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Application of Centrality Measures in Determining Regional Development Priorities in the Graph Representation of Kalimantan Island

Mochamad Suyudi[1*], Fajrul Iqbal Adli[2], Asep K. Supriatna[3]
[1,2,3] Department of Mathematics, University of Padjadjaran, Jatinanor,Indonesia

**Corresponding author email: moch.suyudi@gmail.com*

Abstract

The relocation of the capital of the Republic of Indonesia to the Kalimantan raises new problems in regional development. In this paper the priority areas to be developed on the Kalimantan will be determined using Centrality Measures. The type of centrality measures used are degree centrality, leverage centrality, closeness centrality, Jordan centrality, and betweenness centrality. The results show that Banjar, Ketapang, Sintang, Kutai Kertanegara, and Murung Raya areas are the areas that are central to the island of Kalimantan. Although the center of the island of Kalimantan, it is necessary to study the results of this paper with the actual distance of each region.

Keywords: Kalimantan, the national capital, degree centrality, leverage centrality, closeness centrality, Jordan centrality, betweenness centrality.

1. Introduction

The Government of the Republic of Indonesia has officially announced the new capital city of Indonesia, namely in the North Penajam Paser and Kutai Kertanegara areas, East Kalimantan. As the nation's capital, the North Penajam Paser and Kutai Kertanegara areas will become centers for various economic, political and trade activities. The capital city of a new country in the future will develop very rapidly. The development of the new capital city must be able to make the area around the new capital city get a positive impact, so it needs to be mapped so that it is known which areas are the centers of activity so that structured and planned development can be realized. as Jakarta makes the Jabodetabek area an economic center, and the island of Java is home to 56% of the total population of Indonesia. Mapping of areas around the new capital city or on the island of Kalimantan can be done by representing the level II areas on the island of Kalimantan using graph theory. A graph is a social network model in an undirected relationship, i.e. a line that determines the presence or absence of two nodes. (Wassermean et al., 1994).

Furthermore, graph theory can be applied in network analysis. In network analysis, the term centrality is known. Centrality is a principle in network analysis to measure how central a node in the network (Golbeck, 2013). The basic concept of centrality can be used to determine the priority scale of a program, how important a person's position in the group is or the level of needs of other people in the central person in the group. There are many basic types of the centrality that can be used in network analysis, including degree centrality, leverage centrality, closeness centrality, Jordan centrality and betweenness centrality. Degree centrality is to calculate the degree of the side it has. Furthermore, Leverage Centrality is calculating the degree that a node has, with its neighboring nodes. Closeness centrality is calculating how close a node is to other nodes in the network. Jordan Centrality is to calculate the maximum distance from a node to every node in the network. Betweenness centrality is determining how important a node is in the shortest path in the network. (Golbeck, 2013).

In its development, many mathematicians have applied centrality in other disciplines, including a journal from (Koschutzki et al., 2008) entitled "Centrality Analysis Method for Biological Network and Their Application to Gene Regulatory Networks", in a journal entitled "A New Measures of Centrality for Brain Network". (Joyce et al., 2010). And this paper will discuss centrality measures with the title "Implementation of centrality measures in determining regional development priorities on the representation of the Kalimantan Island graph".

In network analysis, centrality is a very important concept in determining which node is the most central in a network (Costenbader and Valente, 2003). Several types of centrality measures that have been found are degree centrality, leverage centrality, closeness centrality, Jordan centrality, betweenness centrality and many other centrality measures. Degree centrality is counting the number of sides that are directly related to the other sides. (Wassermean,

1994). Leverage centrality is to determine the value between the degree of a node v with all degrees which are neighbors (N_v) of node *v*. (Joyce, 2010). Closeness centrality is calculating the sum of the shortest distances from one node to other nodes. If the distance from one node to another is small, then that node will have the greatest centrality value (Wassermean, 1994). Jordan centrality is measuring the maximum distance of a node with other nodes in the network. (Dekker, 2008). Betwenneess centrality is measuring a node that connects the path in the network (Wassermean, 1994).

Furthermore, by using Dijkstra's algorithm, we can determine the shortest paths from each node in the graph to all nodes in the graph.

