THE ROAD CONNECTIVITY OF HPA-AN TOWNSHIP, KAYIN STATE

Myat Yazar Soe[1], Naw Paw Pale Wah[2]

Abstract

This paper tries to present "The Road Connectivity of Hpa-An Township, Kayin State" from geographical point of view. The quality of life and economy of society rely on good transport system. In Hpa-an Township, there are four modes of transportation: road, waterway, railway and airway. After construction of river-cross bridges on Thanlwin River, motor road has become the most important mode of transportation in Hpa-an Township. All village tracts within Hpa-an Township have no direct motor routes between them. Road density of Hpa-an Township is only more than 0.12 km per square km. Apart from Myotma administrative units, most of the administrative units are characterized by minimum efficiency of road network in terms of connectivity. The node has more connectivity in Hpa-an Township is (V5) Hpa-an Town and the nodes have less connectivity are (V1 and V16) Duyinseik and Mizine. The main objectives of the paper are to explore the modes of transportation in Hpa-an Township, to examine road networks of the study area and to find out the degree of road connectivity of road network of Hpa-an Township. Degree of road connectivity is calculated by mean of Connectivity Matrix. To present the paper, secondary data were mainly applied and field observation was thoroughly done. Connectivity Matrix is mainly used in presenting Connectivity of Hpa-an Township.

Keywords: *Connectivity, Connectivity Matrix, Road density, nodes*

Introduction

Transport is one of the fundamental pillars upgrading economics of the area and it gives positive effects on health of the given area (Dostál & Adamec). Nistor & Popa, 2014, stated that transport leads to the introduction of economic activities and local development and a well-developed internal transport system leads to linking economic activities within a region.

Garrison & Marble (1958) have studied transportation network of a region applying certain graph-theoretic measures. Graph-theory, as a branch of combinatorial topology, provides certain suitable measurements in the analysis of the structure of transportation network (Haggette, 1965).

The efficient transportation can increase firm productivity, the quality of life, markets and jobs, increase the supply of labor and entrepreneurship, and lead to changes in land use and spatial patterns that may improve growth and welfare. Improved transport infrastructure provides important benefits across all sectors and users. These benefits are typically realized in the form of reduced transport costs and times.

In the study area, the upgrading and maintenance of the rural roads resulted in better accessible and advantageous for local people, public institutions and regional markets. Moreover, the people who live in periphery areas deliver their products to the regional markets. And then, students go to schools and ill-health persons have faster and better access to health care centers. Road connectivity is important for economic and community development. Therefore, Hpa-an Township was selected to present road connectivity from geographical point of view.

[1] Assistant Lecturer, Department of Geography, Hpa-An University
[2] Assistant Lecturer, Department of Geography, Hpa-An University

Objectives

The main objectives are-

- to explore the modes of transportation in Hpa-an Township
- to examine road networks of the study area
- to find out the degree of road connectivity of road network of Hpa-an Township.

Methodology

Road network was examined by mean of graph-theory. The main tarred roads within Hpa-an Township were considered as the links and junction points of road network as the nodes. All smaller lanes connecting with other villages were excluded. Nodal connectivity was used to find out the degree of road connectivity of the Township.

Description of Study Area

Hpa-an Township is situated in the middle part of the Kayin State of Lower Myanmar. It lies between 16° 30’ N and 17° 44' N latitudes and also between 97° 21' E and 98° 1' E longitudes. It is bounded by Hlaing-bwe and Kawkareik Townships in the east, Paung, Tha-ton and Bilin townships in the west, and Kawkareik, Kyaikmaraw and Mawlamyine Townships in the south (Kyu Kyu Win, 2007).

Hpa-an Township has an area of 2901.02 square kilometers. The length from the north to the south of the township is 78 kilometre (125 miles) and the width from east to west 30 kilometre (48 miles). The township is composed of 9 administrative units with 9 wards and 91 village tracts.

Most of the high land areas are found in northern region and most of the low laying areas in southern parts. Most of the rivers run from north to south. The main river is Thanlwin River which passes through the middle part of the township. The most famous rivers and chaungs are Gyaing River, Donthami River, Mi-zaing, Hlaing-bwe, Hpa-on, the Hlaing, Kaya and the Zar-tha-pyin chaungs (Figure 1). Having mountain ranges, plains, limestone outcrops and forests in Hpa-an Township, mountain, forest, lateritic and meadow soils are found. Hpa-an Township has a moderate type of climate characterized by heavy rainfall during the monsoon in the month of June to September. The average annual rainfall is about 4500 mm. The summer is from February to May and April is the hottest month with mean daily maximum temperature of 40°C and mean daily minimum temperature of 21°C. The cool season lasts from late November to mid of February, and January is the coldest month with temperature ranging from 14°C to 36°C.

