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Quantification of Road Network Accessibility to Measure Socio-Economic Development
A Case for Alwar District, Rajasthan, India

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Abstract

The road network supports a whole variety of dependent economic activity and serves to integrate the economic system and facilitate its transactions in geographical space (Diamond and Spence 1989). The present paper analyzes the impact of road network accessibility on the socio-economic development of Alwar district. The floating catchment area and normalization techniques (z-square) has been used for the measuring the road network accessibility and availability of socio-economic amenities while using the variety of tools including GIS and AutoCAD software's has been used for the process the spatial data. Also ArcGIS and Imagine process software has been used map making through digitization, closest proximity, shortest path, service area, and network analysis. The statistical tools that as MS-Excel and MS-SQL have been used for analysis. The significant finding from a study suggests that Alwar district is legging in the availability of socio-economic amenities at the threshold distance.

Keywords: Accessibility, Development, Threshold, Socio-Economic Amenities.

Introduction

Transportation is a measure of the relationship between areas of development, and it is the key to development. The road network holds the fabric of all the societies together. Development of road network plays a significant role in the socio-economic improvement of a region. Its impact directly or indirectly to the socio-economic condition of the people. A better road network constitutes the necessary infrastructure that drives the development process by providing efficient connectivity and accessibility, which will helpful for backward region development. Insufficiency of road network provision is the result of poverty and under-development. This impact would directly transform the socio-economic status of the people in the rural area. Hence the development of road network and transportation is must mandatory for regional development.

The study first presents a brief introduction to the case study of Alwar district, followed by the data collection, analysis, and findings, then use of two-step floating catchment area and normalization techniques (z-square) have been used for the measuring the road network accessibility to the socio-economic amenities, while using the variety of tools including GIS and MS-SQL software's has been used for the process the spatial data. Also ArcGIS and Imagine process software has been used map making through digitization, geo-referencing, over-laying the different layers, and buffering analysis. The statistical tools that as MS-Excel and SQL query have used for analysis. Moreover, it would help to find the correlation of road network accessibility with the socio-economic development of the district. Then study present a discussion on the idea of measuring road network accessibility and its implication the socio-economic development of the district, followed by conclusion and recommendation.

Based on the experience gained from the research it has found that, before preparing the road infrastructure and socio-economic amenities investment proposal, the policymaker may refer to the quantification method discussed in this research. Also, the vulnerable region may be identified by using this method. It would help to prioritize the investment in physical infrastructure.

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Review of Literature

Transport has an impact on the level of socio-economic development. Here we chronologically present a brief overview if the case studies. (O. Filani), (SHALINI), (Kayode et al.) and (Biswas and Anwaruzzaman). These studies are selected as each of them focuses on different aspects of quantification of road network measures, which we discuss in the context of our study. These studies are very detailed, and therefore not all aspects are discussed here.

(O. Filani) identified the crucial link between the developments of the transport network and rural development and indicated that the development of transport efficiency has a positive impact on rural development. Rural transport should constitute an integral part of national transport planning and development.

(SHALINI) on Quantification of Rural Accessibility and Development of a need-based approach for Rural Road network planning. To measure the road network connectivity of the selected district in Rajasthan state. Study is focused on the development of a different method to measure the health accessibility of the rural area. The output of the study is the two-step floating catchment area method has been developed to quantify the accessibility for health facilities.

