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Centre for Post-graduate Studies
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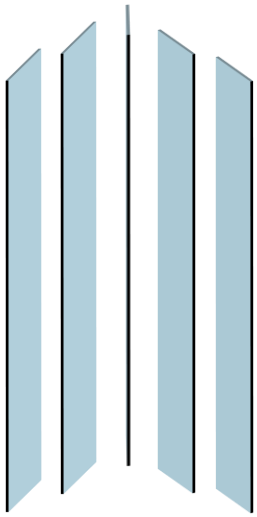

An Assignment

On

Study of Robustness of Road Network
In
Chandragiri Municipality Ward No. 09

Submitted By

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Submitted To
Manda Panta
Transportation Networking

M.Sc. in Transportation Engineering and Management

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List of Symbols

α	Alpha Index
β	Beta Index
γ	Gamma Index
e	Number of links
v	Number of nodes

1. Introduction

Chandragiri Municipality is one of the 10 municipalities in Kathmandu district. This is located at the southwestern part of the Kathmandu district. The main entry point of Kathmandu through Tribhuvan Highway, Nagdhunga lies in this municipality. It spans a total area of 43.92 square kilometers and is divided into 15 wards. It is bordered by Kritipur Municipality to the east, Dhunibeshi Municipality to the west, Nagarjun Municipality to the north, and Thaha Municipality, Makawanpur and Indra-Sarobar Rural Municipalities to the south. Total Population is 136,860 comprising 68,303 Males and 68,557 Females as of 2078BS census. Every ward is connected with road networks to each other.

1.1 Salient Features of the area of study (Chandragiri#09)

Location: Bagmati Province
Kathmandu Nepal
Terrain: Hilly
Population: Total 6069 comprising 3019 Males and 3050 Females as of 2078BS census
Important places: MachchheNarayan Temple, Bishnudevi temple, Bhashmashur Hill

1.2 Robustness of the Network

- Alpha index (α)

Alpha index is a measure of the number of independent circuits in the network. The range of the index is from a value of 0 for a minimally connected network to a value of 1 for a maximally connected. Additional linkages in a network create circuitry.

Let,
Number of linkages = e Number of nodes = v
When the network is minimally connected; then the actual number of linkages is e_{min} = (v – 1)
When circuits exist in the network, the number of linkages is greater than (v – 1) i.e., e > (v – 1)
The number of actual circuits is c = e - e_{min} = e - (v-1) = e-v+1
Maximum number of circuits (c_{max})
cmax = e_{max} - e_{min} = (3v-6) - (v-1) = 2v-5

Then,
Alpha index (α) = $\frac{Actual\ Number\ of\ circuits\ (c)}{Maximum\ Number\ of circuit\ (Cmax)} = \frac{e-v+1}{2v-5}$

For convenience, the numerical value of alpha index may be expressed as a percentage of circuitry in a network. As the value of alpha index increases, the redundancy and complexity of the network also increases, i.e. the network will be more robust.

- Beta index (β)

It is the ratio of links to nodes. The beta index (β) reflects the complexity and completeness of a network. As the value of the beta index increases, the completeness of the network also increases i.e. the network will be more robust.

Let,
Number of linkages = e Number of nodes = v
Then,

Beta index (β) = $\frac{Actual\ Number\ of\ linkage}{Number\ of\ Nodes} = \frac{e}{v}$

- Gamma index (γ)

It is the ratio of the number of edges in a network to the maximum number of possible edges in that network. The numerical range for the gamma index is between 0 and 1. As the value of gamma index increases, the connectivity, circuitry and complexity of the network also increases
i.e. the network will be more robust.

Let,
Number of linkages = e Number of nodes = v
Then,
Gamma index (γ) = $\frac{Actual\ Number\ of\ linkage\ (e)}{Maximum Number\ of\ Linkage\ (emax)} = \frac{e}{3v-6}$

2. Data Collection

To determine the robustness of road network in Chandragiri Municipality ward no. 09, the data are taken from Google earth, published by Google and the GIS section of Chandragiri municipality and website of Chandragiri municipality.

2.1 Municipal Road Network

The major road of this Municipality is Tribhuvan Highway moving from Nagdhunga, Thankot towards Kalanki, Kathmandu and Thankot-Chitlang road and all the remaining roads are secondary roads connecting every ward and toles of the municipality.

