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APPLICATION OF MULTI-CRITERIA ANALYSIS IN RURAL ROADS PROVISION IN DEVELOPING COUNTRIES

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Abstract
This study is based on an approach to resolve conflicts in decision making processes. It is necessary to recognize explicitly that most decision making processes involve multiple participants and are often characterized by multiple and conflicting evaluation criteria. In such situation, to be able to arrive at a decision, methods that contribute toward consensus building among the decision makers are required. The objective of this study is to devise a conflict resolution oriented decision making framework that can be used in decision making in the public arena. In this study a decision making framework was applied to a process of selecting a ward (out of eleven wards) to be provided with a rural road in Ijebu North Local Government Area of Ogun State, Nigeria. Three groups of stakeholders were identified (the citizens, politicians and technocrats) and four criteria were used to evaluate the wards. The result from the analysis of variance shows that there is a significant difference among the wards in terms of the four criteria used. The study devised a decision support system (DSS), using concordance/discordance analysis within a multi-criteria analysis framework, to show how compromise can be reached on the issue of which ward should be selected for road provision. The application of the DSS shows that ward ten will be selected. It is shown in this study how areas can be evaluated for infrastructure provision and the application of a conflict resolution oriented decision process to select a particular area.

Key Words: *Rural Roads, Decision Making Process, Multicriteria Analysis.*

Introduction

Transportation is a requirement for every nation, regardless of its industrial capacity, population size, or technological development (Falola and Olarenwaju, 1986). Unfortunately, road transport which is the most common mode of transportation in Nigeria is not adequate, especially in the rural areas. Rural infrastructure constitutes the substance of rural welfare. It helps sustain daily activities, quality of life and an economic base in rural areas (Tanimu, 2009). Efforts to raise rural welfare must necessarily go beyond the limited approach of raising per capital income through agricultural developments but also through the provision of rural transport facilities (Idachaba, 1985). All over the world poverty reduction in the rural areas is tied to rural transport and it remains the central goal of development efforts. However, it has been observed that spatial variation in availability and access to rural transport

results in spatial disparities in living standards both within and between regions and localities (Barwell *et al*., 1985). Rural transport is of critical importance to rural development. Rural transport helps in the following areas: accelerate delivery of farm inputs; facilitate the evacuation and marketing of farm produce; prevent excess rural to urban migration with the attendant problems; reduce the level of wastage of agricultural products and thereby bring about a reduction in their prices; facilitate flow of information and diffusion of innovation which invariably lead to the introduction and adoption of new ideas and also help to accelerate the delivery of basic needs to the rural majority. Despite all the outlined importance of rural roads above, it is very ironical that many rural communities in Nigeria still lack good roads and consequently find it difficult to transport their goods. It even become difficult and at times impossible to reach some rural communities during the rainy season due to the bad terrain of some roads or collapsed bridges. These conditions have in most cases resulted in longer journey times, higher fares, delayed journeys, high cost and destruction of farm products.

Following from the scenario of the importance and the bad state of rural roads in Nigeria described above, and the limited resources available for rural road provision, this study is to examine the decision process in the provision of rural roads. The primary objective of spatial/location decision making is to identify the 'most desirable' or 'best' location for a facility or service (Maniezzo, *et. al*, 1998). Within the context of the rational-economic (or classical) decision model the best decision will yield the maximum outcome. This decision model assumes an ideal decision maker who is completely rational.

Herbert Simon proposed the bounded rationality decision model. Simon's model is more realistic as it recognizes the limited ability or "bounded" rationality of the decision makers (Lahti, 2003). Thus in practical decision making the "best" is not necessarily the maximal. There are tools, methodologies and software developed to help people make better decisions called decision support systems (DSS). In this study the application of a DSS in the provision of rural roads is examined.