The distribution of Hpa-an Township population and transportation is influenced by physical feature. The land surface of Hpa-an Township is mountainous in the north, and low lying in the south. Therefore, the northern part is less transportation lines than the southern part. The total population of the township was about 421,575 persons (Regional Facts of Hpa-an, 2015) with the population density 145.26 persons per square kilometer. About seventy-five percent of Hpa-an Township population lived in the southern part and the remaining in the north.

Transportation of Hpa-an Township

Transportation is one of the most important elements for regional development. In the transportation sector of Hpa-an Township, there are four modes of transportation: road, inland water way, railway and airway transportations (Khin Win Naing, 2003).

Airway

In Hpa-an Township, there was one airport which is located on the north-east of Hpa-an town. Yangon-Mawlamyine-Hpa-an-Hpapun route ran three times a week until 1986.

Railway

In Hpa-an Township, there is only one railway linking Thaton-Myaingkalay Village and Hpa-an Township. It was built in 1985-86 and was opened in December 1987 to transport the cements produced from the No.1 and No.2 Tatmadaw Cement Factories. The length of the railroad is 39 kilometre (24 miles). Today, railway does not run due to better accessibility of road transportation.

Water Transportation

Before 2000, the waterway of Hpa-an Township was the most important transport mode. The main water routes were Hpa-an-Htone Aing-Zarthabyin-Mawlamyine route, Zarthabyin-Kyonedoe route and Hpa-an-Shwegun route. Htone-aing, Shwe-gun and Kama-maung villages had connection by the water transportation with Mawlamyine Township. After constructing bridges that cross the river such as Thanlwin Bridge, Gyaing-Zarthabyin Bridge and Gyaing-Kawkareik Bridge, the importance of water transportation gradually decreased the use of road transportation has increased.

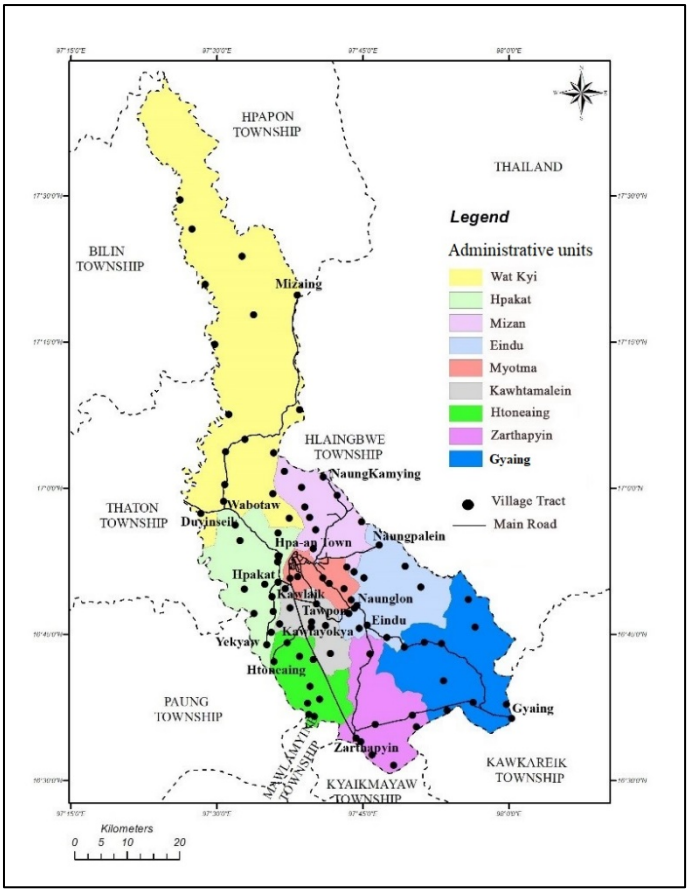
Road Networks of the Study Area

Motor road is the most important mode of transportation for Hpa-an Township. Hpa-an Township is connected with Upper Myanmar, Yangon, Thaton, Mawlamyine, Kawkareik, Myawaddy, Hlaingbwe and Hpa-pun Townships by the road networks. In Hpa-an Township, there are four types of road: tarred road, metalled road, lateritic road and earthen road. These roads connect Hpa-an and its neighbouring areas. Tarred roads and the other important roads in Hpa-an township are shown in table 1 and figure 1.

