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Analysing the Geographical and Potential Accessibility of Dehradun city and its surroundings

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Abstract

Spatial interaction is a fundamental concept that evaluates how regions interact in terms of people, freight, services, energy, and information from one location to the next. It is a demand-supply connection for transportation represented over geographic space. In the field of transportation geography, this method is highly advantageous. In this paper, the case study concerns the economic exchange in the Dehradun city (Capital of Uttarakhand) and between the main urban centres/towns (Vikasnagar, Herbertpur, Central Hopetown, Mussoorie and Rishikesh) geographically belonging to the Dehradun district. The result achieved using geographical Accessibility showed that the most accessible place among all six selected urban centres is Dehradun city and Central Hopetown since it has the lowest summation of distances value of 167.70 and 164.30. Whereas the potential accessibility methods of spatial interaction showed that Dehradun city being a major central business district (CBD), has more emissiveness than attractiveness (822116.03 versus 711063.08); however, both values were highest among all other urban centres followed by Rishikesh (the Yoga capital of the world) which has more attractiveness than emissiveness (119649.11 versus 110411.47). Whereas the lowest values of emissiveness and attractiveness were computed for Herbertpur, followed by Vikasnagar.

Keywords: Spatial interaction, transport, potential Accessibility, geographical Accessibility.

1 Introduction

Cities are seen as engines of regional and national economic growth and development (Polèse 2005). In general, the man-made resources and economic that keep people alive are concentrated in cities rather than scattered uniformly over the earth. Hence, the poor access to urban services and opportunities (a function distance, transportation infrastructure, and city spatial distribution) is a fundamental roadblock for the enhancement of livelihoods and overall development (Weiss et al. 2018). On the other side, physical access to healthcare, financial services and education, as well as employment prospects, trading centres, and essential government services, is critical to the achievement of the most Sustainable Development Goals (Macharia, Mumo, and Okiro 2021). However, the majority of these services are centred in urban areas. Moreover, compared to rural areas, urban centers are frequently the primary beneficiaries of large-scale development initiatives such as national highways, railways, airports and power grids, which improve transportation and communication infrastructure. Consequently, the urban areas serve as trading hubs for agricultural products and also have better food security (Macharia et al. 2021). Moreover, the majority of primary business headquarters and essential government institutions and services are predominantly concentrated in large urban centres (Weiss et al. 2018). As an outcome, employment opportunities in urban areas are higher than in rural areas; thus, the rate of rural to urban migrations in quest of various job opportunities and better living conditions is more heightened.

Therefore, Accessibility becomes an important measure to evaluate how easy it is to get to (and interact with) locations in transportations planning (Farber and Fu 2017) or activities distributed in space (El-Geneidy and Levinson 2006), e.g. around urban and rural areas (Owen and Levinson 2017). Accessibility is frequently linked with a place (or places) of origin. Concerning geography, the Accessibility is an essential element in mobility for people, freight, and information as an "accessibility is the measure of the capacity of a location to be reached from, or to be reached by, different locations. Hence, the capacity and space planning of transportation infrastructure are critical factors in determining accessibility"(Rodrigue 2020). On the other hand, people determine mobility and affects transport policies, infrastructure, and regional development(Rosenberg 2018).

