Comparing Weighting Approaches in Scalogram Analysis in the Wa Municipality in the Upper West Region of Ghana

Fauster Agbenyo[1&2*]

Isaac Nevis Fianoo[3]

Alfred Dongzagla[1]

Abstract

This study examined and compared the objectively-weighted, expert-based-weighted and stakeholder-based weighted Scalogram approaches based on their centrality indices and factors considered in assigning weights to the functions. A mixed-method approach, comprising both quantitative and qualitative techniques were employed to gather primary and secondary data for the study. All the three Scalograms with different weighting techniques were analyzed in Microsoft Excel, focusing on centrality and weighted centrality indices and simple linear regression models. The study discovered that the grand total centrality index of the objective Scalogram is 4,105.60, the expert-based Scalogram is 10,294.2 while the stakeholder-based one is 10,429.80. The co-efficients of determination for the three are 0.9892, 0.9757 and 0.9812 respectively, giving explanatory powers of 98.92%, 97.57% and 98.12% respectively. It is recommended that due to resource constraints, planners should rely more on the objective-based approach, followed by the stakeholder-based approach and then the expert-based approach, since the latter approach has rather reduced the explanatory power of population by increasing values of the centrality indices. Again, bottlenecks to the development of Area Council headquarters (intermediate settlements between Wa and lower-level settlements) should be tackled for efficient spatial distribution of functions. The contribution of this article to the spatial and development planning literature is its juxtaposition of the three techniques in Scalogram analysis.

Keywords: Expert; Functions; Objective; Scalogram; Stakeholder; Weighted Centrality Index

[1]Department of Planning, Faculty of Planning and Land Management, Simon Diedong Dombo University of Business and Integrated Studies, Wa, Upper West Region, Ghana. [2]Department of Planning and Land Administration, Faculty of Sustainable Development Studies, University for Development Studies. Tamale [3]Department of Planning, Faculty of Planning and Land Management, University for Development Studies, Wa Campus, Upper West Region, Ghana *Corresponding Author: Email: fagbenyo@uds.edu.gh

Ghana Journal of Geography Vol. 13 (2), 2021 pages 174-205

https://dx.doi.org/10.4314/gjg.v13i2.7

Introduction

Functionality analysis in regional development planning provides understanding of settlements' functional complexities and their hierarchies (Christaller, 1966; Marshall, 1969; Rondinelli, 1985; Asare, 1994). It is traceable to the Central Place Theory (CPT) by Walter Christaller in 1933, which explains the spatial arrangements, functionality and hierarchy of settlements in a region (Mandal, 2001; Christaller, 1933 translated by Baskin, 1966; Berry & Garrison, 1958). In CPT, high order settlements have functions with larger threshold and range than lower order settlements because they provide more specialized functions than low order settlements (Van Meeteren & Poorthuis, 2017), leading to dominance of one or two primal cities with smaller cities focusing on it (McCann, 2001).

Following the CPT, the Scalogram among other methods, has been devised to classify settlements into hierarchies (Jufri & Nonce, 2016; Kharate, 2009; Isard, 1960; Tiwari Khan, 1984; Rondinelli, 1985). A Scalogram in its basic form is an array of the presence or absence of functions in settlements (Rondinelli, 1985; Spaliviero, 2004). In terms of classifying places into levels, a summation of the different types of functions present in each settlement does not provide an adequate measure of comparability because functions differ in value (Davies, 1966).

In the literature, Scalogram analysis of settlement functions is associated with three different weighting techniques. They are objective-based weighting, expert-based weighting and stakeholder-based weighting techniques (Ali & Varshney, 2012; Adarkwa, 2014; Rondinelli, 1985). Concerning the objective-based weighting technique, analysts simply divide a constant centrality index of 100 (based on the assumption that all settlements have all the functions required within the spatial unit under consideration) by the frequency of a function in all settlements (Rondinelli, 1985; Spaliviero, 2004). Building on the objective-based weighting approach, a second technique has been developed by experts in which weights are assigned in

a descending order of importance. The limitations in these two approaches have resulted in a third weighting technique where stakeholders assign weights to functions not in any particular order of importance (Ali & Varshney, 2012; Adarkwa, 2014; Grove & Huszar, 1964).

Even though the three different Scalogram analyses have been in existence for some time now, a comparison of their outputs is lacking in develop planning literature. This study attempts to compare the centrality of settlements of the three methods in the Wa Municipality in the Upper West Region of Ghana to serve as a basis for recommendation in their applications. The findings of the study on settlements functionality will also guide decision making in meeting Sustainable Development Goal 11 - make cities and human settlements inclusive, safe, resilient and sustainable (United Nations, 2015). Specifically, it will inform decision-making regarding the provision and location of services in any local authority area aimed at strengthening urban-rural linkages as well as promoting territorial cohesion and complementarities between higher and lower order settlements. The rest of the paper is structured as follows: immediately following the introductory section is the description of the analytical framework, which also serves as a theoretical framework for the study; study area and methodology; results and discussion; conclusions and policy recommendations.

Theoretical Framework

To achieve the study objective, three Scalogram analytical techniques were employed- the objective-based weighting analysis, expert-based weighting and stakeholder-based weighting Scalogram analysis, which also serves as a theoretical framework that foregrounds the study. The objective-based weighting Scalogram analysis was guided by Spaliviero (2004) and Rondinelli (1985) in the following steps:

Table 1: The objective-based weighting Scalogram analytical approach

Steps	Corresponding/Required Activity
1	On the left side of a worksheet, list settlements as rows in descending order of their population;
2	Across the top of the worksheet, list functions in the region by groups (e.g. education, health, security etc). For each group, arrange functions from most centralised to the least non-centralised function;
3	Fill in with a dark color, an "X", or '1' in all cells in which a function is actually found in a settlement and leave cells for which a function does not appear in a place blank or filled with "O".
4	Add a row below the last settlement and name it 'number of settlements with a function' (N). To compute this, simply add up the number of times a function appears across the settlements.
5	Add another row below the variable "number of settlements with a function' and name it 'centrality index' (T). This is assumed to be 100 for all functions, with the explanation that all settlements have all the functions they are expected to have.
6	Add another row below the centrality variable and name it 'weighted centrality score' (C), which is computed for each function as T/N.
7	Add a column after the last function on the right side of the worksheet, and name it 'total weighted centrality index'. For each settlement, sum up the weighted centrality scores of all functions to obtain the total weighted centrality indices for all settlements. Sum all the total weighted centrality indices to obtain the grand total weighted centrality index.
8	Add another column after the total weighted centrality index column and name it percentage total weighted centrality index. This is computed by dividing the total weighted centrality index for each settlement by the grand total weighted centrality index and multiplying the result by 100.
9	Classify settlements into orders (e.g. 1st order, 2nd order, 3rd order etc) based on the total weighted centrality indices as well as the presence of centralized/non-centralized functions in settlements.

The expert-based weighting Scalogram analytical technique including the weighted centrality index computation also follow the illustration in Table 2 as formulated by by Adarkwa (2014: 37 - 38) and Grove and Huszar (1964).

Table 2: The Expert-based weighting Scalogram analytical approach

The last approach is the stakeholder-based weighting Scalogram analytical technique **(**Ali & Varshney, 2012**)** as detailed in Table 3.

