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A Geospatial Analysis of Accessibility to Primary Education

İlköğretime Erişimin Mekansal Bir Analizi

Mustafa **KÖSE** [*] Cahit ERDEM [**]
Mehmet **KOÇYİĞİT** [***] Mohammed Idris JEGA [****]

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ABSTRACT: Geographic information systems (GIS) have started to be used in developing information to be used for national and regional development in many areas; however, the use of this system for educational planning has been under-researched. Adopting the case study design, this study evaluated the current locations of primary schools in Afyonkarahisar and offered alternative locations in order to improve access to primary education for the school-aged population using heuristic location-allocation modelling approaches. An intelligent areal interpolation approach was performed to generate the population surface. The demand surface was used as input to a location-allocation analysis, and alternative locations were suggested. With the current distribution of primary schools, the primary school-aged population would have to travel an average distance of 1466.81m to access primary education. The results show that alternative primary school locations decreased the average travel distance by 339.69m, improving overall accessibility to primary schools. The results suggest that geospatial methods can be used to provide documentary evidence to support education planners and policymakers.

Keywords: GIS, educational planning, primary schools, accessibility, geospatial analysis, Afyonkarahisar.

ÖZ: Coğrafi bilgi sistemleri (CBS) birçok alanda ulusal ve bölgesel kalkınma için kullanılacak bilgilerin geliştirilmesinde kullanılmaya başlanmış; ancak bu sistemin eğitim planlaması için kullanımı yeterince araştırılmamıştır. Durum çalışması deseni kullanılarak bu çalışmada, Afyonkarahisar merkez ilçesinde yer alan ilkokulların mevcut konumları değerlendirilmiş ve buluşsal konum tahsis modelleme yaklaşımlarını kullanarak okul çağındaki nüfusun ilköğretime erişimini iyileştirmek için alternatif konumlar sunulmuştur. İlköğretim çağındaki nüfusun dağılışını oluşturmak için mekânsal enterpolasyon yöntemi uygulanmıştır. Okullara olan talep yüzeyi, yeni bir yer tahsisi analizinde girdi olarak kullanılmış ve yeni okullar için alternatif lokasyonlar önerilmiştir. İlkokulların mevcut konumuna göre, ilköğretim çağındaki öğrencilerin okullarına erişmek için ortalama 1466,81m mesafe kat etmesi gerekmektedir. Uygulanan konum tahsis model sonuçları, alternatif ilkokul lokasyonlarının ortalama erişim mesafesini 339,69m azalttığını ve okullara genel erişilebilirliği iyileştirdiğini göstermektedir. Elde edilen bulgular, jeo-uzamsal yöntemlerin eğitim planlayıcıları ve politika yapıcıları desteklemek için belgesel kanıt niteliğinde kullanılabileceğini göstermektedir.

Anahtar kelimeler: CBS, eğitim planlaması, ilkokullar, erişilebilirlik, jeo-uzamsal analiz, Afyonkarahisar.

[*] *Corresponding Author*: Asst. Prof. Dr., Afyon Kocatepe University, Afyonkarahisar, Türkiye, mustafakose@aku.edu.tr, https://orcid.org/0000-0003-3206-2508
[**] Assoc. Prof. Dr., Afyon Kocatepe University, Afyonkarahisar, Türkiye, cahiterdem@gmail.com, https://orcid.org/0000-0001-6988-8122
[***] Assoc. Prof. Dr., Afyon Kocatepe University, Afyonkarahisar, Türkiye. mkocyigit@aku.edu.tr, https//orcid.org/0000-0002-1836-844X
[****] Asst. Prof Dr., National Space Research and Development Agency, Abuja, Nigeria, idrisjega@yahoo.com, https://orcid.org/0000-0002-2671-8526

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Primary education has always been on policymakers, education specialists, parents, and other stakeholders' agendas. Nations invest in schooling, primary education in particular, for long-term social and economic goals. Universalizing primary education is a central goal of the United Nations, and the Education for All movement has worked towards increasing access to primary education. Developing countries need to increase access to primary education (Birdsall et al., 2005). To overcome disparities in education, countries have been exerting strategies to expand access to schools, particularly for primary education (Sifuna, 2007). Access to primary schools has various aspects, such as gender equality (UNESCO, 2004) schooling costs (Lincove, 2009), but not limited to them. Another critical aspect of access is spatial equity. Although disadvantageous or poor groups are negatively affected by the concentration of schools in certain residential areas (Marques et al., 2021), spatial equity of access to primary education is yet under-researched.

The discipline of geography and analysis tools used in this discipline, such as Geographic Information systems (GIS), can be used in educational planning, i.e., evaluating the current locations of schools and coming up with the optimal locations for new schools to improve spatial equity for all (Kelly, 2019; Köse et al., 2021; Mann & Saultz, 2019; Yoon et al., 2018). GIS is a powerful tool because of its diverse sets of information to solve problems (Chamberlin, 2007). Nevertheless, research focusing on spatial access to primary schools is very limited (Burgess et al., 2011; Marques et al., 2021; Talen, 2001). Given that GIS offers innovative ways of studying spatial access to primary schools, more research studies are needed both to contribute to the literature and provide solid implications for policymakers. This type of analysis is particularly needed for countries with rapid population growth and rural-urban migration (Köse et al., 2021).

Although schooling percentages in primary schools are not problematic in Türkiye, there are no studies on spatial access to primary schools. Using an address-based school enrolment system, in which parents enroll their children in the nearest school, Türkiye needs to provide primary schools for students with at least spatial equity. In this regard, the current study focused on evaluating spatial accessibility to primary schools in Afyonkarahisar province, Türkiye. We used GIS to evaluate the current locations of primary schools using population data of primary school-aged children, city maps, paths, and other data. We also offered new spatial arrangements, i.e., optimal places for new schools, using heuristic location-allocation modelling approaches to enhance overall spatial accessibility. To this end, we sought to answer these research questions:

- How well do current primary schools in the Afyonkarahisar province serve the current population distribution?
- How can primary schools in the Afyonkarahisar province be optimally located to maximize accessibility for residents?

Theoretical Framework

Primary Education and Access to Primary Education

Primary education is of critical significance both for individuals and nations. The Universal Declaration of Human Rights, proclaimed in 1948, guarantees that education is a fundamental human right and that primary education should be free, compulsory, and universal. Primary education can be defined as "general school education at the first level, programs designed to give numeracy and literacy skills and build the foundations for further learning" (Independent Evaluation Group, 2006). Accessibility to primary education is a significant issue since it is actually related to human rights and equality of opportunity. As the states are responsible for providing free primary education to all citizens, the physical distance between students' homes and primary schools is critical to equal opportunities.

