APPLICATION OF SETTLEMENT INTERACTION BASED RURAL ROAD NETWORK MODEL IN NAWALPARASI DISTRICT OF NEPAL

by

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ABSTRACT

Since basic issue of urban and rural transportation planning is different, the urban transportation models, which have reached into the advanced level, can be hardly replicated for planning the rural transportation network. Therefore, this study intends to contribute towards providing a theoretically sound and practically applicable model for generating rural road networks in the developing countries.

Based on the research findings, transport network planning models for the developed areas and under-developed areas are prepared. There are certain similarities between these two models. However, the main difference is that the model for the developed areas depends mainly on the interaction among different settlements. The model for the under-developed areas intends to provide a basic accessibility to almost all settlements of a region.

The model is implemented in the Nawalparasi district of Nepal. Firstly, the proposed network model could reduce the district level road length from 440 km, which was proposed by the previous transport plan, to 164 km, a reduction of more than sixty-two percent, without considerably reducing the level of accessibility. Secondly, the proposed methodology has attempted to establish the ownership. Thirdly, it has reduced the travelling time to the market centers by making them the foci of network. Fourthly, by considering the neighboring market centers, the network has recognized that the district is a part of the entire region not as an isolated entity as considered by the previous transport plans. Therefore, the proposed model is more practical and realistic than the previous planning approaches, which may be replicated to other developing countries.

1. INTRODUCTION

The significance of the rural roads for the regional development is increasingly realized by the policy makers in Nepal. The promulgation of the rural road policy and strategies are some of the major evidences towards that direction (HMG, 1998; DOLIDAR, 1999). Towards the systematic planning of the rural roads, the networking plays a pivotal role. However, the urban transportation network planning models, which have reached into the advanced level, are mainly oriented towards choosing improvements or additions to an existing network, to reduce traffic congestion, energy consumption, pollution or other appropriate objectives (Abdulaal and LeBlanc, 1979). Unlike urban transportation, rural

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transportation mainly deals with providing accessibility to the abutting people, mechanizing and commercializing the agriculture, promoting the non-farm sector and providing the extension and administrative services to the local people. Besides that, having lower level of technical capability with the local governments, the urban transportation networking models cannot be used for developing the rural road networks in the developing countries because of the difficulty in solving network design problems. Therefore the network development in the rural regional context remains largely based on the intuitive judgment and such judgment of the local political leaders is inevitable to be biased towards their vote bank rather than the actual requirement. Therefore, there is a need of a simpler but relatively precise rural road-networking model.

Although the gravity model has been used transport planners for long time, the effort for planning the rural road network based on the central place theory and force of interaction is introduced by some of the scholars in the developing countries. Mahendru, Khanna & Sikdar (1983) have introduced the central place based rural road networking approach, which was refined further by Mahendru, Sikdar & Khanna, 1989. Nonetheless, Singh, Gupta and Kumar (1997) have pointed out the limitation of this approach. If, one village has some particular facility (say, education) and another village has some other facility (say hospital) then there should be a good interaction between the two but in this approach, if the difference in score is used which nullifies the score, the approach will give little or no interaction. A similar approach is proposed by Khan and Mohit (1989). The theoretical framework of their study is based on the concept of the hierarchy of settlements, which provides the nodal structure, and graph theory helps to determine the network structure. Shrestha (1997) has developed the district level rural road network based on district accessibility standards, nodal points, existing roads and trails, demand from the local people and geographic characteristics. Besides that, it is participatory in the sense that it involves the local people in every step of decision-making. Secondly, it is incremental in its characteristics because it recognizes the existence of existing and ongoing projects of rural transport infrastructures. However, it ignored the present and potential volume of traffic in a given route.

In order to mitigate the limitations of the present transport network models, particularly in the context of rural road networking of the developing countries, the settlement interaction based network models have been evolved but they are not refined enough for the mass scale application by the local governments in the developing countries. By combining the gravity model with the centrality index and considering the existing rural transportation infrastructures as the basis, this study attempts to provide the solid foundation for developing the rural road network in the developing countries.

2. METHODOLOGY

An Engineer and Policy Maker's Survey was conducted in the 46 sample districts which were selected based on stratified purposive random sampling. Besides that, an Expert and Practitioner Survey was conducted with 28 respondents. After analyzing the survey results, a workshop was organized in Nepal. The workshop discussed on the paper presented and agreed that the nodal points, existing rural transport infrastructures and resource potential areas should be the basis for networking.

The findings of the sample survey and recommendations of the workshop had to be experimented in one of the districts. Nawalparasi district was selected for its representative characteristics in terms of topographic conditions, land area and revenue generating capacity. Another consideration was that the district has prepared a District Transport Master Plan that not only provides the relevant information but also allows a comparison between the newly developed methodology with that of the existing methodology.

Two different types of methodologies are developed for the developed and developing areas. In order to execute these methodologies, different tools like observation of the selected routes, cordon survey, passenger vehicle survey, freight carrier survey, passenger survey and key informant survey were executed. The objective for collecting opinions was not only to find out the improved version of methodology but also to detect the possibility on what can be implemented in a typical District Development Committee environment. Before collecting information from the primary sources, all available secondary sources of information were collected.

3. FINDINGS OF THE STUDY

The findings of expert and practitioners survey are presented in Table 1.

Table 1: Networking Approaches of Rural Transport Infrastructure (N = 28)

No.	Approaches	I	II	III	IV	Total	In %
1	Existing Roads and ZOI Approach	4	2	1		7	20.00
2	Central Places, Resource Potential Areas and Roads, Tracks and Trails	5	7	3	8	23	65.71
3	Opinion of Local Politicians and other people	2	2			4	11.43
4	Geologically fragile areas, Central Places and Existing Roads, Tracks and Trails	1				1	2.86
	Total	12	11	4	8	35	100.0

Note: I = Chief Technical Advisers; II = Consultants; III = Academicians; IV = Government Bureaucrats and Technocrats

Source: Practitioners and Expert Opinion, 2000

Thirty-five responses were received from 28 respondents. None of them has mentioned about the applicability of the mathematical modeling for the rural road network. The experts and practitioners are either totally unaware about the mathematical models or are fully convinced on the non-applicability of the tools in the context of rural transportation. Therefore, mathematical modeling could be discarded. Secondly, there is a certain degree of similarity among the expressed opinions. Almost all respondents have accepted that the existing roads, trails and tracks should be considered for developing the network. However, the majority of the respondents believe that besides considering existing roads, trails and tracks, one should consider the central places.