Table 3: The Stakeholder-based weighting Scalogram analytical approach

Steps	Corresponding/Required Activity
1	The first two steps are similar to the objective-based weighting analytical approach in Table 1.
2	For each group of functions, let stakeholders assign weights (W_{ij}^{b}) in the form of 1, 3, 2, 5, 6, 4, 7 to functions, with '1' allocated to the least important and '7' the most important. where: W_{ij}^{b} = the weight assigned to the facility j in sector b and located in settlement i. v = the total number of different facilities under consideration in functional sector b. Weights assigned here are based on importance attached by stakeholders, thus are in a jumbled form instead of the ascending and descending orders as occurred in the first two weighting approaches. The empirical order of weights in this study, shown numerically above, can be depicted symbolically as p, r, q, t, u, s and v, all occurring in sector, say b, which in this study is exemplified by the educational sector.
3	Fill in with a dark color, an "X", or '1'in all cells in which a function is actually found in a settlement and leave cells for which a function does not appear in a place blank, or filled with "O".
4	Add a row below the last settlement and name it '*number of settlements with a function*' (N). To compute this, simply add up the number of times a function appears across the settlements.
5	Add another row below the variable 'number of settlements with a function' and name it "*centrality index* (T)". This is assumed to be 100 for all functions, with the explanation that all settlements have all the functions they are expected to have.
6	Add another row below the centrality index (T) and name it "*weighted centrality index* (C)", computed for each function as (T*W_{ij}^{b})/N.
7	Add a column after the last function on the right side of the worksheet, and name it '*total weighted centrality index'*. Sum up the weighted centrality indices of all functions to obtain the total weighted centrality index for each settlement. Again, sum up all the total weighted centrality indices in this column to arrive at the grand total weighted centrality index for the whole Scalogram.
8	Create a column after that of the total weighted centrality index and name it "percentage total weighted centrality index" and compute the percentages based on the grand total weighted centrality index.
9	Classify settlements into orders (e.g. 1st order, 2nd order, 3rd order etc.) based on the total weighted centrality indices.

Study Area

The Wa Municipality of Ghana was purposively chosen for the study because the Municipality is the most urbanized settlement within the Upper West Region and deemed to have the full complement of all functions in all settlements within the Region that can be used for the analysis. Figure 1 is map of Wa Municipality depicting the twenty study communities.

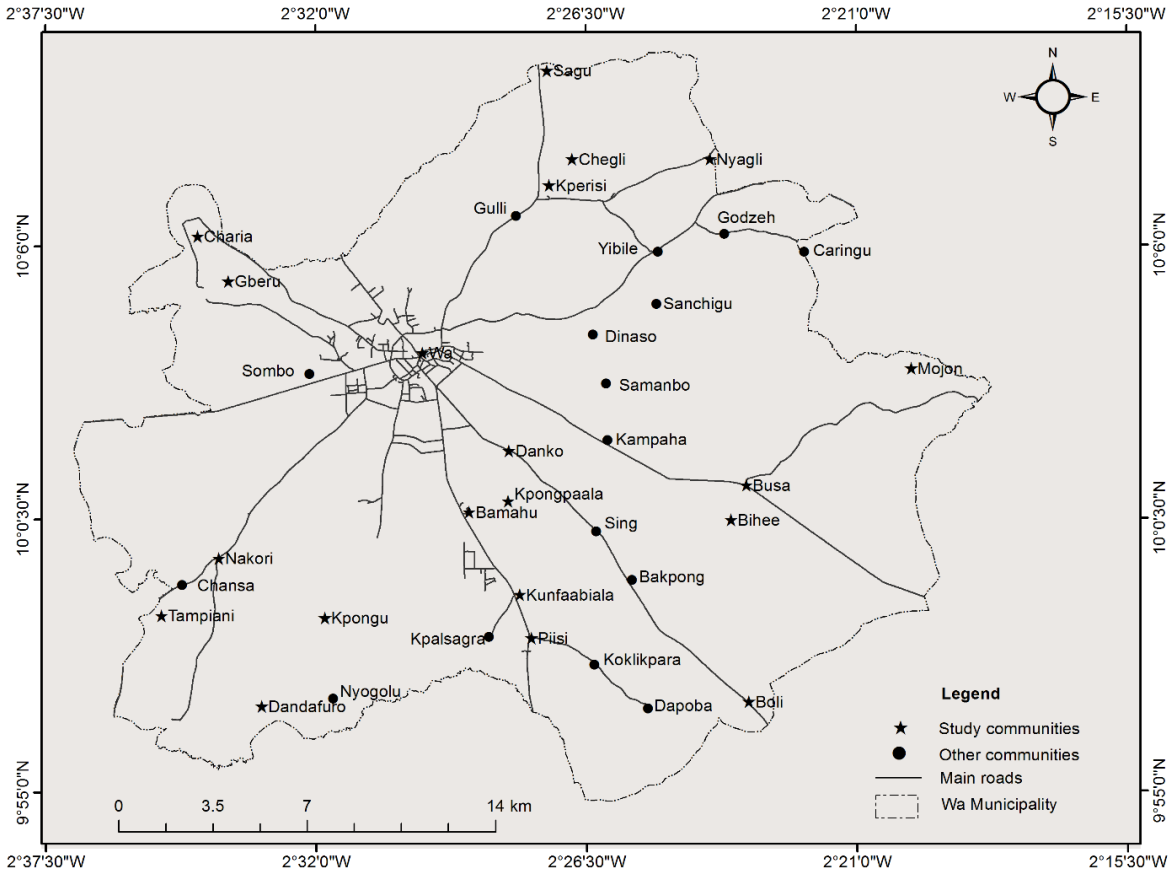


Figure 1: Map of Wa Municipality depicting the 20 [twenty] study communities
Source: Authors' Construct (April 2019)

Wa doubles as the capital of Upper West Region and the Municipality. The projected population for the Municipality for 2019 was 129,546 (Wa Municipal Assembly [WMA], 2019). Its rural/urban population split is 34%/66%. The Municipality has 73 settlements, comprising 72 rural and 1 urban settlements (2018-2021 WMMTDP, 2019). The Municipality has five area/town councils, which include Wa, Busa, Chere, Boli and Kpongu Area Councils.

Methods

The study adopted a mixed methods approach, using both qualitative and quantitative methods for data collection and analysis (Kumar, 2019; Creswell, 2009). Each of the Scalogram analysis techniques was done using settlements, their functions and populations. Data on settlements and their populations were sourced from Wa Municipal Assembly (2019) and Ghana Statistical Services (2014). To minimize cost of data collection, 19 rural settlements and Wa, the only urban settlement in the Municipality were used in the study. A simple random sampling method was employed in selecting the rural settlements (see Tables 4, 5 & 6).

Data on the presence/absence of functions in settlements were collected from the Municipal Development Planning Office using an appropriately developed checklist. These were validated by a cross-section of 20 assemblypersons. The assemblypersons also identified and validated the presence/absence of forty-one essential functions for each of the settlements under study in two separate focus group discussions, each made up of 10 discussants. These functions were broadly classified into 11 categories and used for the analysis (see Tables 4, 5 & 6).

Stakeholder-weighting Scalogram analysis requires data on the relative weights (importance) of functions based on their value judgement. To obtain this, Assembly persons ranked the weight of functions, using 1, 2, 3, … n, with 1 being the lowest and n the highest for functions within each broader domain. For each function, the weights assigned by stakeholders were averaged to arrive at its overall weight (see Table 6), which were based on their judgements, experiences, sentiments, views and/or perceptions; as such, the weighting was not done either in an ascending or descending order as in the previous cases, but muddily.