It's also considered a user-driven choice that may be used to evaluate the influences of infrastructure investment and to pertain to transportation policies on regional growth. The transportation systems that provide more accessible opportunities are deemed well-developed and efficient, and they have a cause-and-effect relationship with a variety of social and economic alternatives. As an outcome, accessibility is related to various socio-economic opportunities, yet congestion can hamper mobility. Because efficient and well-developed transportation networks give high levels of accessibility, and those that are less developed, on the other hand, have lower degrees of accessibility (Rodrigue 2020). In geography and spatial analysis, the idea of accessibility is essential. It is instrumental in shaping the geographical processes and patterns at all spatial scales (Pooler 1987). The accessibility indicators have been used in various policy domains, including individual and/or economic development and their related travel goals, such as job (for workforce), employee (for enterprises), education, shopping, and healthcare accessibility. The possible policy approach to increase accessibility is now considerably broader, and it includes land use alternatives as well as advice on how to coordinate with other policy fields and traditional infrastructure measures (Zondag and Molenwijk 2020). Hence, In doing geographical research, spatial analysis is an essential methodological foundation(Fotheringham and Rogerson 2009). In general, spatial analysis is used to describe a technique that uses geographic information to better understand the processes that cause the observed phenomena (Susilo and Harini 2018). To address this issue, several approaches have been suggested in the literature. On the other hand, the current essay is focused on geographic accessibility; a potential accessibility model. This approach is advantageous in the handling of problems with transportation.

Transport geography relates to computing the flows between sites, also referred to as spatial interactions, and assessing demand for transportation services (Fotheringham 1984; Goodchild 1992). Accessibility-based planning best expresses what people want from a transportation system and gives the broadest range of potential solutions to transportation concerns because access is the ultimate goal of most transportation(Litman 2008). Land transportation (Road) are the most valuable means of transport in Dehradun district Uttarakhand. Be it for passengers or merchandise, as of 2017, 24 lakh vehicles registered in Uttarakhand, out of which 10 lakh (40%) vehicles are registered with the Dehradun Transport Authority. Hence, The city of Dehradun is experiencing severe traffic congestion on its routes (Hindustan Times 2017b), which causes many problems of traffic congestion. To solve this problem, the Dehradun district administration has made a great effort to develop public transportation (road widening at major traffic congestion network, development of flyovers (as of 2021, there is eight fly-overs that exist in the district), Dehradun to Mussoorie ropeway projects, electronic buses etc. On the brighter side, the travel time has been substantially reduced. Simultaneously, the intensity of traffic congestion has significantly increased the Dehradun city, a prime central business district CBD or commercial and business hub of the state. However, the role of the public transportation system is continuously deteriorating in the district, as commuters spend more on privately owned vehicles, even though around 290 city buses ply on 14 routes in the city (The Times of India 2019).

On 09 November 2000, when the Uttarakhand state was formed, it had only 42000 registered vehicles. But as of 2017, there was 24 lakh registered vehicles in the state(Hindustan Times 2017a). The Dehradun city is now experiencing traffic congestion, noise, air pollution, and road safety due to a constant expansion in the vehicle fleet, which is causing dysfunctions in the management of its utilities, roadways, and means of transport. Therefore, the government authorities encourage transportation companies to make more efforts to improve and maintain the quality of the services they offer. This trend is likely to continue achieving the shared goals of decongestion of cities, the suffocating effect of traffic, the opening up of outlying areas, and enhanced environmental quality. The primary purpose of this report is to assist in the reorganisation of Dehradun's Public Transport Company and Merchandise routes. Because the company wants to assess the potential for land transportation demand both inside the Dehradun Municipal Corporation and between the significant neighbouring towns, once this information is provided, it will be possible to optimise transportation planning and determine where the best market opportunities exist (Rodrigue 2020). Concerning Accessibility plays a crucial role in computing the attractiveness and emissiveness of the major market centres.

2 Map of the Dehradun city

The Dehradun city is the capital of Uttarakhand. It is the only metropolitan city in Uttarakhand. In this article, six major urban centres have been selected, including Dehradun city, which extends over 20 to 30 km or radius from Dehradun as shown in Figure 1, which includes, apart from the central business district (CBD) or city centre, one industrial area and four essential areas, such as:

- Selakui (Central Hope Town) zone, based on an open site, is near a major cross-road. Therefore, it benefited from installing industrial zones (special economic zones).
- Vikasnagar, Herbertpur, Rishikesh area is a rapidly developing urban center.
- The area of Dehradun City, a CBD, has a large area commercial area.
- Mussoorie, a former colonial town, has a recreational site.