2. Methods

The graph *G* is defined as a pair of sets (*V*,*E*) written with the notation *G* = (*V*, *E*) where in this case is a non-empty set of nodes (vertices or nodes) and is a set of edges (edges or arcs) that connect a pair of nodes.

Degree Centrality

The general equation of degree centrality is as follows

$$Cd(v_i) = \sum_{j=1}^{n} a_{ij} \ (i \neq j) \tag{1}$$

or

$$Cd(v_i) = deg(v_i) \tag{2}$$

$Cd(v_i)$: the degree centrality value node v_i
a_{ij}: the entry value of the neighboring matrix
deg(v_i): degree node v_i
The standard degree centrality equation is as follows:

$$C'd(v_i) = \frac{\sum_{j=1}^{n} a_{ij}}{(n-1)} \ (i \neq j) \tag{3}$$

$$C'd(v_i) = \frac{deg(v_i)}{(n-1)} \tag{4}$$

$C'd(v_i)$: the standard value of the degree centrality node v_i
a_{ij}: the entry value of the neighboring matrix
deg(v_i): degree node v_i
n: the number of nodes in the graph.

Leverage Centrality

The equation of leverage centrality (Vargas et al., 2008) is:

$$l(v) = \frac{1}{\deg v} \sum_{v_i \in N_v} \frac{deg(v) - deg(v_i)}{deg(v) + deg(v_i)} \tag{5}$$

$l(v)$: leverage centrality node v
deg(v): degree node v
deg(v_i): degree v_i or neighbor degrees v_i

Closeness Centrality

The basic equation of closeness centrality (Costenbader and Valente, 2003) is

$$Cc(N_i) = \frac{1}{\left[\sum_{j=a}^{n} d(N_i, N_j)\right]} \tag{6}$$

$Cc(N_i)$: closeness centrality node N_i
(N_i, N_j): distance from node N_i to node N_j
The standard equation of closeness centrality is

$$C'c(N_i) = \frac{n-1}{\left[\sum_{j=a}^{n} d(N_i, N_j)\right]} \quad (7)$$

$C'c(N_i)$: standard closeness centrality node N_i
(N_i, N_j): distance from node N_i to node N_j
n: the number of nodes in the graph.

Jordan Centrality

The general equation for Jordan centrality (Valente et al., 2008) is

$$C_j(N_i) = \frac{1}{Max\ d(N_i, N_j)} \ (i \neq j) \quad (8)$$

$C_j(N_i)$: value of jordan centrality node N_i
(N_i, N_j): distance from node N_i to node N_j

Betweenness Centrality

The basic equation for calculating betweenness centrality (Zhang and Luo, 2017) is

$$C_b(N_i) = \sum_{j<k} \frac{G_{jk}(N_i)}{G_{jk}} \quad (9)$$

$C_b(N_i)$: value of betwennesss centrality node N_i
$G_{jk}(N_i)$: number of shortest paths from node *j* to node *k* that pass through N_i
G_{jk}: number of shortest paths from node *j* to node *k*
The standard equation to determine betweenness centrality is

$$C'_b(N_i) = \frac{2\sum_{j<k} \frac{G_{jk}(N_i)}{G_{jk}}}{(n-1)(n-2)} \quad (10)$$

$C'_b(N_i)$: standard value of betweenness centrality node N_i
$G_{jk}(N_i)$:number of shortest paths from node j to node k that pass through N_i
G_{jk}: number of shortest paths from node *j* to node *k*
n: the number of nodes in the graph.