Planning activities and environment today centre on resolving complex and ill-structured spatial problems that lack a clear goal and are characterized by multiple and conflicting objectives, multiple considerations, numerous participants with different preferences and a host of uncertainties (Malczewski, 1997; Feick and Hall, 1999). Given the multiple objective/multiple participants context, decision-making does not focus on the rational pursuit of an optimal solution. Rather a group decision making process is often adopted where participatory approach, consensus building, bargaining and negotiation take place in resolving strategic decision problems (Radford, 1988). Central to group decision making process is the use of multi criteria spatial decision support system. Multi-criteria spatial decision support systems (MC-SDSS) can be viewed as a part of a broader field of spatial decision support system (SDSS) which have been extensively covered in the literature (Densham and Goodchild, 1989; Densham, 1991). Geographic component is included in multi criteria spatial analysis in addition to the decision makers' preferences with respect to a set of evaluation criteria (Jankowski, 1995; Malezewski, 1996). This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments of the decision

makers involved in the decision making process. Spatial problems are increasingly involving many stakeholders as environmental legislation are mandating public involvement and participation in environmental assessment procedures (Malczewski *et al.,* 1997; Ferretti, 2011).

The basic question this study is trying to address is: "how is the decision on which rural area to be provided with a new road reached? Thus the broad aim of this study is to provide a framework within which an acceptable decision on rural road provision can be made, given that many objectives or criteria are to be considered and where many stakeholders often with divergent views are involved in the decision making process.

Methodology

Study Area

The study area is Ijebu North Local Government Area (INLGA) in Ogun State, Nigeria (figure 1). The reason for the choice of this area is that it is mainly rural. Apart from Ijebu Igbo (the headquarter), Ago-Iwoye and Oru other settlements within the local government area are rural both in terms of the population size and the availability of basic infrastructures. Also most of the settlements are not connected by motorable roads (see figure 1). This makes the local government area a good test case for examining strategy for rural road provision. The local government was established in 1979 and has it's headquarter in Ijebu Igbo at 6° 57′ N and 4° 00′ E. It has an area of 967 km^2 and a population of 284, 336 (2006 population census). The local government area is to the eastern part of Ogun state. INLGA is partitioned into eleven wards.

Currently the decision on which area of INLGA is to be provided with road is taken by the State Executive Council, headed by the state governor. The factors consider in deciding the settlement to be connected by motorable road are: the ruling political party policy on infrastructure provision, pressure by communities during political campaigns, strategic location of the settlement in contributing to the economy of the state, *etc*. After the decision on the rural settlement to be connected by motorable road is made, the State Ministry of Works then moves in to construct such a road.