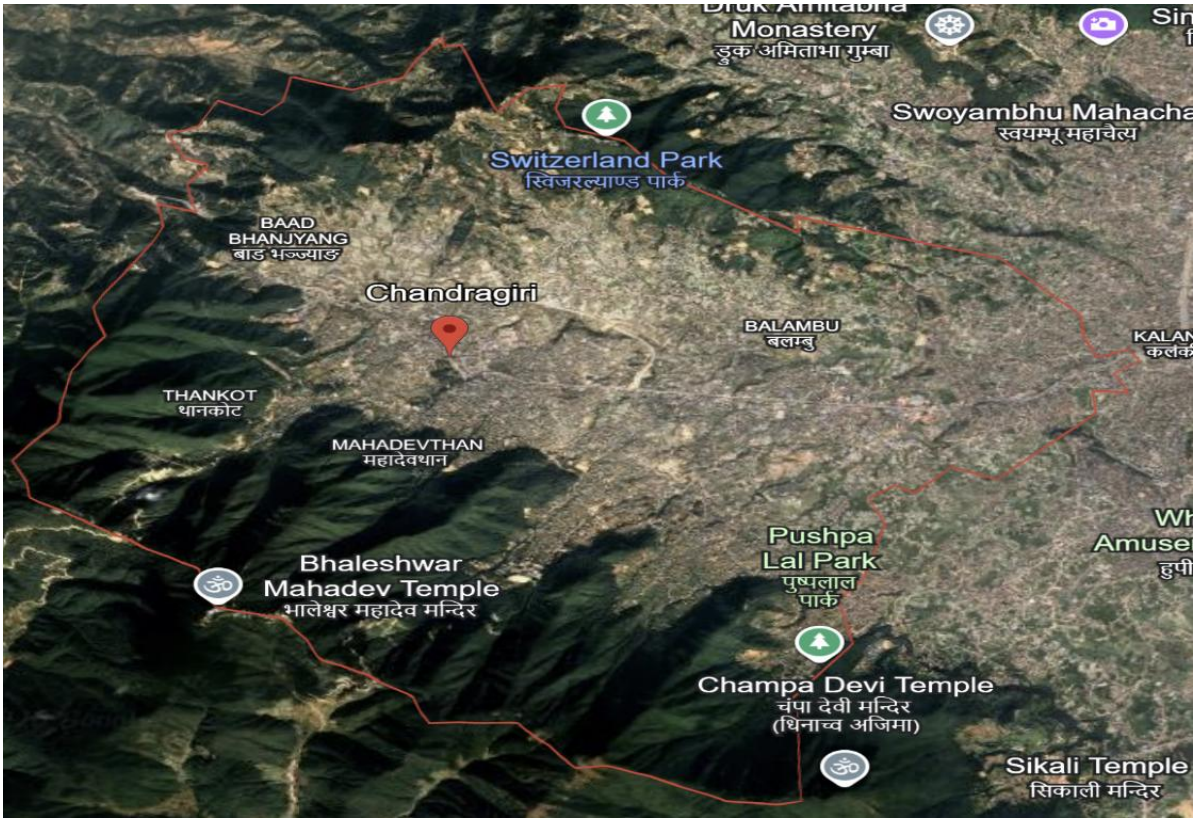

Figure 2-1 Location Map (Source: Google Earth Map)

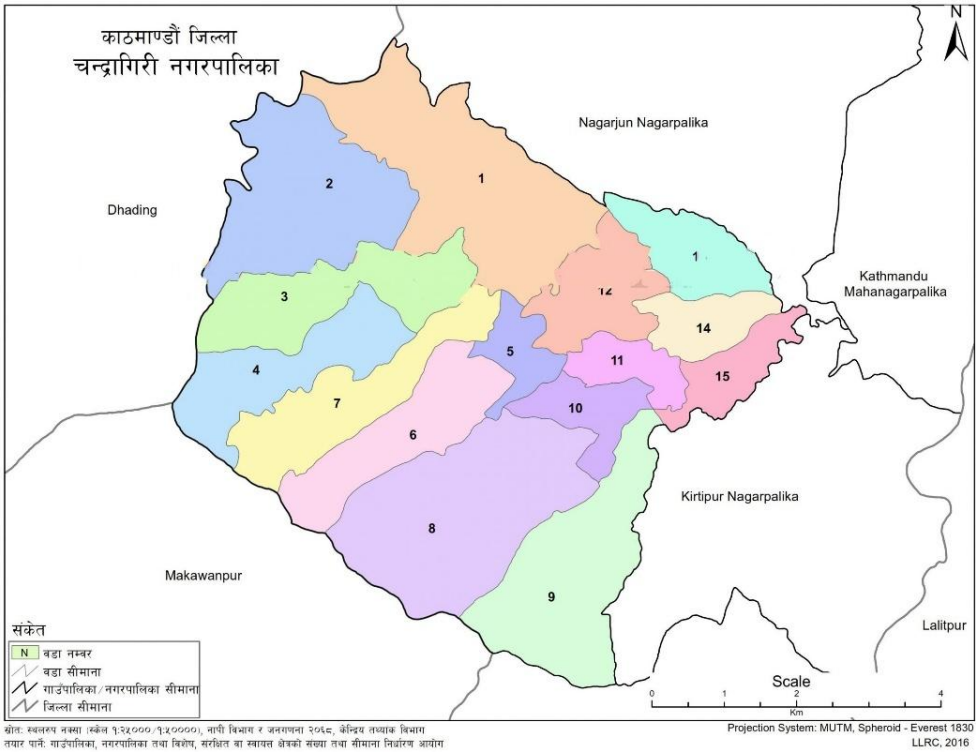

Figure 2-2 Location Map (Source: Chandragiri municipality)

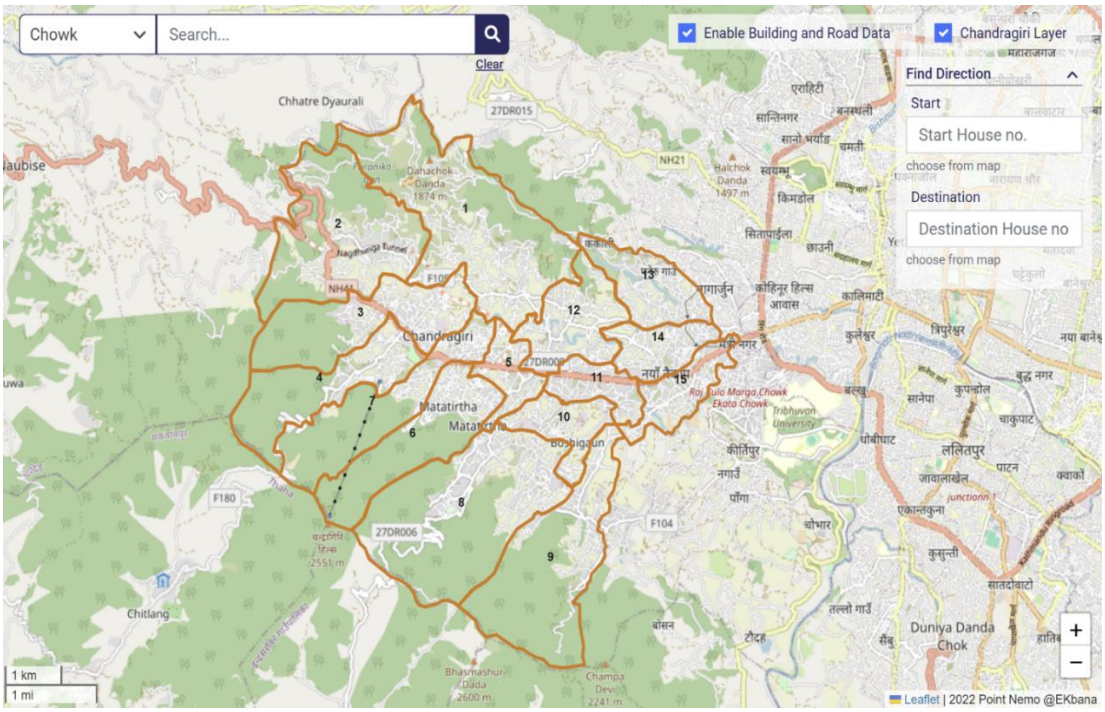

Figure 2-3: Map Under Study-Chandragiri Municipality (Source: https://chandragiriprofile.com/gis-map)