The area covered by Dehradun city has been grown successively over the years; before 2018, Dehradun Municipal corporation had 60 wards which have now increased to 100 wards, and a total of 72 nearby villages has been incorporated in recent demarcations of the year 2018. According to Census 2011, the total population of all six urban centre was 882839. Out of which highest population was found in Dehradun city, followed by Rishikesh and Mussoorie. Whereas the lowest population was found in Herbertpur, followed by Vikasnagar.

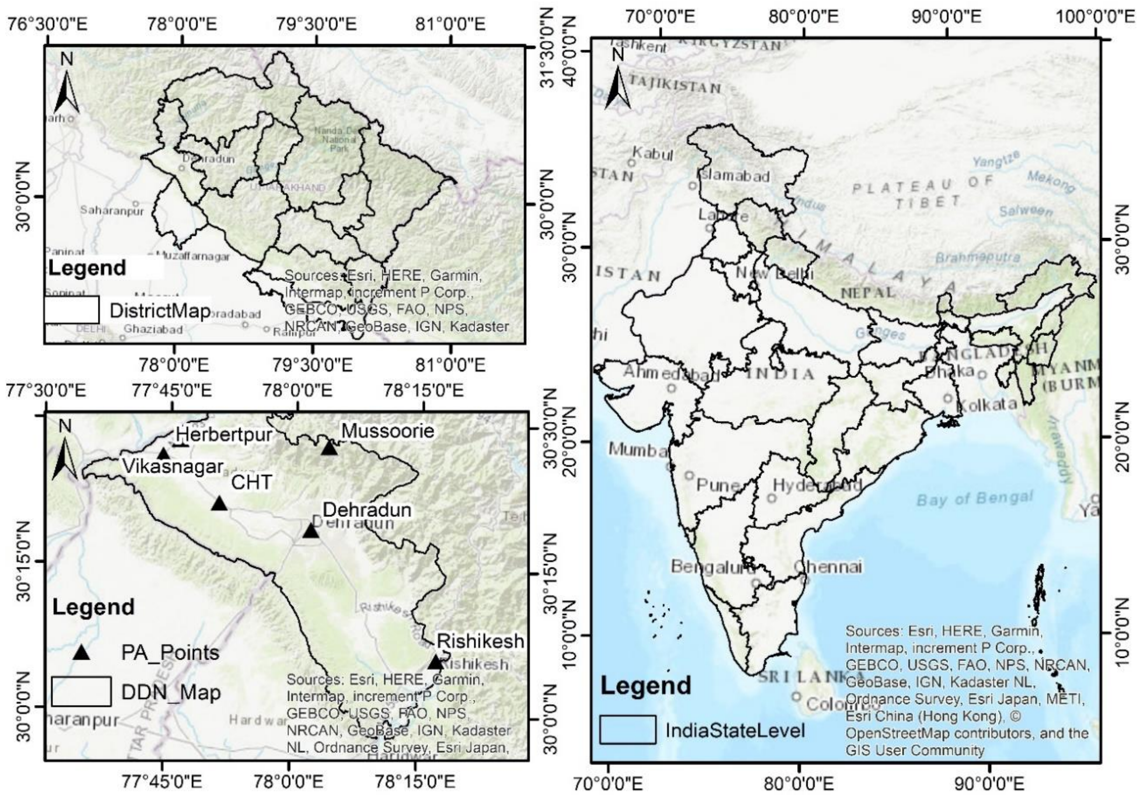

Fig. 1 Map of the study area showing the selected six urban centres of Dehradun District.

3 Geographical Accessibility

Geographical accessibility refers to the ease with which a specific area's population may access services and amenities. In this regard, the most frequent methods for determining geographical accessibility are based on a resource's distance and travel time (Apparicio et al. 2008). The instinct to reduce displacements has long been present in humans. Consequently, they consistently choose the quickest route to travel from one place to another. Therefore the transportation system as an economic activity benefits tremendously from shorter distances between origins and destinations (Goldman and Gorham 2006).