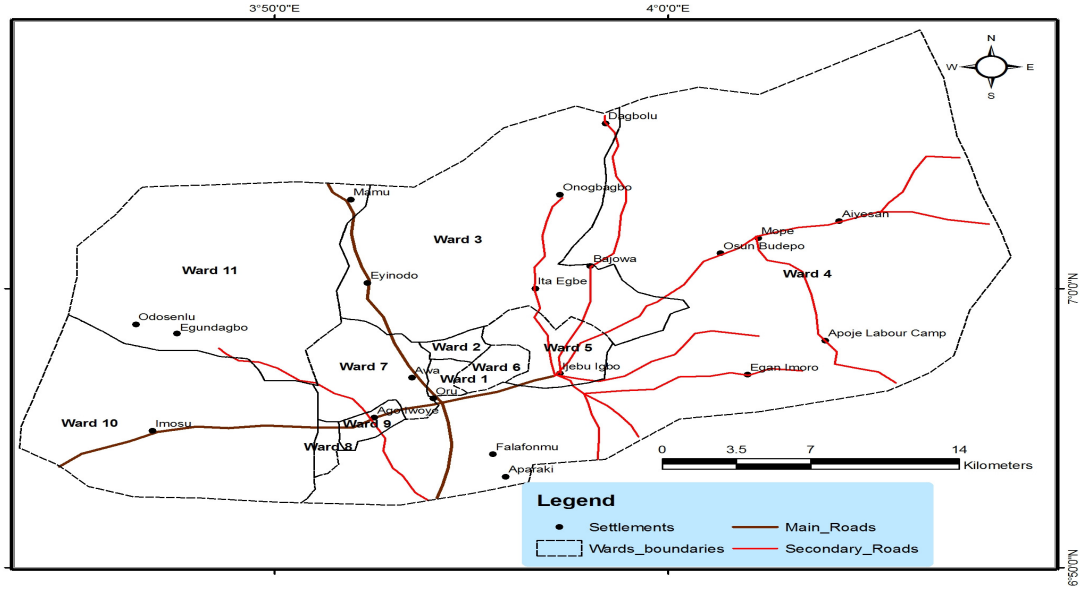

Figure 1: Ijebu North Local Government Area in Ogun State, Nigeria

Data for the Study

Data from primary and secondary sources were used for the study. The data on the four criteria used to assess the wards in the study area are from published sources and field observations. The primary data used are from the various interviews conducted with the stakeholders. The stakeholders include: the technocrats, the politicians and the representative of the people. Officers of the State Ministry of Works, Town Planning Department, and Works Department in the local government constitute the technocrats. They are included as stakeholders because they provide technical guidelines in the decision process on road provision and construction. The secretary to the local government (a political appointment) and the personal assistant to the speaker of the state house of assembly represented the politician. The politicians are considered as part of the stakeholders as they are to approve the resources for the provision of roads. Officers of Justice Development and Peace Commission, a non-governmental organization belonging to the Catholic Mission were selected as the representatives of the people. The representatives of the people are included as stakeholders as they stand for the people's needs and interest.

The four criteria used in the decision process to determine the ward to be provided with a rural road are: (i) population size of the wards; (ii) beta index – a measure of the connectivity of the existing roads within a ward; (iii) number of settlements already connected by roads within a ward and (iv) the amount of basic infrastructures. The population size is a major factor that is used in allocating resources among the federating units in Nigeria and is considered here. The other three factors or criteria in this study are considered as their inclusion is seen as being logical. As pointed out earlier, at the local level, political factor is often considered in public facility decision process. The decision process being proposed in this study will accommodate the political factor at the stage where inputs from the stake holders are used in the decision process.

Road connectivity – this has been measured using the beta index (a measure of network connectivity derived from a topological map). The number of settlements connected by road – this is a measure of settlements that are connected by either tarred road or untarred road as against those connected by foot paths only and the number of basic infrastructures – this is a measure of the presence of primary health facility, primary school and electricity in all the settlements in the eleven wards.

Nine (9) stakeholders from the representatives of the people, the politicians and the technocrats who were involved in the decision making process in the provision of rural roads in Ogun state were selected for interview and were asked to rate the decision criteria. Of the nine stakeholders, five are technocrats, two are politicians and two are representatives of the people. The technocrats are more in number because it is assumed that they are more knowledgeable on issues, factors or criteria pertaining to road provision.

The interview guide for the stakeholders was divided into two parts; sections A and B. Section A includes the attributes of the stakeholders and section B includes questions asking the stake holders to indicate their level of awareness of the issues bordering on multi criteria/ multiple

objectives in decision making in the provision of public facilities. They were also asked to rate the criteria used in the decision process. The map of Ijebu North Local Government Area of Ogun State containing the road networks and the location of the settlements has been used to compute the beta index (topological network analysis) and the number of settlements already connected by roads.

The steps involved in the application of the multi-criteria analysis

The steps involved in the application of the multi-criteria analysis to the decision process include:

The identification of alternatives to be considered and in this study they are the eleven wards in Ijebu North Local government area.

Choice of the criteria to be used to judge the alternatives. The four criteria used in this study include the population size, the level of connectivity of the roads, the number of settlements already connected by roads and the amount of basic infrastructure in the eleven wards.

Weights are assigned to the criteria by the stakeholders.

We then generate matrix of alternative plans, the set of criteria and the assigned weights

Build a concordance matrix

The row total of the concordance matrix yields index of preferability. The alternative with the highest index is the most preferred and is thus executed first.

Result and Discussion

The level of connectivity of the existing road networks in the eleven wards in Ijebu North Local Government Area is measured with the beta index. The beta index (β) is one way to measure road network connectivity under network topological analysis. This index shown in table 1 serves as one of the four criteria used in the decision process discussed in the next section.

Table1: The computed beta indices and the population size for the wards in Ijebu North Local Government Area

Wards	1	2	3	4	5	6	7	8	9	10	11
Beta index	1.2	1.1	1.1	1.1	1.5	1.2	1	1.2	0.9	1	1
Population size	13,432	11,329	1,149	6,524	16,626	23,538	11,445	18,795	10,833	2,132	2,712

It is shown in table1 that Ward 5 has the highest level of road network connectivity with the beta index of 1.5 and Ward 9 has the lowest level of road network connectivity with a beta index of 0.9. The distribution of the wards according to their population size is also shown in table 1. Ward-6 (Oke Sopin, Ijebu-Igbo) has the largest population size, while ward-3 (Osun) has the smallest size. The wards with larger population sizes are mainly urban.