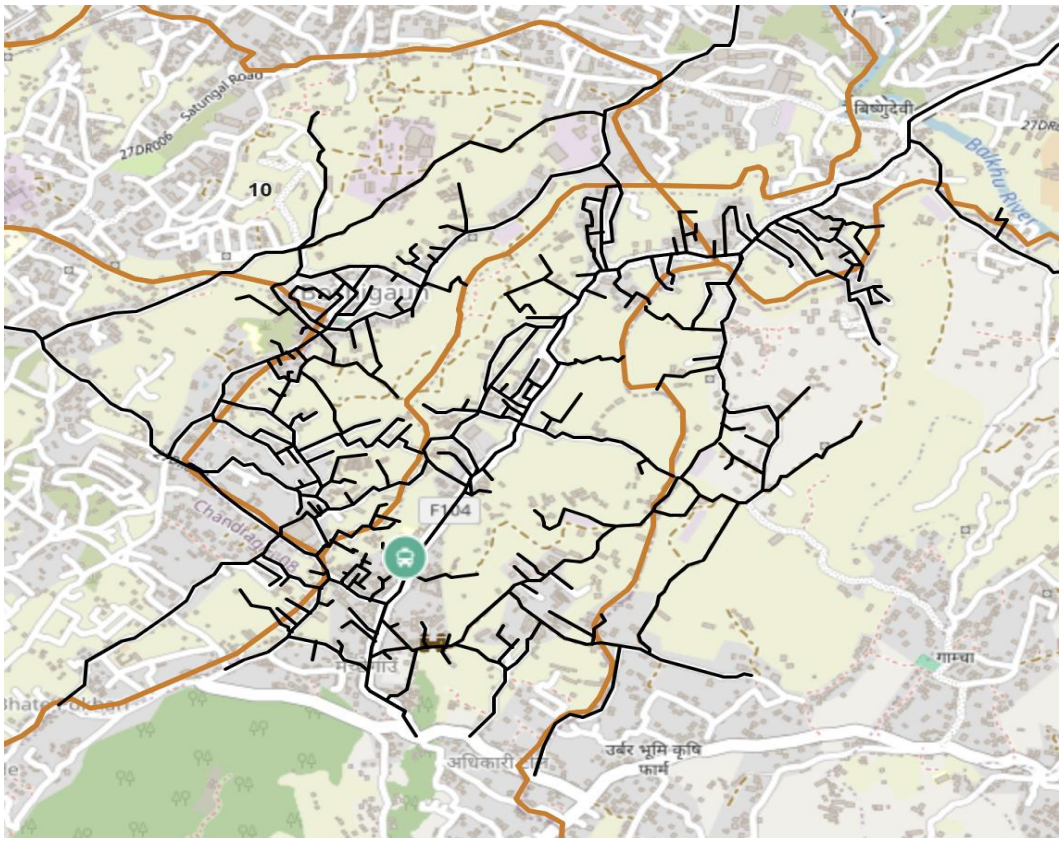

Figure 2-4: Map Under Study-Chandragiri#09 (Source: https://chandragiriprofile.com/gis-map)

