

Analyzing spatial distribution and accessibility of primary schools in Bishoftu Town, Ethiopia

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Abstract Education is a major force in economic, social and cultural empowerment. Primary education is compulsory, and the first stage in the education system of Ethiopia, and urges the provision of accessible service. However, presently, it is unclear that how well the services have been distributed and accessed in Bishoftu town, Ethiopia. For this primary schools in the town are considered and their spatial distribution and accessibility to the residents are explored using geographic information system as a tool for analysis. Location quotient and nearest neighbor analysis have been used to analyze spatial concentration and spatial distribution pattern of the schools, respectively. Computing service areas using road network distance and population density, the spatial accessibility of the schools has been compared and contrasted with standards in planning guide. As a result, inequality of service provision between neighboring areas in the town is found and the overall spatial distribution of the schools shows a clustered pattern. In addition, 23.9% of the residents are expected to travel more than twice of the maximum standard distance, indicates the current service provision is inadequate. The

limitation is due to the combined effect of population distribution, spatial variables, socio-economic, and absence of regular monitoring and evaluation. The study would support the planning efforts being made to improve service provision, and it helps the government in formulating effective policies to the context.

Keywords Accessibility · Spatial distribution · Spatial concentration · GIS · Urban service · Neighborhood analysis

1 Introduction

Education plays a vital role in the life of every citizen and the nation at large. Gao et al. [1] referred to it as a major force in economic, social and cultural empowerment. However, the effectiveness of education varies due to the quality, equality, and adequacy of spatial distribution and accessibility of the services [2–4]. Until recent years, spatial inequality is an important feature of the majority of developing countries, and accessibility to basic education has been identified as a major indicator of human capital formation [4].

In Ethiopia, primary education is compulsory, and the first stage in the education system [5]. Hence, achieving universal primary education has been one of the main millennium development goals of the country [6]. In line with this, imperative efforts by the government through school construction has improved access to the services [7], but the completion rate of primary education is not satisfactory as compared with the desired target of 100% completion [8]. In addition, studies have identified the significant inequalities between different areas of the country in relation to basic educational services [5, 9]. The

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disparities are characterized by uneven spatial distribution and inaccessibility of the services at a reasonable distance [2, 3, 10, 11].

Urban plan and planning guidelines are regarded as a tool to ensure the sustainable development and being practiced in urban centers of Ethiopia. However, in most of the cases, the effectiveness of the plans is limited mainly due to plan quality, implementation quality, and contextual characteristics [12–16]. Consequently, provision of the services seldom follows the plan. In addition, the existing planning guides of the country focus on city or town scale [17]. Due to this, optimal allocation of services in a small-scale such as *Kebele* (Kebele refers to the smallest administrative unit) is usually inconsistent with that in its large-scale counterpart [1]. Hence, information related to the actual condition is required to increase understanding of the level of service provision.

A range of case studies has been conducted to assess the level of spatial distribution and accessibility of primary schools [1, 4, 9, 18–25]. The studies demonstrated the disparity in the provision of the services varies mainly due to the different level of socio-economic, urbanization and planning. Despite these acknowledged studies provided important information about primary school provision, they have deliberated to governmental schools indicating limitations related to scope. Notably, analysis encompassing both Governmental and Non-Governmental (private) increases understanding of the existing reality of the service provision. Such an approach is useful, particularly, in countries like Ethiopia, where the emphasis is given to privatization as a means to overcome the limitations to fund the expansion of the sector [26]. Further, in the majority of the above studies, spatial accessibility analysis is conducted based on straight line distances from the facilities which unlikely represent the actual travel distance, especially in urban areas. Moreover, major factors associated with the resulted distribution are not well explored. Above all, attempts to conduct the combined study of spatial distribution and accessibility is limited [3, 24].

In Ethiopia, evaluating the spatial distribution and spatial accessibility of educational services is uncommon. Particularly, in Bishoftu town, despite the quantitative expansion of primary schools resulted from the dual system (governmental and private), how well the services have been distributed and accessed by the residents remained unclear. Due to this, to what extent the existing level of the primary educational service provision is supporting the sustainable growth of the town is unknown. Given the importance of improving the service provision in serving the growing demand of people in the future, an empirical assessment of the existing condition is critical, as it may

provide information required for the development of sound strategies to ensure sustainable urban growth.

Hence, the study aims at exploring the level of spatial distribution and accessibility of primary schools in Bishoftu town as of 2017 using GIS as a tool for analysis. Based on the result, the study sought to shed light on the major factors attributed to the observed level of service provision.