Access to primary education is measured chiefly based on indicators such as enrolment ratio. The objectives of initiatives on access to primary education include increased enrolment, improved equity, improved access for girls, and improved internal efficiency (Independent Evaluation Group, 2006). However, access is not limited to these indicators. It includes spatial equity, fairness, social equity, or student performance (Talen, 2001). Researchers have addressed access to primary education from various aspects, such as gender disparities in access to school (UNESCO, 2004; Ramachandran, 2004), access problems in underdeveloped countries due to poverty or other problems (Bennell, 2021; Zuilkowski et al., 2018), the rural-urban gap in schooling (Maarseven, 2021), or costs of primary education (Lincove, 2009). Spatial equity of access to primary education, however, is understudied. Yet, issues of spatial equity and access to public services are significant because the concentration of services in certain residential areas affects disadvantaged or poor groups to a great extent (Marques et al., 2021).

Spatial equity of opportunity is formed by capital resources one has in their living environment because the life chances of an individual are determined by those resources (Israel & Frenkel, 2018). According to Rawlsian principles regarding spatial inequity, the institutions should be distributed in a way to ensure equity and provide social justice for particularly disadvantaged groups (Marques et al., 2021). The literature on spatial equity highlights that people need equal access to public services and to ensure equal opportunities for people, planned actions should be put into practice (Fainstein, 2009; Marques et al., 2021). Empirical evidence supports the idea that spatial access to primary schools is significant. In the Scottish context, for example, Macintyre et al. (2008) showed that the allocation of primary schools differed across areas, with state schools having a higher density in low socioeconomic areas while it was vice versa for private schools. Marques et al. (2021) revealed a significant relationship between socioeconomic status and accessibility to primary schools in the Portuguese context, referring to a patterned inequality.

Though researchers worldwide study access to different services such as health care services (Neutens, 2015), irrigation market (Magistro et al., 2007) or lodging properties (Ilgaz Sümer et al., 2016), access to primary schools in terms of spatial equity is understudied. Few studies directly address access to primary schools (Burgess et al., 2011; Marques et al., 2021; Talen, 2001), and it is also studied in a few related studies

(Lee & Lubienski, 2017; Macintyre et al., 2008). Accessibility to primary schools needs to be studied using geographic information systems (GIS) in different contexts to contribute to the literature and provide solid implications for policymakers.

Geography discipline can be used for educational planning. It can help policymakers to terminate or lessen geographic restrictions and systemic inequities stemming from them (Mann & Saultz, 2019). As an efficient tool for this aim, GIS provides an association between socioeconomic information and geospatial datasets (Chamberlin, 2007) as well as providing accurate estimates of accessibility to public spaces, including schools (Higgs et al., 2012). It analyzes data on population, extant schools, and city roads in a given area and offer scientific results for planning new school locations (Köse et al., 2021). In planning school location, GIS can identify schools' catchment areas and measure how the school-aged population can access the extant schools, and where would be the optimal new places based on other factors such as population density or best paths to school (Bejleri et al., 2011; Châu, 2003). GIS is also advantageous in the sense that it visualizes complex accessibility measures and gets the policymakers or leaders to easily understand abstract measures (Kelly, 2019; Mann & Saultz, 2019), which is significant for the decision-making process. In this study, we used GIS to measure the current locations of primary schools and offer optimum new locations for new primary schools.

Primary Education in Türkiye

The Turkish education system comprises pre-school, primary school, lower and upper secondary schools, and higher education elements. Compulsory education consists of 12 years covering primary school and lower and upper secondary schools. Corresponding to ISCED 1, primary school education offers four years of education for students between 66 months and ten-year-old (Eurydice, 2021). National Education Basic Law in Türkiye (Numbered 1739) depends on such principles as equality, the right to education, and equality of opportunities. The Primary Education Law (Numbered 222) posits that primary education is free for all in state schools.

Primary education serves the most common group of citizens in the education systems, and it seeks to actualize the aims of education systems, such as socialization, enculturation, and raising productive individuals at a basic level (Gültekin, 2007). Since primary education is a long-term investment for the countries' development and economy in terms of providing human capital, and it ensures civic education, socio-cultural integration among different groups in a country, and it is a preparation period for further school levels; countries exert great effort for primary education. Accordingly, primary schools were seen as a tool for developing the nation following the foundation of the Turkish Republic in 1923. Policymakers tried to actualize the aims, such as spreading education across the country, increasing literacy, raising citizens in line with the mindset of the new republic, and creating a new national identity through primary schools (Sağlam, 2011). Therefore, primary schools have always been important in Türkiye. This is seen in the statistics. In the 2019-2020 academic year, there were over 18 million students at the K-12 level. Over five million of these students were at primary schools. In the same academic year, the schooling percentage in primary schools is 97.70% for boys and 97.11% for girls. These statistics are also very similar for the Afyonkarahisar province, which is in the scope of this study. In the same year, there were 9775 students in primary schools in Afyonkarahisar (MoNE, 2020). As the statistics suggest, there are no severe problems in Türkiye regarding schooling percentages in primary schools. Almost all children attend primary schools; however, equality of access to primary schools is a matter of question that should be elaborated on.

Spatial accessibility is about the distance between schools and children's homes. Regarding the location of primary schools, The Primary Education Law (Numbered 222) posits that school buildings should be in an appropriate location in terms of health, education, and transportation. They should be at least 100 meters away from such places as bars, electronic game places, or shops selling alcohol. However, there is no regulation that leads to a scientific way to determine the school places for ensuring spatial equity for all citizens. Besides, in Türkiye, an address-based school enrolment system is currently in practice. This system requires parents to enroll their children in the schools that are nearest to their home location. Even in countries such as England, where parents have the right to choose the school for their children, parental school choice is restricted by geographical location, resulting in increasing house prices in the catchment areas of desired schools (Burgess et al., 2011). In an address-based system, the states should provide schools for students with at least spatial equity. Therefore, we aim to evaluate the current locations of primary schools in Afyonkarahisar province in Türkiye and offer alternative spatial arrangements for new primary schools using GIS tools to increase spatial equity.