In this context, the capacity of a location to be accessed by or to reach other locations is measured by accessibility. The accessibility represents the potential of a location to be accessed from other geographically apart locations. Therefore, accessibility is an excellent measure of spatial patterns because it considers both location and the imbalance imparted by distance; the geographical accessibility matrix is calculated using the formula below.

$$A(Geo)_i = \sum_{j=1}^{n} L_{ij} \qquad (1)$$

With;

- A(Geo) = geographical accessibility matrix.
- Lij = the short distance between location i and j.
- n = number of locations.

Figure 2 shows that not all sites are equal because some are more accessible than others, highlighting inequities. As a result, the concept of accessibility is founded on two ideas:

- The first factor is distance, that is based on the physical separation of two points.
- The second is that space relativity is calculated in relation to transportation infrastructures.

Because this is a transposable matrix, the summation values are the same for rows and columns. Hence, the most accessible place is Central Hopetown (CHT) and Dehradun city, followed by Herbertpur since it has given the lowest summation of distances 164.30, 167.70 and 199.70, respectively, as illustrated in Table 3.1. At the same time, the least accessible place was Rishikesh and Mussoorie, as they have the highest summation of distance 340.70, 291 and 212.30, respectively.

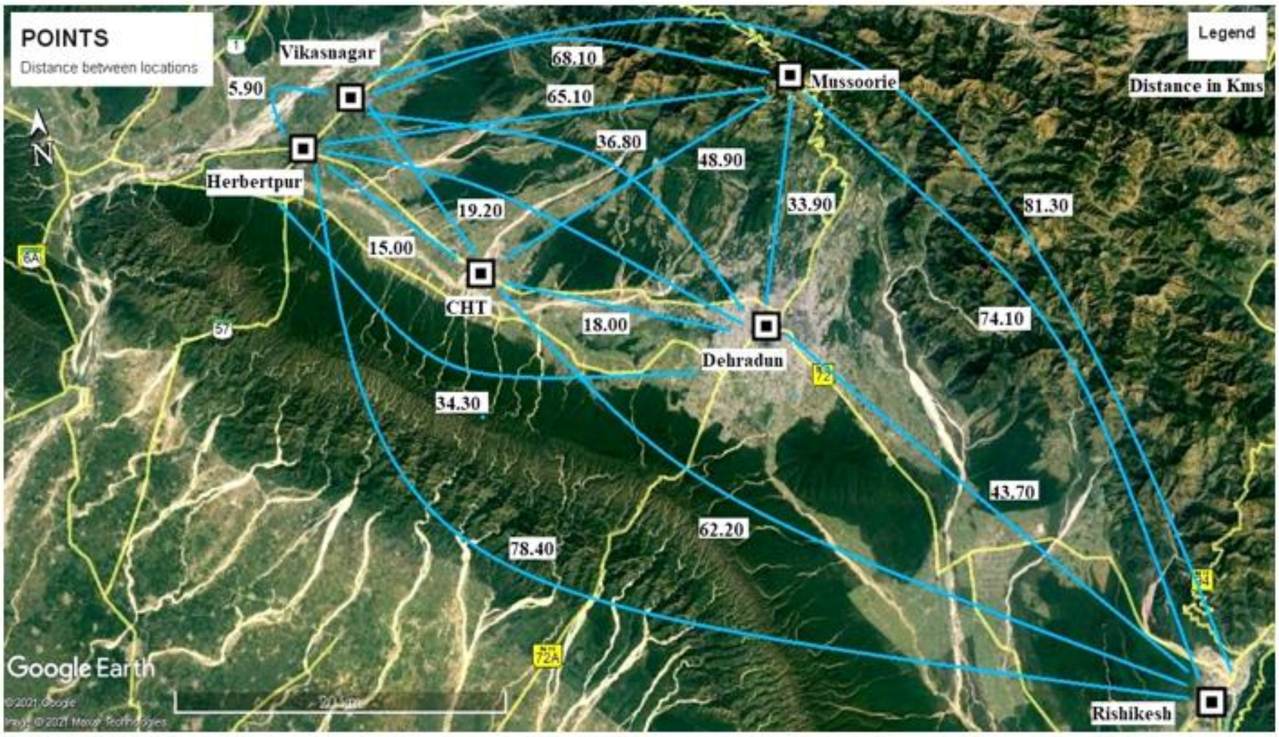

Fig. 2 Illustration of computed distances between selected urban centres of the study area.