2 Study area, materials and methods

2.1 The study area

The study area, Bishoftu town has various advantages that make it an appropriate selection for this study. On top of unclear information regarding the service provision, the town is experiencing rapid urbanization that can contribute to imbalance service distribution. Moreover, the study area is located in a place where it is easy to find data to map, verify, and interpretation of the findings.

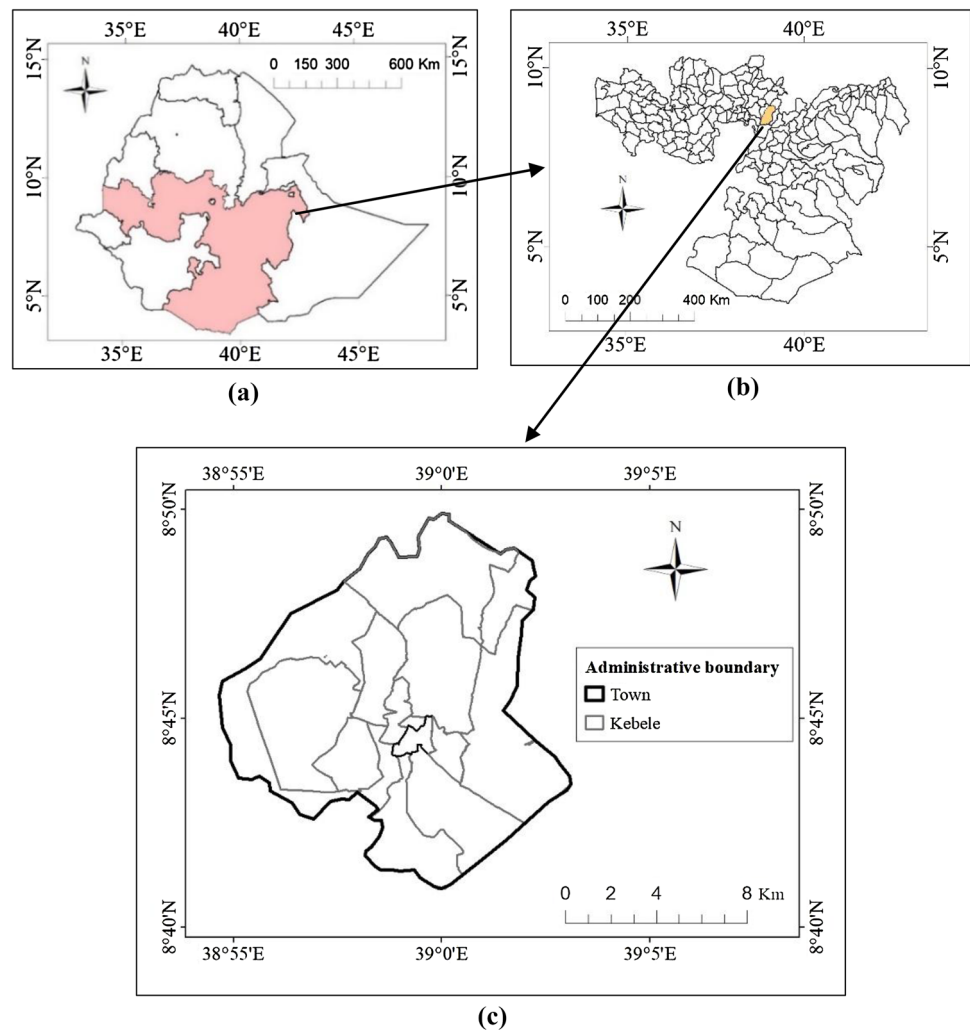
The town is located in Oromia Regional State laying at a distance of 47.9 km southeast of Addis Ababa (capital city of Ethiopia). Geographically it is stretched between 8°43'N–8°48'N latitude and 38°00'E–38°48'E longitude (Fig. 1). According to spatial analysis in this study, the town currently covers the total area of about 14,878 ha which was 4520 ha in the year 2005 [27]. Moreover, the town is suited in tepid to cool sub-moist mid highland at an average altitude of about 1920 m above mean sea level with moderate weather condition. The temperature of the area ranges from 16 to 24 °C. It is truly a resort town, known for five crater lakes: Lake Bishoftu, Lake Hora, Lake Bishoftu Guda, Lake Koriftu, and the seasonal Lake Cheleklaka. In addition, the town is the home of vast military camps, research and educational institutions, industries and urban agriculture. These have contributed to the rapid expansion of the town.