3. Results and Discussion

Kalimantan Island Graph

Table 1. Regional names and node name initiation

v_i	Level II Area	v_i	Level II Area
v_1	Balangan	v_{29}	Barito Timur
v_2	Banjar	v_{30}	Barito Utara
v_3	Baritokuala	v_{31}	Gunug Mas
v_4	Hulu Sungai Selatan	v_{32}	Kapuas
v_5	Hulu Sungai Tengah	v_{33}	Katingan
v_6	Hulu Sungai Utara	v_{34}	Kotawaringin Barat
v_7	Kota Baru	v_{35}	Kotawaringin Timur
v_8	Tabalong	v_{36}	Lamandau
v_9	Tanah Bumbu	v_{37}	Murung Raya
v_{10}	Tanah Laut	v_{38}	Pulang Pisau
v_{11}	Tapin	v_{39}	Sukamara
v_{12}	Banjar Baru	v_{40}	Seruyan
v_{13}	Banjarmasin	v_{41}	Palangkaraya
v_{14}	Bengkayang	v_{42}	Berau
v_{15}	Kapuas Hulu	v_{43}	Kutai Barat
v_{16}	Koyong Utara	v_{44}	Kutai Kertanegara
v_{17}	Ketapang	v_{45}	Kutai Timur
v_{18}	Kubu Raya	v_{46}	Mahakam Ulu

$v19$	Landak	$v47$	Paser
$v20$	Melawi	$v48$	Penajam Paser Utara
$v21$	Mempawah	$v49$	Balikpapan
$v22$	Sambas	$v50$	Bontang
$v23$	Sanggau	$v51$	Samarinda
$v24$	Sekadau	$v52$	Bulungan
$v25$	Sintang	$v53$	Malinau
$v26$	Pontianak	$v54$	Nunukan
$v27$	Singkawang	$v55$	Tanatidung
$v28$	Barito Selatan	$v56$	Tarakan

Then a simple graph can be formed as follow:

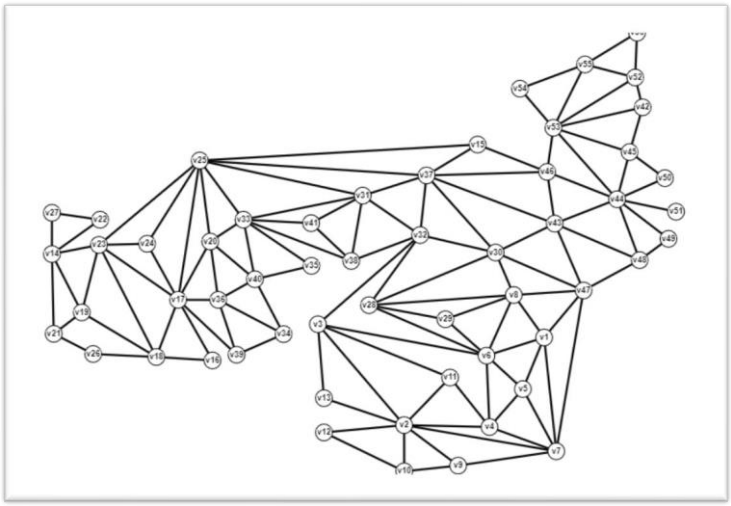

Figure 1. Kalimantan Island Graph.

Value of Centrality Measures
With the help of python software, the centrality value is obtained as follows:

Table 2. Value of centrality measures from the Kalimantan Island graph

Nodes	Degree Centrality	Leverage Centrality	Closseness Centrality	Jordan Centrality	Betwenness Centrality
$v1$	0,090909091	-0,06565657	0,277778	0,166667	0,02262
$v2$	0,145454545	0,396003996	0,245536	0,142857	0,08844
$v3$	0,090909091	0,038045288	0,282051	0,166667	0,12990
$v4$	0,090909091	-0,02544678	0,237069	0,142857	0,00992
$v5$	0,072727273	-0,17373737	0,237069	0,142857	0,00114
$v6$	0,127272727	0,202331002	0,275	0,166667	0,04638
$v7$	0,109090909	0,095382395	0,252294	0,142857	0,10937
$v8$	0,109090909	0,06021756	0,323529	0,2	0,11148
$v9$	0,054545455	-0,26262626	0,214008	0,125	0,00601
$v10$	0,054545455	-0,08484848	0,199275	0,125	0,00034
$v11$	0,054545455	-0,31818182	0,231092	0,142857	0,00133
$v12$	0,036363636	-0,4	0,198556	0,125	0
$v13$	0,036363636	-0,51428571	0,229167	0,142857	0
$v14$	0,090909091	0,225468975	0,233051	0,142857	0,08664
$v15$	0,054545455	-0,36818182	0,333333	0,2	0,06234
$v16$	0,036363636	-0,51428571	0,230126	0,142857	0
$v17$	0,145454545	0,293031968	0,291005	0,166667	0,12833
$v18$	0,090909091	0,129315129	0,237069	0,142857	0,03996
$v19$	0,072727273	-0,06984127	0,233051	0,142857	0,01852
$v20$	0,090909091	-0,12564103	0,282051	0,166667	0,03287
$v21$	0,054545455	-0,06428571	0,192982	0,125	0,00236
$v22$	0,036363636	-0,21428571	0,190311	0,125	0
$v23$	0,109090909	0,071572872	0,289474	0,166667	0,18373
$v24$	0,054545455	-0,41414141	0,279188	0,166667	0
$v25$	0,145454545	0,19486347	0,352564	0,2	0,39697