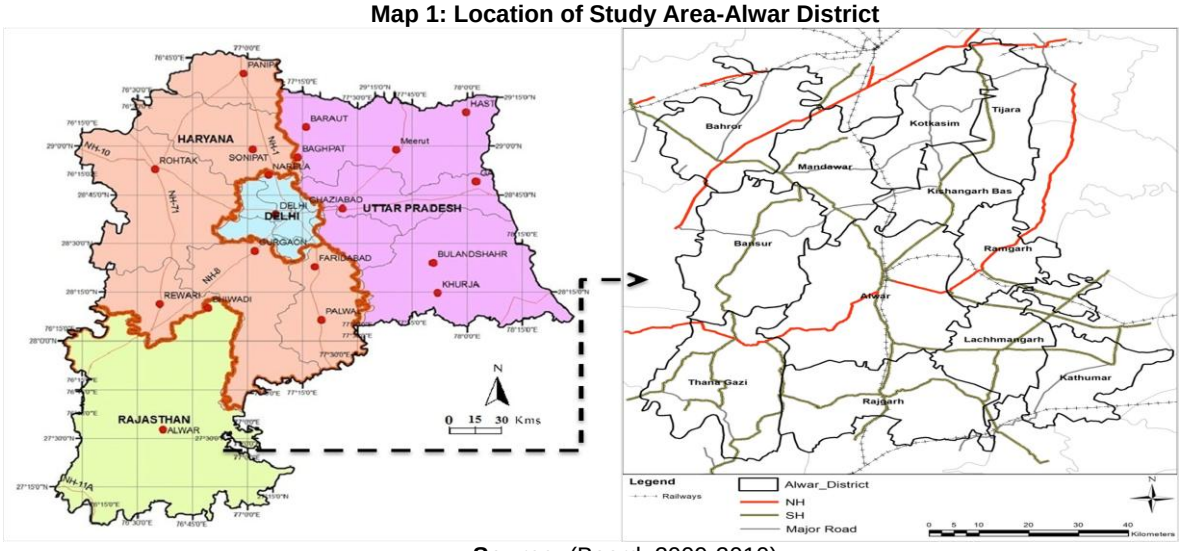
Table 1 Overview of Case Studies

Case Study	Methods	Tools	Output
Gaya District	Cyclomatic index, road density, accessibility at social amenities	GIS, Statistics tools,	Transport Region
Goa	Graph theory ,Shimble index and node accessibility	Statistics tools, Matlab and GIS	Identification of accessibility
Nigeria	Graph theory	GIS and analytical Matlab tools	Measuring accessibility to market area
Rajasthan	RAI index and Catchment area	GIS, Matlab and Remote sensing	Identification of HCH accessibility
Murshidabad district, West bangle	Qualitative data	Focus group discussion	Impact of PMGY on socio-economic development
Nigeria	Ordinary Least Squares	Statistics tools,SPSS	To find the relationship of transport investment and economic growth
Saudi Arabia	Desk base study	Statistics tools	To measure level of impact of road transport on economic development

A Brief Introduction to Alwar District

National capital region (NCR) is the country's first experimental region, which consists of an inter-state region with having the core of NCR. As a constituent of National Capital Region, Rajasthan Sub- Region lies in the south-western part of National Capital Region. The Rajasthan Sub- Region (Alwar) covers an area of 8290 sq. Km. The Alwar city lies 150 km west towards the Jaipur and 170 km North towards the Delhi. NH-8 (Delhi–Jaipur Road) passes through RSR and connects Gurgaon, Maneswar, Bawal and Rewari within the NCR (Map-1) The NH-11A is passing through the Alwar district, and NH 71B connects Rewari to Palwal in the north. The Railway lines connected to the Delhi and Ahmadabad with broad gauge rail line, which passes through the Jaipur, the state capital.

Map 1: Location of Study Area-Alwar District



Source: (Board, 2009-2010)

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Measurement of Road Network Accessibility

Status of Social Infrastructure

Alwar district, to the total area of these twelve tehsils, works out to be 8290 km2, which is 2.5 % of the state and the total length of road is 5431 km. The regional development of Alwar district has been analyzed, with the help of nine socio-economic indicators. The socio-economic indicators have selected based on the literature review and field study. Before analyzing the regional development, it worth to mention that, the only the socio-economic data of rural area has taken. (e.g., if we take the urban area data, then the availability of socio-economic facilities would be higher than the rural area, which not does make any sense for the regional analysis.). The following indicators are as follows;

1. Education
2. Medical
3. Drinking water facilities
4. Post office
5. Bank
6. Agricultural credit society
7. Approach by pucca road
8. Telephone
9. Transport-Communication

Each socio-economic indicator has been converted into the unit less value for mapping the transport region for the district. The different indicators values have converted by using the standardized units of normalization technique, which based on the following formula;

Xij = Xij –Min {Xij} / Max {Xij} – Min {Xij}

Based on the normalization technique, the value of each indicator has come under the 0 to 1. 0 refer to the less transport region and values near to 1 refer to the high transport region.

Table 2 and Table 3 presented socio-economic indicators and development indices of socio-economic factors.

Table 2 : Socio-Economic Indicators

Tehsils	Education (Unit per 10000)	Medical (Units per 10000)	Drinking water (Sources per 1000)	Post office (Units per 10000)	Telephone (Units per 10000)	Transport communications(Units per 10000)	Banking (bank per 10000)	Agricultural credit societies (Units per 10000)	Approach by pucca road (%)
Behror	309	207	313	229	313	216	153	134	64
Mandawar	228	136	232	162	232	138	74	97	57
Kotkasim	129	65	137	76	137	54	35	56	49
Tijara	250	125	257	166	257	95	74	64	50
Kishangarh Bas	205	125	210	155	210	94	85	71	62
Lachhmangarh	259	136	272	174	272	146	87	121	52
Ramgarh	406	207	421	280	421	198	151	126	54
Alwar	252	193	258	200	258	162	137	142	66
Bansur	257	164	264	199	264	165	122	103	61
Thanagazi	224	143	233	176	233	123	95	91	65
Rajgarh	161	107	171	114	171	102	68	60	58
Kathumar	240	138	251	166	251	131	105	126	54

