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Spatial Distribution and Density of Road and Railway Networks in Algeria's Central High Plateaus: Implication for Territorial Development.

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Abstract:

Sustainable human development emphasizes human well-being, social equity, and access to essential infrastructure. Transport networks are essential for improving accessibility, facilitating socioeconomic interactions, and reducing territorial disparities. This study aims to assess the adequacy of road and railway infrastructure in Algeria's Central High Plateaus region in relation to population size and territorial area. A quantitative and comparative methodology is adopted, using indicators of road and railway network density compared with national standards. The analysis seeks to identify potential infrastructure deficiencies and territorial imbalances affecting accessibility and regional development. The results are intended to highlight the extent to which existing transport networks meet demographic and spatial needs and reveal potential disparities in infrastructure distribution. The study concludes that evaluating transport infrastructure through quantitative indicators provides valuable insights for sustainable regional planning. Improving connectivity and ensuring a more equitable distribution of transport services could contribute to reducing territorial inequalities, enhancing quality of life, and promoting balanced human development in Algeria.

Keywords: Sustainable Human Development; Transport Networks; Road Network; Railway Network; Central High Plateaus; Algeria; National Standards.

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1. Introduction and Theoretical Background.

The development of transport and communication networks has a direct impact on achieving development, as these networks serve as a link between human beings, as the primary focus of human development, and economic institutions, educational services, and healthcare services, which are considered among its fundamental pillars. In this regard, the Council of Ministers of Transport of the European Union defines a sustainable transport system as "a system that enables the development needs of individuals, businesses, and society to be met safely, in a manner consistent with human health and the environment, while promoting equity between successive generations" [1].

1. Study Area Overview.

This study focuses on the Central Algerian High Plateaus region, which serves as a link between the four geographical regions of the country and is located approximately 300 km south of the national capital, Algiers. The region covers an area of 75,483 km² [2], representing approximately 3.26% of Algeria's total national territory. Its total population reached 3,932,833 inhabitants [3], according to the 2024 results provided by the Directorates of Planning and Budget Monitoring.

The region is bordered by the provinces of Sétif, Bordj Bou Arréridj, Bouira, Médéa, and Tissemsilt to the north; Ghardaïa Province to the south; Batna, Biskra, and Ouargla provinces to the east; and Tiaret and El Bayadh provinces to the west.

Administratively, the region comprises three provinces: M'Sila, Djelfa, and Laghouat. These provinces are divided into a total of 37 districts (daïras), which in turn comprise 107 municipalities (communes), as illustrated in **(Figure 1).**

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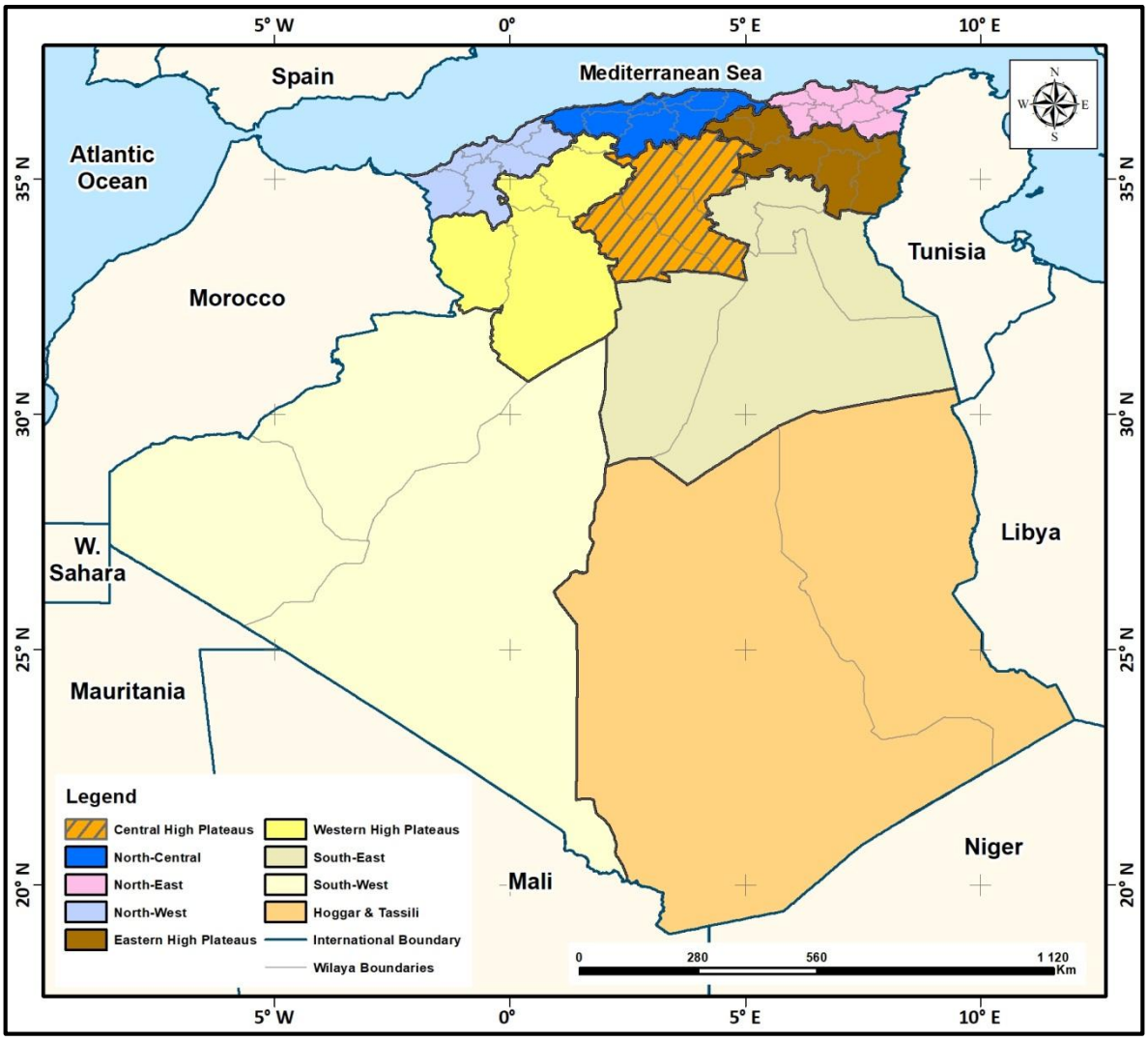