Table 1 Main Road Transport within Hpa-an Township, 2018

No	Road name	Length (km)
1	Duyinseik – Wabodaw – Hpakap – Hpa-an road	45.38
2	Wabodaw – Mizaing road	51.98
3	Hpakap – Yekyaw road	13.70
4	Hpa-an – Tawpone road	10.59
5	Hpa-an – Htoneaing road	23.14
6	Hpa-an – Zarthabyin road	38.43
7	Kawkyaik – Tawpone – Naunglone road	14.18
8	Hpa-an – Naunglone – Eindu – Gyaing road	61.57
9	Hpa-an – Naungkamying road	24.59
10	Hpa-an – Naungpalein road	18.78
11	Zarthabyin – Eindu road	23.50
12	Zarthabyin – Gyaing road	32.32
	Total	**358.16**

Source: Department of Transportation in Hpa-an Township



Source: Department of Transportation in Hpa-an Township

Figure 1 Main Transportation Road Network of Hpa-an Township, 2018

In Hpa-an Township, there are nine administrative units including 91 village tracts (Figure 1). Nine administrative units are Watkyi, Hpakat, Mizan, Eindu, Myotma, Kawhtamalein, Htoneaing, Zarthaphin and Gyaing.

Four out of 17 village tracts are linked with tarred road in Watkyi administrative unit, seven out of 13 village tracts in Hpakat, two in 10 village tracts in Mizan, four in 11 village tracts in Eindu, five out of nine Wards in Myoma, two in eight village tracts in Kawhtamalein, three out of nine village tracts Htoneaing, four out of eight village tracts in Zarthaphin, and five in ten village tracts in Gyaing.

It is clear that the Myoma is located highly accessible area and it links 79 percent of the village tracts within its administrative unit (Table 2). It is located not only in the middle part of the township but also in the central place of economic activities of the township. And then, village tracts are close to one another. Moreover, it is densely populated area in the township. Hpakat, Zarthapyin and Gyaing have slightly high level of connectivity. In the area, about half of village tracts is located near the main tarred roads and lie on the small hill locks. Watkyi, Mizan, Eidu, Kakhtamalein and Htoneaing have low level of connectivity. Most of village tracts are situated in the poorly drainage low land areas and hilly areas. Village tracts also scatter throughout the area. Therefore, the degree of connectivity is directly or indirectly influenced by location, relief, population density and their economic activities.

Table 2 Connectivity of Tarred Road in Hpa-an Township, 2018

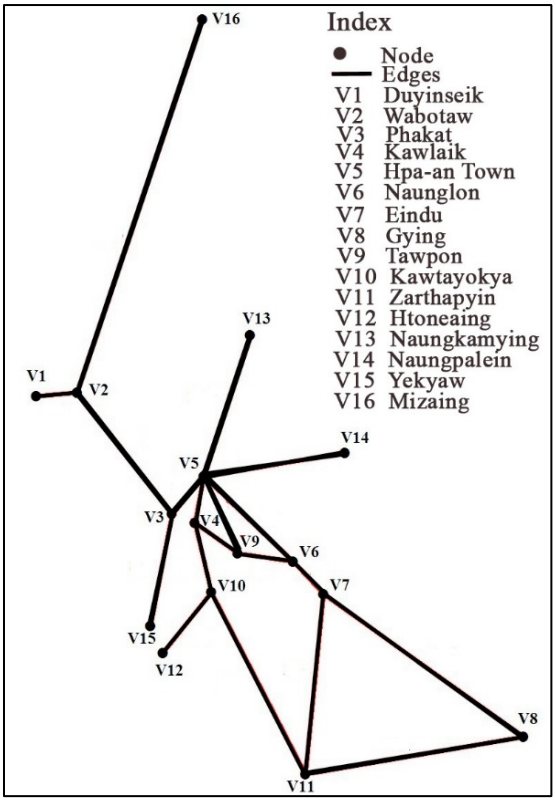
Administrative Units	No. of village tract/ward	No. of village tract/ward linked with tarred road	Percentage %
Watkyi	17	4	24
Hpakat	13	7	54
Mizan	10	2	20
Eindu	11	4	36
Myoma	14	11	79
Kawhtamalein	8	2	25
Htoneaing	9	3	33
Zarthapyin	8	4	50
Gyaing	10	5	50

