Optimal Location of Administrative Center: A Case Study of Province No. 1, Nepal

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Abstract— *In developing nations, administrative facilities do not centers the majority of residing population because of poor geographical accessibility. Selection of optimal administrative center in such locations is a tedious task as the decision is contingent upon various factors. While making such decisions, major focus should be on accessibility of residing people. Thus, this study examines the role of two major factors, population distribution and transportation network distribution, in the selection of administrative centers of any location considering the case study of Province no. 1, Nepal.*

Keywords— Administrative center, Location, Developing countries, Gravity model.

I. INTRODUCTION

Rural road networks that connects the population with the administrative center seems to be in deficient condition in most of the developing countries. Inadequate geographical accessibility has hindered the rural residents from getting opportunities which in turn have decreased their quality of life(Rahman and Smith, 2000). Under this context, several hypotheses have also been made that by increasing accessibility, by constructing superior roads and by choosing optimal location of facility, susceptibility can be reduced and income variability can be minimized. A sufficient rural road network and proper planning of public facilities needs to be done to enhance accessibility for rural resident so that all their requirements are met. As various evidences are exhibiting that the network and facility locations are closely interrelated, it is worthwhile to determine the network design and facility locations concurrently(Melkote and Daskin, 2001; Daskin and Owen, 2003).An analysis on roads planning and optimal public facility locations in an inclusive unified manner would help to address the problems that may arise during resource allocation. Moreover, many researches have been done in transportation network design and facility location, most of which are almost entirely independent to each other. The optimal locations of facilities, both private and public, is restricted by the structure of the designed transportation network and will be genuine only if it serves the people in a right way. Even when facilities are located in an optimum location, residing population will not get adequate services if the networks are not designed appropriately. Therefore, to obtain the solution for above mentioned problem, it is requisite to scrutinize models where transportation networks are designed considering both present and future location of facility. In this study, transportation network configuration and new administrative center are to be optimally designed at the same time so as to allow the residents to access the facilities and thus cater their needs.

As per a 17 January 2018 cabinet meeting held in Nepal, the city of Biratnagar has been declared the interim administrative center of Province No. 1. However, the decision is made without any proper investigation of the factors. After Kathmandu, Biratnagar is the second most densely populated city. However, it does not necessarily mean that accessibility is not complicated for all the population of Province no. 1 as transportation network distribution has not been taken into account for making this arbitrary choice.

It has always been difficult to plan for the public facilities and location in the most efficient way as many factors are involved. According to the 2011 census, there are around 4.5 million people residing in the 14 districts of Province no. 1. The selection of public facility location should be favourable for the whole population. Everyone has the right to use public services and facility provided by the government in the most convenient way. If a certain portion of population is only considered while determining Public Facility Location, it might create conflict among other people. Therefore, there should be equalization of public service facility to prevent such negative aspects.

The study takes place comparing the accessibility among the 19 cities where 14 of them are district headquarters and 5 of them are commercial centers. The required data that are

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collected from secondary sources are later used to conclude on a decision. The specific objectives of this study are:

- To build a general framework for location problems.
- To use this framework to determine the most appropriate administrative center of province no. 1, Nepal.

II. REVIEW OF LITERATURE

Several studies have been done to fix the factors that make the location most appropriate for public facilities. Many problems are to be encountered while selecting the optimal Public Facility Location and various researches have been done to understand these problems. In the developing nations like Nepal, local political leader or government officer makes the choice of public facility location due to which it is less likely for the selected location to be optimum(Rahman and Smith, 2000). Thus, the choice shall be done by eligible person along with proper research. Studies have shown that the use of mathematical model for locational analysis has been very effective to choose the most optimal location(Rahman and Smith, 2000).

For any public facilities, the choice of the location will have to satisfy two major purposes : to be close as far as possible to the demand of the population (so that the transportation cost will be low) and to keep the cost of constructing the facility to a minimum extent (which can be done by decreasing the number of facilities and by settling on a low-cost location)(Leonardi, 1981). There are mainly two problems that arises with the two aims mentioned above: problem of allocation concerned with the aim of minimizing transport cost and the problem of facility location concerned with the aim of selecting low-cost location(Leonardi, 1981).

While picking out the administrative center, the major focus should be on minimizing the allocation-problem that is, lessening transportation costs. Aggregate approach, useful to handle allocation-problem when the list of users is so huge that it is not possible to keep data of every user and to get preference orders is despairing, gives rise to gravity-interaction models(Leonardi, 1981). Gravity models were developed empirically at the beginning however, many theoretical justifications have been proposed for them, which have made it an important topic of consideration for theoretical economists and geographers, mathematicians, and statisticians, besides regional scientists(Leonardi, 1981). Gravity model can consider both factors (road network and demographic), so helps to measure the relative distance clearly and not only the absolute distance while determining administrative center(Haynes and Fotheringham, 1984).

