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Evaluate Accessibility and Centrality of Road Network in The Mahaweli System C, Sri Lanka

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ABSTRACT

In the field of transport geography and planning, road accessibility analysis is one of the important analysis. The evolution of transportation systems has currently led to changes in urban form.Accessibility is the measure of the capacity of a location to be reached by, or to reach different locations. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility.Centrality refers the most closeness and betweenness places in a road network and it helps to establish new developments in that area.This study attempts to examinepotentials for expanding cities in the area according to the road infrastructure facilities. The objective of the study is identifying the level of accessibility and centrality of the Mahaweli C region. Data gathered from the department of survey and to analyze, accessibility in this area have been used geographic accessibility matrix and potential accessibility matrix. As well as to identify the closeness and betweenness centrality of the region and road densities have been used Spatial Design Network Analysis (SDNA) tool in QGIS and Kernel density analysis tool in ArcGIS (10.3). The Mahaweli system C is a resettled area under the Mahaweli Development Project. Basically, the hierarchical structure of the roads which are A, B, C and D class roads. According to the results of connectivity of the area centers and townships, mora accessible places are Dehiattakandiya, Sandunpura, Girandurukotte, Mahawanawela and Nawamedagama. Node Dehiattakandiya has more emissive than attractiveness (14377 versus 9622), while Node Siripura has more attractiveness than emissive (4202 versus 3559). When considering the closeness values and betweenness values Girandurukotte, Mahiyanganaya and Dihiattakandiya town centers can accessible than other area centers. According to the Kernel Density of the centrality of closeness, built-up landscape is shown from northern to south area. According to the results Girandurukotte area is the most accessible and centralized place in the region. It has more potentials for the development and more accessible place for people who are living in theMahaweli System C area.

1. Introduction

In the subjects of planning and spatial analysis, network analysis is performing a vital role. In present, such developments and agglomeration have been spread using a road network concept and accessibility. The evolution of transportation systems has currently led to changes in urban form. The more excessive the changes in transport technology have been, the more the alterations on the city form in an area. Among the most fundamental changes in the city form is the emergence of new clusters expressing new urban activities and new relationships between elements of the urban system. Since accessibility is expressive outcome of transportation activities, namely the capacity of infrastructures to support mobility, it presents the most noticeable influence of transportation on location. Hence, accessibility and economic activities are interrelated. Accessibility plays an important role by offering more customers through an expanded market area, by making distribution more efficient, or by enabling more people to reach workplaces.

Accessibility involves two primary components: a transport component and a land-use component. The transport component refers to the distance, travel time, and travel costs, the travel effort, and the perception and valuation of this time and effort on the part of a traveler. Land use refers to the spatial distribution of demand for activities, the supply of these activities, and the competition between demand and supply. The land-use component is frequently referred to as the “opportunities” available in an area (Road Networks, Accessibility, and Resilience,2015).

Surveying the literature on accessibility, Guers and van Wee (2004) propose a definition of accessibility which incorporates two additional components into the concept of accessibility: a temporal component and an individual component. The temporal component refers to temporal constraints related to variation in the availability of transport systems and in the availability of activities and opportunities over time. The individual component refers to individuals’ “needs, abilities, and opportunities” (Guers and van Wee, 2004).

This results in the following definition of accessibility: **the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s) at various times of the day (perspective of persons), and the extent to which land-use and transport systems enable companies, facilities, and other activity places to receive people, goods, and information at various times of the day (perspective of locations of activities)** (Guers and van Wee, 2004).

Sri Lanka's has a broad network of roads. The roads fall into three basic categories. The National Roads which make up Classes A and B are administered by the Road Development Authority (RDA) which is an agency under the Ministry of Transport, Highways & Civil Aviation. It is charged with providing inter provincial road links and maintaining existing roads. There are 12,390 kms of national roads in Sri Lanka.

The secondary roads network comprises the provincial roads, mostly in Classes C and D which are administered by the eight provincial councils. There are departments or more autonomous authorities through which these roads are managed by each of the councils. The most part of these roads are metaled and most of them support a bus service. The secondary road network is more extensive than the national road network amounting to 15,743 kms.

In the recent past, E class roads (Expressways) were introduced to the road network in Sri Lanka. It is a one of the turning points in the transportation sector (Rural roads and community access in Sri Lanka: an overview, 2003).

The forth tier of the road network is the access roads. These are primarily managed by the PradeshiyaSabhas in rural areas and the municipal or urban councils in urban areas. These roads are usually classified under the village roads. There is also a large extent of village roads that are maintained by other agencies mostly government institutions which are also used as public thoroughfares in rural areas. These belong to the Irrigation Department, Mahaweli Authority, Wild Life Department, plantation companies, Department of Fisheries and the Department of Forest. There are no specific institutional arrangements to maintain these roads. There is no accurate inventory of these roads as yet. The recent most estimate of 68,843 kms dates to 1990. More recent estimates from Uva Province and the Southern Province indicates that there are perhaps 20% more length at the present time. At this level roads are constantly added to the network with an estimated 1,000 kms of new rural roads been built annually mainly through village voluntary works.

According to the Road Development authority which is the premier highway authority in the country and is responsible for the maintenance and development of the National Highway Network, including the Trunk (A Class) roads, Main (B Class) roads and Expressways and the planning, design and construction of new highways, bridges and expressways to amplify the existing road network.

