EVALUATING THE EFFECTIVENESS OF THE LOGISTIC NETWORK OF SRI LANKA (EXISITNG VS PROPOSED) USING MULTIPLE CENTRALITY ASSESSMENT (MCA)

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ABSTRACT

The growing flows of goods, issue attached to the railway in contributing to freight transportation, and the major proposals of the national physical plan -2030 which bring significant changes to the spatial network of logistics raise the need for an overall effectiveness examination of Sri Lanka logistic network. Despite, the conventional approach practiced in Sri Lanka does not really contribute to evaluate the overall network. Taking it cues, this study attempts to evaluate the effectiveness of existing (2011) and proposed (2030) logistics network of Sri Lanka under a contemporary framework 'Multiple Centrality Assessment' in order to contribute the decision makings related to spatial planning and logistic network. In this study, basing the literature findings, scope of the study and applicability of the parameters, effectiveness of the logistic network (A & B class roads, railway and expressways) is measured using betweeness, closeness and straightness centrality measures. Results reveal significant results between the effectiveness levels of existing and proposed logistic network as well as among the systems of the network (road, railway and expressway).

Keywords: Logistic Network, Closeness, Betweeness, Straightness, Multiple Centrality Assessment

1. INTRODUCTION

Planning and implementing a logistic network is important in the field of spatial planning. As logistic has a big impact on the economy and on the development of an area, it is important to consider how effective a particular line is with the whole network in order to direct to an effective conclusion regarding the level of effectiveness.

There are numerous parameters available to measure the effectiveness of the network. Descriptive statistics, Geometric Mean Analysis (GMA) [1], Sensitivity analysis [2], Centrality (Degree, Closeness and Betweenness), Centralisation, Connectivity and Density, Regularity and Hierarchy [3], Accessibility, Network Connectivity (Beta, Alpha and Gamma), Distance matrix and Nodal accessibility coefficient [4] are some of them. Other than the above parameters, in contemporary network effectiveness evaluation practices 'Multiple Centrality Assessment' approach introduced by Porta, Crucitti and Latora [5] is significant in space related network studies. This framework is tested and succeeded in different studies.

Focusing to the Sri Lankan situation, due to the reasons; growing flow of goods, high reduction of railway in contribution to freight transportation and major proposals of expressways and railway lines under National Physical Plan 2030 it needs an evaluation of effectiveness for the SL logistic network.

But in SL effectiveness is evaluated following the conventional method. In case of a new road or railway network proposal the current method of evaluation does not always consider such line with the whole network. Most of the time effectiveness is read in terms of economic terms. As the current practice of measuring the effectiveness of a network is not well established to the level where it can take into account not only the particular line but also the particular line with its whole network and as no such attempts have been done yet to evaluate the overall logistic network, there is a necessity of evaluating the whole logistics network under a contemporary approach; how it is going to function with the overall network and what is the position of it among others, is necessary.

On such a situation, this study attempts to evaluate the effectiveness of the logistic network of Sri Lanka not just a partial but the whole by adopting 'Multiple Centrality Assessment'. So this study will be able to reveal the level of effectiveness of existing network and how feasible the proposed network is.

2. METHODOLOGY

Planning and implementing a logistic network is important in the field of spatial planning. As logistic has a big impact on the economy and on the development of an area, it is important to consider how effective a particular line is with the whole network in order to direct to an effective conclusion regarding the level of effectiveness.

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2.1 Preparation of actual network and axial line map

For this study, logistic network is selected in two different time periods; 2011 and 2030 considering the significant changes in the network. Actual networks were separately prepared for the selected two periods. Then the actual networks were converted to axial line map following the method developed by Porta (2007, 2008) where railway stations and intersection of two or more roads are nodes and the railway line and road line are links. And all the links were weighted to their design speed.

2.2 Calculation of Centrality Parameters

Using the prepared axial map and the derived dataset from axial map, (FID, FNODE, TNODE, LENGTH) calculation of three selected centrality parameters has been performed. Closeness and straightness were calculated using 'CLI.exe' developed by Prof Sergio Porta and National Institute of Nuclear Physics of Catania, Sicily, Italy and betweeness was computed using 'Depthmap 10'.