Source: Computed by the Author based on field observation

Connectivity of Road Networks in Hpa-an Township

Geographers defined networks as "a set of geographic locations inter-connected in a system by a number of routes" (Kansky, 1963). The transportation network consists of a set of geographic locations interconnected in a system by a number of routes (Garrison, 1960). The degree of connection between all vertices is defined as the connectivity of the networks (Taaffe and Gauthier, 1973). Greater connectivity of an area somehow illustrates the more efficient in transportation that supports movements of goods and people of an area. The nodal connectivity is used to know the degree of connectivity of road network of Hpa-an Township. The nodal connectivity includes direct connectivity, indirect connectivity and total accessibility.

To analyse a road network of Hpa-an Township, it is needed to change the road network (Figure 1) into the form of a graph network (Figure 2). Here, points of origin/destination/junction of road network are considered as the nodes and the main tarred roads are considered as the links. Therefore, the converted topological network of Hpa-an Township consists of 16 nodes (v) and 19 edges (e) (Figure 2). Therefore, it's Alpha Index (e-v+1 / 2v-5, where, e = numbers of edges and v = number of vertices) is 0.15, Beta Index (a ratio the total number of edges to the total number of vertices) 1.19, Gamma Index (e / 3(v-2) is 0.45 and cyclomatic number (number of circuits) 4 respectively (Table 8).



Source: Based on Figure 1

Figure 2 Graph Network of Hpa-an Township, 2018

The prepared topological network of Hpa-an Township is represented as matrix. The matrix is usually a square matrix. Number of rows and columns of the matrix equal to the total number of nodes in the prepared graph network of Hpa-an Township. Since the prepared topological network has 16 nodes, the matrix that represents the road network is sixteen rows by sixteen columns grid. The horizontal rows of the matrix are defined as a set of origin and vertical columns are regarded as destination nodes. In this matrix, a value of '1' is filled in the cells that have a direct linkage between nodes and a value of '0' is filled in the cell that has no direct linkage. This matrix is commonly referred to as 'C' matrix /Original matrix/ direct connectivity (Table 3). In the 'C' matrix Table, the total value of each row (or) column equal to the number of direct linkages. Having only one direct linkage in V_1, V_{12}, V_{13}, V_{14}, V_{15}, and V_{16}, the total value of each its row (or) column is 1 and V_5 has the maximum number of direct linkages with 6 links (Table 3). The direct connectivity cannot display the real situation of road connectivity. Thus, it is necessary to consider the indirect connectivity to examine the accessibility.

Table 3 The 'C' Matrix (Original matrix)

	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**Total**
V1	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
V2	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	**1**	3
V3	0	**1**	0	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	3
V4	0	0	0	0	**1**	0	0	0	**1**	**1**	0	0	0	0	0	0	3
V5	0	0	**1**	**1**	0	**1**	0	0	**1**	0	0	0	**1**	**1**	0	0	6
V6	0	0	0	0	**1**	0	**1**	0	**1**	0	0	0	0	0	0	0	3
V7	0	0	0	0	0	**1**	0	**1**	0	0	**1**	0	0	0	0	0	3
V8	0	0	0	0	0	0	**1**	0	0	0	**1**	0	0	0	0	0	2
V9	0	0	0	**1**	**1**	**1**	0	0	0	0	0	0	0	0	0	0	3
V10	0	0	0	**1**	0	0	0	0	0	0	**1**	**1**	0	0	0	0	3
V11	0	0	0	0	0	0	**1**	**1**	0	**1**	0	0	0	0	0	0	3
V12	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	1
V13	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	1
V14	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	1
V15	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	1
V16	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Source: Based on Figure 2

The 'C' matrix is multiplied by itself to determine all linkages or indirect connections. The multiplying 'C' matrix is regarded as 'C^2' matrix. To multiply a matrix, we need to match and produce the element by element of rows and columns in a matrix and then sum them. Table 4 represented a matrix manipulation of the first row (V_1) to the first column (V_1) to get a value for the cell of the first row and column of the 'C^2' matrix. Each cell of the 'C^2' matrix is filled up in this manner (Table 5). Then, the 'C' matrix (Original matrix) and the 'C^2' matrix are added. A new matrix is product (Table 6). When the new matrix is multiplied again and add with the 'C' matrix (Original matrix), a next new matrix 'C^3' is got. The multiplying and adding procedures going on until all zero (0) cells are filled (until the 'C^6' matrix). The total of direct connection 'C' matrix and indirect connection matrix (up to six power) is regarded as the total connectivity matrix or total accessibility (Table 7). Summing the rows indicates the total accessibility for each vertex in the road network of Hpa-an Township. The greater the value is, the higher the accessibility of the node is.