Table 01 - National roads composition in Sri Lanka

Class E Roads	169.845km
Class A Roads	
Class AA Roads	3720.31km
Class AB Roads	466.92km
Class AC Roads	30.19km
Class B Roads	8003.17km
Grand Total of National roads in Sri Lanka	12390.43km

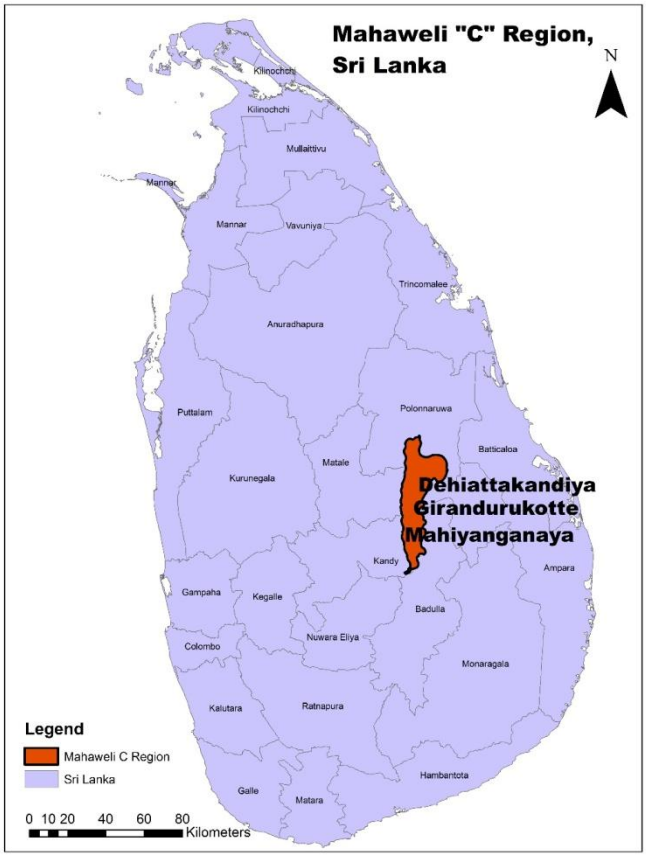
Source: http://www.rda.gov.lk/,2018.

2. Study Area

During the 1970s the average annual growth of agricultural production declined and annual population growth increased and real per capita GDP declined. According to this problem the government of Sri Lanka decided to cultivate more and pay their attention for how to use natural resources for solves this problem. As answer for this problem the government started this programme with 1960s plans. The main purposes of carrying out the Mahaweli programme were the generation of hydroelectric power, controlling flood, making irrigation facilities for dry zone cultivation, settlement of landless and unemployed families by constructing and developing physical and social infrastructure required for human habitation by using the waters of the Mahaweli river Increase local agricultural production and create employment opportunities for the people were among the other expected purposes.

The Mahaweli system C area is situated in the east central sector of Sri Lanka, along the right bank of the Mahaweli River extending over a gross area of 66700 ha. (Map no:01) This area is located among in the three provinces namely Uva, North Central and Eastern. Total population in Mahaweli system "C" 156,1107 and farmer families 230,35, non-farmer families 16292. (Source: Resource Profile,2016)

Map No.01 - The Mahaweli system C area



Source: Prepared by author,2018

The Mahaweli programme has planned integrated network of rural and urban centers under the System C. In Mahaweli system C has two major town centers were purposely planned by the project. They are Girandurukotte and Dehiattakandiya.

In addition to Mahiyanganaya is already in the region and working as the biggest city in the Mahaweli C region. Mahiyanganaya is not a purposely planned town. The Mahaweli System C area consists of seven management blocks (Area Centers). They area Girandurukotte, Medagama, Sandunpura, Siripura, Nuwaragala, Mahawanawela and Veheragala. 31 units are located under these blocks.

Mahaweli system C area has been selected for this analysis, which is consisting of underutilized town centers. According to the location of the Mahaweli C region only few town centers have good connectivity to major town centers of the inter regions by only a road network. Other centers are not developed, because of less road connectivity and not enough threshold population too.

This study attempts to examine the potential for expanding cities in the area, according to the road infrastructure facilities. The findings of the study will be useful in identifying potential areas for upgrading future development strategies.

3. Methodology

The objective of the study is identifying the level of accessibility and centrality of the Mahaweli C region. Basically, the data on network pattern (existing GIS layers of road networks) were obtained from the Department of surveying, Sri Lanka. In addition, data were collected from field observation.