After data collection, each Scalogram was manually constructed following the steps outlined in section 3 of the paper. A final Scalogram, showing the ubiquity of functions, centrality indices and order of settlements was presented in a form of matrices for each technique. This

was supplemented by a proportional map showing the spatial configuration of settlements functionality. The relationship between population and the total weighted centrality indices was explored using a simple linear regression model and scatter-gram. The regression model is theoretically specified as: $Y = \alpha + \beta \times$. where, Y is the dependent variable representing the centrality index of settlements in the Municipality, x is the independent variable representing the population figures of settlements in the Municipality while α and β are parameters determined using observations on population and computations of centrality indices based on ubiquity of functions in settlements in the Municipality. Alpha (α) is the autonomous value of the centrality index; that is the value of centrality index when population is zero (when no human beings are living in the Municipality). Beta (β) is the magnitude with which x (population) changes when there is a unit change in Y (centrality index) within the Municipality.

Results and Discussion

Objective-based Weighted Scalogram

As mentioned earlier in section 3, all three Scalogram approaches applied in this study were constructed with 20 settlements and 41 functions. The number of times a function appears in settlements (i.e. number of settlements with a function) ranged from 1 for university, polytechnic, regional hospital, court, regional police station, district police station, fire station, post office, postal agency, radio station, hotel, commercial banks, rural banks, credit unions, storage facility and administration to 20 for borehole, pit latrine and mobile communication service. All functions with a frequency of 1 in the Municipality were regarded as centralized functions, those with frequencies between 2 and 9 were viewed as semi-centralized functions while those with frequencies between 10 and 20 were classified as non-centralized functions.

The weighted centrality score of functions in the objective-based weighted Scalogram ranged from 5 to 100 (Table 4). It indicates the degree of centrality of functions. The higher the weighted centrality score of a function, the higher its threshold and range. It is worth stating that the weighted centrality score of a function in the objective-based weighted Scalogram is inversely proportional to its frequency. As shown in Table 4, the higher the number of times a function appears in settlements, the lower its weighted centrality score and vice versa.

The total weighted centrality index (centrality index for short) of each settlement was established by summing up the weighted centrality scores of functions for all functions that are present in a settlement. The centrality indices of settlements indicate their relative functionality. The higher the centrality index of a settlement, the higher its functionality. From Table 4, the centrality indices of settlements ranged from 2,106.4 for Wa to 29.4 for Mojon. Wa shows a clear predominance over other settlements. Bamahu has the second highest centrality index of 290. The grand total weighted centrality index for the whole Municipality is 4,105.6. This is with computational error margin of 5.6 due to rounding up of decimals as grand total weighted centrality index is expected to equate the total centrality index, which stands at 4,100.00 (Table 4).

Settlements were manually ordered based on their centrality indices together with a cursory analysis of the category of functions (centralized, semi-centralized and non-centralized) they possessed. Two hierarchical levels of settlements were identified (Table 4). On top of the hierarchy is Wa. Wa was classified as 1st order because it shows a clear predominance over other settlements using the centrality index. Besides, it also has central functions like, polytechnic, regional hospital, court, regional police station, district police station, fire station, post office, postal agency, radio station, hotel, commercial banks, rural banks, credit unions and storage facility, which are absent in other settlements. Below Wa, all other settlements were classified as 2nd level settlements. This is because their centrality indices are not

significantly different. In addition, they are generally dominated by semi-centralized and non-centralized functions like kindergarten, primary school, borehole, mobile service and pit latrines (Table 4).

Table 4: Objective-based weighted Scalogram

FACILITY/ SERVICE			EDUCATION							HEALTH				WATER			SAN.			SEC & JUS.					TELE & COMM				TOUR.		FINANICIAL INSTITUTION				ROADS		DIST.			OTHER SERVICE		ADMIN					
S/N	SETTLEMENT	POPULATION	UNIVERSITY	TRAINING COLLEGE	POLYTECHNIC	S.H.S/VOC./TECH.	J.S. S	PRIMARY	KINDAGARTEN	REGIONAL HOSPITAL	HEALTH CENTRE	CLINIC	CHPS	PIPE BORNE	MECHANIZE BORE HOLE	BORE HOLE	W.C	K.V.I. P	PIT LATRINE	COURT	REGIONAL POLICE HQRS	POLICE STATION	POLICE POST	FIRE STATION	POST OFFICE	POSTAL AGENCY	RADIO STATION	TELEPHONE	GUEST HOUSE	HOTEL	COMMERCIAL BANKS	RURAL BANKS	CREDIT UNIONS	MICRO-FINANCE	2nd CLASS ROAD	FEEDER ROAD	STORAGE FACILITY	MARKET (PERIODIC)	MARKET(DAILY)	FUELING STATION	LORRY PARK	CAPITAL	TOWN/AREA COUNCILS	NO. OF FUNCTIONS	Total weighted central index	% Total weighted centrality index	Order of settlements
1	WA	85851		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	40	2,106.4	51.3	1st
2	BAMAHU	4163	*				*	*	*		*			*	*	*	*	*	*									*							*	*			*	*				16	289.8	7.1	2nd
3	CHARIA	3414				*	*	*	*		*				*	*	*	*	*				*					*						*	*			*	*				15	230.7	5.6	2nd
4	KPONGU	3173					*	*	*				*		*	*		*	*									*	*						*				*					12	97.4	2.4	2nd
5	BOLI	2270					*	*	*				*		*	*		*	*				*					*								*			*				*	13	122.4	3.0	2nd
6	NAKORI	2141					*	*	*				*			*			*									*	*						*	*			*					10	82	2.0	2nd
7	BUSA	2048				*	*	*	*		*				*	*			*				*					*								*			*				*	13	164.1	4.0	2nd
8	KPERISI	1674		*			*	*	*			*			*	*		*	*									*							*				*				*	13	189.7	4.6	2nd
9	DANKO	1570					*	*	*				*	*	*	*		*	*									*								*								11	90.3	2.2	2nd
10	KUNFABIALA	1146														*			*									*							*					*				5	57.4	1.4	2nd
11	CHEGLI	1041					*	*	*				*		*	*		*	*									*							*				*					11	72.4	1.8	2nd
12	NYAGLI	1005					*	*	*				*		*	*		*	*									*							*				*					11	72.4	1.8	2nd
13	SAGU	978					*	*	*				*		*	*			*									*							*				*					10	64.1	1.6	2nd
14	BIHEE	930						*	*						*	*			*									*								*								7	42.4	1.0	2nd
15	PIISI	800					*	*	*				*		*	*		*	*									*							*			*	*					12	122.4	3.0	2nd
16	GBERU	717					*	*	*				*			*		*	*									*								*			*					10	65.3	1.6	2nd
17	TAMPIANI	637					*	*	*				*		*	*		*	*									*								*			*					11	72.4	1.8	2nd
18	KPONGPAALA	390							*				*	*		*			*									*	*							*								7	87.7	2.1	2nd
19	DANDAFURO	337					*	*	*				*			*			*									*							*								8	49.9	1.2	2nd
20	MOJON	202							*							*			*									*								*								5	29.4	0.7	2nd
NO. OF SETTLEMENT WITH A FUNCTION (N)			1	2	1	3	16	17	19	1	4	2	12	4	14	20	3	12	20	1	1	1	4	1	1	1	1	20	4	1	1	1	2	11	11	1	2	14	3	1	1	4	240	4,105.6	100.2	
CENTRALITY INDEX (100)			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	4,100.00			
WEIGHTED CENTRALITY SCORE			100	50	100	33.3	6.3	5.9	5.3	100	25	50	8.3	25	7.1	5	33.3	8.3	5	100	100	100	25	100	100	100	100	5	25	100	100	100	100	100	9.1	9.1	100	50	7.1	33.3	100	100	25			

Source: Authors' construct with Data from WMA (June 2019)

Relation between population and centrality indices of objective-based weighted Scalogram

Based on Table 4, the linear regression equation presented below was obtained (see Adarkwa, 2014): $y=0.0238x + 67.344$ (1)

where, y=dependent variable (centrality index) and x=independent variable (population).