3.1 Existing Roads and Zone of Influence Approach

Twenty- percent respondents have favored the existing roads and the Zone of Influence (ZOI) approach for developing the rural road network. It is obvious that the area beyond the ZOI should be declared as the inaccessible area and it should be provided with an appropriate transport infrastructure. Nevertheless, this approach is almost silent how the

rural road network should be developed in the inaccessible areas. This method fails to offer the appropriate corridor to construct the road. Therefore, it is useful for the preliminary analysis but should be supplemented with the additional techniques for developing the full phased transport plan.

3.2 Central Places, Resource Potential Areas and Roads, Tracks and Trails

Nearly 66 percent of the respondents are in favor of developing the networks based on the central places, resource potential areas and the existing roads, tracks and trails. If one is planning the district level rural road network, he should take only district level or higher hierarchy nodal points. If one takes lower hierarchy nodal points then the network gets complicated and would not be useful. However, which functions should be included for evaluating the central places is the issue that needs to be sorted out. The residential functions of the market centers need not to be included because such functions do not generate trips. The first question to be asked whether to include in the list is the possibility of attracting trips by a function from outside the market center.

After fixing the nodal points, the existing roads, trails and tracks can be overlaid on the nodal points. All the links connecting the nodal points could be considered as the network of rural transport infrastructure.

3.3 Opinion of Local Politicians and Other People

More than 11 percent respondents believe that local people have better knowledge of the environment; their opinion should be the basis for developing the network. That is however, a status quo strategy. At present, the politicians select the road projects and the technicians just implement it. As revealed by the Engineer Survey, most of the Engineers have reported that they are not involved in the decision making process. It means the technical dimension of the road project is grossly undermined. Secondly, the intuitive decision creates ground for the politically biased judgement. Consequently, the DDC members share the available funds equally that fragments the resources in such a way that no meaningful project can be accomplished.

3.4 Geologically fragile areas, Central Places and Existing Roads, Tracks and Trails

This approach is similar to the second approach except that it suggests delineating the geographically fragile areas, where all types of construction works should be restricted. Only 2.86 percent respondents have offered their views in favor of this approach. They suggest that after delineating such areas, the planners should plan for the remaining areas. It makes areas of intervention limited. However, such factors are generally considered by the road designers. Having required constructing additional structures to safeguard the road from landslides and soil erosion, constructing roads in such areas is generally expensive. On the other hand, there might be economic, social and political compulsions to construct roads through such areas. Therefore theoretically, it can be accepted that the fragile areas should be demarcated and construction works that jeopardizes the geological structures should be avoided. However, it should be taken as the initial guidelines but should not be the rigid criteria.

4. RURAL ROAD NETWORKING MODEL OUTLINED

The road density in Nepal ranges between 0 and 0.34 that excludes the capital city districts, which have obviously higher road density. Therefore the range is divided into two groups and 0.17 is considered as the middle point. Two different types of networking models are outlined to fulfill the requirement of developed areas, which have the road density greater than 0.17, and under-developed areas, which have road density less than 0.17.

4.1 Network Model for the Developed Areas

The network model for the developed districts is presented in Fig. 1.