Purpose of the Study

The purpose of this study is to evaluate the current locations of primary schools in Afyonkarahisar province in Türkiye and offer alternative spatial arrangements, thus providing documentary evidence to education planners and policymakers on the accessibility to primary education in Afyonkarahisar province.

Methodology

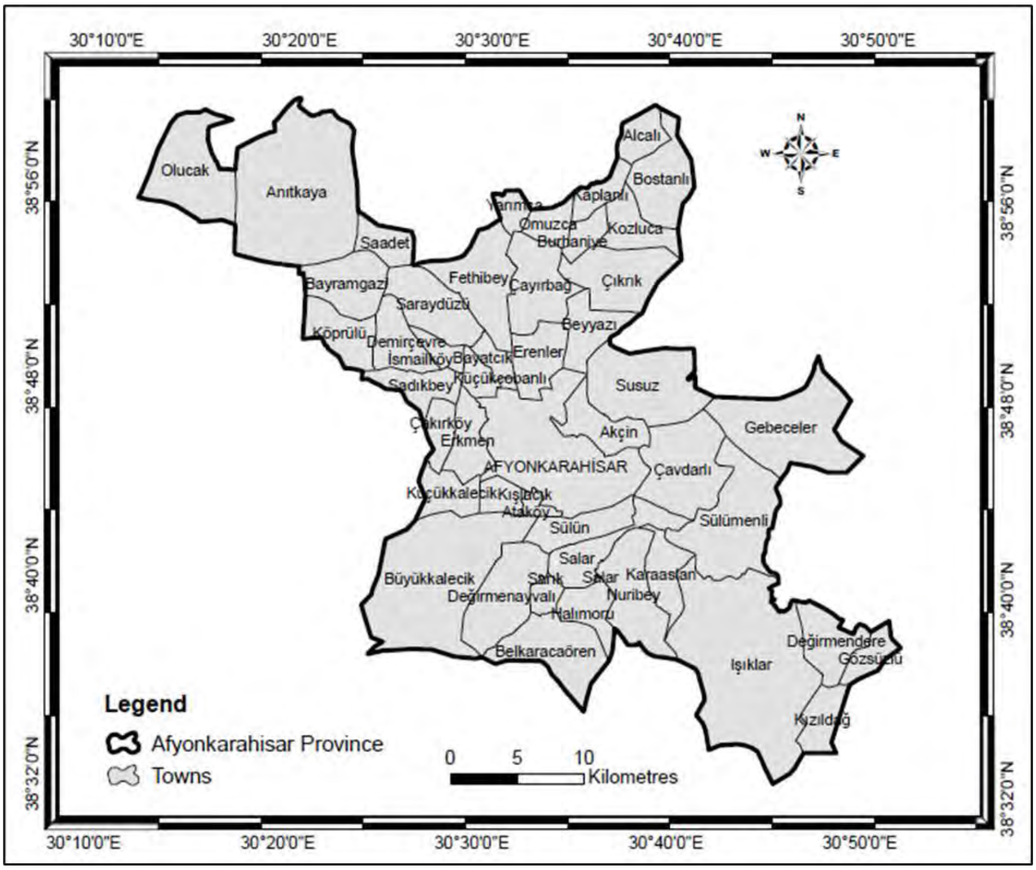
This is a case study performing a geospatial analysis on the locations of primary schools in Türkiye’s Afyonkarahisar province by using GIS and offering alternative spatial arrangements, thus, isolating the case of Afyonkarahisar to act as a decision point for the problem of spatial access to primary education in Türkiye as case study is a research method bounded by defined time, place, and activities of an instance, with the goal of identifying and understanding an issue, and often seeking to isolate critical incidents that act as decision points for change (Creswell & Creswell, 2018; Newby, 2014).

Study Area

This research aims to analyse the locations of primary schools in Afyonkarahisar province, Türkiye. The study area is located in the geographical region of the Aegean in Türkiye. Afyonkarahisar has a population of 313, 063 in 2020 according to the Turkish Statistical Institute (TSI) census records. Afyonkarahisar is one of the provinces with the highest rural population in Türkiye. The study area covers both urban areas and rural villages of the Afyonkarahisar District (Figure 1).

Figure 1

Map of the Study Area Showing Afyonkarahisar's Local Government Area and the Villages of the Central District within Afyonkarahisar



Dataset

The data used for this research include locations of 90 primary schools in Afyonkarahisar province (https://mebbis.meb.gov.tr/KurumListesi.aspx, accessed 26 February 2021), the population of primary school-aged children, and road datasets. Table 1 shows the data used for the analyses. The spatial distribution of roads and 90 primary schools within the study area are shown in Figure 2. The data of current primary schools were derived in Excel format with the address of each school complex. Both private and state schools were digitized using ArcMap 10.3 software according to their geographic locations, and the accuracy assessment of digitization was done using Google Earth Program. Also, the primary school-aged population was derived from the census records of the Turkish Statistical Institute (TSI, 2020). The population totals were obtained for each spatial unit of the neighbourhood and rural village of the central district of Afyonkarahisar. Population datasets were joined with the vector layers in order to transfer population totals to each geographic unit. Generally, population totals are provided, assuming uniform population distribution within the boundaries of settlements. In reality, population total shows the spatially non-uniform distribution in most parts of the world (Köse et al., 2021). In this sense, population density changes between the urban neighbourhoods and villages within the boundary of the Afyonkarahisar administrative area. A dasymetric mapping method (Jega et al., 2017; Mennis, 2009) was performed to better estimate the spatial distribution of primary school-aged population totals. The Corine land cover dataset (2018 dated) was used as ancillary information in dasymetric mapping to create population surfaces of settlements. Finally, the estimated population totals were gridded, and these grid points across Afyonkarahisar were used to show the population totals aged 6-10 in need of primary school services (Figure 4).

Table 1

Data Used for the Analyses

Data	Format	Data Source
Primary Schools (state and private)	Excel	Ministry of National Education official website
Population Data	Excel	Turkish Statistical Institute
Boundary Data of Afyonkarahisar	Shapefile	General Directory of Agricultural Reform (GDAR) of Türkiye
	Shapefile	Open Street Map (©OpenStreetMap)
Road Data	Shapefile	Open Street Map (©OpenStreetMap)
Corine Land Cover	Raster	European Environment Agency (EEA)

For location-allocation analyses, this research aims to evaluate the current locations of primary schools and suggest alternative locations that are more likely to improve overall accessibility to primary education. The p-median problem addresses this objective. Jega et al. (2017) reviewed the p-median problem, and its objective function, which aims to reduce the total weighted distance travelled from residential homes to service facilities (in this case, primary schools). Jega et al. (2017) used Teitz and Bart's (1968) heuristic search algorithm to solve the p-median problem. This research will adopt the methodology applied by Jega et al. (2017) to solve the p-median problem. Please see Jega et al. (2017) for an extensive review of the p-median problem and Teitz and Bart's (1968) heuristic search algorithm.