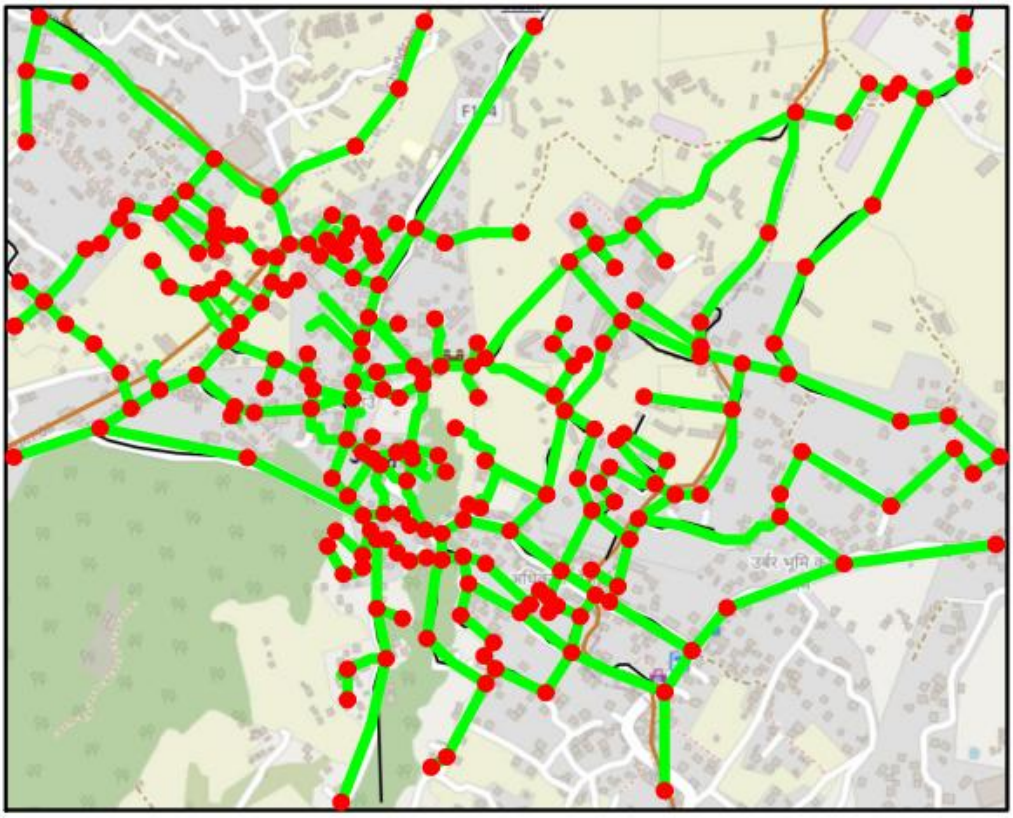

Figure 2-5: Map under study showing nodes

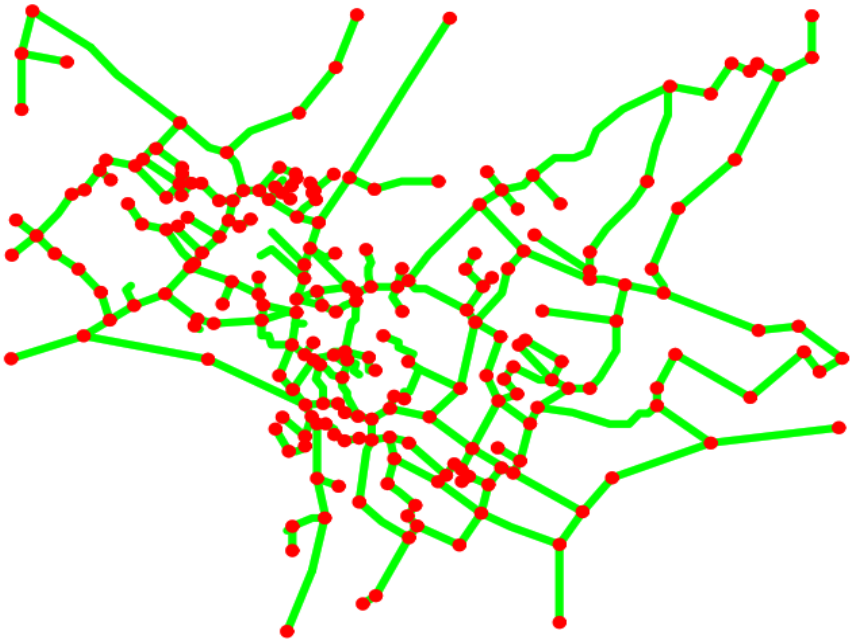

Figure 2-6: Map under study showing nodes

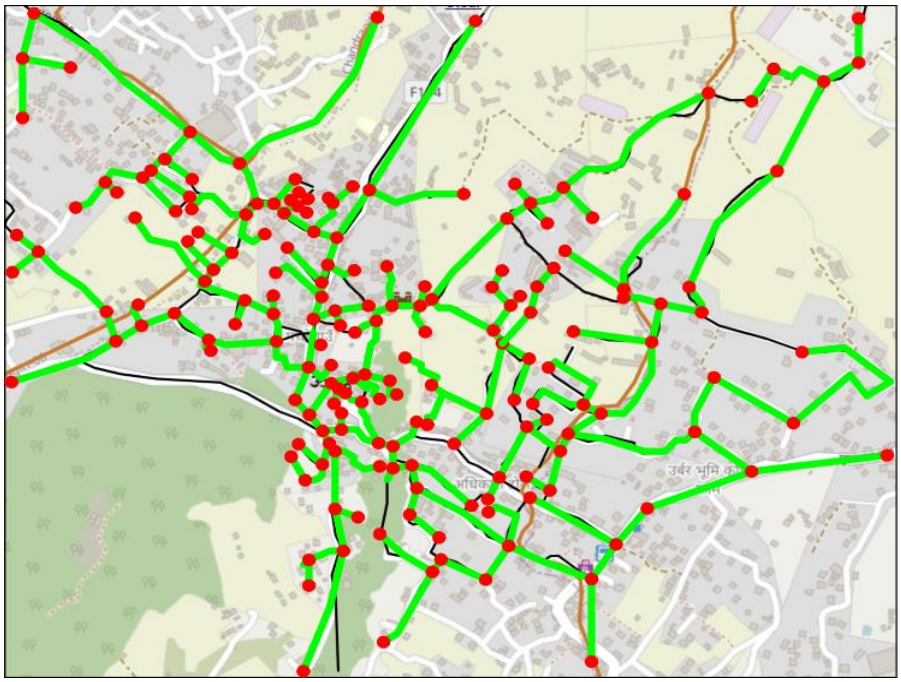

Figure 2-7:MST Map under study showing nodes

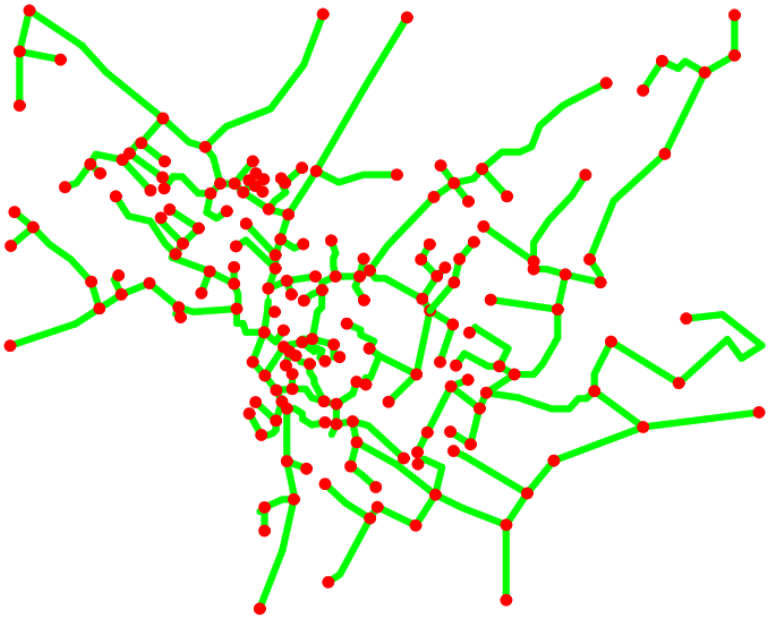

Figure 2-8:MST Map under study showing nodes

Table 2-1 List of National Highways/Provincial Roads

S.N.	Code No	Name of Road	Class	Total Length (km)
1		Tribhuvan Highway	A	5km in this
			Total	municipality

Table 2-2: List of Roads Class "A"

S.N.	Code No	Name of Road	Class	Total Length (km)
1		Tribhuvan Highway	A	5
			Total	

Table 2-3: List of Roads Class "B"

S.N.	Code No	Name of Road	Class	Total Length (km)
	Na	Na	Na	Na

2.2 Data Extraction

Nodes

The node is created by digitizing in goggle earth at all the existing junctions.

Linkage

The linkage is created by digitizing goggle earth at all the existing roads.