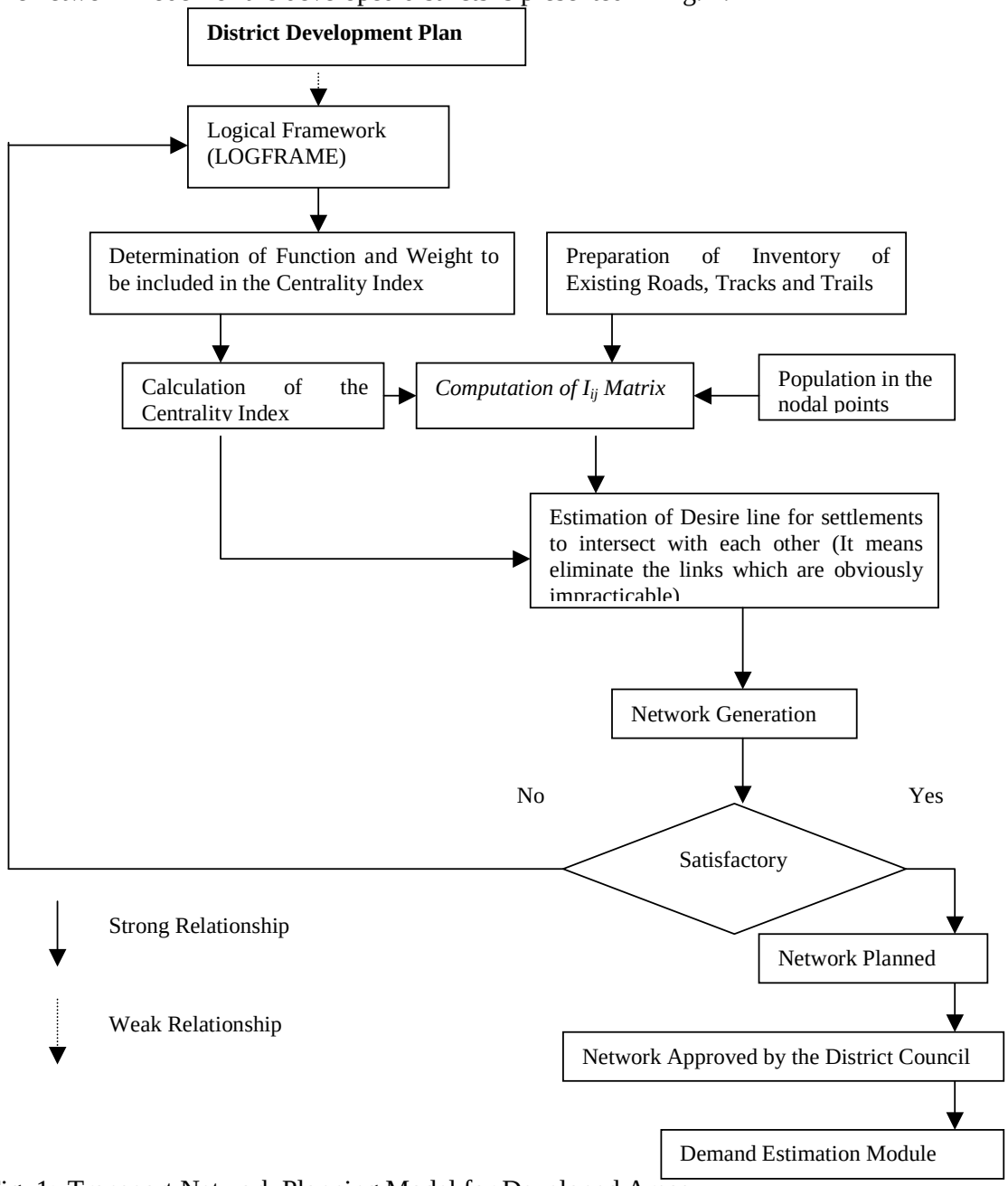


Fig. 1: Transport Network Planning Model for Developed Areas

The District Development Plan and logical framework are the background information for developing the rural road network. Identification of the present and potential nodal points and determination of their size are the basis for developing the network. Majority of the trips are originated from one population center and ended in another population center. The centrality index is used in this study to assess the relative importance of settlements identified as transport nodes. Only those functions should be included in the centrality index, which attract the trips from other settlements. The centrality index of each settlement can be calculated as (Sarma, Routray & Singh, 1984):

$$C_j = \sum_{i=1}^{n} (W_i, X_{ij}) \quad (1)$$

Where,

C_j = Centrality (Composite) Index of the j^{th} market center,
W_i = Weightage of the i^{th} marketing functions,
X_{ij} = Value of the i^{th} function (number of establishments or shops at the j^{th} market centers)

There are several methods for calculating the weight of a function. After making a comprehensive review among Entry Point Threshold Population, Mean Threshold Population Per Market Center, Mean Threshold Population Per Establishment, Median Threshold Population Technique, Bhatt's Technique and Location Coefficient Technique, Sarma, Routray & Singh (1984) have recommended the Median Threshold Population Technique as the best method for calculating the weight of a function. According to that technique, the weight can be calculated as:

$$W_i = \frac{\text{Median Population of the } i^{th} \text{ Function}}{\text{Lowest Median Population of the function occured in the Series}} \quad (2)$$

In the next stage, the intensity of interaction should be calculated between two urban centers. In addition to the population, the functions in a market center play vital role to generate or attract the trips. Normally the educational institutions like colleges and vocational schools, hospitals and private clinics, wholesale shops and other industries should be included since those functions attract the trips. In the gravity modeling, therefore the population should be multiplied with the centrality index. The centrality index can be considered as the weight of the population.

The distance between the urban centers plays the important role for generating the trips. However, the behavior of distance decay function is dependent upon the characteristics of the function. For instance, the trips to the district center for some administrative purpose is perfectly inelastic in relation to the distance. However, it may diminish linearly for the industries, which consume the local raw materials. The areas closer to the sugar-mills have greater intensity of sugarcane production and the land-use in favor of sugarcane diminishes as the distance increases almost linearly. However, for the sake of simplicity the value of b is considered as 1. The discussion leads to the following equation for calculating the force of interaction, which is similar to the gravity model with weight of Isard (1960):

$$I_{ij} = \frac{(W_i . P_i).(W_j . P_j)}{d^b_{ij}} \quad (3)$$

Where,

I_{ij} = Interaction between two nodal points
W_i = Centrality Index of the node i
W_j = Centrality Index of the node j
P_i = Population of the node i
P_j = Population of the node j
d = Road Distance between i and j
b = exponent of d

The I_{ij} provides the preliminary indication regarding the desire lines among the settlements. A subjective judgement is required while developing the desire line.

The generated network should be matched with initial goals and objectives stipulated in the logframe. In the meantime, an interactive dialogue with the local government is essential and because the network should be endorsed by the District Development Committee and ultimately, the District Council approves it. This ends the networking stage of district transport planning. Nonetheless, it should be followed up by the demand estimation, construction and maintenance cost and benefits of the road construction that ultimately leads to the prioritization of the road links for construction and maintenance, which is not within the purview of this study.

4.2 Rural Road Networking in the Under Developed Areas

The flow chart for developing the rural road network in the under-developed areas is presented in Fig. 2.