From the above linear equation, the centrality index of a place without people or when population becomes zero is 67.344. This is possible because some functions like telecommunication network and roads are often provided in advance of settlement evolution.

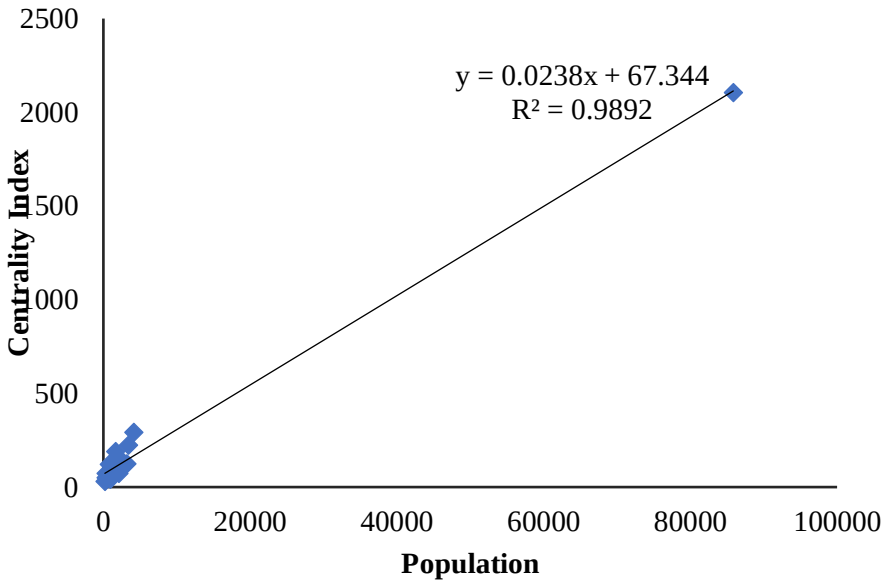


Figure 2 Scatter-gram of population and centrality indices based on objective-based weighting

Source: Authors' construct (July 2019)

The positive value of the gradient (Figure 2) shows that there is a direct relationship between population values and the centrality indices. That is to say, that increasing values of population may lead to the provision of additional services and facilities that will result in additional centrality indices. In addition, the coefficient of determination (R^2) was calculated to be 0.9892 as shown in Figure 2. The R^2 shows that although there are other factors that may influence the

centrality index of settlements within the Wa Municipality, population alone explains almost 99% of the factors. Other factors such as the location of the settlement, political decisions and the functions of the settlements are also considered (Adarkwa, 2014). However, all these factors put together account for only one percent of the centrality index.

Expert-based Weighted Scalogram

The result of the expert-based weighted Scalogram is presented in Table 5. Unlike the objectively weighted Scalogram, functions under this technique are assigned weights by levels. In each group of functions, the most centralized function gets the highest weight while the least non-centralized function gets the lowest weight (Table 5). For instance, the weights for education related functions ranged from 7 for university to 1 for kindergarten. From Table 5, the minimum weighted centrality score is 5 while the maximum is 700. The higher the weight of a function, the higher its centrality and vice versa. In this technique, the weighted centrality score of a function is determined by two factors – weights assigned to functions and the number of times a function appears in settlements. Whereas higher weight increases the weighted centrality score, a higher frequency rather reduces the weighted centrality score. Thus, a high weighted centrality score of a function arises from a higher weight and/or a lower frequency.

The centrality indices of the expert-based weighted Scalogram ranged from 29.4 for Mojon to 5,949.2 for Wa. The difference between the centrality index of Wa and that of the second highest settlement (Bamahu) is 4,816.5. Unlike the objectively-weighted Scalogram in which the grand centrality index and grand total weighted centrality index are equal, under the expert-based weighting Scalogram, the grand centrality index still stands at 4,100.00; however, the grand total weighted centrality index is as high as 10,264.2. This variation is due to the weights assigned to the functions aside from the objective-based weighting system of the Scalogram. Like the objective-based weighted Scalogram, Wa shows a clear predominance over other

settlements in terms of the centrality index. Settlements were manually classified into two orders based on their centrality indices and a careful analysis of the types of functions present in settlements. On top of the hierarchy is Wa, which assumes a position of a 1st order settlement due to its high centrality index over other settlements and the presence of central functions like polytechnic, regional hospital, court, regional police station, district police station, fire station, post office, postal agency, radio station, hotel, commercial banks, rural banks, credit unions and storage facility. These are not present in other settlements (Table 5). Below Wa, all other settlements were classified as second level settlements as there is no significant difference among their centrality indices (Table 5), with dominance of semi-centralized and non-centralized functions.

Table 5: Expert-based weighted Scalogram

FACILITY/ SERVICE			EDUCATION							HEALTH				WATER			SAN.			SEC & JUS.					TELE & COMM				TOUR.		FINANICIAL INSTITUTION				ROADS		DIST.			OTHER SERVICE		ADMIN.				
S/N	SETTLEMENT	POPULATION		TRAINING COLLEGE	POLYTECHNIC	S.H.S/VOC./TECH.	J.S. S	PRIMARY	KINDAGARTEN	REGIONAL HOSPITAL	HEALTH CENTRE	CLINIC	CHPS	PIPE BORNE	MECHANIZE BORE HOLE	BORE HOLE	W.C	K.V.I.P	PIT LATRINE	REGIONAL POLICE	COURT	FIRE STATION	POLICE STATION	POLICE POST	POST OFFICE	POSTAL AGENCY	RADIO STATION	TELEPHONE	HOTEL	GUEST HOUSE	COMMERCIAL BANK			MICRO-FINANCE	FEEDER ROAD		MARKET (PERIODIC)	MARKET(DAILY)	FUELING STATION	LORRY PARK		TOWN/AREA COUNCILS	NO. OF FUNCTIONS (FACILITIES	Total weighted central index	% Total weighted centrality index	Order of settlements
	WEIGHTS		7	6	5	4	3	2	1	4	3	2	1	3	2	1	3	2	1	5	4	3	2	1	4	3	2	1	2	1	4	3	2	1	2	1	3	2	1	2	1	2	1				
1	WA	85851		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	40	5949.2	57.8	1st
2	BAMAHU	4163	*				*	*	*		*			*	*	*	*	*	*									*						*	*			*	*			16	1132.7	11	2nd
3	CHARIA	3414				*	*	*	*		*				*	*	*	*	*				*						*					*		*			*				15	506.1	4.9	2nd
4	KPONGU	3173					*	*	*				*		*	*		*	*										*	*					*				*				12	165.4	1.6	2nd
5	BOLI	2270					*	*	*				*		*	*		*	*				*						*						*				*			*	13	181.3	1.8	2nd
6	NAKORI	2141					*	*	*				*			*			*										*	*					*				*				10	134.5	1.3	2nd
7	BUSA	2048				*	*	*	*		*				*	*			*				*						*						*				*			*	13	364.6	3.4	2nd
8	KPERISI	1674		*			*	*	*			*			*	*		*	*										*						*				*			*	13	532.1	5.2	2nd
9	DANKO	1570					*	*	*				*	*	*	*		*	*										*						*								11	174.2	1.7	2nd
10	KUNFABIALA	1146														*			*										*						*					*			5	99.8	1.0	2nd
11	CHEGLI	1041					*	*	*				*		*	*		*	*										*						*				*				11	113.4	1.1	2nd
12	NYAGLI	1005					*	*	*				*		*	*		*	*										*						*				*				11	113.4	1.1	2nd
13	SAGU	978					*	*	*				*		*	*			*										*						*				*				10	98.8	1.0	2nd
14	BIHEE	930						*	*						*	*			*										*							*							7	55.5	0.5	2nd
15	PIISI	800					*	*	*				*		*	*		*	*										*						*		*	*					12	215.4	2.1	2nd
16	GBERU	717					*	*	*				*			*		*	*										*						*				*				10	82	0.8	2nd
17	TAMPIANI	637					*	*	*				*		*	*		*	*										*						*				*				11	106.3	1.0	2nd
18	KPONGPAALA	390							*				*	*		*			*										*	*					*								7	162.7	1.6	2nd
19	DANDAFURO	337					*	*	*				*			*			*										*						*								8	77.4	0.8	2nd
20	MOJON	202							*							*			*										*						*								5	29.4	0.3	2nd