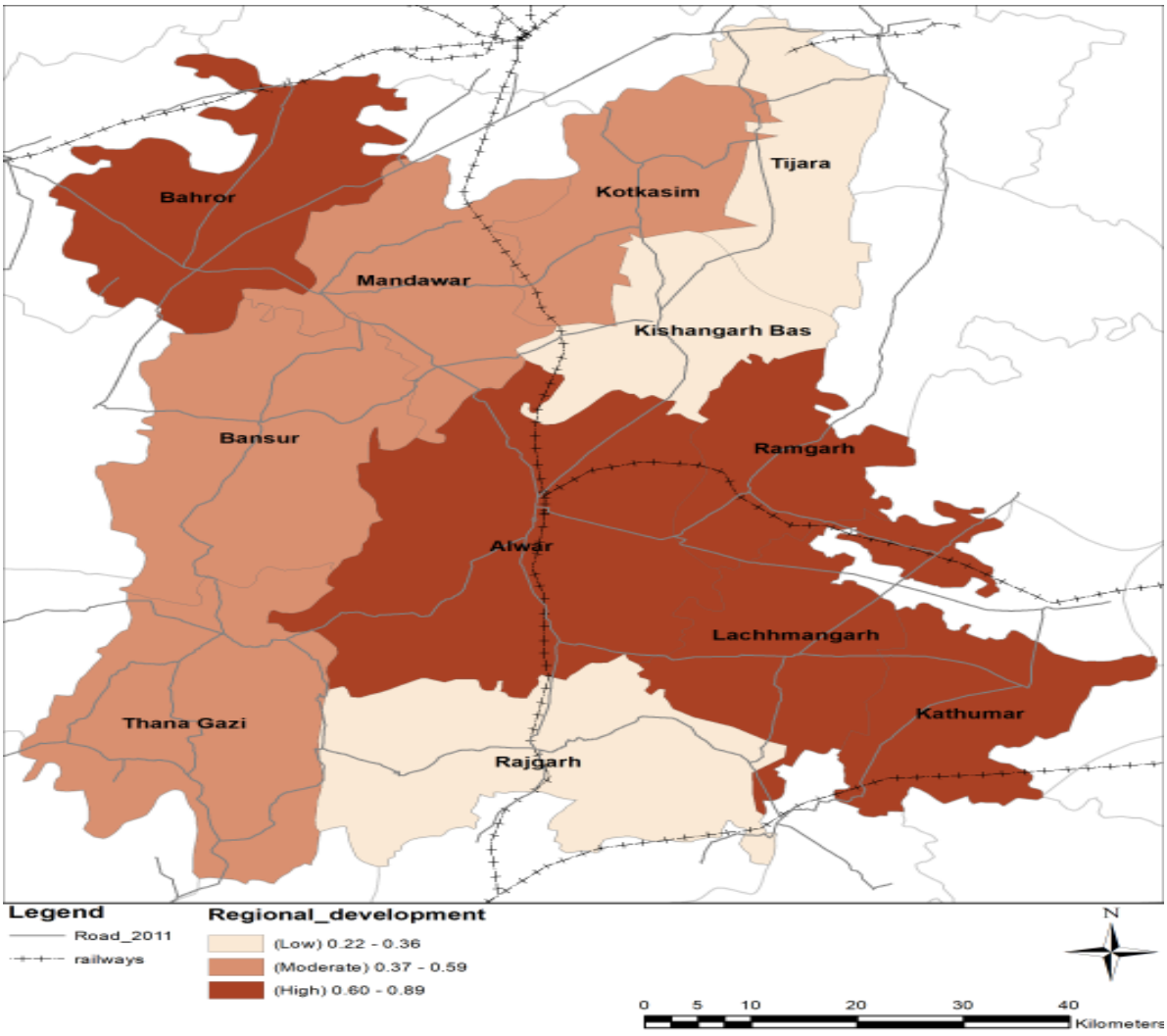
Table 3 : Alwar District Regional Development Indices