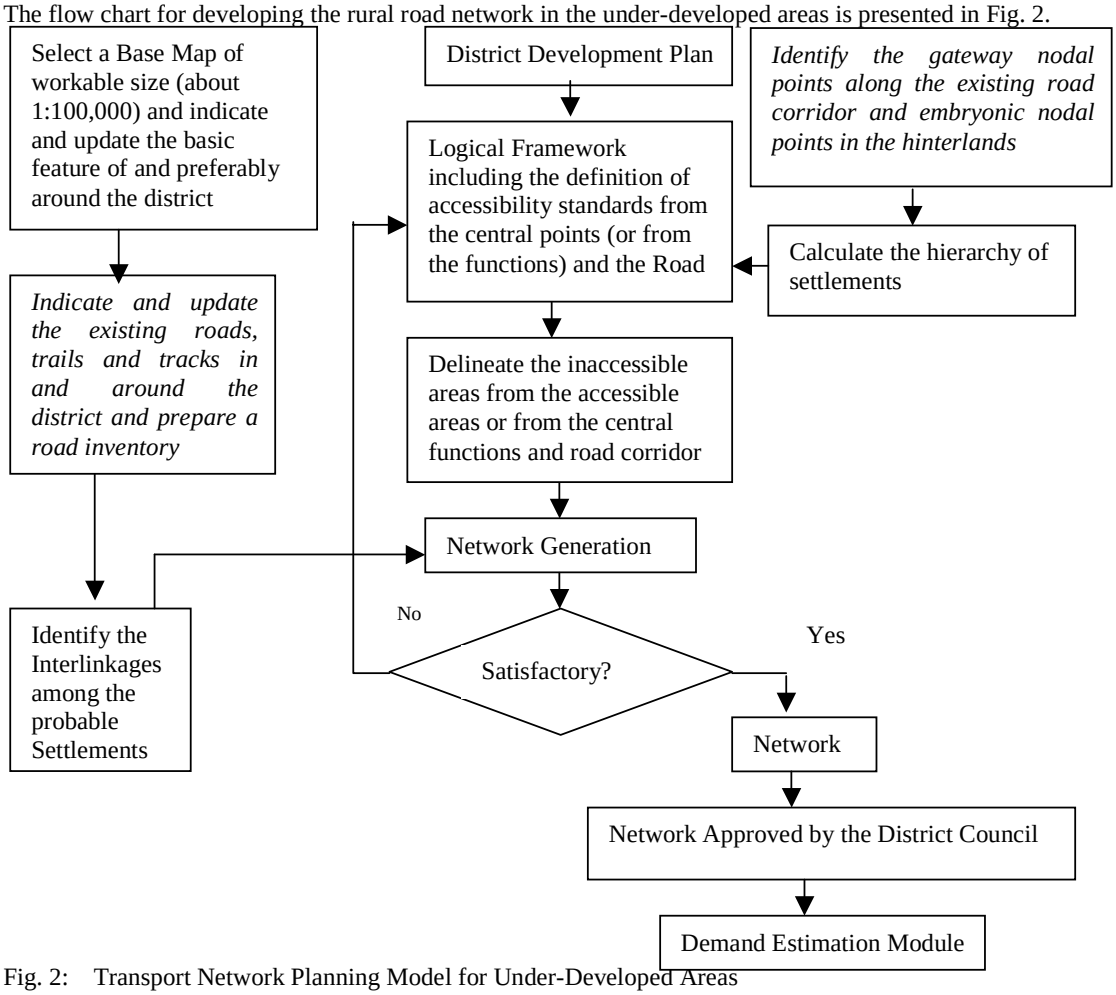


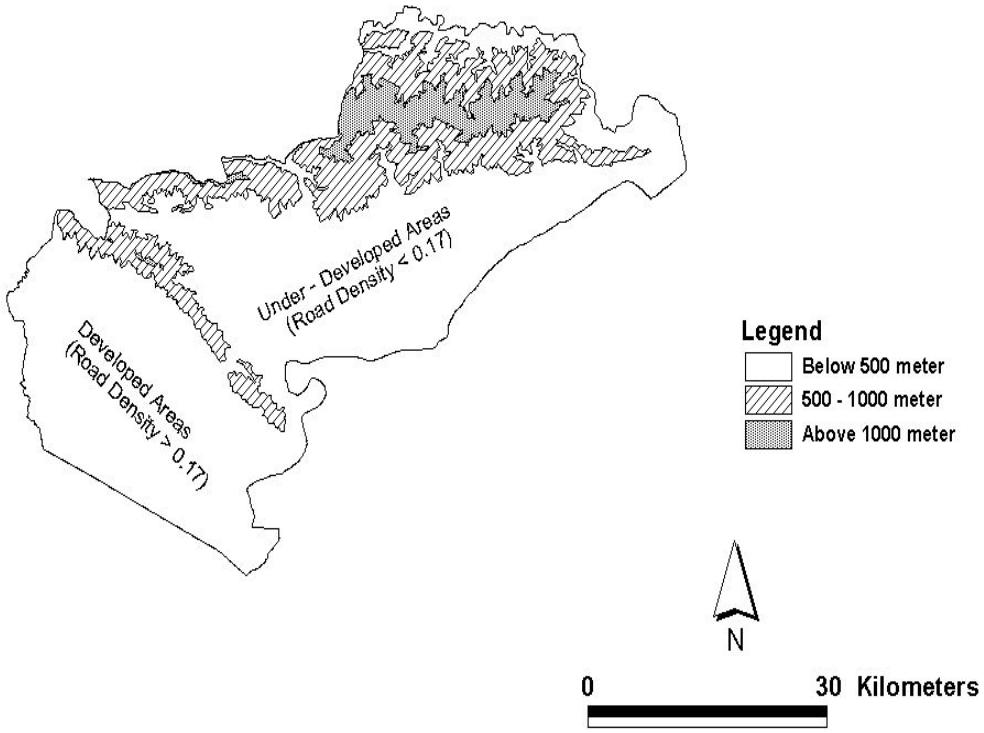
Fig. 2: Transport Network Planning Model for Under-Developed Areas

Some of the activities for the under-developed areas are similar to the developed areas. For instance requirement of the District Development Plan and inventorization of the existing rural transport infrastructures and identifying the interlinkages among different settlements are similar to the developed districts. Nonetheless, basic accessibility already prevails in the developed areas, whereas the under-developed areas have no or very limited amount of transport infrastructure. Therefore, the basic issue is to provide the accessibility within a reasonable time distance. In order to provide the basic accessibility, the accessible areas should be delineated with the inaccessible areas. The status of accessibility should be defined while developing the logical framework. The embryonic market centers should be explored within the inaccessible areas and such market centers should be connected with the gateway nodal points located along the highways. In such a way transport network could be generated in the under-developed areas. If such a network is in consonance to the logical framework, it is satisfactory and it should be endorsed by first the District Development Committee and second by the District Council. Similar to developed areas, the demand should be estimated, construction and maintenance cost should be calculated of each link in the network. However, unlike to the economic evaluation, the road networks in the under-developed areas should be prioritized based on the previously agreed criteria stipulated in the logical framework.

5. APPLICATION OF THE MODEL IN THE NAWALPARASI DISTRICT

The whole district is divided into two parts: the developed (plain) area and the under-developed (hilly) area (Fig. 3). The market centers and district road networks are shown in Fig. 4.

Fig. 3 Under - Developed and Developed Areas Based on Density of Roads



5.1 Networking for the Developed Area

According to the Transport Network Planning Model for the developed areas, the first task to be reviewed is the existence of the District Development Plan. However, Nawalparasi district has no District Development Plan, therefore based on the review of the sectoral plan and interview with the district officials, present and future centrality index is prepared. Based on the executive judgment, a tentative score is allocated for the un-surveyed market centers. The summarized form of the present and potential centrality index is presented in Table 2 and 3 respectively.

Table 2: Centrality Index of Market Centers in Developed Areas

No.	Market Centers	Population	C. Index (Median)	C. Index (Mean)	Remarks
1	Parasi	8,910	69	78	
2	Bardhaghat (Daunnedevi)	13,257	35	40	
3	Sunwal	17,336	27	31	
4	Tribeni Susta/Balmiki Nagar	19,582	39	42	CI and Pop. Approximate
5	Maheshpur/Thutibari	13,386	43	46	CI and Pop. Approximate
6	Gopigunj	6,908	15	17	
7	Butwal	54,179	200	200	CI Approximate
8	Bhairahawa	48,306	150	150	CI . Approximate

Table 3: Future Centrality Index of Market Centers in Developed Areas

No.	Market Center	Future Population	Centrality Index (Median)	Centrality Index (Mean)	Remarks
1	Parasi	12,507	119	137	
2	Bardhaghat	18,608	65	75	
2	Sunwal	24,334	57	66	
3	Tribeni Susta/Balmiki Nagar	26,138	53	58	India, FI and Pop. appro
4	Maheshpur/Thutibari	17,711	63	70	India, CI and Pop. appro
6	Gopigunj	9,697	24	28	
7	Butwal	68,745	300	300	Rupandehi,CI approximate
8	Siddarthanagar	61,293	250	250	Rupandehi, CI approximate

Based on such information, which could be normally derived from the District Development Plan, a logical framework should be prepared. A logical framework is prepared based on the secondary information that was collected for the preparation of the District Transport Master Plan and interviews with the district officials is presented in Fig. 5.