Figure 2

The Spatial Distribution of the 90 Current Primary Schools within Afyonkarahisar District

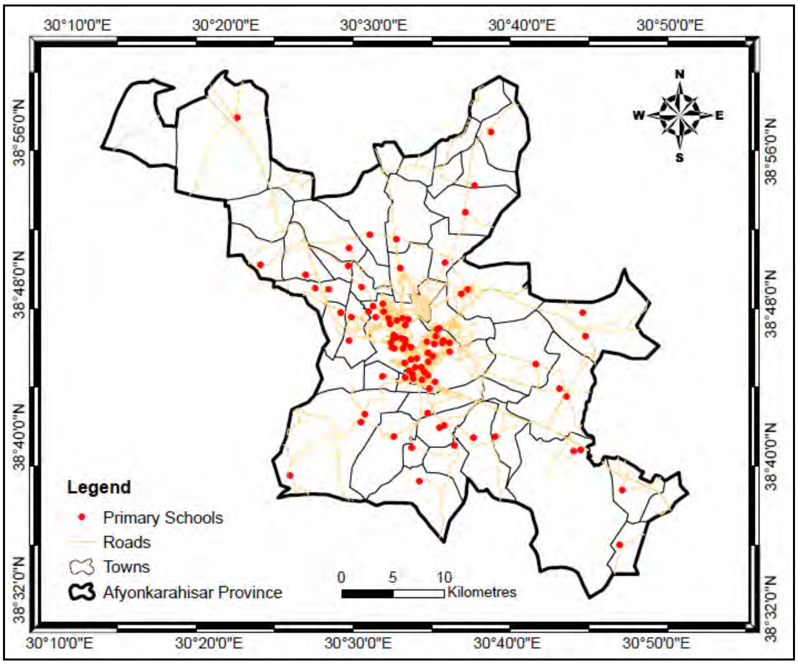
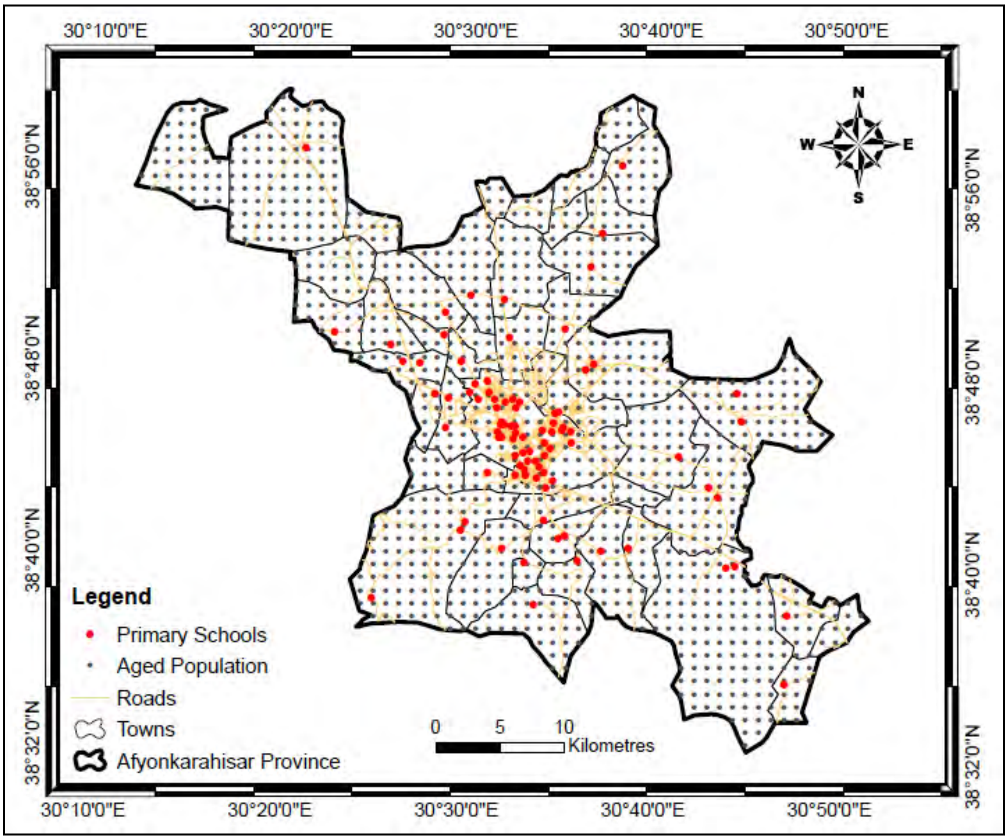


Figure 3

Spatial Distribution of 90 primary schools (red dots), Distribution of 1199 Point Locations of Estimated Primary School Aged Population (black dots), and Network of 11,741 Roads (sand color) within Afyonkarahisar District



Findings and Discussion

This section displays the results for demand allocation for current locations of primary schools, potential primary school locations, and the utility of different locations in both current and potential sets of locations.

Demand Allocation for Current Primary Schools

The demand for school services was allocated to the schools. The model did not allocate demand to 8 schools within Afyonkarahisar town. The schools are; Mehmet Yağcıoğlu, Bayraktepe İlkokulu, Fatih, Gedik Ahmet Paşa, Hacı Hayriye Özsoy, Kadaifçioglu, Sahipata and Yüksel Varlı. This is possibly due to the limitations of the road data used. Table 2 shows the total demand allocated to each of the 82 current primary schools and the mean distances between each primary school and each residential home within its catchment. The average mean distance for the existing primary schools is 1466.81m. This is slightly above the recommendation of Chillón et al. (2015) that young people should walk a maximum of 1400m to access primary schools. The table also shows the percentage of the total demand allocated to each primary school. Teitz and Bart's algorithm assumes that all primary schools in Afyonkarahisar province provide the same services. This implies that for the current locations of primary schools in Afyonkarahisar province to be optimal, the demand should be equally allocated for all the primary schools. The results in Table 3, when sorted from the highest percentage demand allocation to the lowest, show that the first ten schools were allocated about 40% of the demand while the remaining 60% was shared between the remaining 72 schools. Allocating demand to service facilities plays a vital role in policy development for spatial planning, and the results provide evidence for informed decision-making for the selection of new school sites.