Bishoftu town is among the largest urban center in Oromia Region in its population size, and indeed one of few towns in the country with a threshold population of over 100,000 [27]. According to Bishoftu town administration office, the number of registered population of the town as of 2017 is 213,689 which was 100, 114 as of 2007 reported by the population and housing census of 2007 [28]. The town administrative area currently encompasses 9 urban Kebeles and 6 sub-urban Kebeles.

2.2 Data and data sources

Data used in this study were collected from different sources. Digital Orthophoto of the study area captured in 2014 was acquired from town administration. It has a spatial resolution of 15 cm that enables extraction of the

Fig. 1 Location map of the study area: **a** regions of Ethiopia, **b** Weredas of Oromia regional state and **c** Bishoftu town



plot of each school through digitization. Plots of the schools constructed between 2014 and 2017 were collected using handheld GPS and mapped to ensure the coverage of data collection. Land use plan map (.jpg documents) prepared in 2004 was a base for extraction of road network data, Kebele administration boundary, and restricted areas. Demographic data collected from respective Kebele administration offices were the census in 2017 which reflects only registered population.

ArcGIS 10.1 software package was used for spatial data processing, analysis, and output generation. Processing a large amount of information at the same time and present the information in a visualized way was one of the advantages of ArcGIS which made an evaluation of spatial distribution and accessibility of the facilities possible in this study. Among, totally 64 primary schools in the study area, 38 schools are privately owned while the rest 26 are governmental.

X and Y coordinates of the geometric centroid of the plot of each school were computed from the coordinates of

vertices of the respective plot. This is to enhance the representation of each facility with the most representative single point location. The coordinates of the centroid were converted to shapefile for further analysis and descriptive information was entered. Population density (number of population per hectare) was computed using the ratio of demographic data and net built-up area (after deduction of restricted areas) and was rounded to the next integer number. Road network dataset was created for service area generation. All spatial data were processed in common Geodatabase using Universal Transverse Mercator projection system Adindan zone 37 N.

2.3 Methods

This study takes into account the relevant specifications of the urban planning and implementation manual by the federal democratic republic of Ethiopia [17]. The standards show that the rationality of the planning of public facilities generally consists of two dimensions: the service

catchment area and the population index. Main methods used in this study includes analysis of spatial concentration, determining the spatial distribution pattern, creating road network dataset and computation of service area, determination of accessibility of the schools to the residents, and analysis of major factors attributed to the existing distribution of the facilities.

2.3.1 Spatial concentration

The spatial concentration directly reflects inequality of service provision between Kebeles. The extent of concentration of primary schools between Kebeles was analyzed by taking the distribution of population into consideration. In this context, the Location Quotient (LQ) method by Jahan & Oda [29] was adopted. It was used to measure the extent of the primary schools have been provided for particular Kebele relative to the whole town. In other words, LQ was computed using Eq. 1 to quantify and benchmark the degree of relative concentration of primary schools in the analysis of area localization.

$$LQ = \frac{n/p}{N/P} \quad (1)$$

where n , p is the number of schools and population in particular Kebele; N and P are the number of schools and population in the town, respectively.

- < 1 , the concentration of the schools in a particular Kebele is less than that of the town as a whole.
- $LQ = 1$ or close to 1, indicates self-sufficiency, means schools in a given Kebele is exactly sufficient to meet the local demand.
- $LQ > 1$, the per capita availability of schools in a particular Kebele exceeds that of the town as a whole.

2.3.2 Spatial distribution pattern

The spatial distribution of primary schools reflects the pattern of service provision. The distribution pattern was examined using standard distance measure in the spatial statistic in a GIS environment. It measures the degree to which features are clustered or dispersed around their geographic mean center. It was realized using the Average Nearest Neighbor (ANN) analysis. ANN calculates the nearest neighbor index based on the average distance from each feature to its nearest neighboring feature. The average nearest neighbor index (ANNI) was calculated as the ratio of the observed average distance (\bar{D}_0) and the expected average distance (\bar{D}_E) (with expected average distance being based on a hypothetical random distribution with an equal number of features covering the same total area). In

this regard, the distribution of the features being analyzed is considered as:

$$\begin{aligned} & \text{Clustered if } ANNI < 1 \\ & \text{Dispersed if } ANNI > 1 \end{aligned}$$

z-score and p value were also used to measure statistical significance. The former indicates that maximum probability that the distribution likelihood could be the result of random chance. The latter is a probability that the observed spatial pattern is created by some random process. When the p value is very small, it means it is very unlikely (small probability) that the observed spatial pattern is the result of random processes, so the null hypothesis can be rejected. But how small enough? to answer this question, Table 1 shows the critical p values and z-scores for different confidence levels were used in this study.