Before fixing administrative center for a province, areas that are eligible to become administrative center are to be investigated in a proper manner. Mostly, these areas to be researched are city centers and sub- centers. Several studies have been done in order to know the most efficient center in an area.

Many research works have been carried out to explain theoretically, the most appropriate center using finite source of data since the 1950s but it has been few years that number of approaches have been introduced to define the city centers using variety of data sources . The group of four people have done a research work on identifying city centers using human travel flows generated from location-based social networking data using different methods(Sun *et al*., 2016).

The city centers are the crucial part of any cities and Socio-economic activities are concentrated in these centers (Anas, Arnott and Small, 1998). Since, most of the activities are clustered in these part of the city, they being administrative center, is the most sensible thing.

It is obvious that the administrative center will have abundant number of public facilities however, it does not necessarily mean that all of the public facilities are to be established at administrative center only. The place where the decision is made to locate the public facilities will have its land value increased as the demand will be higher(Fujita, 1986). Therefore, the choice may create conflict among people as everyone will want to have their land value increased. Proper research should be done before fixing the public facility location as people at different locality may have different demand. The public facilities should be constructed evenly on different sectors according to the demand of the people and only then it will help to minimize the negative aspects such as imbalance between rich and poor people, huge inconsistency between urban and rural areas and so on(Fei, Wei and Ming, 2013).

III. METHODOLOGY

The study starts with the problem formulation with respect to the relevant literatures followed by collection of data.

A. DATA COLLECTION AND EXTRACTION

This study is undertaken considering Province no. 1 of Nepal as the study location. All the district headquarters and some vital commercial centers within the province have been considered as nodes. The network and node distribution with the study area is shown in *Figure 1*.

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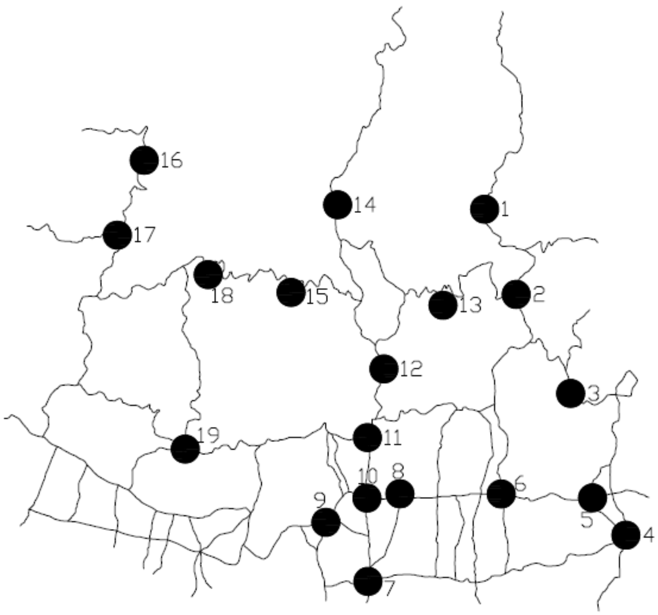

Figure 1: Network and Node Distribution

The number of nodes within the study area and their location is shown in *Table 1*.

Table.1: Nodes within the Study Area

SN	District	Nodes	Node Number
1	Taplejung	Taplejung	N1
2	Panchthar	Phidim	N2
3	Ilam	Ilam	N3
4	Jhapa	Bhadrapur	N4
		Birtamod	N5
		Damak	N6
5	Morang	Biratnagar	N7
		Biratchowk	N8
6	Sunsari	Inaruwa	N9
		Itahari	N10
		Dharan	N11
7	Dhankuta	Dhankuta	N12
8	Terhathum	Terhathum	N13
9	Sankhuwasabha	Khandbari	N14
10	Bhojpur	Bhojpur	N15
11	Solukhumbu	Salleri	N16
12	Okhaldhunga	Okhaldhunga	N17
13	Khotang	Diktel	N18
14	Udayapur	Gaighat	N19

Two categories of data viz. demographic and road network data were needed for the study. These data were collected from the secondary sources. The demographic data for each district within the study zone was collected from national population census data 2011 and is presented in *Table 2*.