Table 2-4: Existing Road Network

S.N	ROAD CODE	NAME OF ROADS	SOURCE Node	DESTINATION Node	LENGTH (M)
1	4548	Tinthana- Machchhenarayan Marga (31)	148	147	40.255
2	4014	Machchhenarayan Matatirtha Marga (10)	147	146	27.608
3	4562	Machchhenarayan Marga (3 Ka)	146	149	74.862
4	5130	Tinthana Machhenaryana Marga (36 Ka)	146	145	42.655
5	4575	Jhulpokhari Marga (12)	1	2	121.829
6	4381	Machchhenarayan Marga (7)	1	3	98.55
7	3134	Tinthana- Machchhenarayan Marga (3 Kha)	1	198	16.317
8	4590	Machchhenarayan Matatirtha Marga (8)	198	199	233.162
9	1339	Bhasmeshwor Marga (10 Kha)	3	4	29.841
10	4564	Machchhenarayan Marga (11 Ka)	4	5	74.663
11	5164	Jhulpokhari Marga (9)	5	6	326.954
12	2849	Tinthana Machchhenarayan Marga (1 Ka)	6	7	88.809
13	4582	Thapagaun Marga (1)	7	8	130.975
14	4537	Kangal Kuwa Marga (1)	7	9	76.664
15	4577	Bhasmeshwor Marga (8)	7	10	85.657
16	4560	Satyanarayan Marga (2)	10	11	84.945
17	3538	Tinthana- Machchhenarayan Marga (24 Kha)	11	13	27.747
18	3764	Tinthana Machhenarayan Marga (20 Kha)	13	12	76.626
19	4015	Machchhenarayan Matatirtha Marga (10 Ka)	13	14	29.849
20	4592	Bhasmeshwor Marga (4)	14	15	82.726
21	4543	Tinthana- Machchhenarayan Marga (22)	15	16	25.217
22	5159	Machchhenarayan Matatirtha Marga (3)	16	17	96.228
23	2848	Tinthana- Machchhenarayan Marga (3 Ga)	17	62	28.392
24	5155	Machchhenarayan Matatirtha Marga (4 Ka)	62	63	17.025
25	1412	Narayankhel Marga (6 Ka)	63	64	103.662
26	1285	Satyanarayan Marga (5 Ka)	64	65	17.444
27	5136	Maslaphedi Marga (14 Ga)	64	66	61.315
28	4580	Jhulpokhari Marga (16)	62	61	182.836
29	5169	Machchhenarayan Marga (5)	61	71	27.723
30	2720	Machchhenarayan Khusikhusi Marga (6)	61	57	127.281
31	4567	Machchhenarayan Marga (13)	71	72	102.605
32	2999	Machchhenarayan Matatirtha Marga (7 Kha)	72	73	221.78
33	1943	Kangal Kuwa Marga (5)	57	58	34.309
34	4583	Thapagaun Marga (2)	58	60	93.773
35	2374	Bhasmeshwor Marga (5 Kha)	60	62	28.331

36	3129	Tinthana- Machchhenarayan Marga (12 Kha)	58	59	18.369
37	4016	Machchhenarayan Matatirtha Marga (9)	59	80	83.083
38	4573	Jhulpokhari Marga (6 Ka)	80	81	54.684
39	1397	Kangal Kuwa Marga (7 Kha)	80	79	63.47
40	5145	Maslaphedi Marga (14 Tha)	79	78	33.75
41	2778	Bhasmeshwor Marga (2)	81	75	90.534
42	2087	Masalaphedi Marga (6)	75	74	22.316
43	4376	Machchhenarayan Marga	75	76	421.848
44	3557	Dhaksi Marga (23)	76	77	210.671
45	2774	Bhasmeshwor Marga (11)	81	85	68.058
46	4542	Tinthana- Machchhenarayan Marga (23	85	87	78.789
47	2721	Dhaksi Marga (15)	87	88	220.538
48	1483	Tinthana- Machchhenarayan Marga (4)	88	40	158.407
49	5133	Maslaphedi Marga (8)	40	89	54.214
50	2376	Jhulpokhari Marga (3)	89	92	91.134
51	2842	Tinthana- Machchhenarayan Marga (16 Ka)/ Bethal Marga (3)	92	100	252.232
52	5149	Chundevi Marga (3)	100	103	61.515
53	4518	Bauthali- Machchhenarayan Marga (5)	103	104	93.028
54	2298	Machchhenarayan Kirtipur Marga (4)	100	102	32.834
55	2736	Masalaphedi Marga (7)	102	105	153.985
56	1399	Kangal Kuwa Marga (6 Ka)	105	111	28.537
57	4572	Jhulpokhari Marga (7)	111	112	66.095
58	4378	Machchhenarayan Kirtipur Marga (1)	111	110	20.597
59	3250	Machchhenarayan Matatirtha Marga (2)	110	109	90.216
60	4587	Ratmate Marga (2)	109	108	141.336
61	1073	Machchhenarayan Marga (10 Ka)	108	107	49.053
62	4382	Tinthana- Machchhenarayan Marga (24)	107	106	103.122
63	3757	Jhulpokhari Marga (4)	112	113	70.68
64	5142	Maslaphedi Marga (14 Jha)	113	114	30.914
65	4578	Machchhenarayan Matatirtha Marga (11)	114	115	174.544
66	5126	Tinthana Machhenarayan Marga (20 Ka)	114	116	31.509
67	4114	Jhulpokhari Marga (8)	116	126	493.333
68	4561	Satyanarayan Marga (2 Ka)	116	117	28.177
69	5129	Machchhenarayan Khusikhusi Marga (1)	117	118	80.804
70	5170	Stupa Marga	118	119	1044.975
71	1808	Narayankhel Marga (3)	119	120	27.813
72	4533	Tinthana- Machhe Narrayan Marga (11)	120	124	151.888
73	4141	Masalaphedi Marga	124	123	1331.07
74	1465	Tinthana- Machchhenarayan Marga (18)	124	125	42.582
75	5152	Machchhenarayan Matatirtha Marga (1 Kha)	125	126	236.675
76	1983	Bohorachautaro Marga (5)	125	172	65.062
77	3767	Machchhenarayan Marga (12)	127	127	89.748
78	4591	Masalaphedi Marga (2 Ka)	127	128	90.693
79	4745	Machchhenarayan Marga (8)	127	129	16.413
80	4550	Tinthana- Machchhenarayan Marga (35)	129	171	101.985
81	4602	Chundevi Marga (1)	129	130	44.287