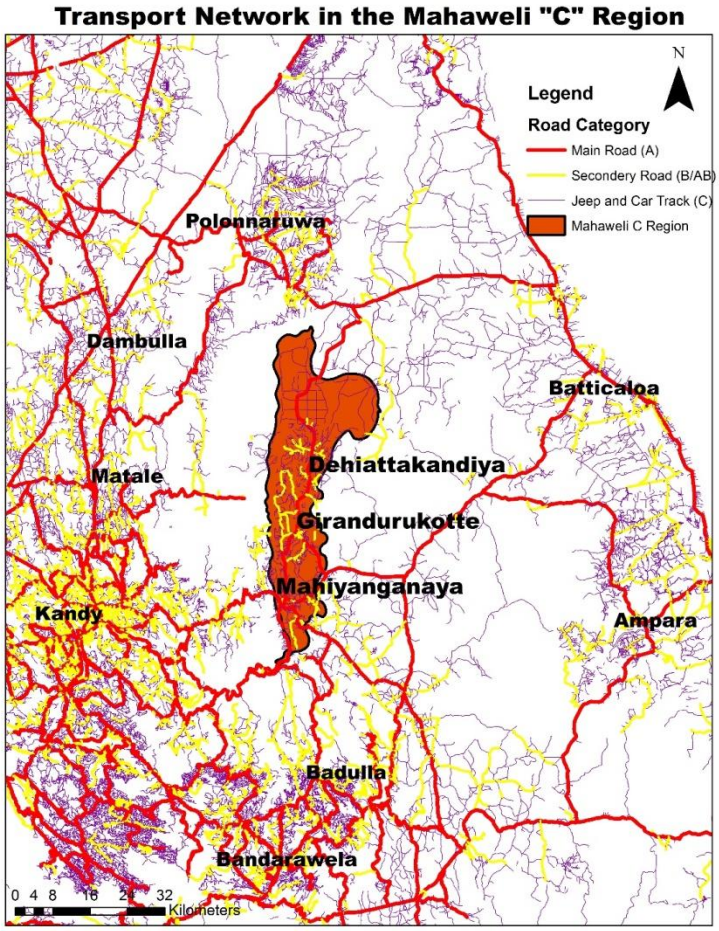
To analyze, accessibility in this area have been used geographic accessibility matrix and potential accessibility matrix. As well as to identify the closeness and betweenness centrality of the region and road densities have been used spatial design network analysis (SDNA) tool in QGIS and Kernel density analysis tool in Arc GIS (10.3).

4. Results and Discussion

The Mahaweli system C is a resettled area. Basically, the hierarchical structure of the roads which are A, B, C and D class roads. When considering the road network of the Mahaweli C region, total road length is 927km. Class A roads represent 67km of the total road length, B class roads 125km, C class road 96km and D class roads are covered by 639km in the region. The main transport corridor of the region Mahiyangana-Aralaganvila A class road which connected by secondary, tertiary and forth order roads.

The existing natural road layout is illustrated in the map below. It is notable to state that, within the Mahaweli C System, Dehiattakandiya and Girandurukotte are the planned new towns implemented. Mahiyanganaya is an existing town of which the current road network is based on the city. Existing Road network is shown in **map no:2.**

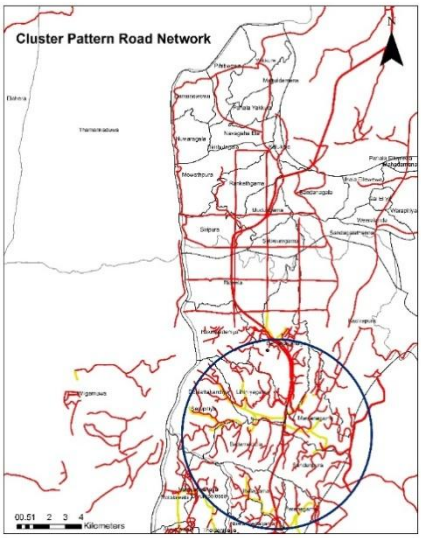
Map No: 02



Source: Prepared by author,2018

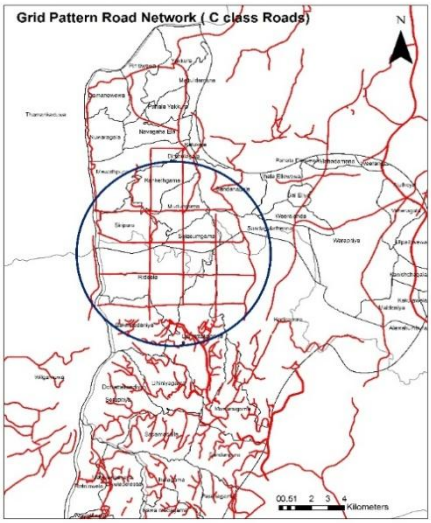
In the region, can identify the Cluster and Grid pattern networks as formation of the road network (Figure 1 and 2) but these are very common in lot of rural parts of the country. Because the minor roads areconnected with main or secondary roads too. As well as this area is an agricultural area. Therefore, the large land extent reserved as agricultural land areas. In upper part of the region (Nuwaragala, Siripura and Dehiattakandiya) consists of grid pattern road network.

Figure No: 1 - Cluster Pattern Road Network



Source: Prepared by author,2018

Figure No:2 – Grid Pattern Road Network



Source: Prepared by author,2018

4.1 Accessibility of the Mahaweli C Region

Transport mobility is important in defining the population's accessibility to services and facilities. Few studies have investigated the relationship between geographical accessibility of urban services for the population living in residential areas and socio-economic parameters.

Accessibility is the measure of the capacity of a location to be reached by, or to reach different locations. Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility. All locations are not equal because some are more accessible than others, which implies inequalities (Source: Rodrigue, J.,2017). Thus, accessibility is a proxy for inequalities. The notion of accessibility consequently relies on two core concepts.

The first one is location where the relativity of space is estimated in relation to transport infrastructures, since they offer the mean to support movements. Each location has a set of referential attributes, such as its population or level of economic activity.The second is distance, which derived from the physical separation between locations. Distance can only exist when there is a possibility to link two locations through transportation. It expresses the friction of distance and the location which has the least friction relatively to others is likely to be the most accessible. Commonly, the friction of distance is expressed in units such as in kilometers or in time, but variables such as cost or energy spent can also be used (Source: Rodrigue, J.,2017).