Tehsils	Education Index	Medical Index	Drinking water Index	Post office Index	Telephone Index	Transport communications Index	Banking Index	Agricultural credit societies Index	Approach by pucca road Index
Behror	0.65	1.00	0.62	0.75	0.62	1.00	1.00	0.90	0.87
Mandawar	0.36	0.50	0.33	0.42	0.33	0.52	0.33	0.48	0.49
Kotkasim	0.42	0.41	0.44	0.45	0.47	0.49	0.43	0.47	0.41
Tijara	0.44	0.43	0.42	0.44	0.42	0.26	0.33	0.10	0.04
Kishangarh Bas	0.28	0.42	0.26	0.39	0.26	0.25	0.42	0.18	0.75
Lachhmangarh	0.50	0.65	0.65	0.70	0.59	0.56	0.86	0.87	0.92
Ramgarh	1.00	1.00	1.00	1.00	1.00	0.89	0.99	0.81	0.28
Alwar	0.44	0.90	0.43	0.61	0.43	0.67	0.87	1.00	1.00
Bansur	0.46	0.70	0.44	0.60	0.44	0.68	0.74	0.54	0.67

Tehsils	Education Index	Medical Index	Drinking water Index	Post office Index	Telephone Index	Transport communications Index	Banking Index	Agricultural credit societies Index	Approach by pucca road Index
Thanagazi	0.34	0.55	0.34	0.49	0.34	0.43	0.51	0.41	0.90
Rajgarh	0.12	0.30	0.12	0.18	0.12	0.30	0.28	0.05	0.49
Kathumar	0.40	0.95	0.89	0.80	0.72	0.71	0.87	0.82	0.28

The composite of nine indicators index map has been created to delimitate the regional development of Alwar district. Based on the normalization a value has been transferring into the map by using GIS software shows the delimitated Alwar district region based on the availability of the socio-economic amenities.

Map 2 : Socio-Economic Amenities Based Delimited Region



The high level of regional development occurs in the southeast part, north, and middle of the district area.

Floating Catchment Area Method

The two steps floating catchment area method is recognized by the different researcher for measuring the accessibility, as it is easy to interpret and has the extended benefits of the gravity model. It uses a proportion of amenities (physician) – population.

The first step in method consistency the digitization of the location and road network. Map 3 shows the digitized map of Alwar district. In the two-step floating method, the following inputs have provided in GIS, including road network, location (habitation) and amenities for measuring the accessibility to socio-economic amenities. The impedance distance or accessing the amenities facilities is 1000 meter of road length from the location (habitation).In other words, the habitation which all are falls within the 1000 meter distance from the all-weather road is considered to have good road connectivity. The outcomes of the network analysis are the location (habitations) falling within the threshold distance from the amenities.

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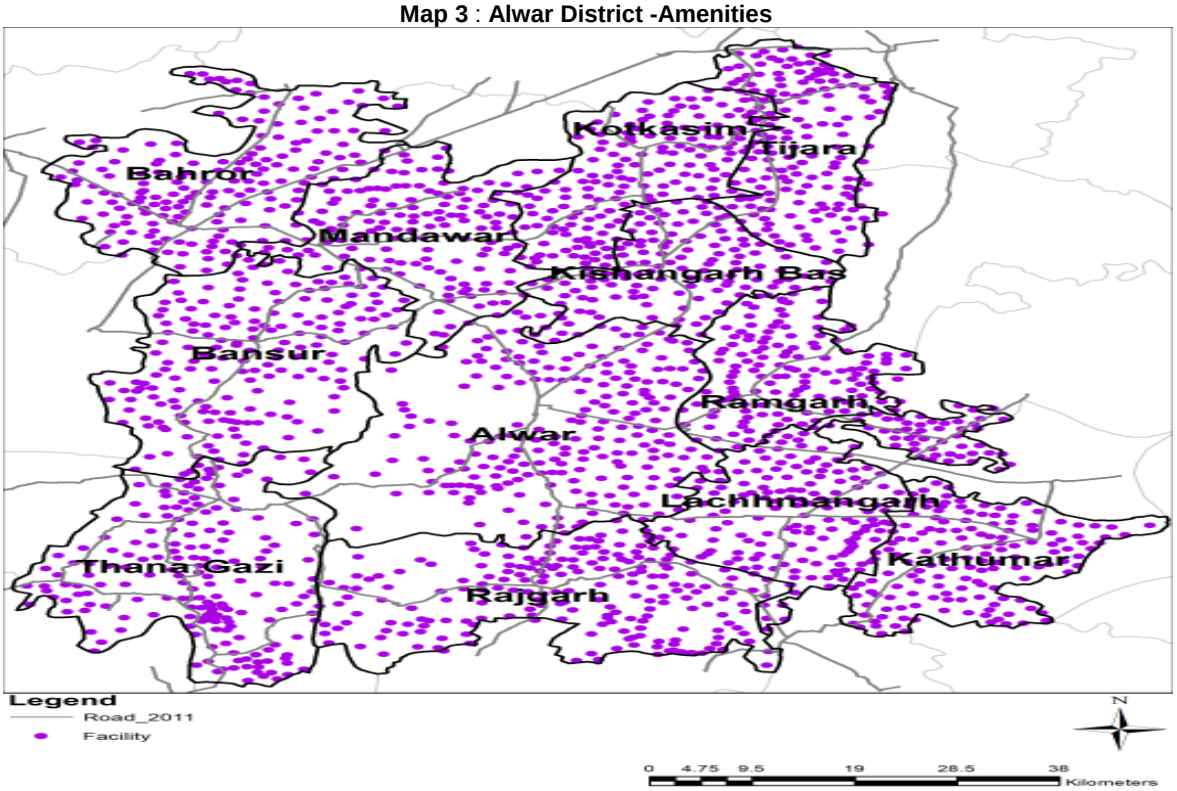
Map 3 : **Alwar District -Amenities**