Summary of Objectives/Activities	Objectively verifiable indicators	Means of Verification	Assumptions
Goal: Improvement of rural access in order to provide better opportunities to the rural population and contribute to poverty alleviation, both in the short term by creating employment through labor-based construction, and in the long term by improving the conditions for economic and social development.	1. Increase the disposable income of the farmers within the Zone of Influence of the existing and proposed roads by 15 percent. 2. Increase agricultural productivity by 10 percent. 3. Increase cash crop coverage by 25 percent.	For all goal level indicators, 2 year and 5 year impact evaluation using before and after research design with control groups.	The demand and supply situation of market will remain unchanged.
Purpose: Development of an all weather rural road network connecting all district level market centers so as to facilitate the movements among the market centers enabling them to foster as interdependent with each other based on their locational advantage and factor endowment. Increased number of visits of the rural settlements to the market centers for agricultural, social, health and educational purposes.	1. Commercial and market-oriented industrial activities are flourished in the market centers along the highway corridor. 2. Agro-based industries like sugar mills, rice mills are grown between Highway and the Indian border. 3. Per household visit to market centers increased by 25 percent.	1. Commercial and Industrial census. 2. Household and cordon survey.	1. The farmers and local people have entrepreneurial skills and can tap the business opportunities. 2. Increased trips to the market centers are economically beneficial to the local people.
Outputs: 1. Nearly 42 Km of district road is constructed/rehabilitated providing year round service to the rural populace. 2. Maintenance system for the existing and the proposed road is effective.	1. All 42 km road is completed within the planning period. 2. All constructed roads meet the engineering standards. 3. The farmers face no obstacles for commuting between their hamlets and the market centers for economic and social purposes.	1. Measurement Book of the Project. 2. Physical verification of the constructed and rehabilitated roads. 3. Interview with the local people.	1. The appropriate vehicles are available in each link after their construction provided by the private sector. 2. The local people cooperate in road construction and maintenance by providing land, forming user's committees and not allowing the practice of tying cattle on the street.

Activities: 1. Preparation and approval of the District level road network plan. 2. Detail survey and design of the roads. 3. Budget arrangement. 4. Preparation of the Tender Documents. 5. Announcement of the tender. 6. Selection and employment of the contractor. 7. Arrangement of supervision and monitoring system. 8. Introduction of the toll tax system.	Required Inputs: *(It needs detail working out of each project, therefore it is left blank now)*	1. The DDC personnel are capable enough and can spare time for planning the rural road network, conducting the detail survey and design. 2. The contractors know the low cost labor based technology. 3. There is no political and social resistance for introducing the toll tax.

Fig. 5: Logical Framework for Development of the Rural Road in Nawalparasi District

As shown in Fig. 1, if the district had the District Development Plan, it would be logical to present the centrality index in the third and fourth stage. However, having no District Development Plan, the future centrality index represented the District Development Plan in the first stage. Therefore, it is not necessary to repeat here. The preparation of the existing inventory of rural transportation infrastructure is another logical step. The inventory is the compilation of all types of roads and their respective length, surface and other details on the geometric standards.

Based on the algorithm, which is described earlier, a settlement interaction matrix for the present situation is prepared and presented in Table 4. The intensity of interaction is computed for present as well as future situations.

Table 4: Intensity of Interaction Among the Market Centers in the Developed Areas (Each Cell should be Multiplied by 10^9)

Market Centers	F.I.	Population	Parasi	Bardhaghat	Sunwal	Tribeni Susta	Maheshpur	Gopigunj	Butwal	Bhairahawa
FI			69	35	27	39	43	15	200	150
Parasi	69	8,910	0	11	32	15	29	4	221	207
Bardhaghat (Daunnedevi)	35	13,257	11	0	13	14	14	5	131	54
Sunwal	27	17,336	32	13	0	8	13	2	241	75
Tribeni Susta/Balmiki Nagar	39	19,582	15	14	8	0	21	5	131	105
Maheshpur/Thutibari	43	13,386	29	14	13	21	0	4	148	138
Gopigunj	15	6,908	4	5	2	5	4	0	24	25
Butwal	200	54,179	221	131	241	131	148	24	0	3,272
Bhairahawa	150	48,306	207	54	75	105	138	25	3,272	0

In this whole matrix, all other links except Maheshpur – Tribeni road have either blacktopped or graveled surface. The intensity of interaction between Maheshpur and Triveni is $21*10^9$ that means relatively in the higher side. Therefore, that road needs immediate intervention. The situation could be further substantiated by the future intensity of interaction, which is presented in Table 5.

Table 5: Future Intensity of Interaction among the Market Centers in the Developed Areas (Each Cell should be multiplied by 10^9)

Market Centers	F.I.	Population	Parasi	Bardhaghat	Sunwal	Tribeni Susta	Maheshpur	Gopigunj	Butwal	Bhairahawa
FI			119	65	57	53	63	24	300	250
Parasi	119	12,507	0	69	231	65	139	23	1,023	1,066
Bardhaghat (Daunnedevi)	65	18,608	69	0	100	66	74	32	658	299
Sunwal	57	24,334	233	100	0	45	75	13	1,373	476
Tribeni Susta/Balmiki Nagar	53	26,138	65	66	45	0	75	20	452	404
Maheshpur/Thutibari	63	17,711	139	74	75	75	0	19	551	573
Gopigunj	24	9,697	23	32	13	20	19	0	103	120
Butwal	300	68,745	1,023	658	1,373	452	551	103	0	13,167
Bhairahawa	250	61,293	1,066	299	476	404	573	120	13,167	0

The future intensity of interaction also reinforced the initial proposition of linking Tribeni with Maheshpur. The interaction between Parasi and Butwal has increased significantly that means the single lane road may not be enough in future. Similarly, a blacktopped road seems to be essential between Bhairahawa and Parasi after sometimes. Based on the pattern of interaction, the following roads (Table 6) are required for connecting the district level market centers.