Figure 01: geographic location of the high plateaus region, central Algeria

2. Transport Network Indicators in the Study Area:

The total length of the transport network in the study area is approximately 9,190.93 km [5], as illustrated in **(Figure 2)** This network is divided into national roads, with a total length of 3,681.89 km, representing 40.06% of the network; provincial roads, extending over 1,499.04 km, accounting for 16.31%; and municipal roads, with a total length of 4,011 km, representing 43.63%. In addition, the railway network extends over 588 km [6]. These figures provide the basis for examining the following indicators:

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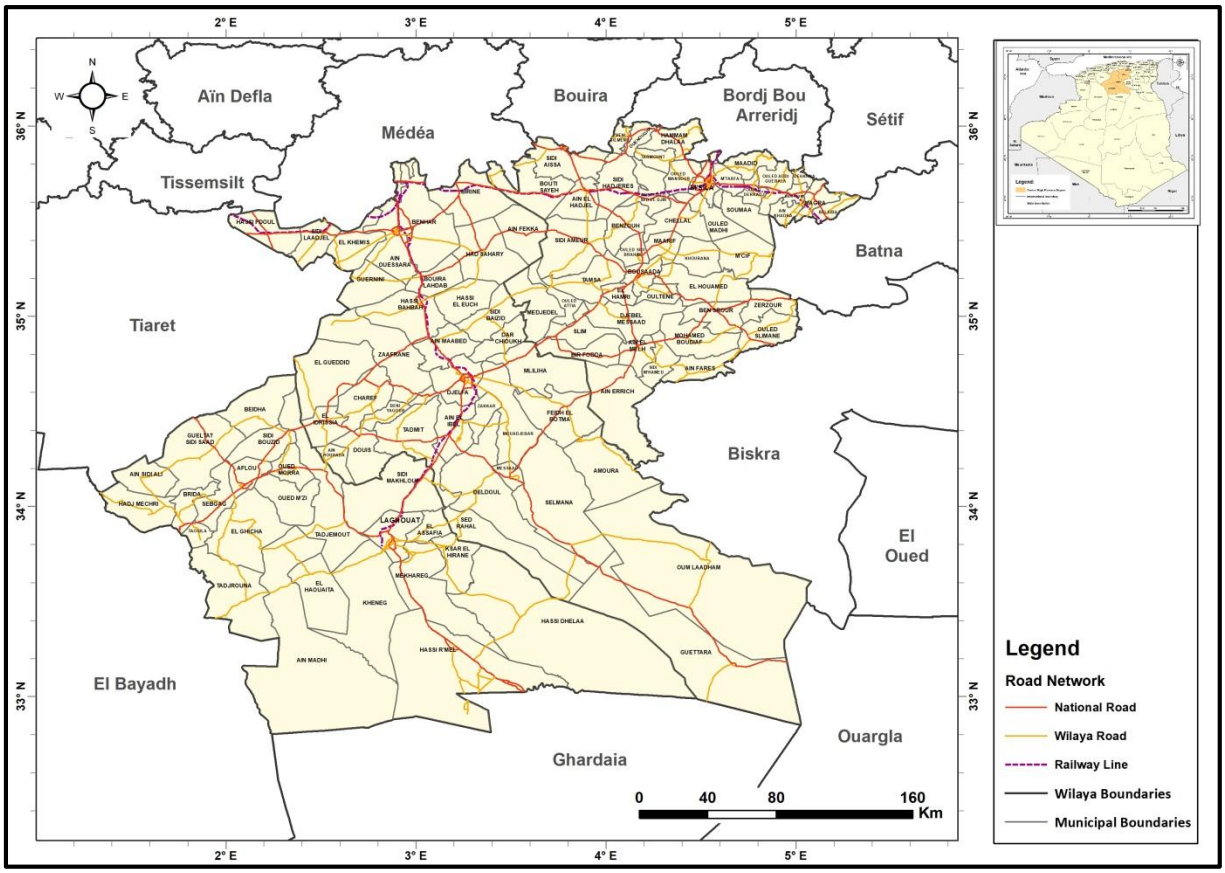