82	2375	Bhasmeshwor Marga (5 Ka)	171	172	36.437
83	1106	Satyanarayan Marga (1)	172	173	33.754
84	4594	Masalaphedi Marga (4)	173	174	137.096
85	3448	Bhasmeshwor Marga (10)	174	109	217.343
86	1953	Machchhenarayan Marga (2)	174	175	76.976
87	4751	Machchhenarayan Marga (3)	175	168	171.107
88	5158	Machchhenarayan Matatirtha Marga (7 Ka)	175	176	124.158
89	1074	Masalaphedi Marga (11 Ka)	176	177	419.329
90	1941	Kangal Kuwa Marga (7)	168	167	236.454
91	1952	Thapagaun Marga	168	169	428.417
92	2177	Machchhenarayan Khusikhusi Marga (6 Kha)	167	161	74.329
93	3548	Kangal Kuwa Marga (7 Ka)	167	133	71.125
94	4600	Masalaphedi Marga (3)	161	160	75.694
95	5143	Maslaphedi Marga (14 Nhya)	161	162	43.996
96	5153	Machchhenarayan Matatirtha Marga(1 Ga)	162	163	258.107
97	1942	Kangal Kuwa Marga (6)	162	166	47.298
98	2621	Machchhenarayan Marga (14)	162	165	95.21
99	4588	Masalaphedi Marga (7 Ka)	133	131	58.589
100	1315	Ratmate Marga (2 Ka)	133	134	83.294
101	1485	Tinthana- Machchhenarayan Marga (1) / 9-15 Simana Sadak	131	132	198.861
102	2088	Masalaphedi Marga (11)	131	130	108.765
103	5154	Machchhenarayan Matatirtha Marga(1 Ga '1')	134	135	38.884
104	3763	Tinthana Machhenarayan Marga (20 Ga)	135	136	103.463
105	4593	Bhasmeshwor Marga (3)	136	137	114.168
106	4541	Tinthana- Machchhenarayan Marga (26 Ka)	137	139	33.475
107	5144	Maslaphedi Marga (14 Ta)	139	140	30.954
108	5148	Maslaphedi Marga (14 Ada)	140	141	48.332
109	2563	Kangal Kuwa Marga	141	142	1036.927
110	5147	Maslaphedi Marga (14 Dha)	142	157	38.667
111	4125	Jhulpokhari Marga	142	143	1547.057
112	1995	Tinthana- Machchhenarayan Marga (15 Ka)	157	156	34.842
113	1857	Bhasmeshwor Marga (10 Ka)	156	155	58.511
114	4559	Satyanarayan Marga (5)	156	181	57.523
115	5150	Chundevi Marga (4)	181	178	173.426
116	1744	Bohorachautaro Marga (2)	178	108	62.698
117	2772	Bhasmeshwor Marga (12)	178	179	47.681
118	4556	Narayankhel Marga (6 Kha)	178	177	161.626
119	3252	Machchhenarayan Matatirtha Marga (5 Ka '1')	181	182	69.911
120	3242	Narayankhel Marga (6 Kha '1')	182	183	58.503
121	4544	Tinthana- Machchhenarayan Marga (28 Ka)	182	97	154.771
122	4122	Tinthana Machchhenarayan Sadak	183	184	3121.841
123	1450	Narayankhel Marga (5)	183	186	29.294
124	4535	Tinthana- Machchhenarayan Marga (17)	184	185	155.13
125	4566	Machchhenarayan Matatirtha Marga (6)	184	153	22.691
126	4571	Jhulpokhari Marga (6)	153	154	338.858
127	3126	Tinthana- Machchhenarayan Marga (16 Ka '1')	153	152	105.98

128	4558	Matatirtha Khusikhusi Marga (7)	152	151	119.032
129	1484	Tinthana- Machchhenarayan Marga (3)	151	146	277.549
130	1114	Tinthana- Machchhenarayan Marga (10)	146	148	42.972
131	4120	Bauthali- Machchhenarayan Marga /Machchhenarayan Khusikhusi Marga	146	145	1331.3
132	1773	Bohorachautaro Marga (1)	145	142	77.375
133	3128	Tinthana- Machchhenarayan Marga (16 Ga '2')	141	141	34.225
134	2737	Ratmate Marga (5)	141	139	76.29
135	5131	Bohorachautaro Marga (3)	139	136	79.114
136	4557	Narayankhel Marga (2)	136	135	119.583
	Total length (m)				22,653.17
	Total length (km)				22.653

Figure 2-9: Existing Road Network Under Study

3. Data Analysis

3.1 Minimum Spanning Tree (MST)

In the graph theory, the minimum spanning tree is the network or connectivity in which there is one and only one, sequence of edges between any two pairs of nodes. In minimum spanning tree network removal of any edge from the graph will divide the network into two disconnected parts.

In Minimum Spanning Tree (MST), the number of edges will always be one less than number of vertices/nodes:

$e_{min} = (v - 1)$

Robustness of the MST network is minimum.

3.2 Prims Algorithm

Prim's algorithm is a greedy algorithm that finds a minimum spanning tree for a weighted undirected graph. This means it finds a subset of the edges that forms a tree that includes every vertex, where the total weight of all the edges in the tree is minimized. The algorithm operates by building this tree one vertex at a time, from an arbitrary starting vertex, at each step adding the cheapest possible connection from the tree to another vertex.

3.3 Construction of Minimum Spanning Tree (MST)

From the distance sheet obtained from the network diagram, minimum spanning tree is obtained. While construction of minimum spanning tree, some of the routes is not followed by the tree, so some additions of links are done. The addition of links in the network is done regarding social and economic importance.

Table 3-1 Distance Data from Minimum Spanning Tree

S.N	ROAD CODE	NAME OF ROADS	SOURCE Node	DESTINATION Node	LENGTH (M)
1	4548	Tinthana- Machchhenarayan Marga (31)	148	147	40.255
2	4014	Machchhenarayan Matatirtha Marga (10)	147	146	27.608
3	5130	Tinthana Machhenaryana Marga (36 Ka)	146	145	42.655
4	4575	Jhulpokhari Marga (12)	1	2	121.829
5	4381	Machchhenarayan Marga (7)	1	3	98.55
6	3134	Tinthana- Machchhenarayan Marga (3 Kha)	1	198	16.317
7	4590	Machchhenarayan Matatirtha Marga (8)	198	199	233.162
8	1339	Bhasmeshwor Marga (10 Kha)	3	4	29.841
9	4564	Machchhenarayan Marga (11 Ka)	4	5	74.663
10	5164	Jhulpokhari Marga (9)	5	6	326.954
11	2849	Tinthana Machchhenarayan Marga (1 Ka)	6	7	88.809
12	4582	Thapagaun Marga (1)	7	8	130.975
13	4537	Kangal Kuwa Marga (1)	7	9	76.664