There are two spatial categories applicable to accessibility problems, which are interdependent: The first type is known as topological accessibility and is related to measuring accessibility in a system of nodes and paths (a transportation network). It is assumed that accessibility is a measurable attribute significant only to specific elements of a transportation system, such as terminals (airports, ports or subway stations).

The second type is known as contiguous accessibility and involves measuring accessibility over a surface. Under such conditions, accessibility is a cumulative measure of the attributes of every location over a predefined distance, as space is considered in a contiguous manner. It is also referred as isochrone accessibility.

Last, accessibility is a good indicator of the underlying spatial structure since it takes into consideration location as well as the inequality conferred by distance to other locations.

When considering the Geographical accessibility (Table 01) of the region,

Table 01: Geographic Accessibility of the Area Centers and Townships in Mahaweli "C" Region

	Nuwaragala	Siripura	Weheragala	Mahawanawela	Dehiattakandiya	Sndunpura	Medagama	Girandurukotte	Hembarawa	Bathalayaya	Mahiyanganaya	Σ	Σ/n
Nuwaragala	0	8	32.9	20.3	15.8	21.8	28.9	42.3	54.2	48.3	60.1	332.6	**30.24**
Siripura	8	0	24.9	12.3	7.8	13.8	20.9	34.3	46.4	40.3	52.1	260.8	**23.71**
Weheragala	32.9	24.9	0	12.6	17.1	23.1	30.2	43.6	55.7	49.6	61.4	351.1	**31.92**
Mahawanawela	20.3	12.3	12.6	0	4.5	10.5	7.1	20.5	32.6	26.5	38.3	185.2	**16.84**
Dehiattakandiya	15.8	7.8	17.1	4.5	0	6	13.1	26.5	38.6	32.5	44.3	206.2	**18.75**
Sndunpura	21.8	13.8	23.1	10.5	6	0	7.1	20.5	32.6	26.5	38.3	200.2	**18.20**
NawaMedagama	28.9	20.9	30.2	7.1	13.1	7.1	0	13.4	25.5	19.4	31.2	196.8	**17.89**
Girandurukotte	42.3	34.3	43.6	20.5	26.5	20.5	13.4	0	11.6	6	17.8	236.5	**21.50**
Hembarawa	54.2	46.4	55.7	32.6	38.6	32.6	25.5	11.6	0	11.6	23.4	332.2	**30.20**
Bathalayaya	48.3	40.3	49.6	26.5	32.5	26.5	19.4	6	11.6	0	11.8	272.5	**24.77**
Mahiyanganaya	60.1	52.1	61.4	38.3	44.3	38.3	31.2	17.8	23.4	11.8	0	378.7	**34.43**

Source: Prepared by author,2018

High accessible places refer by lower values and low accessible pleases are referred by high values. According to the connectivity of the area centers and townships, mora accessible places are Mahawanawela, Dehiattakaniya, Nawamedagama, sandunpura and Girandurukotte. (In here only A and B roads are considered for making topology) These centers are situated in the middle of the region.

According to the Potential Accessibility of the region,

Table 02 - Potential Accessibility of the Area Centers and Townships in Mahaweli "C" Region

	Nuwaragala	Siripura	Weheragala	Mahawanawela	Dehiattakandiya	Sndunpura	Medagama	Girandurukotte	Hembarawa	Bathalayaya	Mahiyanganaya	Population	Σi
Nuwaragala	1105	138.1	33.6	54.4	69.9	50.7	38.2	26.1	20.4	22.9	18.4	1105	1577.8
Siripura	279.9	2239	89.9	182.0	287.1	162.2	107.1	65.3	48.3	55.6	43.0	2239	3559.3
Weheragala	68.1	45.2	1125	89.3	65.8	48.7	37.3	25.8	20.2	22.7	18.3	1125	1566.3
Mahawanawela	20.3	12.3	12.6	1231	4.5	10.5	7.1	20.5	32.6	26.5	38.3	1231	1416.2
Dehiattakandiya	496.6	1006.0	458.9	1743.8	7847	1307.8	599.0	296.1	203.3	241.4	177.1	7847	14377.2
Sndunpura	208.7	329.6	196.9	433.2	758.2	4549	640.7	221.9	139.5	171.7	118.8	4549	7768.2
NawaMedagama	108.0	149.3	103.3	439.6	238.2	439.6	3121	232.9	122.4	160.9	100.0	3121	5215.3
Girandurukotte	95.2	117.4	92.4	196.4	152.0	196.4	300.5	4027	347.2	671.2	226.2	4027	6421.9
Hembarawa	29.2	34.1	28.4	48.5	41.0	48.5	62.0	136.3	1581	136.3	67.6	1581	2212.7
Bathalayaya	66.2	79.3	64.4	120.6	98.3	120.6	164.7	532.7	275.5	3196	270.8	3196	4989.2
Mahiyanganaya	44.9	51.8	44.0	70.5	60.9	70.5	86.5	151.7	115.4	228.8	2700	2700	3625.1
	2522.0	4202.2	2249.4	3378.4	9622.9	7004.6	5164.2	5736.3	2905.7	4933.9	3778.6	32721	

Source: Prepared by author,2018

By considering the same valued graph matrix (Geographical Accessibility) and the population matrix, the potential accessibility matrix can be calculated (Table 02).