Figure 2: Road and Railway Networks in the Study Area, 2024.

2.1. Road Network Density Index:

The road network is one of the most important elements of the human-modified landscape and plays a crucial role in determining the level of human interaction with the environment in all its dimensions. It serves as a medium that facilitates the movement of people from one geographical area to another. Roads can therefore be likened to arteries in the human body, as they contribute to promoting development across all regions [7].

3.1.1. Road Network Density Based on Population Criteria:

Road density based on population is considered one of the most effective indicators for measuring the level of human development. The higher the road network density and its utilization, the better the region's transport network is considered to be. Conversely, low road density indicates that many areas lack adequate access to road network services [8]. Road density based on population is calculated using the following equation:

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Road network density per capita = (Total length of the road network in a given region ÷ Population of that region) × 1,000

It is evident from **(Table 1)** that the road density index relative to population in the study area reached 2.32 km per 1,000 inhabitants in 2024. However, this indicator exhibited considerable variation among the municipalities. One of the most notable findings was the predominance of the category with a road density ranging from 0.5 to 5 km per 1,000 inhabitants, which encompassed the largest number of municipalities, approximately 57, representing 53.27% of the total. This reflects the low density of the road network in more than half of the municipalities in the study area.

The second category, with a road density ranging from 5 to 10 km per 1,000 inhabitants, included 25 municipalities, accounting for 23.36%. Meanwhile, the intermediate-density category, ranging from 10 to 20 km per 1,000 inhabitants, comprised 18 municipalities, representing 16.82%. In contrast, the high-density category, with values ranging from 20 to 50 km per 1,000 inhabitants, recorded the lowest representation, comprising only seven municipalities, or 6.55% of the total.

When compared with the national average for the same year, estimated at 3.03 km per 1,000 inhabitants [9], it becomes apparent that a considerable proportion of the municipalities in the study area fall within the lowest density category (0.5–5 km per 1,000 inhabitants). Although this category includes values that may be either above or below the national average, the concentration of most municipalities within this range indicates an overall level comparable to, or lower than, the national average in many cases.

Conversely, municipalities belonging to categories exceeding the threshold of 5 km per 1,000 inhabitants exhibit road density levels that clearly surpass the national average. Nevertheless, these municipalities account for a limited share of the total, representing only 23.37%, which indicates that road density relative to population in the study area is concentrated in a small number of administrative units.

Categories	0.5–5 km/1,000 inhabitants	5–10 km/1,000 inhabitants	10–20 km/1,000 inhabitants	20–50 km/1,000 inhabitants
Number of municipalities	57	25	18	7
Percentage (%)	53.27	23.36	16.82	6.55

Table 1. Road Network Density Relative to the Population of the Study Area in 2024.

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3.1.2. Road Network Density Based on Area:

It refers to the density of the paved road network relative to the area, expressed in km/km², as shown in the following equation:

Road Network Density Relative to Area = Length of the Paved Road Network (km) / Area Served by Roads (km²) × 1,000 [10].

Based on the data presented in **(Table 2)**, the municipalities in the study area are classified into four (04) categories according to road density relative to area. The data indicate that the most representative category is the medium-density category, which includes municipalities with road densities ranging from more than 100 to less than 300 km/1,000 km². This category comprises 49 municipalities, accounting for 45.79% of the total number of municipalities. This reflects a medium level of road density in nearly half (1/2) of the municipalities in the study area.