2.3.3 Spatial accessibility

Provision of social infrastructures is related to how well they distributed and can serve the users. From the users' perspective, accessibility to social infrastructure is indicated by how well they can access the facility, in this case, in terms of distance traveled by users. Therefore, the evaluation of existing service provision was conducted by checking the number of people which could reach the schools within the specified travel distance.

More specifically, spatial accessibility was analyzed using a road network based service area analysis which answers the question "what is the likely service area of the schools based on actual travel distance?". The service area ensures that the people could find facilities in a certain traffic distance. In this regard, an area to be considered accessible, it should be enclosed by a polygon generated by specified travel distance from a facility along with a road network. Then, the number of served population was determined from the product of spatial extent inside service area and population density (Eq. 2). Similarly, the inaccessible population was computed from spatial extent outside the service area and population density of the area.

$$\text{Served or unserved population} = \sum_{i=1}^{14} a_i * pd_i \quad (2)$$

Table 1 p value and z-score for different confidence level

z-score (SD)	p value (probability)	Confidence level (%)
$< - 1.65$ or $> + 1.65$	< 0.10	90
$< - 1.96$ or $> + 1.96$	< 0.05	95
$< - 2.58$ or $> + 2.58$	< 0.01	99

where a_i is total serviced or unserved area in i th Kebele; pd_i is population density of i th Kebele.

In general, procedures used to carry out this study are summarized in Fig. 2.

3 Results

3.1 The spatial concentration of the schools

The computed value of spatial concentration measure using Eq. 1 is shown in Table 2 alongside with the number of primary schools and population in respective Kebeles. Overall, at town scale, the proportion of schools to the total

population is about 1–3340 which is acceptable as compared to the standard set by the Government (1:5000) in terms of population. At a lower scale (Kebele level) the provision has been limited to meet the standard in 6 Kebeles including the two Kebeles with no primary school and the majority of them are sub-urban Kebeles. The quantity of POPS significantly exceeding GOPS. The number of POPS varies across urban Kebeles while none of the private developers are attracted to sub-urban Kebeles. Among urban Kebeles, the maximum number of schools is found in Kebele 01 as opposed to Kebele 04 with no primary school. However, no significant difference in the number of schools is found in the case of sub-urban Kebeles.