The higher the value, the more a location is accessible, node Dehiattakandiya being the most accessible. The matrix

being non-transposable, the summation of rows is different from the summation of columns, bringing forward the issue of attractiveness and emissive. Node Dehiattakandiya has more emissive than attractiveness (14377 versus 9622), while Node Siripura has more attractiveness than emissive (4202 versus 3559). Sandunpura is the second accessible place in the region. Girandurukotte is the third one of the higher accessible places of the area according to the potential accessibility matrix. But it has low population than Dehiattakandiya. There are some reasons affect badly for the development in Girandurukotte. They are, human elephant conflict, not enough threshold population, improper land use (high amount of land extent reserved for under-utilized farm areas) and further negative aspects of road network usages in the area

Note:

- Emissiveness/Emissive is the capacity to leave a location, the sum of the values of a row in the matrix. (Summation of the column value is more than row value)
- Attractiveness is the capacity to reach a location, the sum of the values of a column in the matrix. (Summation of the row value is more than column value) (Source: Rodrigue, J.,2017)

4.2 Centrality of the Mahaweli C Region

While centrality focuses on the terminal (its vicinity) being a point of origin and destination of traffic, intermediacy focuses on the terminal being a point of transit between different systems of circulation. The concept of centrality is straightforward as the vicinity (hinterland) of the terminal is either the origin or the destination of the movement, which in turn is linked with the level of economic activity.

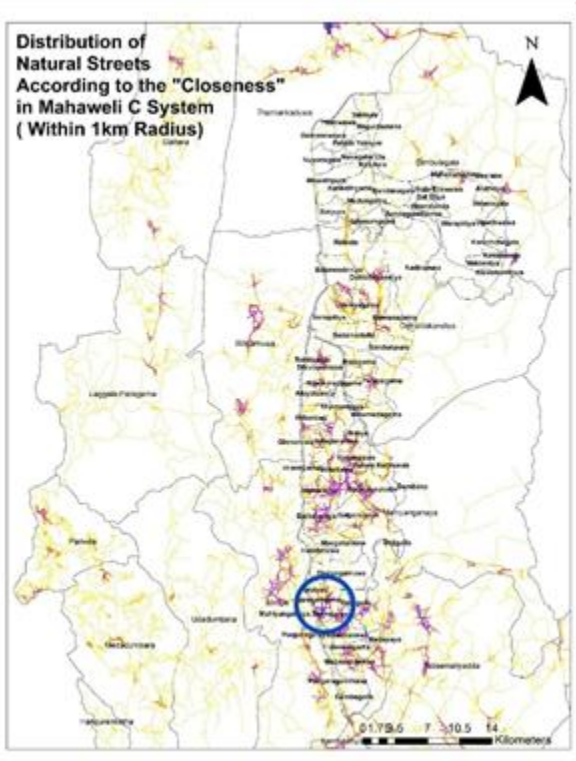
There are Three major parts of the centrality, they are **Closeness centrality, Betweenness Centrality and Degree Centrality**.

In a connected graph, closeness centrality (or closeness) of a node is a measure of centrality in a network, calculated as the reciprocal of the sum of the length of the shortest paths between the node and all other nodes in the graph. Thus, the more central a node is, the closer it is to all other nodes. When speaking of closeness centrality, people usually refer to its normalized form which represents the average length of the shortest paths instead of their sum.

4.2.1 Closeness Centrality of the Mahaweli C Region

When considering the closeness centrality of the region high closeness centrality shows in Blue color line, Purple color line shows moderately high integration, Red color line shows moderate integration, Orange color line shows low moderate integration and Yellow color line shows low integration in the road network analysis.

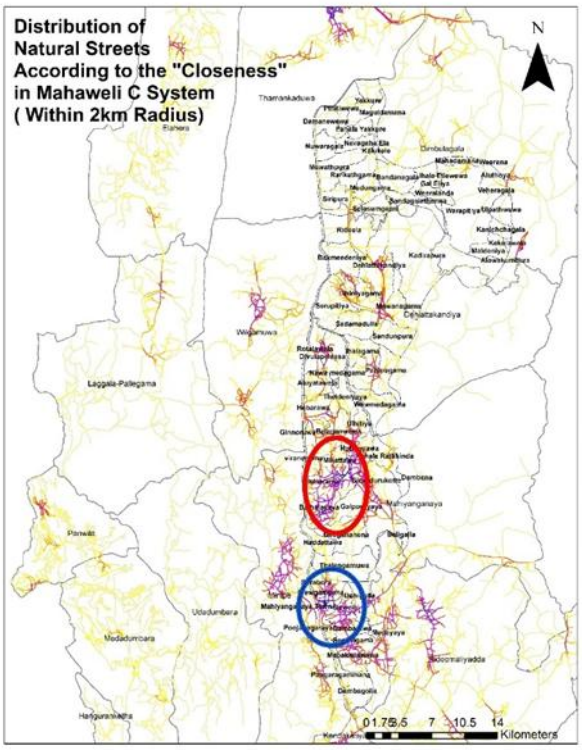
Map No: 03



Source: Prepared by author,2018

According to the map no. 03, within one-kilometer radius Mahiyanganay Town area (Blue round) and Girandurukotte town area have high closeness centrality. But extend of area has been low.