Table.2: Population Data for Each Nodes

Node	Population
N1	127,461
N2	191,817
N3	290,254
N4	270884
N5	270883
N6	270883
N7	482685
N8	482685
N9	254496
N10	254496
N11	254495
N12	163,412
N13	101,577
N14	158,742
N15	182,459
N16	105,886
N17	147,984
N18	206,312
N19	317,532

For number of nodes within the district, equal distribution to each nodes were made. The network included in Statistics of Strategic Road Network (SSRN) published by Department of Road (DOR), Nepal was only considered in the study. SSRN of Eastern Development Region was used to record the distance between each nodes.

B. MODEL FRAMEWORK

The study location consists of a number of nodes connected by a transportation (road) network. Considering the entire nodes, distance matrix can be formed in the transportation network. Commonly, shortest path algorithms such as Dijkstra (Gallo and Pallottino, 1986) can be used to calculate distance between any two destinations in the network. Moreover, a short path matrix of the network can be found utilizing Floyd-Warshall algorithm (Floyd, 1962) which gives the shortest distance to other destinations. The shortest path matrix of the network is presented in *Table 3*.

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Table.3: Shortest Path Matrix of the Network

Origin/ Destination	Shortest Path Matrix (Distance between two nodes in km)																		
	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19
N1	0	86.503	150	229.46	233.123	198.363	299.383	296.463	326.653	308.003	298.273	249.683	189.503	310.453	328.683	583.783	525.883	416.683	358.873
N2	86.503	0	77.42	156.88	146.62	111.86	212.88	209.96	240.15	221.5	211.77	163.18	103	223.95	242.18	497.28	439.38	330.18	272.37
N3	150	77.42	0	79.46	69.2	98.71	135.46	132.54	162.73	144.08	165.3	197.93	180.42	223.95	300.93	574.7	516.8	407.6	225.9
N4	229.46	156.88	79.46	0	12.53	42.04	56	75.87	74.67	87.41	108.63	157.22	217.4	242.52	260.22	468.11	410.21	301.01	145.88
N5	233.123	146.62	69.2	12.53	0	29.51	86.34	63.34	93.53	74.88	96.1	144.69	204.87	229.99	247.69	455.58	397.68	288.48	143.48
N6	198.363	111.86	98.71	42.04	29.51	0	56.83	33.83	64.02	45.37	66.59	115.18	175.36	200.48	218.18	426.07	368.17	258.97	113.97
N7	299.383	212.88	135.46	56	86.34	56.83	0	23	18.67	21.28	42.5	91.09	151.27	176.39	194.09	401.98	344.08	234.88	89.88
N8	296.463	209.96	132.54	75.87	63.34	33.83	23	0	30.19	11.54	32.76	81.35	141.53	166.65	184.35	392.24	334.34	225.14	80.14
N9	326.653	240.15	162.73	74.67	93.53	64.02	18.67	30.19	0	18.65	39.87	88.46	148.64	173.76	191.46	383.55	325.65	216.45	71.45
N10	308.003	221.5	144.08	87.41	74.88	45.37	21.28	11.54	18.65	0	21.22	69.81	129.99	155.11	172.81	380.7	322.8	213.6	68.6
N11	298.273	211.77	165.3	108.63	96.1	66.59	42.5	32.76	39.87	21.22	0	48.59	108.77	133.89	151.59	372.7	314.8	205.6	60.6
N12	249.683	163.18	197.93	157.22	144.69	115.18	91.09	81.35	88.46	69.81	48.59	0	60.18	85.3	103	358.1	300.2	191	109.19
N13	189.503	103	180.42	217.4	204.87	175.36	151.27	141.53	148.64	129.99	108.77	60.18	0	120.95	139.18	394.28	336.38	227.18	169.37
N14	310.453	223.95	223.95	242.52	229.99	200.48	176.39	166.65	173.76	155.11	133.89	85.3	120.95	0	112.3	367.4	309.5	200.3	194.49
N15	328.683	242.18	300.93	260.22	247.69	218.18	194.09	184.35	191.46	172.81	151.59	103	139.18	112.3	0	255.1	197.2	88	233
N16	583.783	497.28	574.7	468.11	455.58	426.07	401.98	392.24	383.55	380.7	372.7	358.1	394.28	367.4	255.1	0	57.9	167.1	312.1
N17	525.883	439.38	516.8	410.21	397.68	368.17	344.08	334.34	325.65	322.8	314.8	300.2	336.38	309.5	197.2	57.9	0	109.2	254.2
N18	416.683	330.18	407.6	301.01	288.48	258.97	234.88	225.14	216.45	213.6	205.6	191	227.18	200.3	88	167.1	109.2	0	145
N19	358.873	272.37	225.9	145.88	143.48	113.97	89.88	80.14	71.45	68.6	60.6	109.19	169.37	194.49	233	312.1	254.2	145	0

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Case I: Considering Road Networks Only

First, only the road networks within the study zone was analysed. For each node, the sum of distance to all the nodes considered was calculated using equation [1]. The problem can be formulated as the minimization of Interaction (D_i) of the set of nodes i.

$$\text{Min } D_i = \sum d_{ij} \quad [1]$$

Where, d_{ij} is the distance between the considered i^{th} node and j other nodes.

