GIS a Tool for Transportation Infrastructure Planning in Ghana
A Case Study to the Department of Feeder Roads

Stephen Yao FIATORNU, Ghana

Key words:

SUMMARY

With the development of GIS technology, network transportation analysis within a GIS environment has become a common practice in many application areas.

The key problems in transportation network system analysis are the deterioration problem and insufficient maintenance policies put in place due to lack of funds for infrastructure maintenance policies put in place due to lack of funds for infrastructure. This demand for information requires new approaches in which data related to transportation network should be identified, collected, stored, retrieved, managed, analyzed, communicated and presented for the decision support system of the organization.

The adoption of newly emerging technologies such as Geographic Information System (GIS) can help to improved the decision making process in this area for better use of the available limited funds.

The paper thus reviews the suitability of Geographical Information System (GIS) which was used as a pilot phase project in the Northern Region of Ghana to improve the decision making process in this area for better use of the available limited funds.

The paper thus reviews the suitability of Geographical Information System (GIS) technology for managing the transport infrastructure in Ghana.

GIS a Tool for Transportation Infrastructure Planning in Ghana
A Case Study to the Department of Feeder Roads

Stephen Yao FIATORNU, Ghana

1. INTRODUCTION

Many development projects have serious dependence on transport network. Authentic information on the transport infrastructure is fundamental requirement for many decision making process; therefore information is required to be reliable, updated, relevant, easily accessible and affordable. Better information doesn't guarantee better decision-making capability but its absence precludes it. This demand for information requires new approaches in which data related to transportation network should be identified, collected, stored, retrieved, managed, analyzed, communicated and presented. The road transport related data in particular involves activities like traffic counting, sign inventories, accident investigation, recording of construction and maintenance projects and funding, right of way surveys, bridge inventories, pavement condition surveys, geometry design inventories, and other data collection and maintenance activities.

These activities are mostly uncoordinated within the organizations and across the organizational boundaries. Because of lack of co-ordination or of narrow concept of data use and application, data collected for one purpose is rarely usable for others. If two users need the same data or very similar data, the data is often collected twice. However, if the data is integrated properly by using the appropriate referencing system concept it can be put to maximum use for transportation as well as for many other purposes. Considering the complexities in developing, updating and processing of the transport related data and the declining trend in cost of data management and storage facility there is and urgent need to adopt new concepts and technologies for designing and developing the information resource management of transport infrastructure in the country. Therefore, the development in the field of information technology such as GIS Expert System and Database Management Systems are especially relevant to the field to transportation engineering.

1.1 Initial Problems Faced without the Usage of GIS

The database that existed before did not allow the user to manipulate, access, and query the database other than in a very limited way. The user is limited to textual queries only, the selection and viewing of crossing attribute data with respect to spatial and topological relationships is not possible. Over related data, such as land use, population, and the road network characteristics of the area in the crossings vicinity, cannot be accessed in the present database. The ability of GIS, along with the final presentation of results on a digital base map, will allow the user a better perception of the problem, enable better decisions, and allow a better understanding of what is to be achieved in a broader sense. The ability to define conditional queries, perform statistical analysis, create thematic maps, and provide charting by allowing for better understandability of the data.

2. GIS FOR TRANSPORTATION INFRASTRUCTURE PLANNING

The main advantage of using GIS is its ability to access and analyze spatially distributed data with respect to its actual spatial location overlaid on a base map of the area of coverage that allows analysis not possible with the other database management systems. The main benefit of using the GIS is not merely the user-friendly visual access and display, but also the spatial analysis capability and the applicability to apply standard GIS functionalities such as thematic mapping, charting, network-level analysis, simultaneous access to several layers of data and the overlayment of same, as well as the ability to interface with external programs and software for decision support, data management, and user-specific functions.

3. A CASE STUDY IN RELATIONSHIP TO DEPT OF FEEDER ROADS

- Road network in Ghana is more than 50,000km of road length
- The planning and management of such a huge network in the country has been primarily done at three levels
- About 13,367km of Trunk Roads
- About 4,029km of Urban Roads
- And about 32,600km of Feeder Roads

It really became a problem managing such roads, so a pilot phase project was put in place using GIS to see how effective this system would work for the decision making process of the Ministry. Many development projects have serious dependence on transport network. Authentic information on the transport infrastructure was fundamental requirement; therefore information required was to be reliable, updated, relevant, easily accessible and affordable for the decision making process of the Ministry.

ROAD SYSTEM OF GHANA	
TRUNK ROADS	**Length (Km)**
Rigid Pavement	38
Asphalt Surfaced	1,566
Bituninous Surfaced	4,733
Gravel	6,357
Missing Links	673
Total	13,367
URBAN ROADS	**Length(Km)**
Asphalt Surfaced	427
Bituninous Surfaced	1,496
Gravel	2,106
Total	4,029
FEEDER ROADS	**Length(Km)**
Gravel	32,600
Total	32,600
TOTAL LENGTH OF NETWORK	**49,996**

3.1 Purpose

The Purpose of this Pilot phase project Inventory was in three parts:

- Planning
- Management
- Engineering

4. SURVEY

The surveys were done in four parts which were:

- Desk Study / DFR Consultation
- District Consultation
- Field Survey
- Delivery the data.