Table 2 below shows the wards and the number of settlements that are connected by road and the basic infrastructures in the eleven wards. These are part of measures that are used to assess the wards in the decision process to select a ward for a new road construction.

Table 2: Number of settlements that are already connected by roads and the basic infrastructure available in the wards in Ijebu North Local Government Area

Wards	1	2	3	4	5	6	7	8	9	10	11
No. of settlements already connected by roads	1	2	3	21	1	1	4	2	5	1	3
Number of existing health facilities	1	2	1	6	1	1	2	2	3	0	3
Number of existing primary schools	1	2	3	7	1	1	4	3	4	4	5
Number of settlements with electricity	1	2	0	6	1	1	4	3	5	1	3

As shown in the table ward 4 has the largest number of settlements already connected by road. In ward-4 (Omen), there are 21 settlements already connected. The wards with the least number of settlements connected by roads are Ward-1, Ward-5, Ward-6 and Ward-10. However we need to point out here that some of these wards are mainly urban, as such they are counted as one settlement connected. This will give a lower value to such an urban ward in the final analysis compared to a purely rural ward. However, the focus of this work is actually on the application of multi criteria analysis in rural regions.

The basic facilities examined are electricity, primary health facilities and primary schools. Water, as a basic amenity has been deliberately left out because the exact data on where portable water is available is difficult to get. The number of the basic facilities in the eleven wards of the local government area under study is used as one of the criteria to assess the wards. This is based on the premise that the road which is our main concern is also regarded as a basic facility. In the process of evaluating the basic facilities as one of the criteria used in the decision process of selecting a ward for road construction, the presence or absence of such facility in a particular settlement has been recorded. The method is to allow us add together the data for the three facilities considered and thus arrive at a composite figure to represent all the three facilities. The composite figure has been used in the final analysis of the decision process.

Table 2 shows the wards and the number of existing health facilities. Ward-4 has the highest number of existing health facilities. In Ward-4, there are 6 health facilities with ward-10 having no health facility. As could be seen in table 2 ward-4 has seven primary schools which is the highest in the study area. As shown in table 2 ward-4 also has the highest number of settlements with electricity. In ward-4, there are 6 settlements with electricity while none of the settlements in ward-3 has electricity.

This study also used the analysis of variance to examine if all the eleven (11) wards in Ijebu North LGA are the same or different with respect to the four criteria taken together. The result generated using the *SPSS*, a statistical software, is presented in table 3.

Table 3: Analysis of variance test of the significance of the difference among the wards with respect to the criteria used in the group decision process

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F-value	Observed Significance Value
Between groups	956,913,119	3	318,971,039.8		
Within groups	519,712,474	40	12,992,811.84	24.55	0.0
Total	1,476,625,593	43			

As shown in the above table, the computed F^3_{40} = 24.55 and this value is significant at 5% level of significance as the observed significance value is 0.0. Hence, we conclude that there is a significant difference between the wards in terms of the criteria used in the decision process. On this note we can as well just construct the proposed road within the ward with the lowest score on all the criteria or factors. However, we need to note that the decision makers weighting or preferences for the different criteria count in the final decision process.

Application of the multi-criteria analysis in the process of selecting wards to be provided with a proposed rural road

In this section we are going to discuss the application of multi-criteria analysis in the process of selecting wards to be provided with rural roads. The choice process is characterised by a search for consensus or compromise solution among diverse interest groups. Table 4 shows the scores given to the four criteria by the three groups of stakeholders. For each criterion the scores of the nine stakeholders have been added together to give the total score and this total has been divided by nine (number of stakeholders) to give the average for each criteria. The weights for the four criteria are to add up to one (Massam, 1980) and as such the derived average scores were divided by one hundred to give the criteria weights. These criteria weights will be used in the impact or evaluation matrix to generate the concordance matrix.

The impact or evaluation matrix contains the evaluation of the eleven wards in Ijebu North Local Government Area based on the four chosen criteria. The eleven wards as contained in table 5 are compared in pairs using their performance on the criteria and the ward with the higher score is consequently allocated the criteria-weight (from table 4) for that criteria. The results of these pair wise comparison (concordance analysis) are entered in the concordance matrix.