As for municipalities where road density is below 100 km/1,000 km², this category includes 33 municipalities, representing 30.84% of the total. This indicates that a considerable proportion (more than one-quarter) of the municipalities suffers from inadequate road coverage, which is often associated with the large geographical extent and rural nature of certain areas.

Meanwhile, the third category, with road densities ranging from more than 300 to less than 500 km/1,000 km², is relatively underrepresented, comprising only 16 municipalities, or 14.95% of the total. This indicates that high road density is concentrated in a limited number of municipalities.

The highest-density category, comprising municipalities with road densities exceeding 500 but remaining below 900 km/1,000 km², includes nine (09) municipalities, representing 8.42% of the total. This highlights the fact that certain municipalities benefit from a relatively high level of road density.

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When comparing road density in the study area with the national average, a marked disparity becomes evident. At the national level, road density relative to area stands at 6.07 km/1,000 km² [11], whereas in the study area it reaches 117.35 km/1,000 km² [12]. This suggests that the study area enjoys a relatively satisfactory level of road coverage compared with the national average. However, this improvement remains unevenly distributed among the municipalities and provinces within the study area.

Accordingly, evaluating the road network in the study area requires more than simply comparing it with the national average. It also necessitates expanding the spatial coverage of the network and reducing existing disparities between municipalities and provinces, given that equitable distribution of transport infrastructure is one of the key factors supporting sustainable human development and improving the quality of life of the population.

Table 2. Road Network Density Index per Unit Area in the Study Region, 2024.

Categories	Less than 100 km/1,000 km²	More than 100 and less than 300 km/1,000 km²	More than 300 and less than 500 km/ 1,000 km²	More than 500 and less than 900 km/1,000 km²
Number of Municipalities	33	49	16	9
Percentage (%)	30.84	45.79	14.95	08.42

3.2. Railway Network Density Index:

The railway network is considered an efficient and cost-effective means of transporting large numbers of passengers and substantial volumes of freight over long distances. The efficiency of rail transport increases with the volume of traffic and the distances covered. Furthermore, railway infrastructure requires a relatively small land area compared with road networks, as the width of a railway corridor can be less than 10 metres [13].

3.2.1. Railway Network Density Index Relative to Population.

Railway network density relative to population is calculated using the following equation:

Railway network length in a given area / Population of the area × 100,000 people [14].

It is evident from **(Table 3)** that the study area recorded a railway network density of 14.95 km per 100,000 inhabitants, based on a total railway network length estimated at 588 km in

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2024, according to data from the World Population Review website. This figure exceeds the national average, estimated at 10.25 km per 100,000 inhabitants [15]. indicating that the study area has a higher railway network density than the national average. However, this density remains below the global average, estimated at 16.40 km per 100,000 inhabitants [16], according to the Organisation of Islamic Cooperation .Accordingly, it can be concluded that the study area occupies a relatively favorable position in terms of railway network density at the national level, although its density remains below the global benchmark.

Table 3: Railway Network Density in Relation to Population and Area in the Study Area, 2024.

Level	Railway line length per 100,000 inhabitants (km)	Railway line length per 1,000 km² of area (km)
Study area	14.95	7.78
National level	10.25	2.01
Global level	16.40	9.40

3.2.2. Railway Network Density per Unit of Area.

The railway network density per unit area can be calculated using the following equation:

Railway network density per unit area = (Total length of the railway network (km) / Area of the region (km²)) × 1,000

The analysis of railway network coverage density, as presented in **(Table 3)**, reveals that the study area recorded an average of 7.78 km per 1,000 km² in 2024 [17], which is higher than the national average of 2.01 km per 1,000 km²[18] , but remains below the global average of 9.40 km per 1,000 km² [19]. The data also highlight disparities in spatial coverage among the provinces within the study area, as the railway network serves 11 municipalities in each of the provinces of M'Sila and Djelfa, compared with only two municipalities in the province of Laghouat, reflecting the limited spatial extent of the network. Accordingly, there is a clear need to expand and strengthen the railway network to improve coverage density, reduce spatial disparities among municipalities, and enhance the role of rail transport in promoting regional integration and supporting the economic and social development of the study area.

Conclusion

The findings of this study highlight that road and railway networks constitute two fundamental pillars for assessing the level of sustainable human development in the Central

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High Plateaus region, given their direct impact on improving quality of life and enhancing the population's ability to participate in various economic and social activities. However, the results also reveal that infrastructure indicators, particularly road and railway network density in relation to population size and the total area of the region, remain among the major challenges facing sustainable human development in the study area. Most indicators demonstrate a persistent gap between the region and national averages. This underscores that improving living conditions requires not only the availability of healthcare services, but also the development of infrastructure, which provides the essential framework for ensuring accessibility to these services.

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