NO. OF SETTLEMENT WITH A FUNCTION (N)		1	2	1	3	16	17	19	1	4	2	12	4	14	20	3	12	20	1	1	1	4	1	1	1	1	20	4	1	1	1	1	2	11	11	1	2	14	3	1	1	4	240	10,294.2	100.0
CENTRALITY INDEX (100)			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			100		100		100	100	100	100	[illegible]	100	4,100.00		
WEIGHTED CENTRALITY SCORE			300			[illegible]		5.3			100			14.3	5										300		5		100													25			

Source: Authors' construct with Data from WMA (June 2019)

Relation between population and centrality indices of expert-based weighted Scalogram

A simple linear regression model of the relationship between population and the centrality indices of settlements based on expert-based weighted Scalogram is as follows:

$$Y = 0.0682x + 124.43 \quad (1)$$

where, y = dependent variable (centrality index) and x = independent variable (population).

From the regression, the centrality index of a place without people or when population becomes zero is 124.43. The positive value of the gradient depicted in Figure 3 shows that there is a direct relationship between population values and the centrality indices. In addition, the R^2 is 0.9757. This implies that population alone accounts for 97.6 percent of the factors that influence the centrality index of settlements.

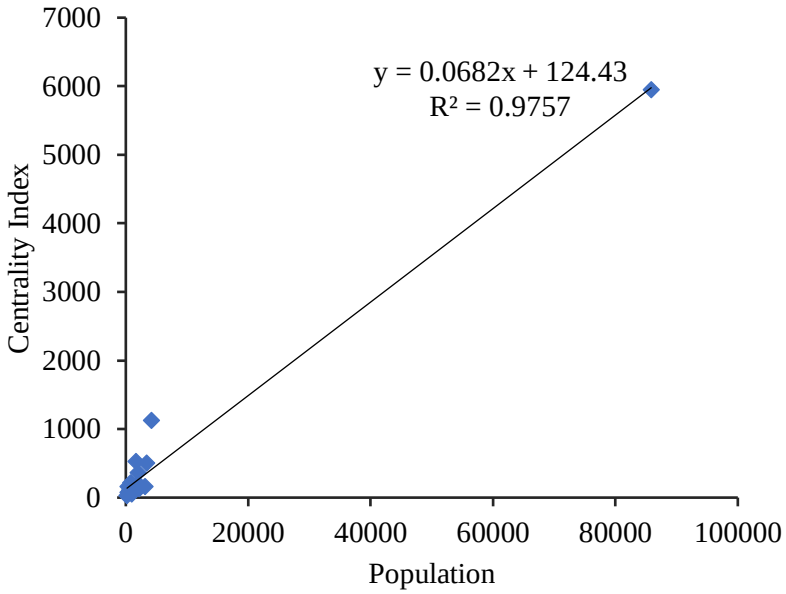


Figure 3: Scatter-gram of population and centrality indices based on expert-based weighting
Source; Authors' construct (July 2019)

Stakeholder-based Weighted Scalogram

Unlike the expert-based weighted Scalogram where weights of functions were allocated by an expert, weights under this approach were assigned by stakeholders. It is interesting to note that University, the highest level of function under education related functions was weighted the

least (1) by stakeholders while Kindergarten, the lowest level of function within the education category was weighted the highest (7) by stakeholders (Table 6). This is a direct opposite of the weights allocated under the expert-based weighting approach (Table 5). It thus, suggests that a higher order function may not necessarily be important to stakeholders/users.

In this approach, the weighted centrality scores of functions ranged from 5 for borehole and pit latrine to 400 for fire station, radio station and commercial bank. Like the expert-based weighting approach, the weighted centrality score of a function is determined by weights assigned to functions and the number of times a function appears in settlements. Whereas a high weight increases the weighted centrality score, a high frequency of function rather reduces the weighted centrality score. For instance, both health centre and radio station were assigned a weight of 4 by stakeholders. However, the weighted centrality score of radio station was higher than health centre because 4 settlements have health centres while only 1 settlement has a radio station (Table 6). In assigning the weights, stakeholders considered the underlisted factors: condition of the facility, the quality of services rendered at the facilities, the distance to these facilities, trust issues with relation to the financial institutions and the cost of service. This is in sharp contrast with the weighting systems employed under the objective- and expert-based weighting approaches, which both used only order of service as a factor to assign the weights.

In terms of the centrality index, Wa again emerged with a predominantly high centrality index of 4,935.9 (Table 5). This was followed by Charia, with a centrality index of 751.2. Mojon again came last with a centrality index of 71.2. Under the stakeholder-based weighting system, the grand centrality index stands at 4,100.00 while the grand total weighted centrality index is as high as 10,404.80; a variation that is explained by the weights assigned to the functions aside from the objective-based weighting system. Two levels of settlements were discernible. Based

on the centrality indices, Wa stands out clearly as a 1st order settlement. The centrality indices of the remaining settlements were generally low and thus classed as 2nd order settlements.