Fig. 2 Flowchart of the methodology used in the study

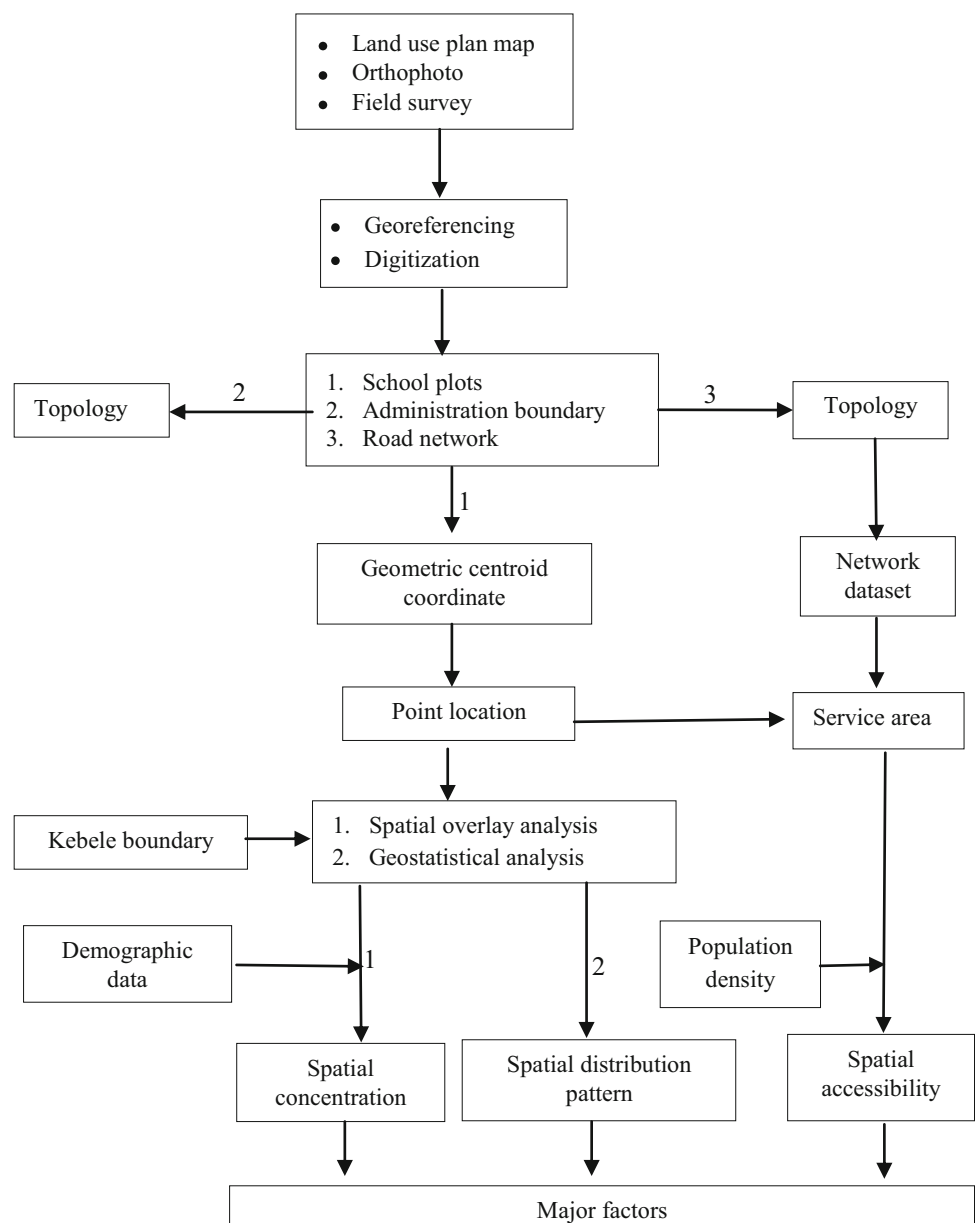


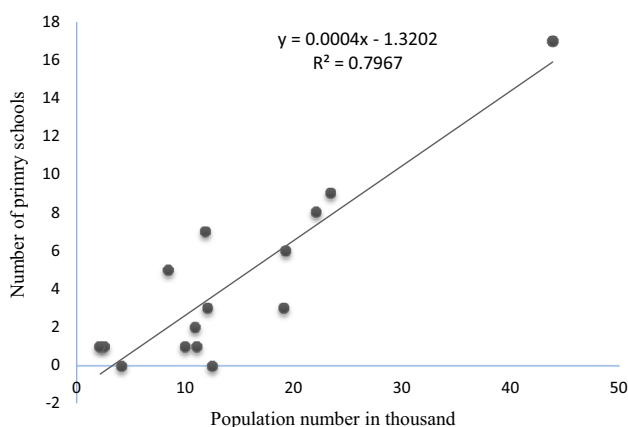
Table 2 Spatial concentration of primary schools in urban Kebeles of Bishoftu town as of 2017

Kebele name	Pop. no.	No. of primary schools			LQ	Remark
		GOPS	POPS	Total		
01	43,915	6	11	17	1.3	Urban Kebeles
02	23,338	1	8	9	1.3	
03	8482	1	4	5	2.0	
04	4192	–	–	–	–	
05	19,211	4	2	6	1.0	
06	12,118	1	2	3	0.8	
07	19,118	2	1	3	0.5	
08	11,879	2	5	7	2.0	
09	22,000	3	5	8	1.2	
Garbicha	10,050	1	–	1	0.3	Sub-urban Kebeles
Gorba	10,961	2	–	2	0.6	
Qurqura	2609	1	–	1	1.3	
Kajima_dibayu	11,099	1	–	1	0.3	
Kality	12,543	–	–	–	–	
Danbi	2174	1	–	1	1.5	
Total	213,689	26	38	64		

GOPS government-owned primary schools, *POPS* private-owned primary schools, *LQ* location quotient

In addition, the computed LQ demonstrates that the concentration of primary schools in each Kebele possesses different ranges (under normal concentration, self-sufficient, above normal concentration) with the maximum value (2.0) in Kebele 03 and Kebele 08 as opposed to 03 in Garbicha and Kajima. This indicates that the level of concentration of schools varies quite significantly across Kebeles in the town and leads to believe that considerable disparity exists among the Kebeles in terms of primary school provision.