$v26$	0,036363636	-0,31428571	0,19573	0,125	0,00157
$v27$	0,036363636	-0,21428571	0,190311	0,125	0
$v28$	0,090909091	-0,03787879	0,279188	0,166667	0,01239
$v29$	0,054545	-0,32777778	0,260664	0,166667	0
$v30$	0,109091	0,002331002	0,327381	0,2	0,03217
$v31$	0,109091	0,039438339	0,34375	0,2	0,10402
$v32$	0,109091	0,050815851	0,333333	0,2	0,17208
$v33$	0,127273	0,224553225	0,292553	0,166667	0,08630
$v34$	0,054545	-0,16666667	0,203704	0,125	0,00103
$v35$	0,036364	-0,49206349	0,231092	0,142857	0
$v36$	0,090909	0,053846154	0,237069	0,142857	0,01471
$v37$	0,127273	0,115384615	0,387324	0,25	0,37687
$v38$	0,072727	-0,13246753	0,287958	0,166667	0,02348
$v39$	0,054545	-0,23484848	0,231092	0,142857	0,00655
$v40$	0,090909	0,102380952	0,23913	0,142857	0,02490
$v41$	0,054545	-0,29206349	0,2657	0,166667	0
$v42$	0,054545	-0,22857143	0,215686	0,142857	0,00092
$v43$	0,109091	0,011854812	0,337423	0,2	0,11652
$v44$	0,145455	0,385592186	0,283505	0,166667	0,14079
$v45$	0,072727	-0,03246753	0,229167	0,142857	0,00656
$v46$	0,090909	-0,08100233	0,327381	0,2	0,20553
$v47$	0,109091	0,048484848	0,298913	0,166667	0,10937
$v48$	0,072727	-0,1	0,287958	0,166667	0,04174
$v49$	0,036364	-0,46666667	0,236052	0,142857	0
$v50$	0,036364	-0,46666667	0,223577	0,142857	0
$v51$	0,018182	-0,77777778	0,221774	0,142857	0
$v52$	0,072727	0,050865801	0,215686	0,142857	0,01836
$v53$	0,127273	0,267676768	0,268293	0,166667	0,17088
$v54$	0,036364	-0,44444444	0,214008	0,142857	0
$v55$	0,072727	0,098484848	0,215686	0,142857	0,01800
$v56$	0,036364	-0,33333333	0,179153	0,125	0

Priority Areas for Development on Kalimantan Island
From the previous discussion, the results for areas that are development priorities are as follows:

1. If viewed from the number of areas that are directly adjacent to an area, the center of the island of Kalimantan is the Banjar, Ketapang, Sintang, and Kutai Kertanegara areas.
2. If viewed from the distance between an area to all areas on the island of Kalimantan, the center on the island of Kalimantan is the Murung Raya area.
3. If viewed from the point of view of how often an area becomes a liaison with other regions, the center of the island of Kalimantan is the Sintang area.

4. Conclusion

The area that is the center on the island of Kalimantan can be seen in terms of direct boundaries with other regions, distance from all other regions and the frequency with which regions become liaisons between regions on the island of Kalimantan. The areas that become the center on the island of Kalimantan are the Banjar, Ketapang, Sintang, Kutai Kertanegara, and Murung Raya areas.

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