Table 2

Demand Allocated to Primary Schools in Afyonkarahisar Province

S/No	Name of Primary School	Demand	Mean.dist	Maximum	% Demand
1	Ticaret_Borsası_ŞÖHD İlkokulu	227	11.24	11.24	0.89
2	Mehmet Yağcıoğlu	0	0	0	0
3	Ahmet Ömer Kocaşaban	681	960.61	1,767.39	2.67
4	Akçin İlkokulu	65	847.41	1,251.87	0.25
5	Ali Çetinkaya	227	271.71	271.71	0.89
6	Ataköy İlkokulu	427	1,268.89	2,182.52	1.67
7	Anıtkaya Faik Deniz	172	5,924.00	12,939.46	0.67
8	Atatürk İlkokulu	227	190.55	190.55	0.89
9	Ayşegül Arsoy	227	323.24	323.24	0.89
10	Bayraktepe İlkokulu	0	0	0	0
11	Belkaracaören	83	2,957.47	5,778.64	0.33
12	Beyazıt İlkokulu	2748	2,421.95	4,292.71	10.76
13	Beyyazı İlkokulu	537	1,784.00	3,043.43	2.10
14	Bozdoğan Halımoru	91	2,067.92	4,402.75	0.36
15	Bostanlı	67	2,568.29	4,526.18	0.26
16	Büyükkalecik Bahçederesi	113	3,233.91	6,584.64	0.44
17	Büyükkalecik	58	2,229.50	4,960.93	0.23

18	Büyükkalecik Kocatepe	123	3,232.22	5,961.78	0.48
19	Cumhuriyet	454	502.99	758.86	1.78
20	Çavdarlı Şehit Hüseyin	209	2,819.21	5,108.78	0.82
21	Çayırbağ	400	3,289.89	7,608.72	1.57
22	Çıkrık İlkokulu	247	2,239.00	4,513.97	0.97
23	Değirmenayvalı	173	2,189.18	5,148.89	0.68
24	Değirmendere	138	2,802.34	5,764.77	0.54
25	Demirçevre	108	2,322.19	5,107.93	0.42
26	Erenler	360	1,483.78	2,808.71	1.41
27	Ekrem Yavuz	227	109.86	109.86	0.89
28	Erkmen	339	2,163.15	4,391.44	1.33
29	Erkmen TOKİ Nurullah Oymak	118	861.32	1,229.13	0.46
30	Ertuğrul Gazi	717	1,286.27	2,271.89	2.81
31	Fatih	0	0	0	0
32	Fethibey	221	3,580.95	8,576.96	0.87
33	Gebeceler	208	2,804.11	6,402.92	0.81
34	Gedik Ahmet Paşa	0	0	0	0
35	Hacı Hayriye Özsoy	0	0	0	0
36	Hisarbank 100 Yıl	227	457.88	457.88	0.89
37	Hocaahmet Yesevi	227	1,006.49	1,006.49	0.89
38	Hürriyet	454	1,232.86	1,721.86	1.78
39	Işıklar Balı Sultan	296	3,651.54	7,560.48	1.16
40	Hüseyin Türkmen	454	819.11	1,308.80	1.78
41	İnaz İlkokulu	45	1,104.86	1,648.85	0.18
42	Işıklar Dumlupınar	107	1,845.57	2,969.56	0.42
43	Kadaifçioğlu	0	0	0	0
44	İsmail Köy	195	1,205.76	2,488.29	0.76
45	Karaaslan	339	3,146.27	6,533.31	1.33
46	Karşıyaka	1589	1,783.76	2,948.44	6.22
47	Kasımpaşa	227	397.88	397.88	0.89
48	Kışlacık	105	1,526.00	2,879.28	0.41
49	Kazım Özer	227	336.21	336.21	0.89
50	Kızıldağ	367	3,812.13	8,108.49	1.44
51	Kozluca	108	3,127.71	7,300.06	0.42
52	Kocatepe	227	335.82	335.82	0.89
53	Küçük Çobanlar	74	1,054.40	1,766.77	0.29
54	Mareşal Fevzi Çakmak	299	1,168.06	1,755.61	1.17
55	Köprülü	139	4,121.02	7,747.96	0.54
56	Maver Kemal Arsoy	681	707.63	1,113.44	2.67
57	Merkez TOKİ	227	404.80	404.80	0.89
58	Namık Kemal	454	1,554.57	1,975.71	1.78
59	Nurettin Karaman	227	200.37	200.37	0.89
60	Nuribey	134	2,148.61	4,207.45	0.52
61	Nurten Telek	227	616.75	616.75	0.89
62	Oruçoğlu	227	388.06	388.06	0.89
63	Osman Atilla	227	231.96	231.96	0.89
64	Saniye Sayıoğlu	454	544.27	698.60	1.78
65	Sadıkbey	127	1,159.99	1,637.35	0.50
66	Sahipata	0	0	0	0

67	Salar Atatürk	48	778.14	1,116.76	0.19
68	Salar	184	1,451.48	2,760.82	0.72
69	Salim Pancar	227	124.11	124.11	0.89
70	Saraydüzü Oğuz Akdağ	62	3,704.26	8,006.47	0.24
71	Sarık	88	1,370.09	2,727.76	0.34
72	Selçuklu	454	509.32	624.95	1.78
73	Susuz Atatürk	581	1,727.78	3,872.77	2.28
74	Susuz	214	3,137.47	5,976.03	0.84
75	Sülümenli	137	1,910.45	3,540.75	0.54
76	Sülümenli Yavuz Selim	113	1,978.92	3,644.02	0.44
77	Sülün Balı-Mubahat Açıkgözoğlu	164	1,259.60	2,353.06	0.64
78	Şehit Murat Saraç	227	757.50	757.50	0.89
79	Şehit Yakup Suna	155	3,358.51	5,917.68	0.61
80	Şehit Yasin Mergen	974	2,525.36	4,662.70	3.81
81	TOKİ Mevlana	239	661.77	1,159.99	0.94
82	Yavuz Selim	386	527.79	837.23	1.51
83	Yüksel Varlı	0	0	0	0
84	27 Ağustos	227	997.10	997.10	0.89
85	Özel Afyon Girne Koleji	67	1,551.01	2,330.48	0.26
86	Özel Afyon İstek	382	957.00	1,361.07	1.50
87	Özel Afyon Neziha Arslan	1431	2,028.93	4,032.91	5.60
88	Özel Afyonkarahisar Bahçeşehir	227	513.03	513.03	0.89
89	Özel Nar Tanesi	227	133.95	133.95	0.89
90	Özel TED Afyon Koleji	39	1,211.98	2,138.95	0.15