Steps 1: Socio-Economic Amenities to Population Ratio

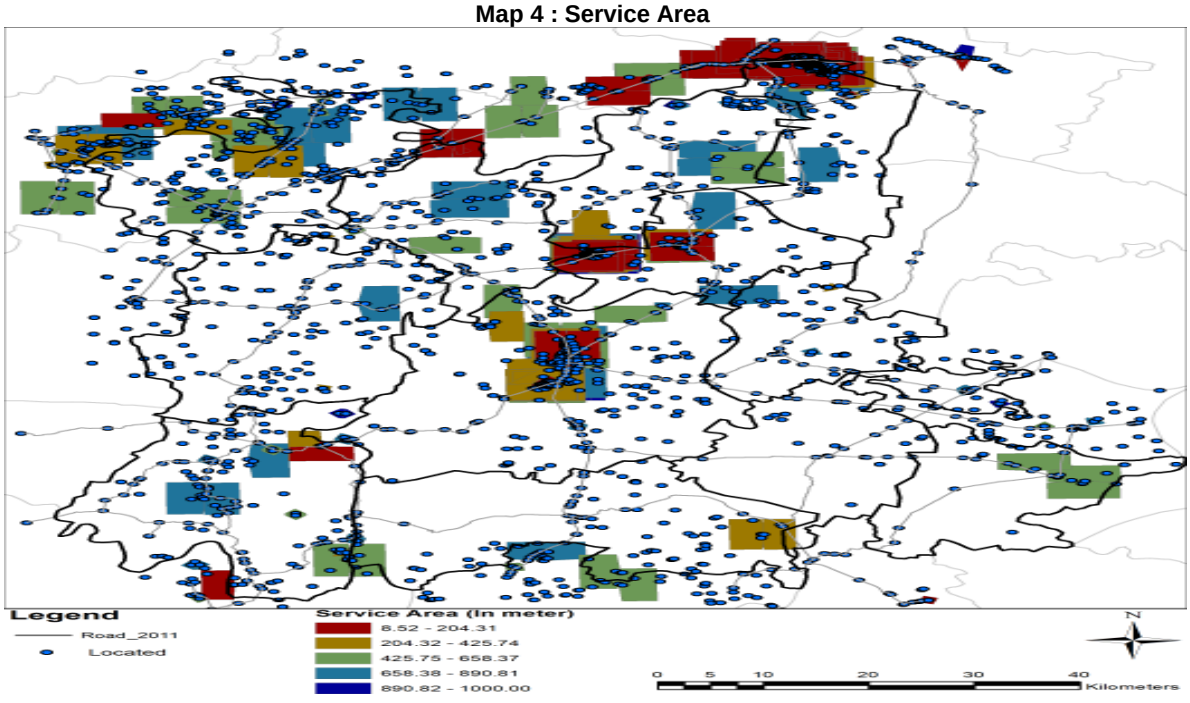
The analysis for the location (habitation) of a facility has depended upon the influence distance. It calculates the Rj (total amenities within the total tehsil population falling within the influence distance).

Map 4 and

Map **5** shows the services area and catchment buffer ,it derived from the network analysis.