Further, to investigate the relationship between population and number of primary schools, Pearson Product Moment Correlation Coefficient technique was applied to the data. The result depicted in Fig. 3 shows that there is a

**Fig. 3** Correlation between the number of population and primary schools in Bishoftu town as of 2017

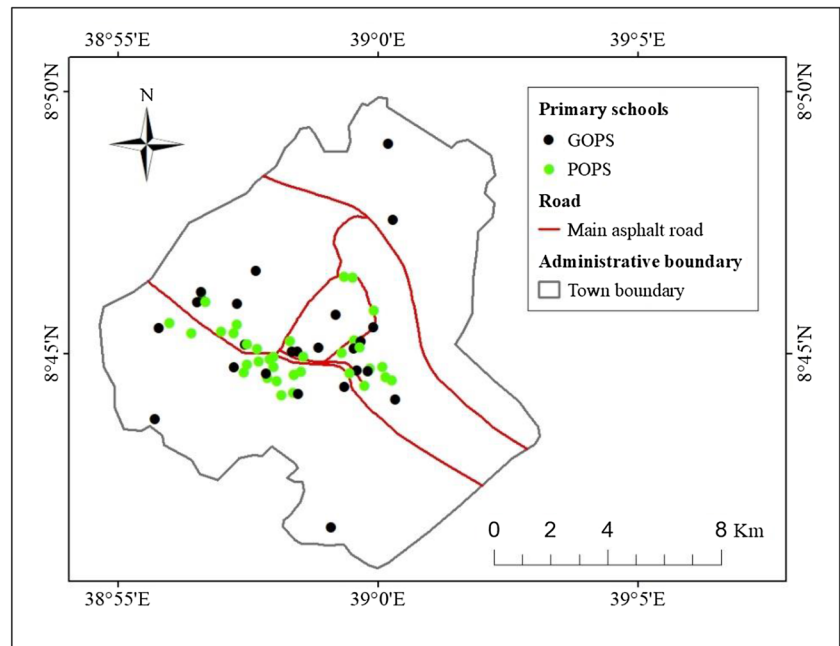
positive relationship between the number of primary schools and the population of Kebeles. The line of best fit is linear, while the coefficient of correlation (r) in this case 0.89 is significant at 0.05 (95%) significant level. The coefficient of determination (R-square) value of 0.7967 indicates that about 79.67% of the variance in primary schools moderately influenced by the number of population of the respective Kebeles.

3.2 Spatial distribution pattern

The result of the spatial mapping of the schools in this study is depicted in Fig. 4. It demonstrates that most of the primary schools are located in the central part of the town, which might be related to urban biased as a result of high population density except three primary schools located in sub-urban Kebeles. In addition, the result shows that majority of the private-owned primary schools are found in the main transportation corridor due to ease of transportation.

The result of nearest neighbor analysis for the spatial distribution of the schools reveals two major spatial patterns: overall general pattern at the town level and specific pattern at Kebele level. The computed value of Nearest Neighbor Ratio (NNR) for the former case using the total area of the town and total primary schools in the town resulted in $NNR = 0.771$, and the p value less than 0.001 suggests rejecting the null hypothesis. From this evidence, it can be concluded that the overall distribution primary

Fig. 4 Spatial distribution of primary schools in Bishoftu town with overlaid with the main road as of 2017. GOPS, Government-owned primary schools; POPS, Private-owned primary schools



schools in Bishoftu town exhibit a clustered pattern at 99% (0.01) significant level.

The result of NNR computation at Kebele is summarized in Table 3. Due to the insignificant number of schools, sub-urban Kebeles are left out from the distribution pattern analysis. However, in urban Kebeles, the result demonstrates that different spatial patterns occurring in the Kebeles of Bishoftu town. The NNR in the majority of Kebeles is greater than 1 implies the patterns are more dispersed. However, in order to reject the null hypothesis, further analysis of z-scores and *p* values is important. Accordingly, *p* values of Kebeles 02, 03, 06, 07, 08, 09 are small and their patterns as a result of neighbor analysis are classified as dispersed. Moreover, z-scores Kebeles is greater than the critical values which are + 2.58 and, at the same time, their *p* values are less than the critical value (0.01). Hence, it can be concluded that the spatial

distribution pattern of primary schools in these Kebeles shows dispersed pattern at 99% significant level. Furthermore, the *p* values of Kebele 03 and 09 are between 0.05 and 0.01 indicating that the distribution pattern in these Kebeles shows dispersed at a 90% confidence level. In contrary, in the case of the remaining urban Kebeles null hypothesis is accepted i.e. the pattern exhibited could very likely be the result of random spatial processes.