Table 6: Stakeholder-based weighted Scalogram

	FACILITY/ SERVICE		EDUCATION							HEALTH				WATER			SAN.			SEC & JUS.					TELE & COMM				TOUR.		FINANICIAL INSTITUTION				ROADS		DIST.			OTHER SERVICE		ADMIN.				
S/N	SETTLEMENT	POPULATION	UNIVERSITY	TRAINING COLLEGE	POLYTECHNIC	S.H.S/VOC./TECH.	J.S. S	PRIMARY	KINDAGARTEN	REGIONAL HOSPITAL	HEALTH CENTRE	CLINIC	CHPS	PIPE BORNE	MECHANIZE BORE HOLE	BORE HOLE	W/C	K.V.I.P	PIT LATRINE	COURT	REGIONAL POLICE HQRS	POLICE STATION	POLICE POST	FIRE STATION	POST OFFICE	POSTAL AGENCY	RADIO STATION	TELEPHONE	GUEST HOUSE	HOTEL	COMMERCIAL BANK	RURAL BANKS	CREDIT UNIONS	MICRO FINANCE	2nd CLASS ROAD	FEEDER ROAD	STORAGE FACILITY	MARKET (PERIODIC)	MARKET(DAILY)	FUELING STATION	LORRY PARK	CAPITAL	TOWN/AREA COUNCILS	NO. OF FUNCTIONS (FACILITIES	Total weighted central index	% Total weighted centrality index	Order of settlements
	WEIGHTS		1	3	2	5	6	4	7	2	4	1	3	3	2	1	3	2	1	1	3	2	5	4	2	1	4	3	1	2	4	2	3	1	2	1	1	2	3	2	1	2	1				
1	WA	85851		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	40	4935.9	47.3	1st
2	BAMAHU	4163	*				*	*	*		*			*	*	*	*	*	*									*							*	*			*	*			16	669.4	6.4	2nd
3	CHARIA	3414				*	*	*	*		*				*	*	*	*	*				*					*						*		*			*				15	751.2	6.9	2nd
4	KPONGU	3173					*	*	*				*		*	*		*	*									*	*						*				*				12	243.7	2.3	2nd
5	BOLI	2270					*	*	*				*		*	*		*	*				*					*								*			*			*	13	359.6	3.7	2nd
6	NAKORI	2141					*	*	*				*			*			*									*	*						*				*				10	212.9	2.0	2nd
7	BUSA	2048				*	*	*	*		*				*	*			*				*					*								*			*			*	13	609.6	5.8	2nd
8	KPERISI	1674		*			*	*	*			*			*	*		*	*									*							*				*			*	13	418.8	4.0	2nd
9	DANKO	1570					*	*	*				*	*	*	*		*	*									*								*							11	263.3	2.5	2nd
10	KUNFABIALA	1146														*			*									*							*						*			5	109.8	1.1	2nd
11	CHEGLI	1041					*	*	*				*		*	*		*	*									*							*				*				11	218.7	2.1	2nd
12	NYAGLI	1005					*	*	*				*		*	*		*	*									*							*				*				11	218.7	2.1	2nd
13	SAGU	978					*	*	*				*		*	*			*									*							*				*				10	202.1	1.9	2nd
14	BIHEE	930						*	*						*	*			*									*								*							7	109	1.0	2nd
15	PIISI	800					*	*	*				*		*	*		*	*									*							*			*	*				12	268.7	2.6	2nd
16	GBERU	717					*	*	*				*			*		*	*									*								*			*				10	195.4	1.9	2nd
17	TAMPIANI	637					*	*	*				*		*	*		*	*									*								*			*				11	209.6	2.0	2nd
18	KPONGPAALA	390							*				*	*		*			*									*	*							*							7	196.1	1.9	2nd
19	DANDAFURO	337					*	*	*				*			*			*									*							*								8	166.6	1.6	2nd

20	MOJON	202							*							*				*								*								*								5	71.2	0.7	2nd
NO. OF SETTLEMENTS WITH A FUNCTION (N)			[illegible]	[illegible]	[illegible]	3	16	17	19		4															1											[illegible]	14	[illegible]	[illegible]	[illegible]	4	240	10,404.80	100.0	
CENTRALITY INDEX (100)			100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	4,100.00			
WEIGHTED CENTRALITY SCORE			[illegible]	[illegible]	[illegible]	166.5	37.8	23.6	37.1		100															100											[illegible]	21.3	[illegible]	[illegible]	[illegible]	25				

Source: Authors' construct (June 2019)

Relation between population and centrality index of stakeholders-based weighted Scalogram

The regression equation was y= 0.0554x + 204.66, where y = centrality index and x = population. In absolute terms, when the population is zero, centrality index will stand at 204.66. This can be explained by the existence of some services and facilities, such as the presence of communication networks comprising mobile telecommunications, television, radio and road networks in uninhabited areas within the Municipality. In reality, however, it can be argued that this large value of the constant is due to the stakeholder-based weights assigned to the services/facilities. The scatter plot in Figure 4 yields a R^2 of 0.9812. This means that population alone accounts for 98.12 percent of the factors influencing the centrality index of a settlement.

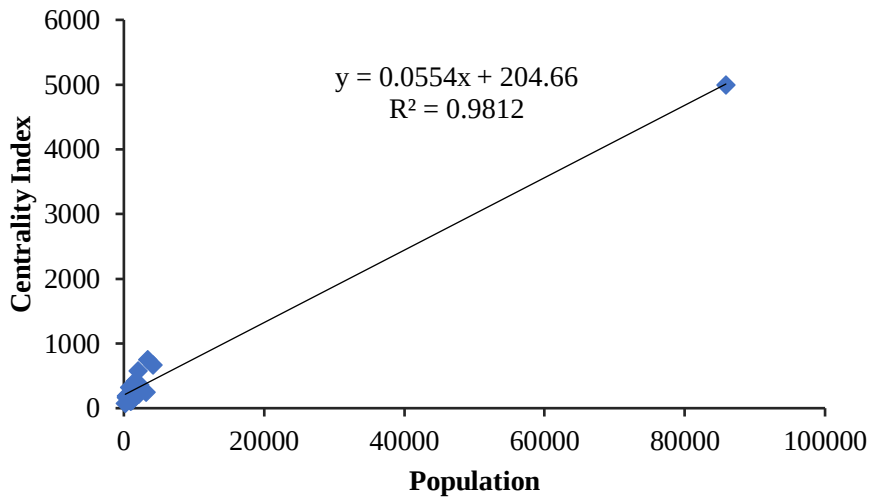


Figure 4 Scatter-gram of population and centrality indices based on stakeholder based-weighting

Source: Authors' construct (July 2019)

Comparison of the three Methods

From Tables 4, 5 and 6 it can be seen that the centrality indices of settlements differ due to the introduction of assignment of weights. These are seen in the expert-based assignment of weights in a descending order (Table 5) and stakeholder-based weighting approaches to the Scalogram (Table 6). Table 4, which is the Scalogram with the objective-based weighted centrality indices where weights were not subjectively, but objectively assigned has a Grand Total Weighted Centrality Index as low as 4,105.60 while Table 5, which is a Scalogram in which the expert has assigned weights in a descending order. This takes into cognizance the importance of the function; the Grand Total Weighted Centrality Index is more than twice that of the objective-based Scalogram with a value of 10,294.2. The stakeholder weighted Scalogram where weights were subjectively assigned to services and facilities by stakeholders the Grand Total Weighted Centrality Index is as high as 10,404.80, more than twice that of the objective-based weights and slightly higher than the expert-based objective Scalogram. This implies that the stakeholder-based weighted centrality approach appears to have the highest functional complexity over the objectively weighted and expert-based weighted centrality approaches. This complexity is, however, not because of the number of functions considered in the stakeholder-based Scalogram but the criteria and factors considered before the assignment of the subjective weights. In addition, the same can be said for the weighted centrality index for the services or facilities.