Closeness	$CC_i = (N-1)/\sum_{j=1}^{k} L_{ij}$ Where: CCi = Closeness centrality of node i Lij = Cumulative impediment between nodes i and j, with j∈N and i≠j N = all nodes in the network	Indicates how closely to the others, a link is situated within the network. So the high closeness value represents the high accessibility. Since logistic network connect many places, a transport line should be more accessible from other lines of the network.
Betweeneness	$CB_k = \sum P_{ij}(k)/(N-1)(N-2)$ CB_k = Betweenness centrality for route segment k $P_{ij}(k)$ = paths between nodes i and j that pass through segment k, for all i,j∈N and i≠j N = all nodes in the network	It applied to measure the relative importance or significant of route segment. It shows preferred network paths that lead through each route segments of the entire network. In planning the logistic network of the country, level of significance of any path in flowing through the each route segment is an essential characteristic.
Straightness	$CS_i = \frac{1}{(N-1)}\sum_{j=1}^{k} \frac{L_{ij}^{Eucl}}{Lij}$ Where: CSi = Straightness centrality of node i Lij = Cumulative no of straight link between nodes i and j LijEucl = the Euclidean distance between nodes i and j N = all nodes in the network	Indicates how straight a segment is to all others within the network. A segment with high straightness is accessible from all others through paths that are more likely to be straight linear and direct. Importance of straightness in logistic network is that comparatively straight and linear a route segment between two logistic nodes is more positive in making ease travel opportunities than a complex route segment.

2.3 Preparation of Network Centrality Index and Spatial Representation of Network Centrality Values

Based on the calculated values of existing and proposed logistic network, network centrality parameters were calculated for overall network, roads, railway and expressways. For a better understanding of the level differences of centrality values and to visually interpret the network hierarchy in terms of effectiveness all the edge values of centrality parameters (existing and proposed) are mapped using ArcGIS. Above tables and figures show the numerical as well as spatial representation of derived results of centrality values.

Table 1: Betweeness Centrality Index

		Average	Minimum	Maximum
Existing	Railway	27,482,857	0	840,565,820
	A Class Roads	71,092,607	0	828,587,330
	B Class Roads	29,720,064	0	503,900,220

Proposed	Railway	10,343,428	0	2,158,272,500
	A Class Roads	27,581,464	0	459,656,160
	B Class Roads	14,691,578	0	1,467,408,600
	Expressways	280,289,834	0	1,427,552,800

Table 2: Closeness Centrality Index

		Average	Minim um	Maximum
Existing	Railway	6,744	0	442,015
	A Class Roads	42,562	0	6,723,790
	B Class Roads	5,061,578	65	40226800000
Proposed	Railway	17,951	185	776,968
	A Class Roads	2,824,487	221	1,255,000,000
	B Class Roads	24,717	193	2,108,790
	Expressways	139,566	347	3,049,560

Table 3: Straightness Centrality Index

		Average	Minimum	Maximum
Existing	Railway	178.42	1.16	6,922.09
	A Class Roads	1411.52	0.29	456,459
	B Class Roads	15,856.22	0.21	11,349,900
Proposed	Railway	301.12	1.14	72,163.5
	A Class Roads	2,228.14	0.71	388,430
	B Class Roads	1,979.75	0.13	1,470,950
	Expressways	172.68	29.54	806.67

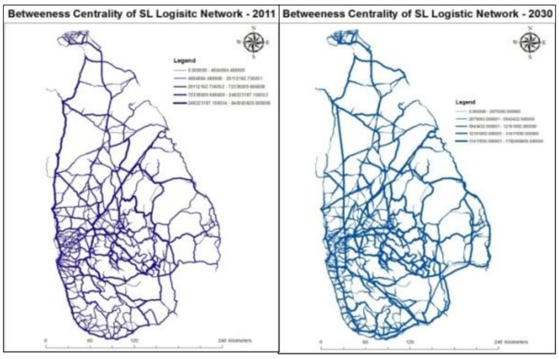

Figure 1: Betweenes Centrality of Existing and Proposed Networks

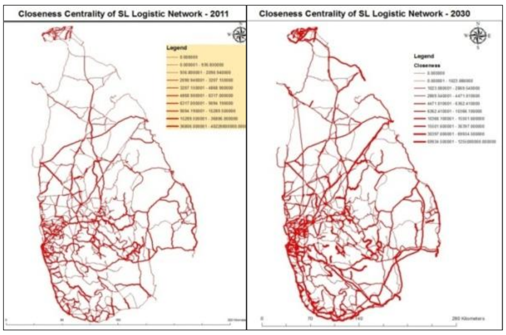

Figure 2: Closeness Centrality of Existing and Proposed Networks

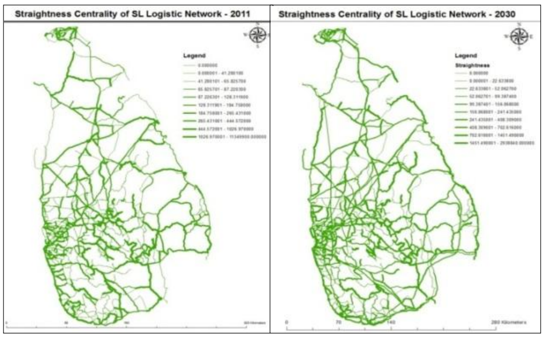

Figure 3: Straightness Centrality of Existing and Proposed Networks

2.4 Analysis

Finally, the derived network centrality values of existing and proposed logistic networks are analyzed in three broader analyses; Network characteristic analysis (network characteristic of existing and proposed logistic detailed investigation on overall and system network), Spatiotemporal Analysis (how the centrality of existing and proposed networks is spatially distributed) and Assessing the Compatibility of Major Proposals of NPP 2030 with the Centrality Based Network Hierarchy.