$Rj = HCj / \sum Pi^1$

Map 4 : Service Area



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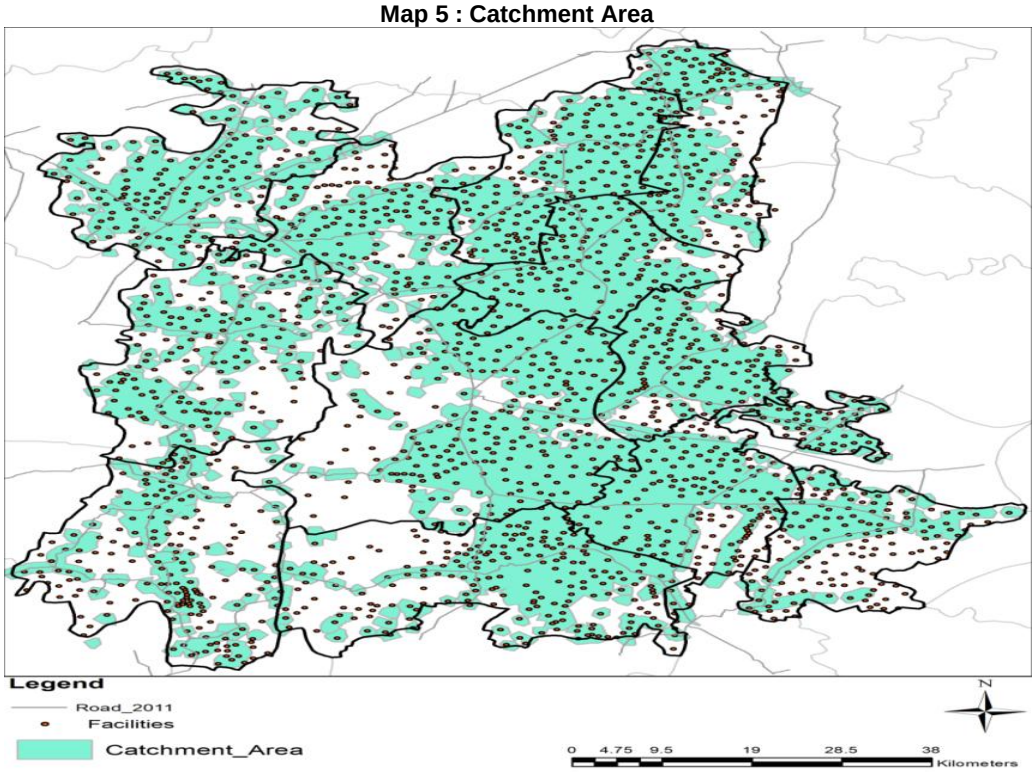
Map 5 : Catchment Area



The calculation of Rj values for each tehsils level has derived by using the SQL query tool. The calculated Rj values for each tehsil has shown in table 4. Since the population values (denominator) are exceptionally high compared to the number of amenities (numerator) exists in the tehsil, the Rj value is shallow. Thus to make Rj value readable, they have been multiplied by the 10^4.

Table 4, it has observed that the Alwar tehsil has higher amenities to population ratio since the total population under the catchment area is less compare to others.

Table **4Table 4 : Socio-economic amenities to population ratio**

Tehsil	Total Population under catchment area	Rj	Rj (10^4)
Behror	129329.28	0.00069	6.902000
Mandawar	106548.88	0.00059	5.946000
Kotkasim	82403.40	0.00047	4.706000
Tijara	151629.80	0.00049	4.867000
Kishangarh Bas	88340.28	0.0006	5.952000
Lachhmangarh	114192.54	0.00054	4.450000
Ramgarh	99633.10	0.00049	4.460000
Alwar	82703.68	0.00075	7.474000
Bansur	63279.12	0.00062	6.249000
Thanagazi	58348.75	0.00061	6.144000
Rajgarh	66524.25	0.00063	6.292000
Kathumar	105417.06	0.00055	4.452310

Step 2 – Calculation of Accessibility Index of the population

The second approach of the methods is to calculated accessibility of location (habitation), it is similar to the step 1 by using the network analysis tool (closet facility) presented in Map 6: Accessibility measurement at Habitation level

$$Ai = \sum(Rj*Fj)^2$$

$$Fj = dm\text{-}dij / dm^3$$

Here the particular location (habitation) searches for the amenities facility falling within their respective catchment area. i.e., accepted influence distance to access the amenities is 1000 meter and sum up the ratio of the population to amenities. The Ai (accessibility) of habitation is derived through the sum of the Rj multiple by the Fj Impedance weight travel distance to access the amenities.

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Map 6 : Accessibility Measurement at Habitation level