Table 4 Computing A Value for The Cell of The First Row and Column in A Matrix

The first row		**the first column**		**Cell**
(V1)	**x**	**(V1)**	**=**	**V1 V1**
0	x	0	=	0
1	x	1	=	1
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0

The first row (V1)	**x**	**the first column (V1)**	**=**	**Cell V1 V1**
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
0	x	0	=	0
Sum			=	1

Source: Based on Table 3

Table 5 The 'C^2' matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	Total
V1	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	**1**	3
V2	0	**3**	0	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	5
V3	**1**	0	**3**	**1**	0	**1**	0	0	**1**	0	0	0	**1**	**1**	0	**1**	10
V4	0	0	**1**	**3**	**1**	**2**	0	0	**1**	0	**1**	**1**	**1**	**1**	0	0	12
V5	0	**1**	0	**1**	**6**	**1**	**1**	0	**2**	**1**	0	0	0	0	**1**	0	14
V6	0	0	**1**	**2**	**1**	**3**	0	**1**	**1**	0	**1**	0	**1**	**1**	0	0	12
V7	0	0	0	0	**1**	0	**3**	**1**	**1**	**1**	**1**	0	0	0	0	0	8
V8	0	0	0	0	0	**1**	**1**	**2**	0	**1**	**1**	0	0	0	0	0	6
V9	0	0	**1**	**1**	**2**	**1**	**1**	0	**3**	**1**	0	0	**1**	**1**	0	0	12
V10	0	0	0	0	**1**	0	**1**	**1**	**1**	**3**	0	0	0	0	0	0	7
V11	0	0	0	**1**	0	**1**	**1**	**1**	0	0	**3**	**1**	0	0	0	0	8
V12	0	0	0	**1**	0	0	0	0	0	0	**1**	**1**	0	0	0	0	3
V13	0	0	**1**	**1**	0	**1**	0	0	**1**	0	0	0	**1**	**1**	0	0	6
V14	0	0	**1**	**1**	0	**1**	0	0	**1**	0	0	0	**1**	**1**	0	0	6
V15	0	**1**	0	0	**1**	0	0	0	0	0	0	0	0	0	**1**	0	3
V16	**1**	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	**1**	3

Source: Based on Table 3

Table 6 The New Matrix (The 'C' Matrix (Original matrix) + The 'C^2' matrix)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16
V1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
V2	1	3	1	0	1	0	0	0	0	0	0	0	0	0	1	1
V3	1	1	3	1	1	1	0	0	1	0	0	0	1	1	1	1
V4	0	0	1	3	2	2	0	0	2	1	1	1	1	1	0	0
V5	0	1	1	2	6	2	1	0	3	1	0	0	1	1	1	0
V6	0	0	1	2	2	3	1	1	2	0	1	0	1	1	0	0
V7	0	0	0	0	1	1	3	2	1	1	2	0	0	0	0	0
V8	0	0	0	0	0	1	2	2	0	1	2	0	0	0	0	0
V9	0	0	1	2	3	2	1	0	3	1	0	0	1	1	0	0
V10	0	0	0	1	1	0	1	1	1	3	1	1	0	0	0	0
V11	0	0	0	1	0	1	2	2	0	1	3	1	0	0	0	0
V12	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	0
V13	0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0
V14	0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0
V15	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0
V16	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1

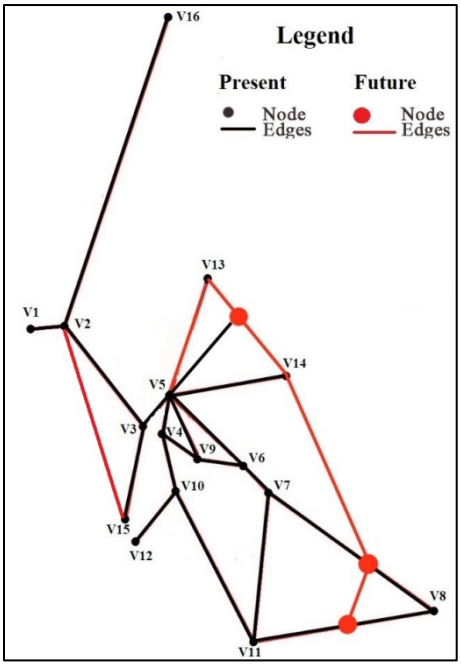
Source: Based on Table 3 and Table 5

Table 7 The Total Connectivity Matrix of the road network of Hpa-an Township, 2018