Table 6: Road Network in Developed Areas

No.	Road	Length (km)	Ownership	Surface	Road Class
1	Mahendra Highway (Bardhaghat – Mahoo Khola)	23	DOR	BT	NH
2	Sunwal-Parasi	8.9	DOR	BT	FR
3	Parasi - Maheshpur	12.0	DOR	BT	FR
4	Parashi-Mahoo	7.4	DDC	Gravel	DR
5	Parasi-Narayan Chowk	13.3	DDC	Gravel	DR
6	Bardhaghat- Triveni	25.8	DOR	Gravel	FR
7	Canal Road	32.0	DOI	Gravel	CR
8	Tribeni-Maheshpur	20.9	DDC	Earth	DR
	Total Road Length	143.3			
	District Level Road Network	41.6			

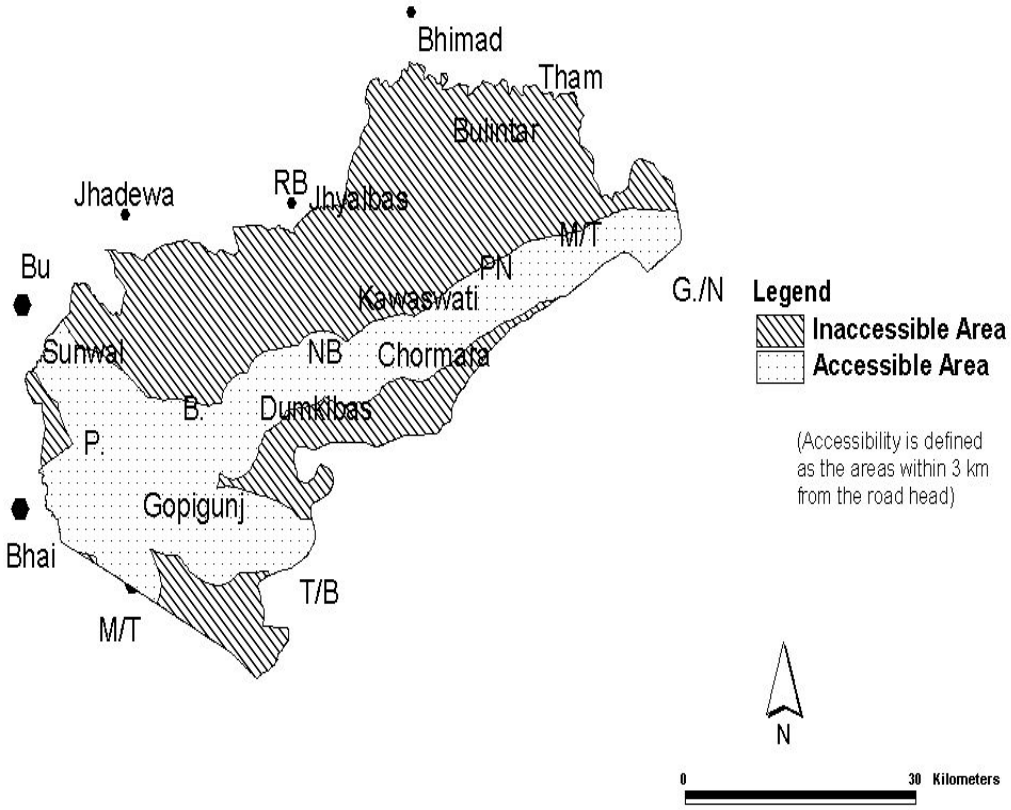
Table 6 shows that the length of District level road is only 41.6 km, whereas the previous District Transport Master Plan (PLRP, 1997) had proposed 185.25 km of district level roads, which is nearly 4.5 times longer in comparison to the present plan. The previous master plan did not follow the nodal point based networking, which allowed it to undertake the roads that should be essentially under the Village Development Committee. Therefore, the previous plan is not manageable by the District Development Committee from the resource as well as manpower point of view. It also does not confirm the previously stipulated definition of the district road. The present network has assigned more responsibility to the Village Development Committees to make them accountable for the construction, rehabilitation and maintenance of the road networks, which are within their territory.

5.2 Networking for the Under Developed Area

Developing a network in the under-developed areas is rather simpler than in the developed areas. There are also some similarities between them. The concept of District Development Plan and logical framework is also the point of departure in the case of under-developed areas as well. Similarly, identification of the central places is the identical concept. However, the market centers are not well developed in the under-developed areas. The planner has to identify such potential market centers, which do not exist now but have potential for development in future if the access to such market centers could be improved.

In the developed areas, almost all areas are accessible, at least during the dry season. However, in the under-developed areas, most of the areas remain inaccessible throughout the year. Therefore, the delineation of inaccessible areas with that of accessible areas is the foremost task in the case of underdeveloped areas. According to that, the inaccessible areas of the Nawalparasi district is delineated and presented in Fig. 6.

Fig. 6 Delineation of Inaccessible Areas with Accessible Areas



The DDC meeting of the Nawalparasi district decided that the areas within 3 km from the road should be defined as the accessible area and beyond that is defined as the inaccessible area. As shown in the Fig. 6 almost all hilly settlements are inaccessible. Therefore, the embryonic nodal points in the inaccessible areas should be explored. Considering the cultivated land, density of population and some local groceries and textile shops, few settlements like Thambensi, Bulintar, Dedgaon (Bhimad), Hupsekot, Rukse Bhanjyang (Palpa) and Jhadewa (Palpa) are identified. Based on the secondary information, key informant survey and executive judgement, the centrality index of those market centers which could not be surveyed are also estimated and presented in Table 7. The future centrality index is presented in Table 8.

Table 7: Present Centrality Index of Market Centers in Under Developed Areas

No.	Market Centers	Population	Centrality Index (Median)	Centrality Index (Mean)	Remarks
1	Gaindakot/Narayanghat	82,659	201	204	CI of Narayanghat approximate
2	Mukundapur/Beldiya/Rajahar	18,932	42	48	Combined three centers
3	Chormara	8,496	15	16	
4	Naya Belhani	11,976	25	28	
5	Dumkibas	8,503	17	20	
6	Jhadewa	5,500	8	8	CI approximate
7	Rukshe Bhanjyang	2,148	7	7	CI approximate
8	Bhimad	5,456	10	10	CI approximate
9	Kawaswati	8,017	54	62	
10	Pragatinagar	11,737	26	29	
11	Jhyalbas (Mainaghat)	3,375	6	6	
12	Thambensi (Kotthar)	3,362	5	5	
13	Hupsekot	3,690	5	5	
14	Bulintar	3,934	6	6	