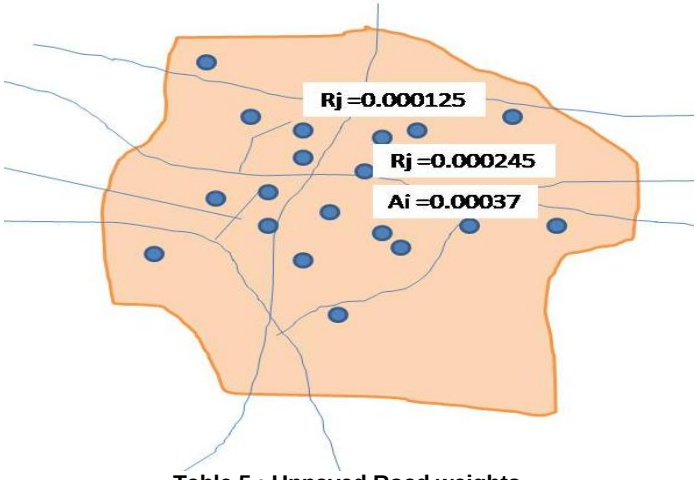

Table 5 : Unpaved Road weights

Tehsil	Total road length	Unpaved road length	Weight
Behror	617.26	221.47	0.64
Mandawar	400.37	170.24	0.57
Kotkasim	410.32	209.51	0.49
Tijara	414.94	208.84	0.50
Kishangarh Bas	329.08	125.05	0.62
Lachhmangarh	468.50	222.82	0.52
Ramgarh	397.20	183.67	0.54
Alwar	725.20	243.81	0.66
Bansur	445.17	174.91	0.61
Thanagazi	375.14	132.76	0.65
Rajgarh	463.11	196.54	0.58
Kathumar	385.40	178.17	0.54

Table 6 : Accessibility of Habitation

Tehsil	Fj	fdij	Ai (10^6)
Behror	0.006	1000	6.19
Mandawar	0.006	1000	6.47
Kotkasim	0.005	1000	5.23
Tijara	0.004	1000	3.70
Kishangarh Bas	0.007	1000	7.09
Lachhmangarh	0.006	1000	5.55
Ramgarh	0.010	1000	9.86
Alwar	0.003	1000	5.76
Bansur	0.007	1000	6.90
Thanagazi	0.007	1000	7.01
Rajgarh	0.003	1000	3.10
Kathumar	0.006	1000	6.24

The threshold influence distance to access the basic amenities has assumed to 1000 meter from the location (habitation).

Table 7 shows the total population served by the amenities. It has observed that The population served by the catchment area is higher in tehsil of Alwar, Rajgarh, and Tijara.

Table : 8 shows the number of habitation fall within the catchment area. It has observed that the tehsil as Lachhmangarh, Ramgarh and Tijara and Behror has a higher ratio of the habitation fall in catchment area out of the total habitation.

Table 7 : Inaccessible Population

Tehsil	Total Population	Population density	Average population served by amenities	Total Population under catchment area	Inaccessible population (%)
Behror	359248	493.71	17244	129329	53.04%
Mandawar	231628	393.41	11118	106549	54.23%
Kotkasim	137339	271.25	6592	82403	58.47%
Tijara	396575	825.64	19036	138801	65.27%
Kishangarh Bas	201279	292.91	9661	84537	58.49%
Lachhmangarh	288671	534.02	13856	121242	52.11%
Ramgarh	256605	459.47	12317	127019	50.50%
Alwar	703856	599.55	33785	225234	68.24%
Bansur	263663	262.70	12656	63279	76.36%
Thanagazi	233395	399.09	11203	58349	75.37%
Rajgarh	356727	453.97	17123	139124	61.31%
Kathumar	245193	506.13	11769	102981	58.15%

Table 8 : Number of habitation fall within catchment area

Tehsil	Total Habitation	Total habitation fall within the catchment area
Behror	180	124
Mandawar	146	115
Kotkasim	117	79
Tijara	194	146
Kishangarh Bas	113	102
Lachhmangarh	207	189
Ramgarh	178	153
Alwar	203	159
Bansur	147	84
Thanagazi	175	104
Rajgarh	258	185
Kathumar	154	97

The socio-economic amenities guidelines policy suggests, number of amenities based on the population at specific distance, i.e. Primary education facilities should be 500 meters from the local habitation, and same as for the medical facility should be avail for the population less than 10000. From the analysis, it has observed that there is a need to build more socio-economic amenities at a uniform distance to cover all habitation in the individual tehsil level. Also the maximum distance travel by individual to avail any socio-economic amenities is mention in Table 9.

Table 9 : Maximum Influence Travel Distance to Avail Amenities

Tehsil	Population density	Maximum travel to avail amenities
Behror	493.71	2.15
Mandawar	393.41	4.00
Kotkasim	271.25	4.12
Tijara	825.64	3.24
Kishangarh Bas	292.91	3.84
Lachhmangarh	534.02	1.23
Ramgarh	459.47	1.15
Alwar	599.55	2.43
Bansur	262.70	3.56
Thanagazi	399.09	2.21
Rajgarh	453.97	3.54
Kathumar	506.13	1.45

From the result obtained for all tehsil, it has observed that the maximum accessibility index has found in the Ramgarh (9.86). As the value of accessibility high, it determines good access to the socio-economic amenities. The trend of accessibility in depending upon the population served by the catchment area of the amenities decreasing as the population increased proportionally.i.e the Rj value would be high. In other words, as the less population to share the amenities, higher the Rj value and high accessibility. The next steps are to draw a map of accessibility of the habitation of the district. The value of the accessibility index has derived by standard deviation and mean value of it.