Vertex	C1	C2	C3	C4	C5	C6	Total Accessibility
V1	1	3	8	24	56	172	264
V2	3	5	21	53	169	442	693
V3	3	10	32	116	325	1091	1577
V4	3	12	45	164	505	1674	2403
V5	6	14	72	227	793	2400	3512
V6	3	12	46	168	519	1715	2463
V7	3	8	34	105	339	1005	1494
V8	2	6	22	69	205	618	922
V9	3	12	50	175	571	1829	2640
V10	3	7	30	91	298	879	1308
V11	3	8	29	94	273	850	1257
V12	1	3	10	33	94	301	442
V13	1	6	20	78	233	799	1137
V14	1	6	20	78	233	799	1137
V15	1	3	13	35	119	328	499
V16	1	3	8	24	56	172	264

Source: Computed by The Author

The total connectivity values help to determine not only the isolation but also centrality or accessibility levels. According to the total connectivity matrix, the least connectivity values are V1 and V16 (Duyinseik and Mizine) with 264 connections due to their marginal location. Although V1 (Duyinseik), V12 (Htoneaing), V13 (Naungkamying), V14 (Naungpalein), V15 (Yekyaw) , and V16 (Mizaing) have only one direct linkage respectively, V13(Naungkamying), and V14 (Naungpalein) are directly connected with V5 (Hpa-an Town) that is the most connectivity values, V12 (Htoneaing) with V3 (Phakat) that has ranked 7th in terms of total accessibility, V15 (Yekyaw) with V10 (Kawtayokya) that has ranked 5th in terms of total accessibility, and V2 (Wabotaw) that has ranked 12th in terms of total accessibility is connected by V1 and V16 (Duyinseik and Mizine). Therefore, V1 and V16 (Duyinseik and Mizine) are more isolated location than V12 (Htoneaing), V13 (Naungkamying), V14 (Naungpalein), and V15 (Yekyaw). The most accessible node is V5 (Hpa-an Town) with 3512 connections because of it is not only a junction points of the major roads but also an urban area. Therefore, the more central place V5 (Hpa-an Town) has higher connectivity. It follows by V9 (Tawpon) with 2640 connections, V6 (Naunglon) with 2463 connections, V4 (Kawlaik) with 2403 connections and so on.



Source: Based on Figure 1 and Figure 2

Figure 4 Graph Network of Hpa-an Township

Table 8 Connectivity Index of Current and Future Prospect

Connectivity Index	No. of Nodes (v)	No. of Edges (e)	Cyclomatic number (μ)	Alpha Index (α)	Beta Index (β)	Gamma Index (γ)	A.T.S
Current (2018)	16	19	4	0.15	1.19	0.45	5.79
Future Prospect	19	27	9	0.27	1.42	0.53	11.22

Source: Computed by The Author

In 2018, there were 16 nodes, 19 edges, 0.15 Alpha Index, 1.19 Beta Index, 0.45 Gamma Index and 4 cyclomatic number respectively (Table 8). If the red links shown in figure 3 and figure 4 gradually upgraded to tarred road, the road connectivity increased nearly two times. As the additional number of node and edges contained in graph network of Hpa-an Township are 3 and 8, there will be 19 nodes and 27 edges. Then, its alpha, beta and gamma indices increased from 0.15 to 0.27, from 1.19 to 1.42 and from 0.45 to 0.53 respectively. As well as, cyclomatic number became nine circuits (Table 8). As settlement area increased, the transport network also increased and vice versa.