Generally, it can be inferred that the higher the order of service, the higher the weighted centrality index and vice versa but when subjectivity is introduced into the analysis this form changes. The study discovered that with the objective-weighted Scalogram the weighted centrality index for the Training College was 50 but with the stakeholder-based weighted Scalogram the value changed to 150 (i.e. 300 ÷ 2), because of the introduction of an expert-based weight of 3. In the same vain, with the introduction of expert-based weights, the weighted

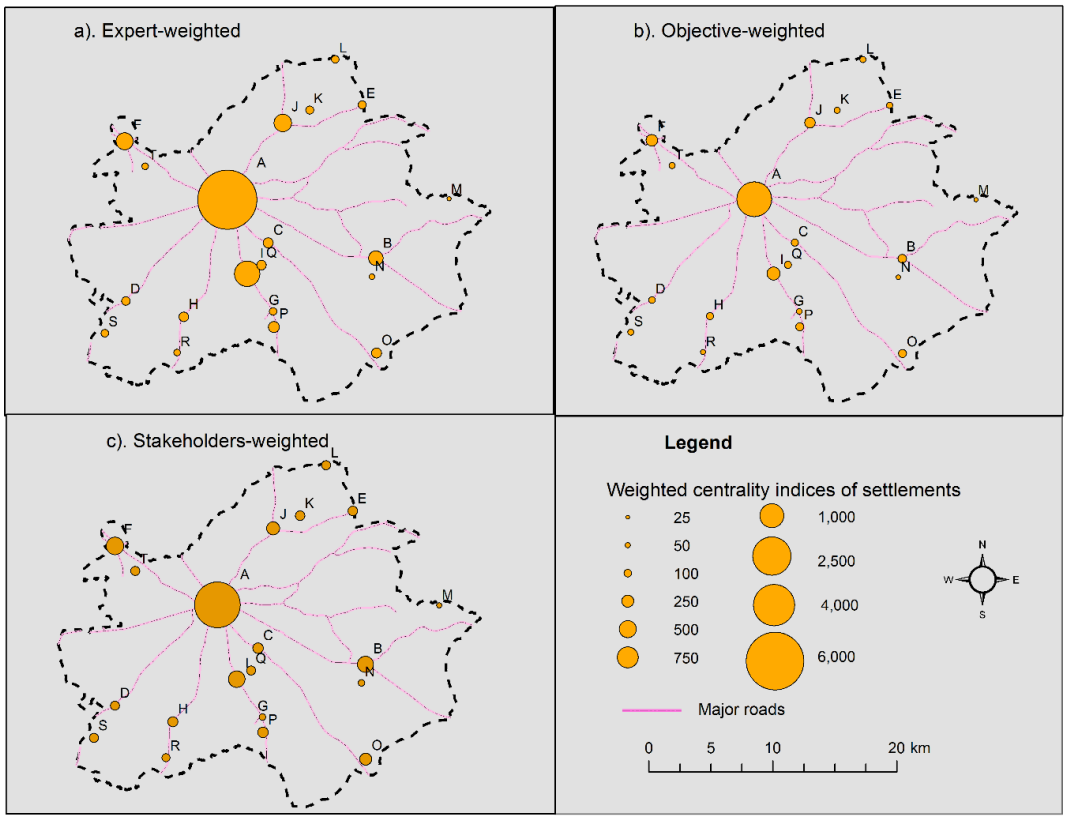
centrality index for training college is as high as 300 (i.e. 600 ÷ 2) also because of the introduction of the objective-based weight of 6, with the difference between the two coming from the magnitude of the centrality indices. Clearly, from the computations above, the weighted centrality indices and their associated Grand Total Weighted Centrality Indices in the two Scalograms in which weights have been assigned are higher than the Scalogram with the objective-based weighting system.

Again, the percentage difference in both Scalogram approaches is not the same. The percentage difference between Boli and Nakori communities under the Scalogram with objective-based weight is 33.01 that of the expert-based Scalogram is 25.81 while that of the stakeholder-based weighted Scalogram is 40.80 and runs in this same manner for all the other settlements. The R^2 for the three approaches vary but very slightly. It stands at 98.92 for the objectively weighted approach, 97.57 for the expert-based approach and 98.12 for the stakeholder-based weighted approach. It can be inferred that the objective-based and the stakeholder-based approaches have higher explanatory power than the expert-based objective approach to Scalogram, as population increase alone explains 98.92 percent of provision of additional functions under the objective-based approach, 98.12 percent under the stakeholder-based approach and 97.57 percent under the expert-based approach within the Municipality. This implies that all the other factors put together explain only 0.8 percent addition of functions under the objective-based approach, 1.88 percent under the stakeholder-based approach and 2.43 percent under the expert-based approach, thus making the expert-based approach to possess the weakest explanatory power among the three (Mensa-Bonsu, 2014; 186).

Again, it was discovered in the study that even though the centrality indices of the three approaches diverge significantly from each other, the variations among their coefficients of determination between the centrality index and population of the various communities is insignificant. It is only 0.8 percent between the objective-based and the stakeholder-based

approaches, only 0.55 percent between the expert-based and the stakeholder-based approaches and 1.35 percent between the objective-based and expert-based approaches. The inverse relationship between the Grand Total Weighted Centrality Index and Coefficients of Determination (R^2) under the expert-based approach is due to the fact that while the Grand Total Weighted Centrality Index, was simply responding to expert-based weights assigned to functions, the R^2 was measuring the explanatory power of the independent variable (population) in the face of reversal of the weights assigned to functions. Since this reversal is to make room for sphere of influence of the functions (see Adarkwa, 2014; Grove & Huszar, 1964) it has rather reduced the explanatory power of population as an independent variable. It can be inferred that though the introduction of expert-based weights is innovative in that, it has been able to introduce a third variable (sphere of influence); the net effect has been marginal and insignificant. The marginality can be accounted for by the consistency in the sequencing of the weights to the functions as regards their spheres of influence. For instance, a weight of 7 for university, which has the capacity to award certificates, diplomats and degrees (undergraduate, masters and PhDs) and confer professorial titles can be said to be too low as against 6 and 5 for teacher training college and polytechnic respectively which award only certificates and diplomats (at the time of this study). If the weighting is properly done, considering the order and sphere of influence of the functions, the results will not only produce an inverse relationship but also a more significant reduction in the R^2, giving more importance to order and sphere of influence as factors in Scalogram analysis. In the same vein, a regional hospital takes on a weight of 4, while a health centre has 3; the weighting is heavier in favour of the health centre as against the regional hospital. Under the stakeholder-based approach, even though weights were introduced, they did not produce the same inverse effect as in the case of the expert-based approach because they were muddled; thus, making population the single most important variable in deciding on allocation of functions in space.

The study further reveals differences in the functional importance of settlements within the Municipality depicted by the sizes of the proportionate circles in Figure 4. Such relative differences are the cause of emergence of the functional hierarchy of settlements within the study area (see Adarkwa, 2014; Ali &Varshney, 2012; Donkoh, 2015). Nevertheless, regardless of the weighting approach, two functional levels of settlements were identified. In all the three Scalograms, Wa emerged as the primate settlement in the Municipality with all other settlements focusing on it. Although Wa is surrounded by second order settlements, the spatial configuration is at variance with the hexagonal geometric pattern of hierarchy of settlements observed by Christaller in Southern Germany (Christaller, 1966). It rather echoes Losch's (1954) continuous distribution of settlements. The Municipal and Regional capital statuses of Wa, which have justified the location of both municipal and regional levels administrative services and infrastructure within it, have contributed to its primacy within the Municipality. The persistence of this trend of primacy of Wa for spatial development is that Wa will continue to predate or prey on the smaller settlements for its growth to the dissipation of resources from its hinterlands (see Myrdal, 1957; Friedman, 1966).