3.3 Spatial accessibility

The result of spatial accessibility analysis of the schools is depicted in Fig. 5 and Table 4. Accessibility was computed using Eq. 2 at 2 km, 3 km, 5 km, and greater than 5 km. Overall, the result indicates that at larger spatial scale (i.e. town level), the primary schools in the town are accessible to 98,808 residents (46.2%) at a maximum of 2 km distance which is maximum acceptable distance as per the recommendation of the standard. Further, 31,648 people are able to access the schools with 2–3 km travel distance, while 32, 233 residents are expected to travel up to 5 km. On the contrary, 51,000 of the town residents are more disadvantaged, as they should travel more to access the primary schools.

In terms of Kebele, a large number of population (33,360) in Kebele 01 are served within the first range of travel distance as opposed to 2073 in Kebele 04. In addition, in the second range of travel distance, Garbicha is identified with more served population as compared to Kajima in which the least number of served population. In contrary Kebele 06 and Kebele 05 are relatively better served in the travel distance of 3–5 km. unserved

Table 3 Statistics of the distribution pattern of primary schools in Kebeles of Bishoftu town as of 2017

Kebele	NNR	Z-score	<i>p</i> values
01	1.036	0.286	0.775
02	1.607	3.483	0.0005
03	1.449	1.922	0.0546
05	1.351	1.646	0.998
06	3.284	7.567	0.000
07	3.483	8.229	0.000
08	1.574	2.907	0.0036
09	1.295	1.691	0.0907

Fig. 5 Spatial accessibility of primary schools at different travel distances in Bishoftu town as of 2017

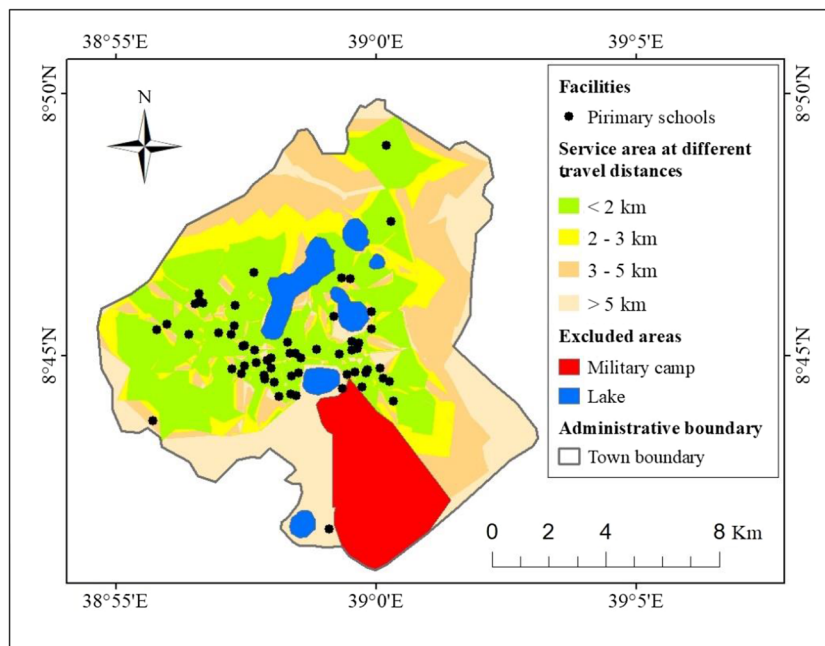


Table 4 spatial accessibility of the primary schools to residents in Bishoftu town as of 2017

Kebele	Number of population served at different distances (km)				Total
	0–2	2–3	3–5	> 5	
01	33,360	3814	3895	2601	43,670
02	9036	3012	3921	7237	23,206
03	2096	127	65	6055	8343
04	2073	371	198	1441	4083
05	9108	4462	5032	373	18,975
06	4917	659	6368	172	12,116
07	6794	532	649	11,000	18,975
08	10,135	1087	465	100	11,787
09	12,271	3573	3312	2098	21,254
Kajima	35	74	93	9848	10,050
Garbiichaa	4496	4859	53	1553	10,961
Qaallittii	158	360	1922	169	2609
Gorbbaa	2419	3721	2318	2641	11,099
Qurquraa	1501	4628	3927	2487	12,543
Dambi	409	369	15	1381	2174
Total	98,808	31,648	32,233	51,000	213,689

population (23.9%) are forced to travel more than 5 km from all Kebeles with the greater share from Kebele 07.

4 Discussion

In this study, spatial distribution and accessibility of primary schools in Bishoftu town are examined in a GIS environment. By spatial mapping of the location of primary schools, the level of concentration and spatial distribution

pattern of the service are evaluated at Kebele level and the town as well. Moreover, the spatial accessibility of each school was measured using a road network distance.