Table 8: Future Centrality Index of Market Centers in Under-Developed Areas

No.	Market Center	Future Population	Centrality Index (Median)	Centrality Index (Mean)	Remarks
1	Gaindakot/Narayanghat	167,549	319.0	330.8	
2	Mukundapur/16 No./Rajahar	26,574	75.2	88.1	Three centers combined
3	Chormara	11,925	29.6	34.7	
4	Naya Belhani	16,810	47.6	54.8	
5	Dumkibas	11,935	37.9	43.6	
6	Jhadewa	7,042	25	25	Palpa, CI approximate
7	Rukshe Bhanjyang	2,725	20	20	Palpa, CI approximate
8	Bhimad	6,922	20	20	Tanahun, CI approximate
9	Kawaswati	11,253	115.5	132.1	
10	Pragatinagar	16,475	46.0	53.1	
11	Jhyalbas (Mainaghat)	4,283	12	12	CI estimated
12	Thambensi (Kotthar)	4,265	15	15	CI estimated
13	Hupsekot	4,682	12	12	CI estimated
14	Bulintar	4,992	15	15	CI estimated

Based on the centrality index, population and distance, the intensity of interaction among the market centers are calculated and presented in Table 9 and 10.

Table 9: Present Intensity of Interaction among the Market Centers (Each Cell should be multiplied by 10^9)

Market Centers	C.I.	Pop.	G.kot/N.ghat	M.pur/Beldiya/Rajahar	Chormara	Naya Belhani	Dumkibas	Jhadewa	Rukshe Bhan.	Bhimad	Kawaswati	Pragatinagar	Jhyalbas	Thambensi	Hupsekot	Bulintar
CI			893	160	75	85	77	25	20	150	319	85	6	5	5	6
Gaindakot/Narayanghat	201	82659	0	36,634	1,873	3,817	1,573	69	43	49	8,743	7,428	153	57	62	53
Mukundapur/Beldiya/ Rajahar	42	18932	36,634	0	137	257	99	3	2	2	768	1,922	12	3	4	3
Chormara	15	8496	1,873	137	0	185	2	1	0	0	196	88	9	0.39	1	0
Naya Belhani	25	11976	3,817	257	185	0	175	1	1	1	272	144	13	0.91	2	1
Dumkibas	17	8503	1,573	99	2	175	0	1	0	0	87	50	4	0.43	1	0
Jhadewa	8	5500	69	3	1	1	1	0	0.05	0	2	1	0.09	0.05	0	0
Rukshe Bhanjyang	7	2148	43	2	0	1	0	0	0	0	1	1	0.06	0.03	0	0
Bhimad	10	5456	49	2	0	1	0	0	0	0	1	1	0	0	0	0
Kawaswati	54	8017	8,743	768	196	272	87	2	1	1	0	870	16	1	2	2
Pragatinagar	26	11737	7,428	1,922	88	144	50	1	1	1	870	0	9	1	2	1
Jhayalbas	6	3375	153	12	9	13	4.09	0.09	0.06	0.06	16	9	0	0.06	0.14	0
Thambensi	5	3362	57	3	0	0.91	0.43	0.05	0.03	0.04	1	1	0.06	0	0.04	0.03
Hupsekot	5	3690	62	4	1	1.70	0.78	0.07	0.04	0.05	2	2	0.14	0.04	0	0.04
Bulintar	6	3934	53	3	0	0.99	0.47	0.06	0.03	0.09	2	1	0.07	0.03	0.04	0

Table 10: Future Intensity of Interaction among the Market Centers (Each Cell should be multiplied by 10^9)

Market Centers	C.I.	Pop.	G.kot/N.ghat	Muku.pur/Beldiya/Rajahar	Chormara	Naya Belhani	Dumkibas	Jhadewa	R. Bhan.	Bhimad	Kawaswati	Pragatinagar	Jhyalbas	Thambensi	Hupsekot	Bulintar
CI			319	75	30	48	38	25	20	20	115	46	12	15	12	15.00
Gaindakot/Narayanghat	319	167,549	0	294,682	38,712	32,913	15,594	3,841	1,665	370	84,198	59,976	1249	7475	1768.6	3428
Mukundapur/Beldiya/Rajahar	75	26,574	294,682	0	975	1,730	769	170	79	221	5,772	2,243	75	108	85.2	189
Chormara	30	11,925	38,712	975	0	1,415	355	46	30	93	162,797	630	66	16	34	43
Naya Belhani	48	16,810	32,913	1,730	1,415	0	1,448	123	97	49	2,190	970	87	31	57	73
Dumkibas	38	11,935	15,594	769	355	1,448	0	88	35	25	811	391	32	21	24	32
Jhadewa	25	7,042	3,841	170	46	123	88	0	10.97	9.47	140.80	75.13	5.57	12.41	5.09	6.70
Rukshe Bhanjyang	20	2,725	1,665	79	30	97	35	11	0	3	77	38	3	2	2	3
Bhimad	20	6,922	370	221	93	49	25	9	3	0	101	54	3	10	3	7
Kawaswati	115	11,253	84,198	5,772	162,797	2,190	811	141	77	101	0	6,563	121	72	85	146
Pragatinagar	46	16,475	59,976	2,243	630	970	391	75	38	54	6,563	0	56	33	42	115
Jhayalbas	12	4,283	1248.5	74.7	66.1	86.6	32.1	5.6	3.0	3.1	121.4	55.6	0.0	2.3	10.5	4.3
Thambensi	15	4,265	7474.8	108.1	16.4	31.4	21.3	12.4	2.0	9.8	71.6	33.3	2.3	0.0	2.03	3.83
Hupsekot	12	4,682	1768.6	85.22	33.52	56.75	24.37	5.09	2.46	2.95	84.65	42.03	10.5	2.03	0	3.41
Bulintar	15	4,992	3428.13	189	43	73	32	7	3.22	7	146	115	4.31	3.83	3.41	0

In the present situation, the intensity of interaction is strongest between Mukundapur and Gaindakot. Kawasoti and Pragatinagar also have relatively stronger relationship with Gaindakot/Narayanghat. All these market centers are located along the Mahendra Highway; therefore, no additional road needs to be constructed for strengthening the interlinkages. As an indicator of the underdevelopedness, the intensity of interaction among the market centers along the Mahendra Highway and the settlements in the hinterland is extremely poor. In the future centrality index, after the construction of the district level roads linking the market centers along the national highway with some of the potential settlements in the hinterlands, the intensity of interaction increased considerably.