Map No: 04

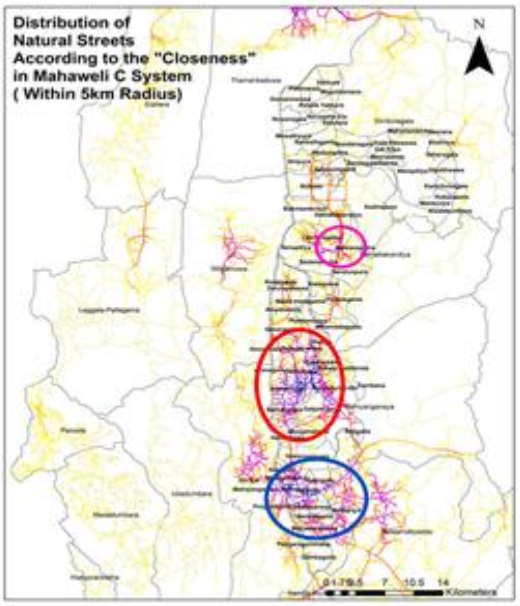


Source: Prepared by author,2018

Within 2km radius Mahiyanhanaya (blue) and Girandurukotte (red) town area have expanded than 1km of the

radius. The high integration along the Mahiyanganaya – Redeemaliyadda road and Girandurukotta town area in the road network.

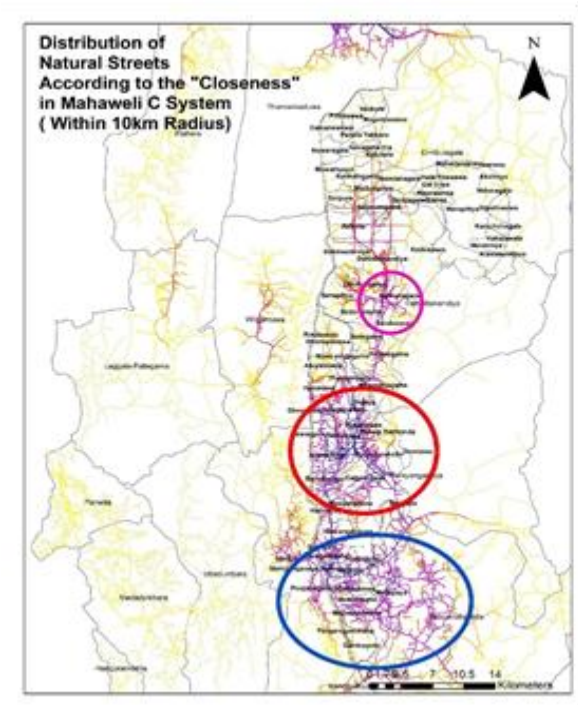
Map No: 05



Source: Prepared by author,2018

According to the map no. 05, Closeness centrality of the Grandurukotte area have been expanded Bathalayaya, Aluttarama, Hobariyawa and Millattawa. Mahiyangana area also expanded Elewela and Wewgampaha. As well as Minipe area has high closeness centrality within 5km radius.

Map No: 06



Source: Prepared by author,2018

According to the map no. 06, can identify the closeness centrality of the Mahiyanganaya and Girandurukotte area have become more lager than above maps. Dehiattakandiya also have high closeness within 10km radius (Purple round). The high integration can be seen along the Mahiyangana – Aralaganvila main road.

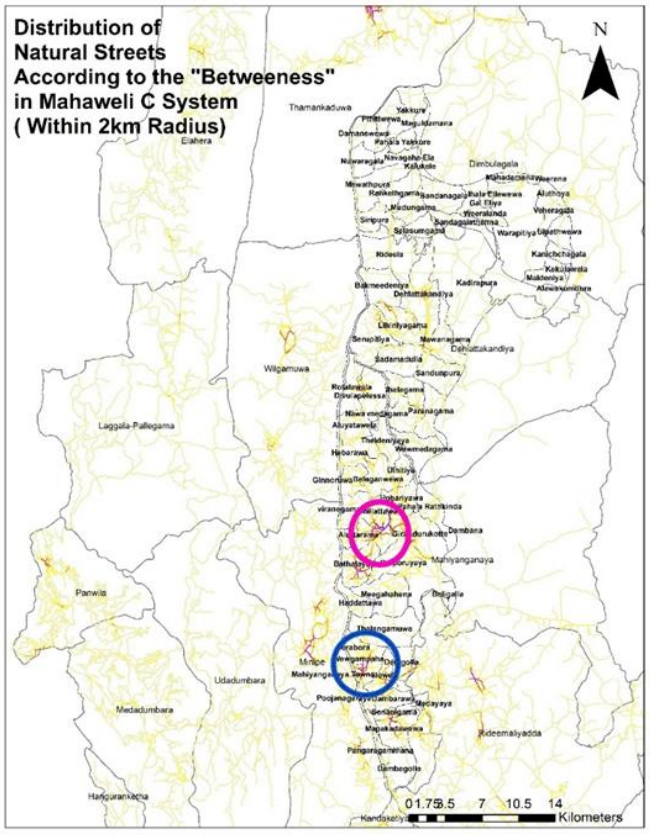
Accordingly, Mahiyangana New Town has a good level of accessibility. Dehiattakandiya and Girandurukotte has moderately high level of accessibility. While Bathalayaya, Galporuyaya, Hobariyawa, Mawanagama and NawaMedagama has moderate level accessibility within the system.

Further, outside the system, but in the immediate context, Polonnaruwa has a high density. Wilgamuwa, Minipe, Rideemaliyadda are some areas with moderately high accessibility outside the region.