Table 3.1. The matrix of geographical accessibility

Lij (km)	*Mussoorie*	*Dehradun City*	*Rishikesh*	*CHT*	*Herbertpur*	*Vikasnagar*	*A(Geo)j*
Mussoorie	1	33.90	74.10	48.90	65.10	68.10	291.10
Dehradun City	33.90	1	43.70	18.00	34.3	36.80	167.70
Rishikesh	74.10	43.70	1	62.20	78.40	81.30	340.70
CHT	48.90	18.00	62.20	1	15.00	19.20	164.30
Herbertpur	65.10	34.3	78.40	15.00	1	5.90	199.70
Vikasnagar	68.10	36.80	81.30	19.20	5.90	1	212.30
A(Geo)i	*291*	*167.70*	*340.70*	*164.30*	*199.70*	*212.30*	*1375.80*

4 Potential Accessibility (PA)

The potential is a geographical accessibility index that has been used in the geographical and planning literature for a long time (Haynes, Lovett, and Sünnenberg 2003). The standard definition of accessibility is the potential for interaction and exchange (Fotheringham 1984), and it is widely acknowledged that Hansen was the first to use the term PA (Hansen 1959). *Accessibility* (or just *access*) refers to the ease of reaching goods and services, destinations & activities, which together are *opportunities*. Whereas, Geurs and Van Eck (Geurs and JR 2001) defined accessibility "as the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)." In our situation, however, the PA index is built on the idea that the advantage of access to an urban centre grows with population size and decreases with travel time, distance, or cost. At present, Geographic information systems (GIS) advancements have opened up new techniques to assess accessibility. (Yoshida and Deichmann 2009). PA is the expression used by researchers (Geurs and JR 2001; Handy and Niemeier 2016; Straatemeier 2005).

On the other hand, the PA is a more complicated metric than geographic accessibility since it incorporates the idea of distance along with location attributes. It is also worth noting that not all sites are created equal, and some are more essential than others. The PA is measured as follows formulation:

$$A(\mathrm{Pot})_{\mathrm{i}} = \sum_{j=1}^{n} \frac{\mathrm{Pot}_{\mathrm{j}}}{\mathrm{L}_{\mathrm{ij}}} \qquad (2)$$

Where;

- A(Pot) = potential accessibility matrix,
- Pot_j = attributes of location j,
- n = the number of locations.
- Lij = the distance between location i and j (derived from valued graph matrix),

The PA matrix is unique in that it is not transposable since locations do not have the exact attributes; similarly, columns & rows demonstrate attractiveness and emissiveness, respectively:

- Attractiveness (α) is the capacity to reach a location, the sum of the values of a column in the Σ j matrix.
- Emissiveness (λ) is the capacity to leave a location, the sum of the values of a row in the Σ i matrix.

The findings of the PA matrix computation may then be summarised: the greater the value, the more accessible a location is, with Dehradun city being the most accessible, as highlighted in Tables 4.1 and 4.2. The summing of rows differs from the summation of columns due to the non-transposability of the matrix, highlighting their relative attractiveness and emissiveness. It's worth noting that emissiveness and attractiveness both communicate information about available resources and possibilities (Richards-Rissetto and Landau 2014). The analysis result is illustrated in Table 4, which shows that the Dehradun city has more emissiveness than attractiveness (822116.03 versus 711063.08); however, both percentage of emissiveness and attractiveness is significantly higher in Dehradun city.