Some of the most sensible transport routes and their present and potential intensity of interaction are presented in Table 11.

Table 11: Sensible Transport Routes and Intensity of Interaction

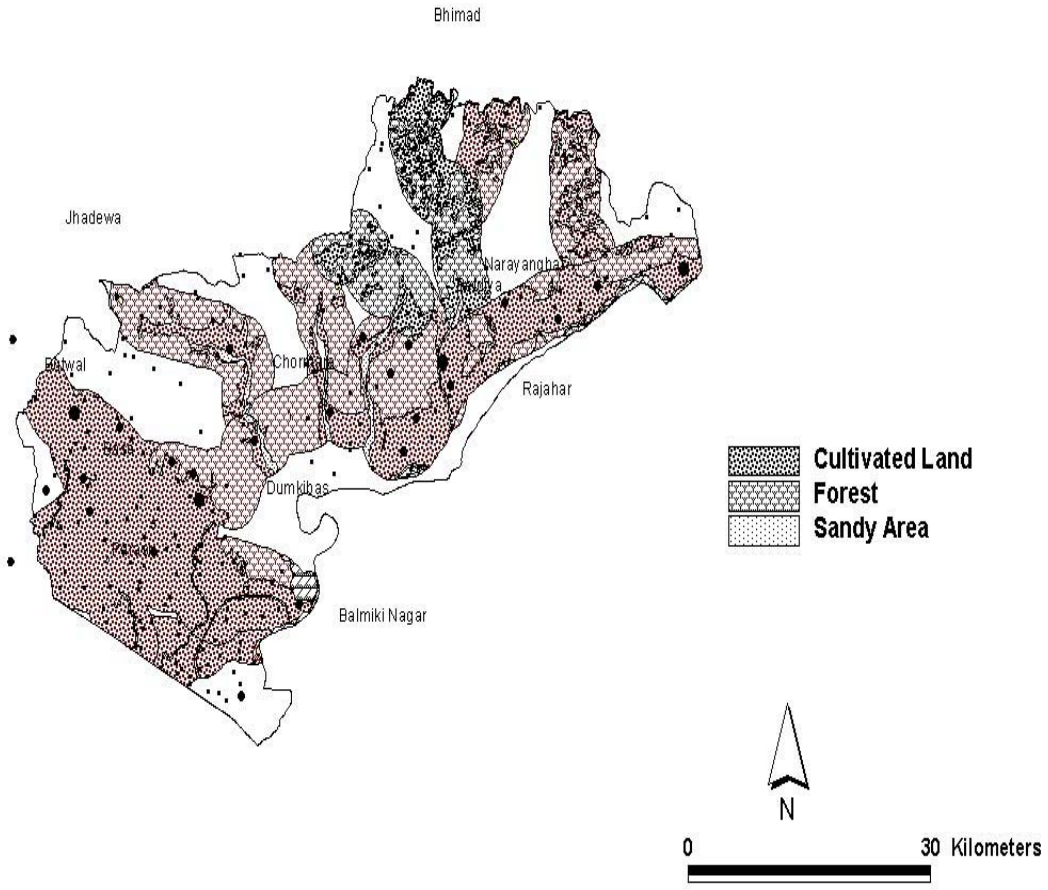
Transport Route	Intensity of Interaction	
	Present	Future
Dhobadi (Kawasoti – Bulintar)	$2*10^9$	$146*10^9$
Mukundapur - Thambensi	$3*10^9$	$108.1*10^9$
Kawasoti – Bhimad (Dedgaon)	$1*10^9$	$101*10^9$
Naya Belhani (Arun Khola) – Rukse Bhanjyang (Majhkot)	$1*10^9$	$97*10^9$
Dumkibas - Jhadewa	$1*10^9$	$88*10^9$
Jhyalbas - Hupsekot	$0.14*10^9$	$10.5*10^9$

Among the gateway nodal points and the embryonic nodal-points in the hinterlands the intensity of interaction between Mukundapur – Thambensi is strongest one followed by Kawasoti – Bulintar. The Jhyalbas – Hupsekot road seems to be extremely poor in terms of the intensity of interaction. However, the scenario changes in the ex-post situation. The Kawasoti – Bulintar occupied the first position followed by Mukundapur – Thambensi Road. Other roads except Jhyalbas – Hupsekot have tentatively identical force of interaction.

According to the new plan, the district level road length could be decreased from 254.8 km to 123.2 km. With the decrease in length, the status of accessibility did not decrease. Only those roads are omitted which either do not connect the present or potential market centers or they are not instrumental for ameliorating the level of accessibility. The previously proposed Triveni – Dumkibas road that traverses totally through the forest and with the extremely fragile *Siwalik* mountain range is omitted from the present plan. Similarly the Mainaghat and Dhobadi (Kotthar) are not the nodal points and the density of population along that route is extremely sparse, therefore that road is also deleted from the proposed plan. As the nodal points are the foci of the network of the present plan, the point of origination for the road leading to Dedgaon (Bhimad) is shifted from Daldale (Pragatinagar) to Kawasoti, the sub-district center and a thriving market center.

The Fig. 7 shows the Zone of Influence of the proposed roads in developed as well as under-developed areas. As shown in the figure the entire district will be accessible after constructing the proposed rural transport infrastructures. The uncovered portions are mainly the forest areas.

Fig. 7 Zone of Influence of the Present and Proposed Roads (ZOI = 3 Km from the road head)



6. CONCLUSIONS

The central places and existing roads, tracks and trails should be the basis for the rural road networking. By incorporating the population, functions, distances and interactions among the settlements, the Settlement Interaction Based Rural Road Network Model could be able to decrease the length of the district level rural road network from 440.05 km to 164.8 km, a decrease of more than 62 percent without reducing the level of accessibility. The previous as well as the present plans have included almost all settlements within the Zone of Influence of three kilometer. Consideration of the neighboring nodal points is another noteworthy point of the present models. The networking is, however, one of the modules of the entire transport planning exercises, which should be followed up by the transport demand estimation, construction and maintenance cost and calculation and forecasting of the benefits of a road for prioritizing the links in the rural road networks. Therefore, the final decisions on links should be taken after completing the entire planning cycle.

Acknowledgements

This study was mainly sponsored by the International Labour Organisation, Advisory Support, Information Services, and Training – Asia Pacific (ASIST-AP). Besides that the Asian Institute of Technology (AIT), Thailand and International Center for Integrated Mountain Development (ICIMOD), Kathmandu also supported morally and financially.

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