The findings reveal that, at the town level, the quantity of primary schools provided is acceptable as compared to the standard set for population index. This can be seen as an evidence of Government attempts to address the demand for primary education facilities for the population of the town. However, when the lower administrative unit is considered, the significant number of Kebeles have been

identified associated with deficiency of the service. This inconsistency indicates the limitation of generalizability of the service provision.

Further, the computed value of NNR (0.771) shows the general pattern of the service distribution in the town exhibits a clustered pattern. The result is moderately less than that of Mustapha et al. [22] which was 0.93 pertaining to the distribution pattern of government primary schools in West Local Government in Nigeria. The observed variation might be due to the difference in scope of ownership type of schools considered. On the other hand, the result of NNR analysis at lower scale in the present study indicates a dispersed pattern in about half of the urban Kebeles at 99% confidence level.

The findings also reveal that the primary schools in the town are accessible to 46.2% of the population at the standard distance set as compared to 23.9% of the population is expected to travel more than twice of the standard to access the services. The result is moderately less than that of Mustapha et al. [22] which was 62% resulted in the analysis of spatial accessibility level of primary schools in Ilorin West Local Government using students' data. The difference might be due to differences in the level of urbanization, planning, and data used for instance in this study instead of students' data, population data was used as per the urban planning standards for social service provision in Ethiopia. The result of this study is pertaining to analyzed primary schools and applicable to analyze spatial distribution and accessibility of primary school provision in Bishoftu town in Ethiopia.

In general, based on this evidence, it is enough to conclude that spatial distribution and accessibility of primary schools in town has a limitation in the provision of balanced service between Kebeles. The observed limitation might be due to the following *four* potential factors

- *Population distribution* As indicated by correlational analysis in this study the population size of the Kebeles correlated with the number of primary schools provided. The result of R-squared (0.7967) shows 79.67% of the variance in the number of primary schools is due to the population of the study area. This portends moderate influence of population factor meaning the distribution of primary schools is not entirely based on population. Obviously, other factors other than population could have influenced the spatial distribution of primary school in Bishoftu.
- *Socio-economic* In line with a significant number of POPS identified in this study, the purchasing power of the population can influence the distribution pattern of the service. Apart from other factors, private developers are usually market-oriented, the decisions they made for the locations are mostly based on cost–benefit

analysis instead of the public benefit. This explains why privately owned schools are more in Kebele 01.

- *Monitoring and evaluation* The lack of monitoring and evaluation might be another important reason for the uneven distribution of primary schools in Bishoftu. Because, technically, through regular monitoring and evaluation, using geospatial technologies i.e. geographic information system and remote-sensing, it would be possible to identify the unserved area and take measures to ensure adequate provision of the services in a timely manner. In addition, the inconsistency of service provision at lower spatial scale identified in this study could be due to the absence of regular monitoring and evaluation.
- *Spatial variables* Proximity to likely public infrastructures and major transportation corridors and urban bias have significantly affected the spatial distribution of educational facilities in Bishoftu. As noted in different study, transportation routes are responsible for unbalanced public amenities provision [24, 30], the spatial variables support the visual results of this study and indicate that most of the schools are concentrated along major road passing in the town which might be due to better transportation access and other infrastructure developments in these areas.

5 Conclusion

The present study evaluates spatial distribution and accessibilities of primary schools in Bishoftu town as of 2017. The result reveals that primary schools in Bishoftu town are distributed unevenly across all Kebeles indicating inequality of the service provision between neighbors. Further, overall spatial distribution of the schools exhibits in a clustered pattern. Moreover, 23.9% of the population of the town have little access to primary schools, as they are expected to travel more than twice of the maximum distance set by planning guide. From this, it is concluded that the provision of primary schools in Bishoftu town is inadequate. The observed limitation is related to, variation in population distribution, spatial variables, socio-economic, and evaluation and monitoring. The findings support the existing planning efforts to improve service provision. Moreover, it supports the government to formulate effective policies to the context.

Although this study provides important information on the spatial distribution of educational facilities in Bishoftu and major influencing factors, the results should be considered as only an initial step towards understanding the provision of the services. Hence, further researches are needed on several fronts, and more studies are

recommended in other urban centers in the country, as comparative analysis would provide an increased understanding of effective social service planning. Essentially, studies are required to examine the trend of underlying factors in spatial and temporal bands that can support the formulation of a sustainable development policy.

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