Demand Allocation for Potential School Locations

Potential school locations were generated using random grids across the study area. The grids were spaced 500m apart, and only grid points within a 30m from the road network were selected. This is done to be sure the potential locations are accessible on the road network. Similar criteria were used by Jega et al. (2017) and Köse et al. (2021). A total of 215 potential sites were selected from the grid points. To compare with the current setting of 90 primary schools, the model was configured to select 90 optimal locations from the 215 potential school locations. Table 3 shows the demand allocated to each of the 90 potential locations with the percentage demand allocation and the mean distances from each home to each potential school location. These locations are assumed to be optimal locations for siting primary schools in Afyonkarahisar province. The results show the average mean distance from each resident to each potential primary school location to be 1127.12m. This has reduced the average mean distance for the current primary schools by 339.69m.

Table 3

Demand Allocated to Potential Primary Schools' Location in Afyonkarahisar Province

Potential Primary School	**Demand**	**Mean.dist**	**Maximum**	**% Demand**
1	214.00	1,211.20	7,919.03	0.89
2	21.00	1,459.55	2,360.51	0.09
3	932.00	1,005.10	4,684.60	3.90
4	1,013.00	2,356.20	10,681.17	4.23

5	1,259.00	2,155.02	17,693.94	5.26
6	1,272.00	3,202.10	17,680.11	5.32
7	1,081.00	2,210.30	18,680.32	4.52
8	1,372.00	3,256.21	25,341.98	5.73
9	1,281.00	5,687.20	31,854.51	5.35
10	13.00	1,968.27	2,900.66	0.05
11	2,842.00	3,200.24	18,318.55	11.88
12	5.00	871.81	1,342.96	0.02
13	3.00	414.04	414.04	0.01
14	51.00	1,744.94	3,341.65	0.21
15	3.00	316.12	316.12	0.01
16	21.00	1,563.82	2,900.66	0.09
17	10.00	822.52	1,391.09	0.04
18	84.00	2,486.89	5,116.45	0.35
19	142.00	2,264.97	4,714.49	0.59
20	24.00	613.35	826.03	0.10
21	178.00	570.66	7,525.22	0.74
22	24.00	1,488.11	2,533.50	0.10
23	129.00	400.32	4,701.76	0.54
24	15.00	1,054.41	1,826.54	0.06
25	40.00	708.68	1,003.31	0.17
26	106.00	1,223.53	2,333.78	0.44
27	28.00	1,070.31	1,710.04	0.12
28	6.00	570.49	726.93	0.03
29	21.00	1,190.29	2,336.12	0.09
30	19.00	1,548.74	2,641.83	0.08
31	133.00	396.50	5,673.98	0.56
32	162.00	1,681.06	3,205.48	0.68
33	36.00	1,827.06	3,189.19	0.15
34	131.00	1,756.76	3,552.78	0.55
35	123.00	600.21	2,416.99	0.51
36	48.00	1,160.07	1,514.15	0.20
37	150.00	861.71	1,342.96	0.63
38	82.00	356.90	2,416.99	0.34
39	83.00	1,395.92	2,631.49	0.35
40	11.00	560.03	719.39	0.05
41	8.00	646.13	861.94	0.03
42	14.00	1,720.83	4,098.56	0.06
43	2.00	1,003.31	1,003.31	0.01
44	31.00	411.20	4,078.25	0.13
45	111.00	760.86	1,105.05	0.46
46	25.00	1,086.06	2,100.79	0.10
47	27.00	726.93	726.93	0.11
48	32.00	1,095.25	1,887.09	0.13
49	337.00	1,286.24	2,118.87	1.41
50	454.00	1,413.13	2,099.34	1.90
51	94.00	876.43	1,431.86	0.39
52	473.00	645.18	855.59	1.98
53	8.00	1,545.38	2,385.05	0.03

54	335.00	1,020.30	1,514.15	1.40
55	96.00	1,384.58	2,599.99	0.40
56	55.00	455.20	3,828.28	0.23
57	95.00	1,152.71	1,974.04	0.40
58	227.00	298.38	298.38	0.95
59	227.00	298.38	298.38	0.95
60	227.00	316.12	316.12	0.95
61	2.00	1,413.13	2,099.34	0.01
62	227.00	826.03	826.03	0.95
63	565.00	1,527.78	2,436.32	2.36
64	72.00	1,878.77	3,881.59	0.30
65	454.00	775.14	1,251.89	1.90
66	227.00	316.12	316.12	0.95
67	227.00	298.38	298.38	0.95
68	454.00	910.51	1,504.90	1.90
69	92.00	560.20	4,771.74	0.38
70	696.00	1,056.57	1,725.90	2.91
71	23.00	1,242.18	2,118.87	0.10
72	454.00	1,308.02	1,790.01	1.90
73	43.00	1,405.37	2,416.99	0.18
74	227.00	298.38	298.38	0.95
75	8.00	1,081.58	1,725.90	0.03
76	227.00	298.38	298.38	0.95
77	227.00	316.12	316.12	0.95
78	908.00	976.85	1,725.90	3.79
79	174.00	788.65	8,275.12	0.73
80	290.00	2,210.30	8,104.02	1.21
81	227.00	806.00	806.00	0.95
82	227.00	400.67	400.67	0.95
83	227.00	719.39	719.39	0.95
84	14.00	450.22	2,086.32	0.06
85	227.00	414.04	414.04	0.95
86	227.00	298.30	1,105.05	0.95
87	227.00	298.38	298.38	0.95
88	227.00	298.38	298.38	0.95
89	227.00	316.12	316.12	0.95
90	454.00	576.99	855.59	1.90

Selecting Different Number of Locations

The heuristic search algorithm, Teitz and Bart's (1968) was also used to select different number of locations for both current primary schools and the potential locations of schools. This is similar to the work of Jega et al. (2017) and Kose et al. (2021) to ascertain if reducing the number of current primary school locations would minimize the average mean distances from primary school-age population homes to current locations of primary schools. Table 4 shows the number of primary schools (subsets) selected for both current locations and the potential locations, the mean distance from residential homes to selected school locations in the current settings (current distances), the mean distance from residential homes to selected potential school locations (modelled distances) and the difference between current distances and modelled distances for each subset. From Table 4, for all the subsets analysed, the modelled distances were less than the current distances. This suggests that the method used in this research has the capability of minimizing the average travelled the distance from residential homes to services facilities, in this case, primary schools. The current and modelled distances were plotted against the number of primary schools in a subset, as shown in Figure 5.