3. RESULTS

In terms of closeness centrality, closeness of the proposed network is increased from the existing network. B Class roads have the higher closeness compare to others in the existing network. But A Class road has the significant role in both existing and proposed while railway has a lower value compare to others. Also Closeness value of highways shows a positive result.

Evaluation results of betweeness show no significant changes between existing and proposed network. In the existing network railway does not get an active role in being intermediary to others. But the proposed lines in 2030 get high betweeness value compared to the existing lines. So the potential is there for the proposed lines to be used in logistic activities in future. Also in the proposed network, expressways are getting the role most preferred path as it is being more intermediary to others.

The straightness value of the proposed network does not show big different from the existing. Alike the value of other two centrality measures, the straightness centrality of railway is low in both existing as well as proposed networks.

And although expressways are good enough in being close to others and being intermediary to others, it is not straighter to others.

All the above results finally indicate that the effectiveness of the railway network is low compare to others in exiting as well as proposed network. However the effectiveness level of railway increases in the proposed network while the highway is more effective in being close to others through shortest paths and being intermediary to many other segments of the network. Further A class roads are continued to be a dominant systems in existing and proposed network. Also the changes are positive for A Class roads in increasing the effectiveness from existing.

In addition to the above results the highlight of the study is the results derived from the analysis of the compatibility of Metro countries and region's proposal from NPP 2030 and centrality values. It concludes that promoting the Batticaloa and Kalmunai region is not totally compatible with the centrality values as this region and such towns are low in centrality. However Hambantota region is possible to be promoted. But it is not to the level of the Western region. Further as the Northern region has a good hierarchy among its towns in terms of all three centralities, it will be possible to easily promote a metro region in Jaffna. Following figures show the comparison between the centrality of the networks and proposed metro regions.

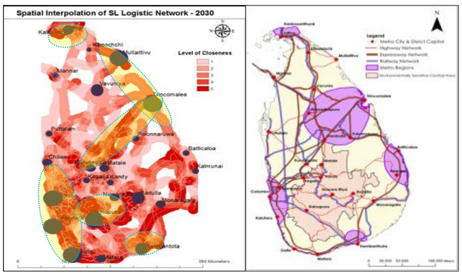

Figure 4: Closeness Centrality and Proposed Metro Regions under NPP 2030

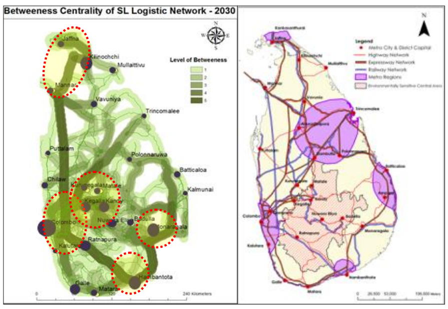

Figure 5: Betweeness Centrality and Proposed Metro Regions under NPP 2030

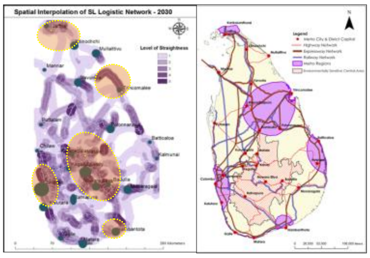

Figure 6: Straightness Centrality and Proposed Metro Regions under NPP 2030

4. CONCLUSION

The main objective of this study is 'to evaluate the effectiveness of existing (2011) and proposed (2030) logistics network of Sri Lanka'. Accordingly results derived through analysis prove how the objective is achieved. The findings of this study are useful in the field of spatial planning where it can be used in proposing urban centers, specialized regions, industrial zones and infrastructure promotions such as transport network, port establishment, etc. and in logistics planning as policy guidance for the future decision making and promotion of logistics related activities based on the level of effectiveness. Further 'Multiple Centrality Assessment Framework' becomes one of another suggestion for future network effectiveness evaluation practices.

This study can also be developed to use further complex methods to weight the links, in particular the impacts of major nodes. Also it can be further done to assess the local level effectiveness of the network using different other appropriate parameters.

5. REFERENCES

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