Conclusion

In 2018, Hpa-an Township had total 358.16 km roads. It had road density more than 0.12 km per square km which was not satisfactory in position. Although there are 91 village tracts and 9 wards, more than half of village tracts have no direct motor routes between them**.** There are 16 nodes and 19 edges in the road network of Hpa-an Township. Therefore, it has 0.15 Alpha Index, 1.19 Beta Index, 0.45 Gamma Index and 4 cyclomatic number respectively. V5

(Hpa-an Town) has the highest connectivity and the highest level of centrality in the network. V1(Duyinseik) and V16 (Mizine) are the isolated locations due to its positions in the system and having only one directly linkage with V2 that is the almost last ranking in term of total accessibility score. The connectivity between nodes in the networks for Hpa-an Township is high but connectivity is low for each administrative units. Therefore, number of roads in all village tracts should be increased to achieve the better connectivity and accessibility. To achieve good efficiency, not only the quantity but also the quality of the road network should be developed. Due to limitations of airway, railway and water transport, the dependence on the road transportation system will continue in the future. Knowledge of the degree of connectivity will help to find out the requirements for transport development. The degree of connectivity is the index of the degree of socio-economic development of the area.

Acknowledgements

First and foremost, we would like to thank to Dr. Tun Ko, Professor and Head of Geography Department, University of Yangon, for his permission on this research. We would like to express our special gratitude to Dr. Myat Soe Khine, Professor, Head of Geography Department, Hpa-an University, for her permission to conduct this research paper. We are also specially thank to Dr.Mi Mi Kyi, (E.C member, Myanmar Academy Arts and Science) for her editorial suggestions and refinements of this research paper. We are also indebted to Referee Dr.Win Thint, Pro-Rector (Retd), University of Taungoo, for his thorough examination and valuable advice. Nest, we wish to express our special thanks to Dr. Myint thida, Professor, Geography Department, Hpa-an University, for her genuine encouragement and suggestions with which we accomplished our research. Lastly, we would like to say thanks to all our teachers and colleagues who have helped us with great sincerity as well as patience and students who have collected necessary documents.

References

Dostál, I. & Adamec, V., Transport and its Role in the Society ,Transactions on Transport Sciences, Volume 4, Number 2, (https://tots.upol.cz/pdfs/tot/2011/02/01.pdf)

Garrison, W and Marble, D (1958), Analysis of Highway Networks: A linear programming formulation Highway Research Board, Proceedings of the 37th Annual meeting, Washington B.G.

Garrison, W. (1960a), "Connectivity of the Interstate Highway System? Papers of the Regional Science Association 6 s p,121-137.

Haggette, P. (1965),"Network", "Nodes" and "Hierarchies" in Locational Analysis in Geography, London, Edward Printer, Chap.3-5.

Kansky, K.J, (1963), Structure of Transportation Networks, University of Chicago, Dept. of Geography, Research paper No.84

Khin Win Naing (2003), Transportation and Communication of Hpa-an Township, Unpublished M.A (Qualifying) Term Paper, Department of Geography, Hpa-an University, Myanmar.

Kyu Kyu Win (2007), Transportation Network of Hpa-an Township, Unpublished M.A Thesis, Department of Geography, Hpa-an University, Myanmar.

Nistor, F. & Popa, C., (2014), The Role of Transport in Economic Development, Naval Academy Scientific Bulletin, Volume XVII, Issue 2, (https:// www. researchgate. net/ publication/ 280313162 The Role Of Transportation In Economic Development/link/55c1a9ef08ae092e96685575/download)

General Administrative Department, (2015), Regional Facts of Hpa-an

Taffec, J. E., Gaathiar, L. E.,(1973), Geography of Transportation, Foundation of Economic.

The 'C^3' matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	Total
V1	1	3	1		1										1	1	8
V2	3	3	5	1	1	1			1				1	1	1	3	21
V3	1	5	3	2	8	2	1		3	1			1	1	3	1	32
V4		1	2	5	10	4	3	1	7	5	1	1	2	2	1		45
V5	1	1	8	10	10	10	2	1	10	2	2	1	6	6	1	1	72
V6		1	2	4	10	5	5	2	7	3	2		2	2	1		46
V7			1	3	2	5	5	5	2	2	6	1	1	1			34
V8				1	1	2	5	4	1	2	5	1					22
V9		1	3	7	10	7	2	1	7	2	2	1	3	3	1		50
V10			1	5	2	3	2	2	2	3	5	3	1	1			30
V11				1	2	2	6	5	2	5	5	1					29
V12				1	1		1	1	1	3	1	1					10
V13		1	1	2	6	2	1		3	1			1	1	1		20
V14		1	1	2	6	2	1		3	1			1	1	1		20
V15	1	1	3	1	1	1			1				1	1	1	1	13
V16	1	3	1		1										1	1	8