14	4577	Bhasmeshwor Marga (8)	7	10	85.657
15	3538	Tinthana- Machchhenarayan Marga (24 Kha)	11	13	27.747
16	3764	Tinthana Machhenarayan Marga (20 Kha)	13	12	76.626
17	4015	Machchhenarayan Matatirtha Marga (10 Ka)	13	14	29.849
18	4592	Bhasmeshwor Marga (4)	14	15	82.726
19	4543	Tinthana- Machchhenarayan Marga (22)	15	16	25.217
20	5159	Machchhenarayan Matatirtha Marga (3)	16	17	96.228
21	2848	Tinthana- Machchhenarayan Marga (3 Ga)	17	62	28.392
22	5155	Machchhenarayan Matatirtha Marga (4 Ka)	62	63	17.025
23	1412	Narayankhel Marga (6 Ka)	63	64	103.662
24	1285	Satyanarayan Marga (5 Ka)	64	65	17.444
25	5136	Maslaphedi Marga (14 Ga)	64	66	61.315
26	4580	Jhulpokhari Marga (16)	62	61	182.836
27	5169	Machchhenarayan Marga (5)	61	71	27.723
28	2720	Machchhenarayan Khusikhusi Marga (6)	61	57	127.281
29	4567	Machchhenarayan Marga (13)	71	72	102.605
30	2999	Machchhenarayan Matatirtha Marga (7 Kha)	72	73	221.78
31	1943	Kangal Kuwa Marga (5)	57	58	34.309
32	4583	Thapagaun Marga (2)	58	60	93.773
33	2374	Bhasmeshwor Marga (5 Kha)	60	62	28.331
34	3129	Tinthana- Machchhenarayan Marga (12 Kha)	58	59	18.369
35	4016	Machchhenarayan Matatirtha Marga (9)	59	80	83.083
36	1397	Kangal Kuwa Marga (7 Kha)	80	79	63.47
37	5145	Maslaphedi Marga (14 Tha)	79	78	33.75
38	2778	Bhasmeshwor Marga (2)	81	75	90.534
39	2087	Masalaphedi Marga (6)	75	74	22.316
40	4376	Machchhenarayan Marga	75	76	421.848
41	3557	Dhaksi Marga (23)	76	77	210.671
42	2774	Bhasmeshwor Marga (11)	81	85	68.058
43	4542	Tinthana- Machchhenarayan Marga (23	85	87	78.789
44	2721	Dhaksi Marga (15)	87	88	220.538
45	1483	Tinthana- Machchhenarayan Marga (4)	88	40	158.407
46	5133	Maslaphedi Marga (8)	40	89	54.214
47	2376	Jhulpokhari Marga (3)	89	92	91.134
48	2842	Tinthana- Machchhenarayan Marga (16 Ka)/ Bethal Marga (3)	92	100	252.232
49	5149	Chundevi Marga (3)	100	103	61.515
50	4518	Bauthali- Machchhenarayan Marga (5)	103	104	93.028
51	2298	Machchhenarayan Kirtipur Marga (4)	100	102	32.834
52	2736	Masalaphedi Marga (7)	102	105	153.985
53	1399	Kangal Kuwa Marga (6 Ka)	105	111	28.537
54	3250	Machchhenarayan Matatirtha Marga (2)	110	109	90.216
55	4587	Ratmate Marga (2)	109	108	141.336

56	1073	Machchhenarayan Marga (10 Ka)	108	107	49.053
57	4382	Tinthana- Machchhenarayan Marga (24)	107	106	103.122
58	3757	Jhulpokhari Marga (4)	112	113	70.68
59	5142	Maslaphedi Marga (14 Jha)	113	114	30.914
60	4578	Machchhenarayan Matatirtha Marga (11)	114	115	174.544
61	5126	Tinthana Machhenarayan Marga (20 Ka)	114	116	31.509
62	4114	Jhulpokhari Marga (8)	116	126	493.333
63	4561	Satyanarayan Marga (2 Ka)	116	117	28.177
64	5129	Machchhenarayan Khusikhusi Marga (1)	117	118	80.804
65	5170	Stupa Marga	118	119	1044.975
66	4533	Tinthana- Machhe Narrayan Marga (11)	120	124	151.888
67	4141	Masalaphedi Marga	124	123	1331.07
68	1465	Tinthana- Machchhenarayan Marga (18)	124	125	42.582
69	1983	Bohorachautaro Marga (5)	125	172	65.062
70	3767	Machchhenarayan Marga (12)	127	127	89.748
71	4591	Masalaphedi Marga (2 Ka)	127	128	90.693
72	4745	Machchhenarayan Marga (8)	127	129	16.413
73	4550	Tinthana- Machchhenarayan Marga (35)	129	171	101.985
74	4602	Chundevi Marga (1)	129	130	44.287
75	1106	Satyanarayan Marga (1)	172	173	33.754
76	4594	Masalaphedi Marga (4)	173	174	137.096
77	3448	Bhasmeshwor Marga (10)	174	109	217.343
78	1953	Machchhenarayan Marga (2)	174	175	76.976
79	4751	Machchhenarayan Marga (3)	175	168	171.107
80	5158	Machchhenarayan Matatirtha Marga (7 Ka)	175	176	124.158
81	1074	Masalaphedi Marga (11 Ka)	176	177	419.329
82	1941	Kangal Kuwa Marga (7)	168	167	236.454
83	1952	Thapagaun Marga	168	169	428.417
84	2177	Machchhenarayan Khusikhusi Marga (6 Kha)	167	161	74.329
85	3548	Kangal Kuwa Marga (7 Ka)	167	133	71.125
86	4600	Masalaphedi Marga (3)	161	160	75.694
87	5143	Maslaphedi Marga (14 Nhya)	161	162	43.996
88	5153	Machchhenarayan Matatirtha Marga(1 Ga)	162	163	258.107
89	1942	Kangal Kuwa Marga (6)	162	166	47.298
90	2621	Machchhenarayan Marga (14)	162	165	95.21
91	4588	Masalaphedi Marga (7 Ka)	133	131	58.589
92	1315	Ratmate Marga (2 Ka)	133	134	83.294
93	1485	Tinthana- Machchhenarayan Marga (1) / 9-15 Simana Sadak	131	132	198.861
94	5154	Machchhenarayan Matatirtha Marga(1 Ga '1')	134	135	38.884
95	3763	Tinthana Machhenarayan Marga (20 Ga)	135	136	103.463
96	4593	Bhasmeshwor Marga (3)	136	137	114.168
97	5144	Maslaphedi Marga (14 Ta)	139	140	30.954
98	5148	Maslaphedi Marga (14 Ada)	140	141	48.332