Figure 4

Spatial Distribution of 90 Optimal Locations out of 215 Potential Locations (blue dots) and 90 Current Locations of Primary Schools (red dots)

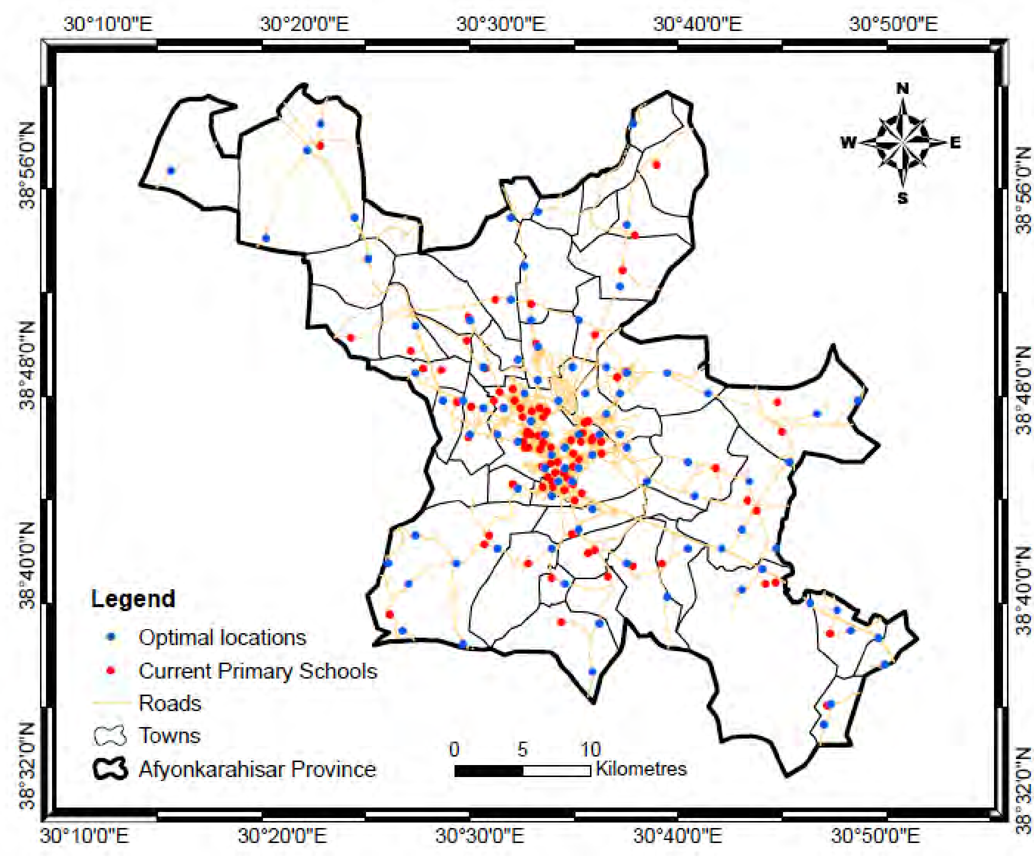


Table 4

Selecting Different Number of Primary Schools

Primary Schools	Current Distances	Modelled Distances	Difference (m)
50	2035.05	1840.88	194.17
60	1842.30	1596.03	246.27
70	1677.62	1361.98	315.64
80	1599.72	1304.54	295.18
90	1466.81	1127.12	339.69

The graph in Figure 5 shows that the average travelled distance for both the current and modelled distances reduces as the number of locations in the subset increases. Also, the modelled distances compared to the current distance have shown a significant reduction in the total travelled distances for all the subsets. This is similar to the findings of Jega et al. (2017) and Kose et al. (2021). The results suggest a decrease in the average travelled distance (modelled distances) for all the subsets, suggesting that a significant improvement can be achieved by changing the current locations of primary schools in Afyonkarahisar province.