A=Wa, B=Busa, C=Danko, D=Nakori, E=Nyagli, F=Charia, G=Kunfabiela, H=Kpongu, I=Bamahu, J=Kperisi, K=Chegli, L=Sagu, M=Mojon, N=Bihee, O=Boli, P=Piisi, Q=Kpongpaala, R=Dandafuro, S=Tampiani, T=Gberu

Figure 4: Proportional representation of settlements centralities in the Wa Municipality
Source: Authors' (December 2020)

Conclusion

The Scalogram is a tool used by planners and other professionals in the built environment to depict a picture of how functions are distributed across space. The study set out to compare the three Scalogram analysis approaches (objective-based weighting, expert-based weighting and stakeholder-based weighting Scalogram analysis approaches) using the centrality of settlements with the aim of determining whether there exist any significant differences among them to serve as a basis for recommendation in their applications. It was revealed that under the stakeholder-based weighted Scalogram, the assembly persons within the Wa Municipality considered factors such as; the condition of the facility, the quality of services rendered at the facilities, proximity to these facilities, trust issues in relation to the financial institutions and

the cost of service in subjectively assigning weights to the various functions within the Municipality.

It was also discovered that even though the centrality indices of the three approaches vary significantly, their coefficients of determination between the centrality index and population of the various communities did not differ significantly. It is only 0.8 percent between the objective-based and the stakeholder-based approaches, only 0.55 percent between the expert-based and the stakeholder-based approaches and 1.35 percent between the objective-based and expert-based approaches. The inverse relationship between the Grand Total Weighted Centrality Index and coefficients of determination can be explained by the fact that while the Grand Total Weighted Centrality Indices, under the expert-based approach, were simply responding to expert-based weights assigned to functions, the R^2 was measuring the explanatory power of all the independent variables (factors) taken into consideration before assigning the weights. In effect, it can be concluded that even though infusion of subjectivity into Scalogram analysis inevitably increases the absolute value of the centrality indices, its ability to explain variations in it is highly insignificant. This is because, Scalogram from the technical point of view is meant to analyse the distribution of functions in space but not to take such factors as conditions, efficiency, utility among others of these facilities and services into consideration. Thus, no matter how Scalogram is twisted it can never satisfy those factors. It is, therefore, recommended that planners should develop other tools, which can cater for the concern of such other factors. This will help in taking into consideration the views of the affected beneficiaries since planning is by and for the people. Since the differences in the coefficients of determination between the centrality indices and population of settlements are very low, the use of all the three approaches are recommended with the choice left to the discretion of the professionals, which will dependent on availability of resources and time. Nonetheless, preference should be given to the objective-based and stakeholder-based

weighting Scalograms because the expert-based assignment of weights has rather reduced the explanatory power of population as an independent variable of centrality index. It is, further, recommended that more development interventions should be focused on the area council headquarters, with elimination of bottlenecks to development, to enable them play their expected roles as minimal urban or service centres and to bridge the hierarchical gaps between them and the primate settlement, Wa, for efficient spatial development in terms of services, facilities and functional distributions.

References

Adarkwa, K. K. (2014). *Human Settlement and Service Delivery in Ghana*. Kumasi (Ed.): University Printing Press; 15-124.

Ali, J. and Varshney, D. (2012). Spatial Modeling of Urban Growth and Urban Influence: Approach of Regional Development in Developing Economy (India). *Journal of Urban and Regional Analysis,* Vol. IV (2): 129 -148.

Asare, S. A. (1994). *Settlement Systems Analysis: An Approach towards an Effective Spatial - Functional Integration in the Nkoranza District*. http://hdl.handle.net/123456789/3309 .

Berry, B. J. L. & Garrison, W. L. (1958). The Functional Bases of the Central Place Hierarchy. *Economic Geography*, 34 (2) 145-154.

Christaller, W. (1933). *Central Places in Southern Germany*, translated by Carlisle W. Baskin in 1966, Prentice Hall Inc, New Jersey.

Creswell, J.W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches.* SAGE Publications; New Delhi.

Davies, W. K. D. (1966). The Ranking of Service Centres: A Critical Review. The Royal Geographical Society.

Donkoh, A. A. (2015). The Comparative Roles of Service Centres within the Urban Space of the Brong-Ahafo Region. University of Ghana *http://ugspace.ug.edu.gh*. Accessed: June, 2019.

Friedmann, J. (1966). *Regional development policy: A case study of Venezuela.* Cambridge, Mass: M.I.T. Press.

Ghana Statistical Service (2014). *2010 Population and Housing Census: District Analytical Report Wa Municipal Assembly*, Accra, Ghana.

Grove, D. and Huszar, L. (1964). The Towns of Ghana: The Role of Service Centres in Regional Planning. *Planning Research Studies Number II*. University of Science and Technology, University Press; 20-84.

Isard, W. (1960). *Methods of Regional Analysis: An Introduction to Regional Science, Appendix*. MIT Press.

Kharate, V. B. (2009). 'Hierarchical Patterns of Rural Central Places in the Painganga Valley', Shodh, Samiksha aur Mulyankan. *International Research Journal*, Vol.II (5), 471-474.

Kumar, R. (2019). Research Methodology: A-step-by-step approach for beginners. (5th ed). London. Sage Publication Ltd; 49-55.

Jufri, J. and Nonce H. (2016). Determining the Centers of Economic Growth and Regional Development Using Scalogram Analysis: An Empirical Studyin West Halmahera Regency, Indonesia. *Journal of Economics and Finance.* 7(4); PP 31-36.

Losch, A. (1954). The Economics of Location. W. H. Woglom and W. F. Stolper, trans. New Haven: Yale University Press. (First published in 1943).

Mandal, R. B. (2001). *Introducntion to rural settlements* (2nd ed.). New Delhi: Concept Publishing Company.

Marshall, J. U. (1969). The Location of Service Towns. Toronto: University of Toronto Press

McCann, P. (2001) Urban and Regional Economics (Oxford: Oxford University Press).

Mensa-Bonsu, I.F. (2014). Greater Accra Region. In Adarkwa, K. K. (2014). *Human Settlement and Service Deliveryin Ghana*. Kumasi (Ed.): University Printing Press: 162 – 193.

Myrdal, G. (1957). *Economic theory and under-developed regions.* London; G. Duckworth.

Rondinelli, A. D. (1985). *Applied Methods of Regional Analysis: The Spatial Dimension of Development Policy*. USA: Westview press.

Spaliviero, G. (2004). *From Regional to Urban Planning: Experiences in Africa Maputo, Mozambique*. Unpublished Work.

Tiwari, R. C. and Khan, N. V. (1984). 'Spatial Organisation of Rural Service centres in Pratapgarh District', *National Geographer*, Vol. XIX (2); 87-104.

United Nations. (2015b). *Transforming Our World: The 2030 Agenda for Sustainable Development. A/RES/70/1*. Retrieved from: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf. Date Accessed: 29/10/2016.

Van Meeteren, M., & Poorthuis, A. (2017). Christaller and "big data": recalibrating central place theory. Urban Geography DOI:/10.1080/02723638.2017.1298017

Wa Municipal Assembly (2019). *District Medium Term Development Plan*; 2018-2021. Wa.