4.3 Betweenness Centrality of the Mahaweli C Region

Betweenness is a centrality measure of a vertex within a graph (there is also edge betweenness, which is not discussed here). Betweenness centrality quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. It was introduced as a measure for quantifying the control of a human on the communication between other humans in a social network. Vertices that have a high probability to occur on a randomly chosen shortest path between two randomly chosen vertices have a high betweenness.

Map No: 05



Source: Prepared by author,2018

According to the Betweenness centrality (Map no: 07) can identify the Mahiyangana Town (Blue Color) and

Girandurukotte (Pink Color) town have been more betweenness places of the region. Therefore, those places can be more accessible than other places. Accordingly, the townships can be developed than other areas. But, relatively Girandurukotte is backward than Mahiyangana in the development scenarios. Because the settlers in the remote area continue to maintain already established linkages with the older centers that were existence before the establishment of Girandurukotte. Therefore, people prefer to Mahiyangana than Girandurukotta new town. As well as Girandurukotte is a planned city, so then the city is situated in little bit far from the main road. In the planning time of the city, connecting road was introduced by connecting the town area. But in present public transport drivers are not use the connecting road. They also used existing road via Mahiyangana- Aralaganvila main road for travelling to Pollonnaruwa or Mahiyanganaya. Authorities should be paid attention to the development of the Girandurukotte area. They can improve Social infrastructures such as schools, hospitals, co-operative shops, telecommunication facilities etc.

Accordingly, the next approach is to identify whether potentials for new emerging towns are visible within this system. To identify the emerging town centers can be used the **"Kernel Density" tool**in ArcGIS 10.3.

The density of roads could be seen as a factor showing the level of urbanity within a region. When a small town develops with new accessibility roads, it gets further expanded by subdividing the existing land plots, creating new roads or streets. The present situation of an urban context is an evolution of this process.

The results show that road density estimated by Kernel density (km/km^2) elucidates the spatial pattern of the road network in the region. Areas with higher road density are dominated by a larger proportion of built-up landscape and less possession of forest and vice versa. Road networks segregated the landscape into smaller pieces and a greater number of patches. The resultant map are as follows (Map No: 08).

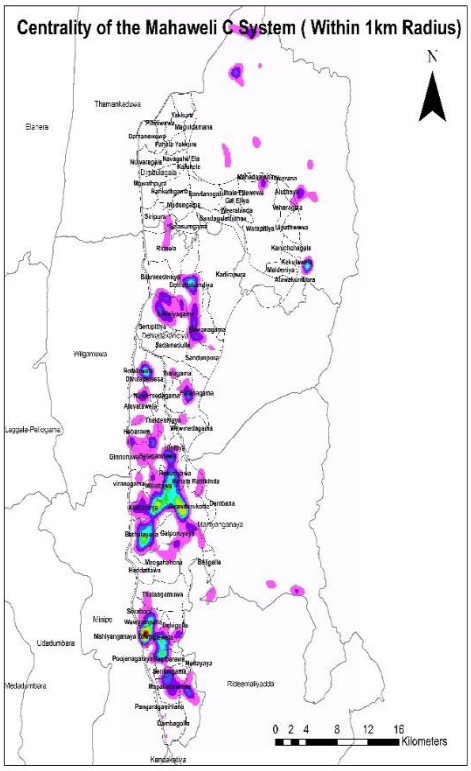
According to the **Kernel Density** of the centrality of closeness, built-up landscape is shown from northern to south area. **Girandurukotte Town** area can be developed than other areas. Because Girandurukotte town area can be expanded than Mahiyanhana town area. Therefore, development can be built using the road network and its design concept.

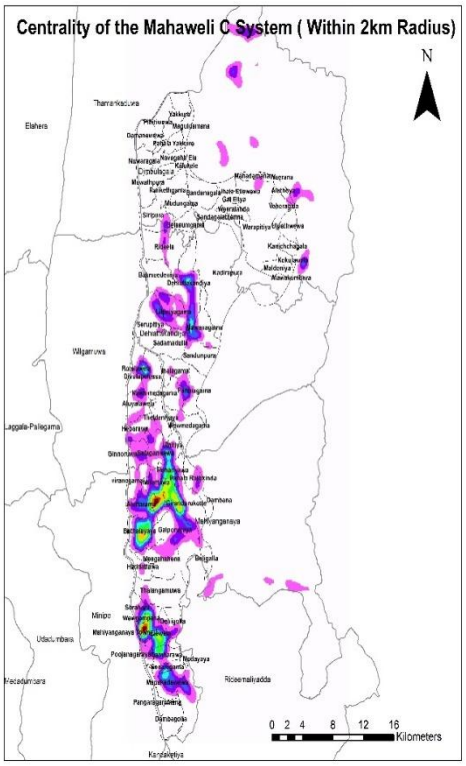
The maps (Map No: 08) clearly indicate NawaMedaga, Lihiniyagama, Mawanagama, Rotalawela, Paranagama areas potentials for new emerging towns are visible within this system. In the field observation, can be seen **NawaMedagama** area is immerging as a small new town center with trade, commercial and services. It has their own threshold population and the place acts as an economic center between Dehiattakandiya and Girandurukotte.