Figure 5

Change in Current and Modelled Distances

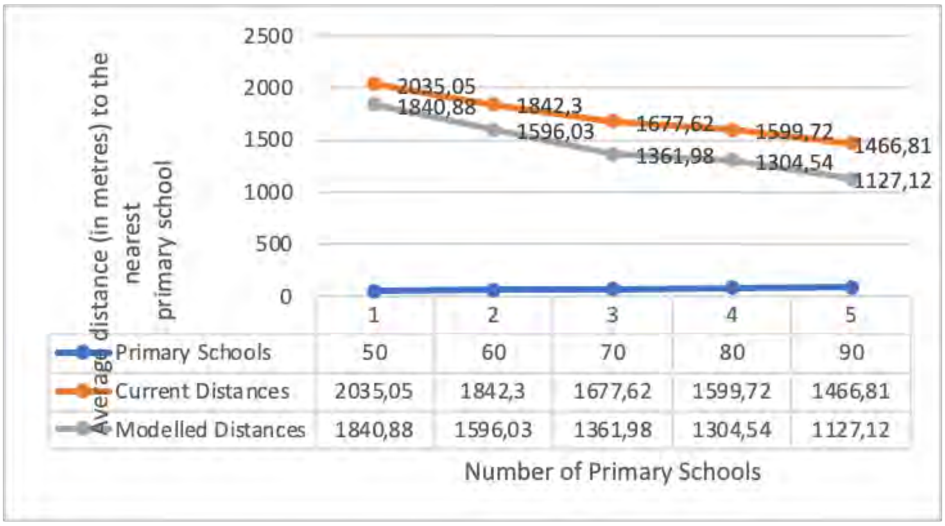
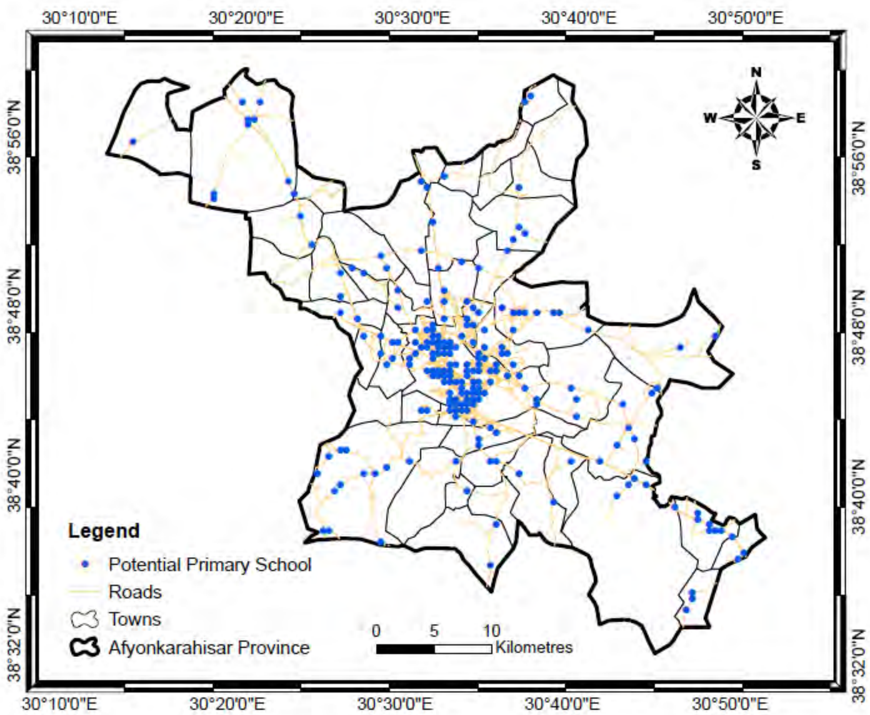


Figure 6

Spatial Distribution of 215 Potential Locations for Primary Schools (blue dots)



Conclusion

Current and potential primary school locations and the average travel distance of the children from various homes to schools were analysed using Teitz and Bart's (1968) heuristic search algorithm. The results show the average mean distance from each home to each primary school to be 1466.81m. This is 66.81m above the maximum threshold Chillón et al. (2015) recommended for young people to access primary schools. Alternative school locations that are more likely to reduce the access distance were generated and evaluated. The results show the average mean distance from each resident to each potential primary school location to be 1127.12m. This has reduced the average mean distance for the current primary schools by 339.69m. These results provide the main implication of the current study. The alternative school locations for establishing new primary schools should be considered by the policymakers in Afyonkarahisar province to increase the accessibility to primary school institutions. The results show that analysis of this nature provides documentary evidence to support decisions in locating and allocating demand to service facilities. Further geospatial analysis research is needed for different school levels and types in Afyonkarahisar, including high schools or special education institutions, to help policy and decisionmakers in their educational planning. Indeed, this data-based method for determining alternative school locations should be used throughout the country to alleviate educational planning practices for both increasing access to education and ensuring proper utilization of public resources.

The main limitation of this research is the primary school-aged population data used. The population data, which was obtained from Turkish Statistical Institute (TSI), is reported yearly. For the population distribution of each neighbourhood 6, 7, 8, 9, and 10 years, population totals were obtained and redistributed using the dasymetric technique to have an estimate of the population. Another limitation of this research involves the roads dataset, which was obtained from open street map sources. The road data did not completely cover the geographic area of the Afyonkarahisar District. The heuristic search algorithm could not allocate demand to 8 current primary schools because of this limitation. The road datasets also do not have speed limits for all types of roads within the geographic area. Indeed, roads do have different speed limits in residential and non-residential areas and on highways. The heuristic search algorithm used also assumes that all schools provide the same services. In reality, schools in urban areas have a larger capacity in terms of the student population than schools in rural areas. However, as the Primary Education Law pointed out, school complexes should be built in an appropriate location regarding health, education, and transportation. They should be at least 100 meters away from such places as bars, electronic game places, or shops selling alcohol. The study area does not have an urban atlas that contains building usage information. The dataset, which includes the usage information of the buildings, can be used as ancillary data in determining the areas away from alcohol shops, electronic playgrounds, and bars in order to build new school buildings. It must be noted that these limitations may likely affect the results but barely affect the validity of analyses and findings of this research.

Statement of Responsibility

All authors contributed to the study. Initial Conceptualization and drafting of the original manuscript were carried out by Köse, Erdem and Koçyiğit. Methodological design and analysis were carried out by Köse and Jega. Data curation, Software and Visualization were carried out by Köse, Erdem and Koçyiğit. Writing, Revision and Editing were performed by Köse, Erdem, Koçyiğit and Jega.

Conflicts of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

Author Bios:

Mustafa Köse received his BA in Geography department at Kahramanmaraş Sütçüimam University, Turkey (2008), integrated doctorate degree at University of Leicester in Geography in UK (2015). He is an assistant professor at the faculy of science and literature at Afyon Kocatepe University. His academic interests include geographical information systems, geoscience, geostatistics, population geography, urban geography and planning geography.

Cahit ERDEM received his BA in English Language Teaching department at Bogazici University, Turkey (2009) and his PhD in curriculum and instruction department at Anadolu University, Turkey (2018). He is an associate professor at education faculty at Afyon Kocatepe University. His academic interests include factors related to academic achievement, media literacy, internationalization of higher education, teacher identity, and curriculum theory and instruction.

Mehmet KOÇYİĞİT received his BA in English Language Teaching department at Selçuk University, Turkey (2008), master's degree at Afyon Kocatepe University in educational sciences (2011) and his PhD in Educational Administration at Eskişehir Osmangazi University, Turkey (2017). He is an associate professor at the faculy of education at Afyon Kocatepe University. His academic interests include educational management, organizational behaviour, teacher education, and educational policy.

Mohammad Idris Jega received his BA in Bachelor of Engineering (B.Engr.), Land Surveying (Surveying) department at Ahmadu Bello University, Nigeria (1998), master's degree at Leicester University (UK) in Geography (2009) and his PhD in geography in Leicester University, UK (2015). He is an assistant professor at National Space Research and Development Agency in Nigeria. His academic interests include geographical information systems, geoscience, geostatistics and Land Survey.

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