Table.4: Interactions of each Nodes Considering Road Networks only

Node	Interaction (D_i)
N1	5389.768
N2	3947.063
N3	3843.13
N4	3125.52
N5	3017.633
N6	2623.503
N7	2636.003
N8	2515.233
N9	2668.553
N10	2467.353
N11	2479.553
N12	2614.153
N13	3198.273
N14	3627.383
N15	3619.963
N16	6848.673
N17	5864.373
N18	4226.373
N19	3048.493

One node with least D_i can be considered as the efficient administrative center location based on transportation network only. Here, Node N10 (Itahari) has least D_i, thus N10 (Itahari) is the administrative center if only the road networks are considered.

Case II: Considering Population and Road Networks

Demographic data consideration has been done to analyse the effect of population and population distribution in the determination of most appropriate administrative center. This consideration helps in identifying the location that will be nearer to higher proportion of the population. It is assumed that the total population of the district is concentrated on the district headquarter and they have to travel from the same. In the case, where there are commercial centers, the total population of the district is divided into district headquarter and commercial centers in an equal ratio. Demographic and geographic centers should be combined in order to take the study into shape. The gravity model has been used to incorporate the demographic and geographic centers here. The fusion between these two centers for any location helps to obtain the appropriate administrative center considering residing population and road networks.

Gravity Model

Newton's gravitational law is used to calculate the relationship between the objects. This newton law has been modified to predict the movement of people and information between the cities by the social scientists which is termed as gravity model. The effect of road network and demographic condition for the selection of appropriate administrative center can be modelled using gravity model.

For each city, let the population be represented by P, and the distance between cities be represented by d. Each pair of cities is designated by the subscripts i and j. Interaction between any pair of cities is specified as T_{ij}. To generalize, this interaction can be expressed as a ratio of the multiplied populations over the distance between any pair of cities,

$$T_{ij}=P_iP_j/d_{ij} \quad [2]$$

The above equation [2] is a basic equation of gravity model which requires certain modifications depending upon different cases. The distance element d_{ij} of the basic equation is multiplied by an exponent β. To derive the correct exponent(β) for gravity model formulation many literatures have stimulated by physical science interpretations, including the Newtonian analogy where the square of distance, dij^2, is the appropriate power(Haynes and Fotheringham, 1984). So, the equation can be written as:

$$Tij=PiPj/dij^2 \quad [3]$$

This equation [3] has been used to integrate the network analysis and demographic analysis in this study to obtain the interaction of each nodes considering demographic and geographic center.

In this case, the problem is formulated as the maximization of Interaction (I_i) of each nodes from the set of nodes is as shown in equation [4].

$$\text{Max } I_i = \sum Tij \quad [4]$$

Table.5: Interaction of each Nodes Considering Population and Road Network

Node	Interaction (I_i)
N1	11170559.1
N2	30673735.5
N3	76931990.5
N4	623954008
N5	657869471
N6	372838196
N7	1279663011
N8	1838236764
N9	781428188
N10	1615276101
N11	447590698
N12	79155801.2
N13	22724912.8
N14	24114840.5
N15	26510319.9
N16	8241028.24
N17	12736572.1
N18	23594459.1
N19	127376994

One node with maximum I_i can be considered the most efficient administrative center location based on population and transportation networks of the study area. Here, Node N8 (Biratchowk) has maximum I_i, thus N8 (Biratchowk) is the efficient administrative center when both the factors are considered (demographic and road network).

IV. RESULTS AND DISCUSSIONS

Planners often mislead in locating public facility centers in developing countries. This study explores how the administrative center location becomes inefficient when considering transportation network only. Two different results are obtained when only transportation network is taken into account and when both transportation network and population distributions within the study zone are considered, which justifies the inefficiency. The case study of Province No. 1, Nepal shows that Biratchowk is the most efficient administrative center of the study area considering both residing population and existing road networks distribution. If the network distribution is only considered in the study, the location of administrative center comes out to be Itahari. This may mislead in solving the problem of locating administrative center. Hence, while considering these type of problems the effects of both demographic and geographic distribution should be taken into consideration.

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