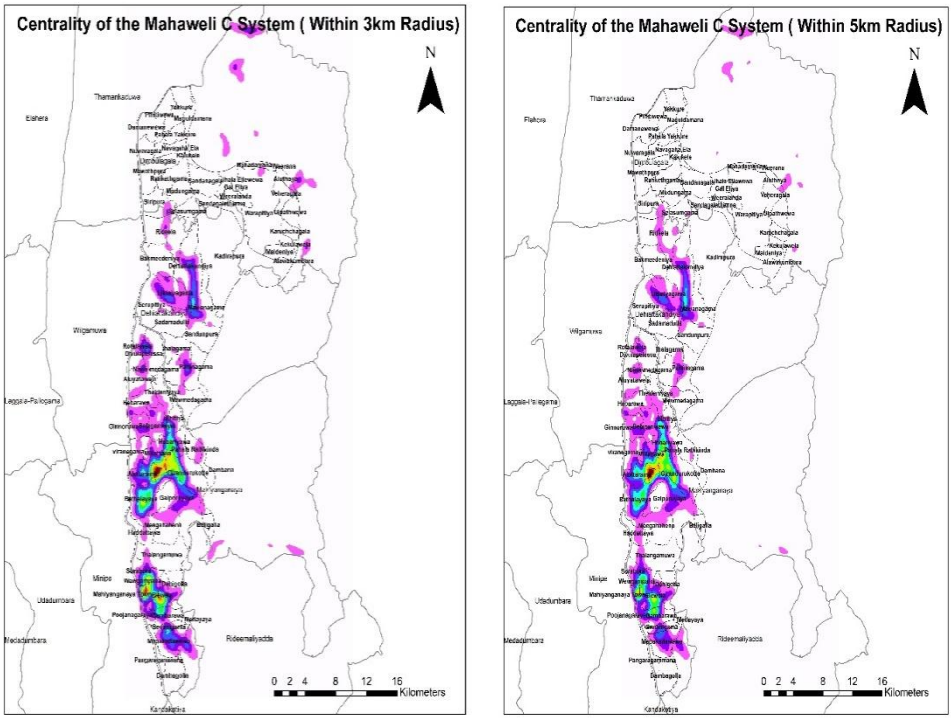
In the upper part of the region, especially Nuwaragala and Veheragala areas have low density of roads. Therefore, those areas are not addressed by the development potentials.

Map No: 08 – Comparison of Closeness Centrality in Mahaweli C region

Note: Red color shows high road density in the area, Green color shows moderately high density, Blue color shows moderate density, Purple color shows moderately low density and White color space is represented no significant dense areas.







Source: Prepared by author,2018

5. Conclusion

Accordingly, when compared the centrality in the region high integration shows in Mahiyanganaya and Girandurukotte areas. Because more roads are basically connected with these town centers. When considering the factors of accessibility and centrality (closeness and betweenness), Girandurukotte is more accessible place in the region. Girandurukotte is a planned township. Therefore, it should be fulfilled the planning objectives and should be become more attractive than Mahiyanganaya.Mahiyangaya is already established before the resettlement of the System C. It is an old township area in Sri Lanka. But in the present, Girandurukotte is economically backward than Mahiyanganaya. There are some reasons badlyaffected for the development in Girandurukotte. They are, human elephant conflict, not enough threshold population, improper land use (high amount of land extent reserved for under-utilized farm areas) and further negative aspects of road network usages in the area. But it has more potentials fordevelopment and its more accessible than other areas. Therefore, authorities must pay their attention for enhancing the development of Girandurukotte area and as well as spread the development for new emerging town areas as identified above too. Then development can be expanded all over the system. In addition, the road network in the upper part of the region should be improved. Because the upper part has limited accessible levels and poor road infrastructure facilities than the middle and the later part of the area.

References

1. Briceño-Garmendia, C., Moroz, H., and Rozenberg, J. Road Networks, Accessibility, and Resilience:The Cases of Colombia, Ecuador, and Peru An LCR Regional. The World Bank Latin America and the Caribbean region office of the chief economist global practice of transport and ICT study. (2015). http://pubdocs.worldbank.org/en/780311492653985192/P147268-LCR-RegionalStudy-with-annexes.pdf
2. Condeco-Melhorado, Ana, Reggiani, A., and Javier Gut◌̣ierez. “Accessibility and Spatial Interaction: An Introduction.” In Accessibility and Spatial Interaction, eds. Ana CondecoMelhorado, Aura Reggiani, and Javier Gut◌̣ierez, 1–12. Cheltenham: Edward Elgar Publishing. (2015).
3. Guers, Karst T., and Bert van Wee. “Accessibility Evaluation of Land-use and Transport Strategies: Review and Research Directions.” Journal of Transport Geography. (2004). 12: 127–40.
4. Information Service of the Ministry of lands and land development and Ministry of Mahaweli Development. Mahaweli Projects and Programme. Colombo 10, Sri Lanka. (1983).
5. Rodrigue, J.P. *The Geography of Transport System* (4th ed.). New York: Routledge. (2017). ISBN 978-1138669574
6. Kumarage, S.A. Rural roads and community access in Sri Lanka: an overview (Final Report). Colombo, Sri Lanka. (2003). https://kumarage.files.wordpress.com/2015/03/2003-r-01-ti-kumarage-a-s-rural-roads-and-community-access-in-sri-lanka-sida-39pp.pdf
7. Planning and Monitering unit. Resource Profile. Mahaweli Authority of Sri Lanka. (2016).
8. Road Development Authority. http://www.rda.gov.lk/. [Accessed:25.02.2019]