On the other side, the lowest percentage of emissiveness value of 1.24% and attractiveness value of 3.50% was computed for Herbertpur. It is also worth noticing that the highest and lowest populations were observed in Dehradun city and Herbertpur, respectively. While Rishikesh is a tourist destination of Dehradun widely known as yoga capital of the world (Nagar nigam Rishikesh 2021) has more attractiveness than emissiveness values of 119649.11 110411.47 respectively. It's also worth mentioning that the conclusion of the potential accessibility evaluation is based on Census 2011 data; thus, the results aren't guaranteed to be reliable; however, it successfully represents the methodology concerning geographical accessibility and potential accessibility.

Table 4.1. The potential accessibility matrix

Urban centres(i/j)	*Mussoorie*	*DehradunCity*	*Rishikesh*	*CHT*	*Herbertpur*	*Vikasnagar*	*Σi*
Mussoorie	33657	992.83	454.21	688.28	517.00	494.23	36803.56
Dehradun City	20829.62	706124	16158.44	39229.11	20586.71	19188.15	822116.03
Rishikesh	1382.85	2344.83	102469	1647.41	1307.00	1260.38	110411.47
CHT	345.19	937.78	271.38	16880	1125.33	879.17	20438.85
Herbertpur	150.26	285.19	124.77	652.13	9782	1657.97	12652.32
Vikasnagar	204.51	378.45	171.30	725.36	2360.51	13927	17767.14
Σj	*56569.43*	*711063.08*	*119649.11*	*59822.30*	*35678.55*	*37406.90*	*1020189.37*

Table 4.2 The potential accessibility matrix

Urban Centres	*Population*	λ *(Σi)*	λ *(Σi) %*	α *(Σj)*	α *(Σj) %*
Mussoorie	33657	36803.56	3.61	56569.43	5.54
Dehradun City	706124	822116.03	80.58	711063.08	69.70
Rishikesh	102469	110411.47	10.82	119649.11	11.73
CHT	16880	20438.85	2.00	59822.30	5.86
Herbertpur	9782	12652.32	1.24	35678.55	3.50
Vikasnagar	13927	17767.14	1.74	37406.9	3.67
Total	882839	1020189	100	1020189	100

5 Conclusion

Presently, a paradigm shift is taking place in transportation planning (a fundamental change in how problems are defined and solutions evaluated). This involves a change from *traffic-based analysis, accessibility-based analysis, mobility-oriented analysis*(Litman 2008). Historically, transportation organisation and planning have been used to tackle transportation issues. The major goal of this work is to assist in reorganising Dehradun's Public Transportation system and routes by adopting new service strategies that focus on strengthening the public transportation system instead of privately owned. The spatial interactions model has helped us understand the interaction that happens between selected six urban centres. The result derived from the Geographical accessibility index showed that the most accessible place is Central Hopetown and Dehradun city followed by Herbertpur since it has the lowest summation of distances 164.30, 167.70 and 199.70 respectively, whereas the least accessible place was Rishikesh, Mussoorie and Vikasnagar as they have the highest summation of distance 340.70, 291 and 212.30 respectively. Subsequently, the outcome of the potential accessibility model showed that the Dehradun city has more emissiveness than attractiveness (822116.03 versus 711063.08); however, both percentage of emissiveness and attractiveness is significantly higher among all other urban centres. Likewise, as a capital city, Dehradun is witnessing an alarming rate of traffic congestion at several intersections, especially after the development of several flyovers in and around the city, which has successfully overcome the problem of extreme traffic congestion at several intersections. Consequently, the travel time from rural or surrounding areas to the core of the city has been considerably reduced, thus intensifying the attractiveness and emissiveness. Then, Dehradun city is followed by Rishikesh (the Yoga capital of the world), which has more attractiveness than emissiveness values of 119649.11 and 110411.47, respectively. Hence there is an immediate need to ease the traffic congestion by strengthening the existing public transport system and making it more sustainable.

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