability. The hybrid approach of integrating AHP and GIS enables the analysis of complex multi-criteria problems, resulting in a comprehensive result. As this method continues to advance and new data analysis methods emerge, the field of measuring walkability thereby planning successful TOD and shaping the future of urban mobility and creating more sustainable, vibrant, and resilient TOD cities.

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Image Sources

Fig.1: Authors' elaboration:

Fig.2: Authors' elaboration combines the city map and Google earth;

Fig.3: Authors' elaboration;

Fig.4: Authors' elaboration;

Fig.5: Authors' elaboration;

Fig.6: Authors' elaboration;

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