Table 4: Scoring of the criteria by the stake holders and derivation of the weights

Sn.	Criteria	Stakeholders											
		1	2	3	4	5	6	7	8	9	Total score	Average score	Weight
1	Road connectivity (Measured by beta index)	20	25	35	25	22	20	30	20	29	226	25.11	0.251
2	Population size	30	25	25	40	30	45	30	35	32	292	32.44	0.324
3	Number of settlements already connected by roads	25	20	25	10	28	15	24	20	21	188	20.89	0.208
4	Basic infrastructures in the wards	25	30	15	25	20	20	16	25	18	194	21.55	0.215
	Total												1.0

Table 5: The impact or evaluation matrix used in the multi-criteria analysis

		Wards					
Sn	Criteria	1	2	3	4	5	6
1	Road connectivity measured by beta index	1.2	1.1	1.1	1.1	1.5	1.2
2	Population size	13,432	11,329	1,149	6,524	16,626	23,538
3	Number of settlements already connected by roads	1	2	3	21	1	1
4	Basic infrastructures in the wards	3	6	4	19	3	3

		Wards					Weight by
Sn	Criteria	7	8	9	10	11	stakeholders
1	Road connectivity measured by beta index	1	1.2	0.9	1	1	0.251
2	Population size	11,445	18,795	10,833	2,132	2,712	0.324
3	Number of settlements already connected by road	4	3	5	1	3	0.208
4	Basic infrastructures in the wards	10	8	12	5	11	0.215

We will now examine the concordance analysis that will enable us to generate the 'index of preferability' for determining the most preferred ward for the construction of the proposed road. As described briefly above the concordance analysis involved comparison of the eleven wards on the four criteria by taking them two at a time (pair wise comparison). On comparison, the ward with lower performance on a particular criteria is awarded the criteria weight (from the stake holders). For a pairwise comparison the weight across the criteria are added and are recorded in the concordance matrix in table 6. The row total of the concordance matrix yields the 'index of preferability' and the ward with the highest index is the most preferred for the construction of the proposed road.

Table 6: The full concordance matrix

	Wards											
Wards	1	2	3	4	5	6	7	8	9	10	11	Total
1		0.423	0.423	0.423	0.886	0.661	0.423	0.873	0.423	0.319	0.423	5.277
2	0.576		0.23	0.548	0.575	0.575	0.747	1	0.423	0	0.423	5.097
3	0.575	0.694		0.873	0.575	0.575	0.747	0.894	0.747	0.539	0.643	6.862
4	0.575	0.45	0.126		0.575	0.575	0.324	0	0.324	0	0	2.949
5	0.114	0.425	0.425	0.425		0.536	0.523	0.747	0.423	0.319	0.423	4.36
6	0.339	0.425	0.425	0.425	0.464		0.423	0.549	0.423	0.212	0.423	4.108
7	0.577	0.26	0.253	0.676	0.477	0.577		0.575	0.423	0.126	0.341	4.285
8	0.127	0	0.106	1	0.253	0.451	0.425		0.423	0	0.319	3.104
9	0.577	0.577	0.253	0.676	0.577	0.577	0.577	0.577		0.251	0.251	4.893
10	0.681	1	0.461	1	0.681	0.788	0.874	1	0.577		0.873	7.935
11	0.577	0.577	0.357	1	0.577	0.577	0.654	0.681	0.749	0.127		5.876

Note: Row is first in pair, column is second

Conclusion

The matrix in table 6 shows that the most preferred ward in Ijebu North Local Government Area for the construction of the proposed rural road is ward ten with the highest index of 7.94. An insight into the procedures used to arrive at a ward for the construction of the proposed road shows that the judgment of the stakeholders has been at play in the final selection of a ward for road construction. Thus the three groups of stakeholders (i.e. the technocrats, the politicians and the citizens (the users of the proposed road) have an input in the final selection and any envisaged conflict would have been taken care of. The decision process outlined in this study is supposed to be iterative. Where the outcome of the decision process is not acceptable to all the stakeholders, they can go back to review the weights attached to the factors. The ability of the multi-criteria analysis to handle situations involving many groups usually with different and conflicting opinions is making it to be relevant in application for resolving conflicting societal problems.

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