99	2563	Kangal Kuwa Marga	141	142	1036.927
100	5147	Maslaphedi Marga (14 Dha)	142	157	38.667
101	4125	Jhulpokhari Marga	142	143	1547.057
102	1995	Tinthana- Machchhenarayan Marga (15 Ka)	157	156	34.842
103	4559	Satyanarayan Marga (5)	156	181	57.523
104	5150	Chundevi Marga (4)	181	178	173.426
105	1744	Bohorachautaro Marga (2)	178	108	62.698
106	2772	Bhasmeshwor Marga (12)	178	179	47.681
107	4556	Narayankhel Marga (6 Kha)	178	177	161.626
108	3252	Machchhenarayan Matatirtha Marga (5 Ka '1')	181	182	69.911
109	3242	Narayankhel Marga (6 Kha '1')	182	183	58.503
110	4544	Tinthana- Machchhenarayan Marga (28 Ka)	182	97	154.771
111	4122	Tinthana Machchhenarayan Sadak	183	184	3121.841
112	1450	Narayankhel Marga (5)	183	186	29.294
113	4535	Tinthana- Machchhenarayan Marga (17)	184	185	155.13
114	4566	Machchhenarayan Matatirtha Marga (6)	184	153	22.691
115	4571	Jhulpokhari Marga (6)	153	154	338.858
116	3126	Tinthana- Machchhenarayan Marga (16 Ka '1')	153	152	105.98
117	4558	Matatirtha Khusikhusi Marga (7)	152	151	119.032
118	1484	Tinthana- Machchhenarayan Marga (3)	151	146	277.549
119	1114	Tinthana- Machchhenarayan Marga (10)	146	148	42.972
120	4120	Bauthali- Machchhenarayan Marga /Machchhenarayan Khusikhusi Marga	146	145	1331.3
121	1773	Bohorachautaro Marga (1)	145	142	77.375
122	3128	Tinthana- Machchhenarayan Marga (16 Ga '2')	141	141	34.225
123	2737	Ratmate Marga (5)	141	139	76.29
124	5131	Bohorachautaro Marga (3)	139	136	79.114
125	4557	Narayankhel Marga (2)	136	135	119.583
		Total	Total length (m)		21,850.32
			Total length (km)		21.850

With the same coverage of road network, it shows that the length of road network is decreased by more than 3.5 percentage on minimum spanning tree. The MST is shown in Figure 3.1 below.

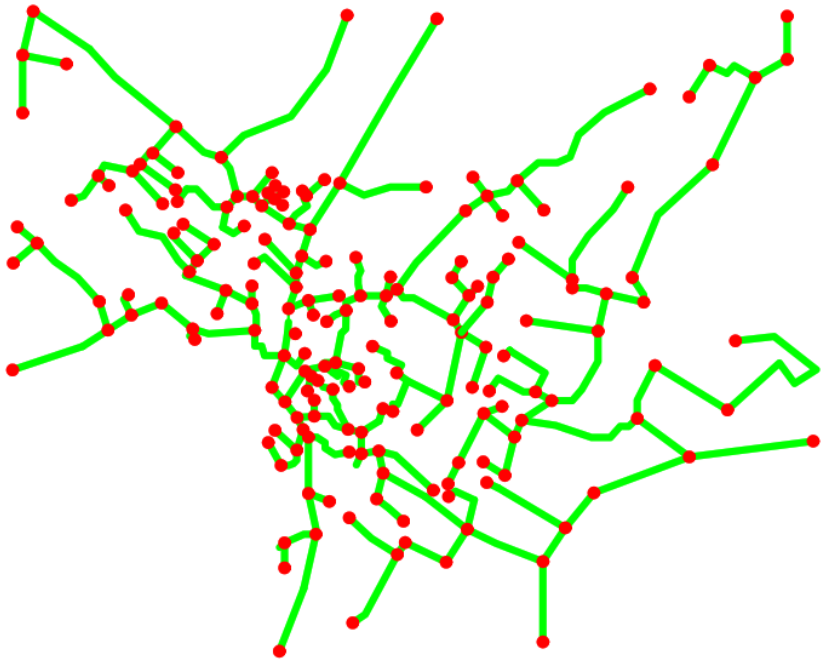

Figure 3-1 MST Diagram Under Study

4. Results and Discussion

4.1 Analysis of Existing Network, MST Network and Short Path Network

There are 136 links and 126 nodes all together on the existing networks. After the construction of the minimum spanning tree, the total number of links is 125, whereas the no. of nodes is not changed. There are all together 9 links which are not followed by the MST network.

Table 4-1: Comparison of Number of Nodes and Links

S. N.	Parameter Taken	Existing Network	MST Network
1	Number of Nodes(v)	126	126
2	Number of Links (e)	136	125

The extracted data is analyzed through the Alpha, Beta and Gamma index, the result is tabulated as below:

Table 4-2 Comparison of Alpha, Beta and Gamma Indexes

S. N.	Indicator		Existing Network	MST Network
1	Alpha (α)	$(e-v+1)/(2v-5)$	0.044	0
2	Beta (β)	e/v	1.079	0.992
3	Gamma (γ)	$e/(3v-6)$	0.365	0.336

For the desired level of idleness and connectivity of the road network, recommended values from the previous research for alpha, beta and gamma indexes are taken for reference, which is shown in table below:

4.2 Discussion of Result

From the indicators which are used for the analysis of robustness of road network presented in Table 4.2, it is concluded that

- With the increase in link (i.e. addition of links), the alpha value is also increased and
  vice versa. Thus, we conclude that the redundancy value is increased while increasing the link number and vice versa. It means the Robustness of a network is increased with the increase in redundancy and vice-versa.
- With the increase in link (i.e. addition of links), the beta value is also increased and
  vice versa. Thus, we conclude that the completeness value is increased while increasing the link number and vice-versa. It means the Robustness of a network is increased with the increase in completeness and vice versa.
- With the increase in link (i.e. addition of links), the gamma value is also increased and vice versa. Thus, we conclude that the connectivity value is increased while increasing the link number and vice versa. It means the Robustness of a network is increased with the increase in connectivity and vice-versa.

5. Conclusion and Recommendation

This kind of study is very rare in context of Nepal. The analysis can be used to determine the completeness and idleness of road network; however, the scope of work is limited due to the time and resources. Extensive research should be done to determine the suitable indicators to evaluate road network robustness.

Determination of road network robustness helps planners and traffic engineers mostly to better understand the ideal, complexity and completeness of road network for the future planning and improvement of existing networks. In countries like Nepal, where there is limited resources and unlimited requirements the analysis is very important to prioritize the investment.

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