Map 7 shows the index of accessibility of tehsils. It has observed that the higher index is in Ramgarh, whereas the moderated accessibility index has observed in the tehsil of Behror, Kishangarh, Alwar, Lachhmangarh, and Kathumar.

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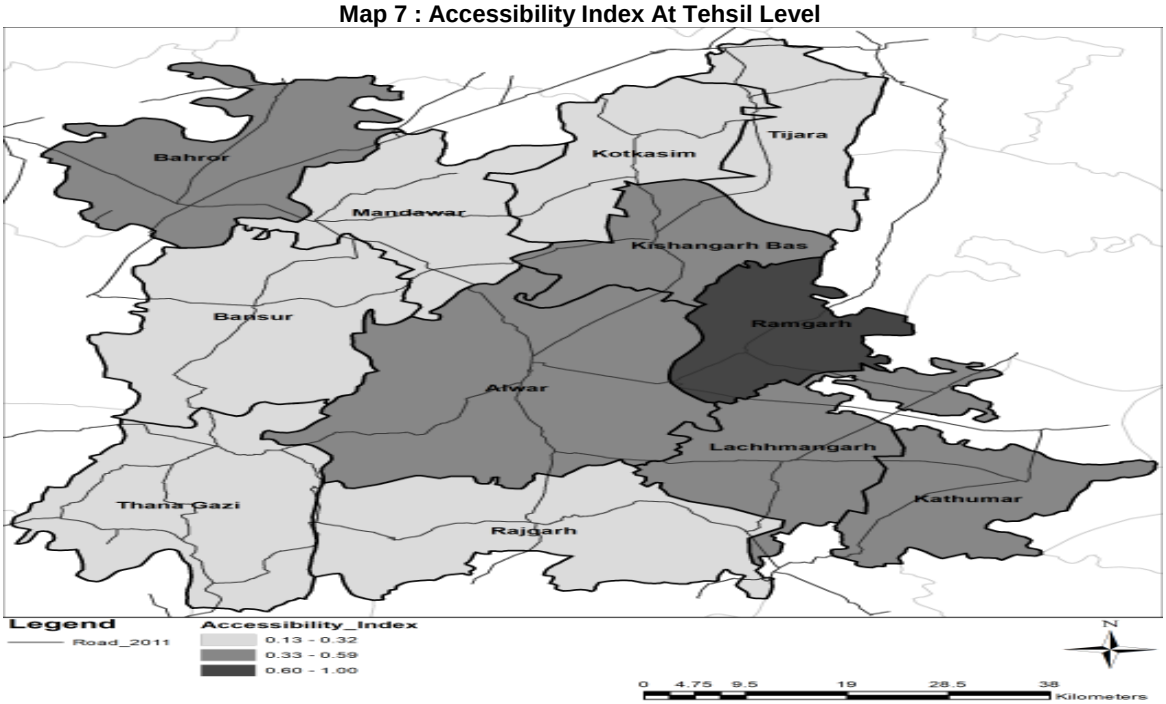
Map 7 : Accessibility Index At Tehsil Level



Conclusion & Recommendation

Improving physical accessibility and mobility is a crucial factor for socio-economic development. The current study analyzes the road network characteristics and accessibility of the Alwar district. Based on the floating catchment area and normalization techniques (Z-square) have been used to identify the utmost and vulnerable accessible locations in the region. All indicators have aggregated into the single plate form, for identified homogeneity and heterogeneity of the transport region in the district. From the analysis of road network following observation has drawn;

1. The high level of regional development occurs in the southeast part, north, and middle of the district area. The following tehsil has high transport region as, Bahror, Alwar, Ramgarh, Lachhmangarh, and Kathumar.
2. The tehsil such as Kotkasim, Mandawar, Bansur, and Thana Gazi –West part of the Alwar district moderated in the availability of socio-economic amenities.
3. The two steps floating catchment area method has applied in the research. The two steps floating catchment area is recognized by the different researcher for measuring the accessibility, as it is easy to interpret and has the extended benefits of the gravity model.
4. In terms of accessing the basic socio-economic amenities at the threshold distance, A tehsil includes Ramgarh has the best performance.
5. As the population of the habitation increased the supply of road network accessibility has decreased. Also, it has observed that the road density per km is higher in the densely populated area.
6. The fitting impedance function is higher for the less populated area, whereas it is lower in the high population density area.

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