The 'C^4' matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	Total
V1	4	3	6	1	1	1			1				1	1	1	4	24
V2	3	14	5	2	11	2	1		3	1			1	1	6	3	53
V3	6	5	19	13	12	13	2	1	13	2	2	1	9	9	3	6	116
V4	1	2	13	25	23	22	6	4	20	7	10	6	11	11	2	1	164
V5	1	11	12	23	56	23	14	4	32	14	5	2	10	10	9	1	227
V6	1	2	13	22	23	25	9	8	20	6	11	3	11	11	2	1	168
V7		1	2	6	14	9	19	12	11	11	13	2	2	2	1		105
V8			1	4	4	8	12	12	4	8	12	2	1	1			69
V9	1	3	13	20	32	20	11	4	27	11	5	2	11	11	3	1	175
V10		1	2	7	14	6	11	8	11	16	7	3	2	2	1		91
V11			2	10	5	11	13	12	5	7	19	6	2	2			94
V12			1	6	2	3	2	2	2	3	6	4	1	1			33
V13	1	1	9	11	10	11	2	1	11	2	2	1	7	7	1	1	78
V14	1	1	9	11	10	11	2	1	11	2	2	1	7	7	1	1	78
V15	1	6	3	2	9	2	1		3	1			1	1	4	1	35
V16	4	3	6	1	1	1			1				1	1	1	4	24

The 'C^5' matrix

	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**Total**
V1	4	14	6	2	11	2	1		3	1			1	1	6	4	56
V2	14	14	31	15	15	15	2	1	15	2	2	1	11	11	6	14	169
V3	6	31	23	28	76	28	16	4	39	16	5	2	13	13	19	6	325
V4	2	15	28	53	103	51	36	16	71	41	18	8	24	24	13	2	505
V5	11	15	76	103	116	103	33	19	104	31	32	14	56	56	13	11	793
V6	2	15	28	51	103	55	44	21	71	36	24	6	24	24	13	2	519
V7	1	2	16	36	33	44	37	33	30	22	43	11	14	14	2	1	339
V8		1	4	16	19	21	33	26	16	19	33	8	4	4	1		205
V9	3	15	39	71	104	71	30	16	75	28	26	11	33	33	13	3	571
V10	1	2	16	41	31	36	22	19	28	20	35	16	14	14	2	1	298
V11		2	5	18	32	24	43	33	26	35	35	8	5	5	2		273
V12		1	2	8	14	6	11	8	11	16	8	4	2	2	1		94
V13	1	11	13	24	56	24	14	4	33	14	5	2	11	11	9	1	233
V14	1	11	13	24	56	24	14	4	33	14	5	2	11	11	9	1	233
V15	6	6	19	13	13	13	2	1	13	2	2	1	9	9	4	6	119
V16	4	14	6	2	11	2	1		3	1			1	1	6	4	56

The 'C^6' matrix

	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**Total**
V1	15	15	32	15	15	15	2	1	15	2	2	1	11	11	6	15	173
V2	15	62	36	32	99	32	18	4	45	18	5	2	15	15	32	15	445
V3	32	36	129	132	145	132	37	21	133	35	36	16	77	77	24	32	1094
V4	15	32	132	218	253	212	85	54	209	80	94	42	104	104	28	15	1677
V5	15	99	145	253	504	255	155	65	325	150	83	31	117	117	77	15	2406
V6	15	32	132	212	255	221	101	69	211	81	102	36	104	104	28	15	1718
V7	2	18	37	85	155	101	123	82	114	91	94	22	33	33	16	2	1008
V8	1	4	21	54	65	69	82	68	56	58	80	19	19	19	4	1	620
V9	15	45	133	209	325	211	114	56	249	109	74	28	105	105	39	15	1832
V10	2	18	35	80	150	81	91	58	109	95	62	21	31	31	16	2	882
V11	2	5	36	94	83	102	94	80	74	62	114	36	32	32	5	2	853
V12	1	2	16	42	31	36	22	19	28	21	36	17	14	14	2	1	302
V13	11	15	77	104	117	104	33	19	105	31	32	14	57	57	13	11	800
V14	11	15	77	104	117	104	33	19	105	31	32	14	57	57	13	11	800
V15	6	32	24	28	77	28	16	4	39	16	5	2	13	13	20	6	329
V16	15	15	32	15	15	15	2	1	15	2	2	1	11	11	6	15	173