4.1 Desk Study/ DFR Consultation

Our initials consultations with officials of Department of Feeder Roads focused on:

- Assemble all available data concerning the project and previous studies carried out by other consultants, and how relevant reports and documents could be accessed as well as other information from DFR headquarters and Regional Offices

- Maps prepared for the Department by Remote Sensing Unit of the University of Ghana, Legon. (CERSGIS Maps and other maps).
- Lists of Roads
- Lists of structures.

4.2 District Consultation

On the District level, various meetings and discussions were held with stakeholders comprising the Assemblies and other relevant agencies listed below that may be beneficiaries or may be affected in some way by the project implementation. The discussions held focused on the following:

- Safety and protection of the Environment
- Existing conditions and problems that was likely to be encountered.
- Our overall approach to the study
- Other matters were discussed.

4.3 Field Survey

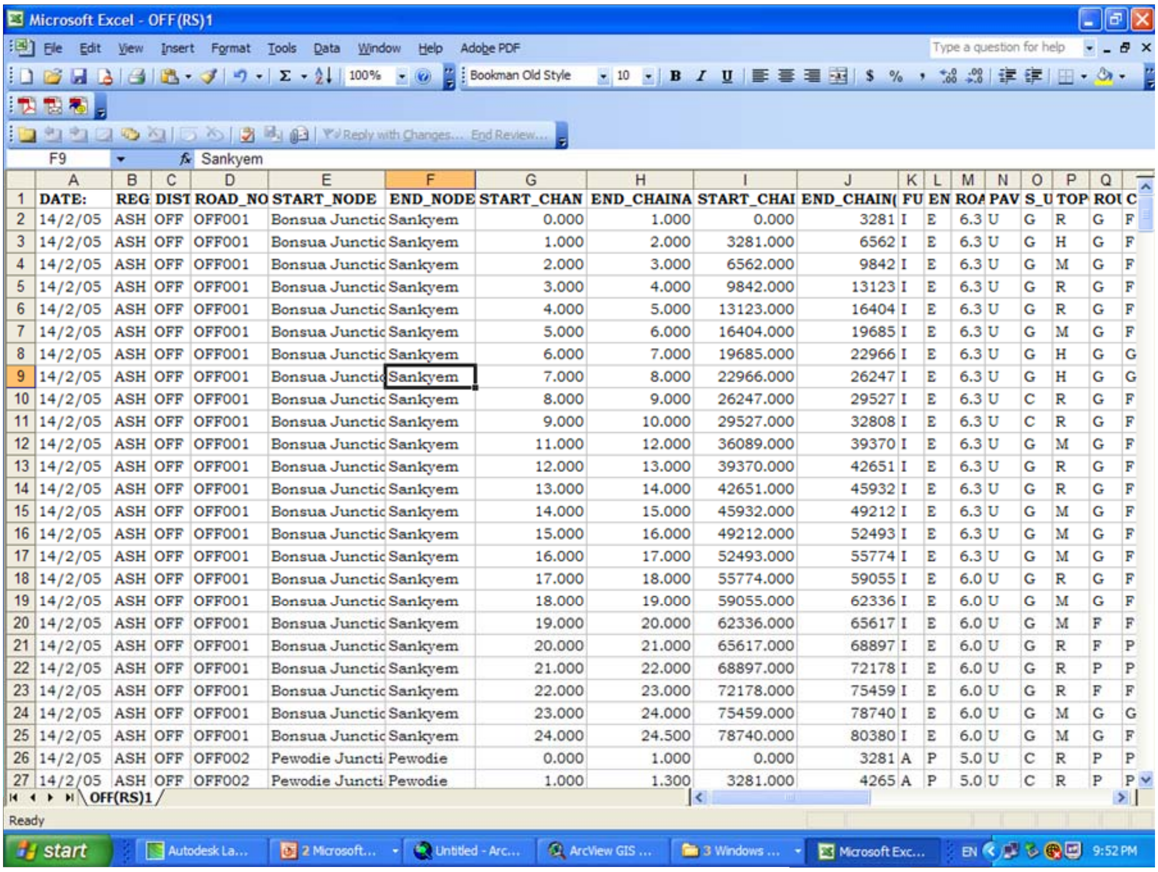
Prior to the study on field survey we did a field reconnaissance approach, basically driving and walking through the project area. Apart from the obvious observations in the project area, the reconnaissance provided us a rapid update of the existing conditions and the level of accessibility. We then adopted the system of GIS survey and then we paid special attention to the assessment of the geometric characteristics of the road alignment, profiles and typical cross-sections. We were able to structure our field survey in the following forms:

- Structures Survey Form SS1
- Road Survey Form RS1
- GPS Survey

4.3.1 Road Survey Form RS1

Columns

- Date- - District code- - Road Id- -Start Node Name-
- End Node Name- -Start Chainage- -End Chainage- -Functional Class I/C/A-
- Eng_Class E/P/N- -Road Width- - Pavement P/U- -Surface R/G/S/C-
- Topography- -Roughness G/F/P- - Camber G/F/P- -Drainage G/F/P-
- -Traffic H/M/L- -Notes-



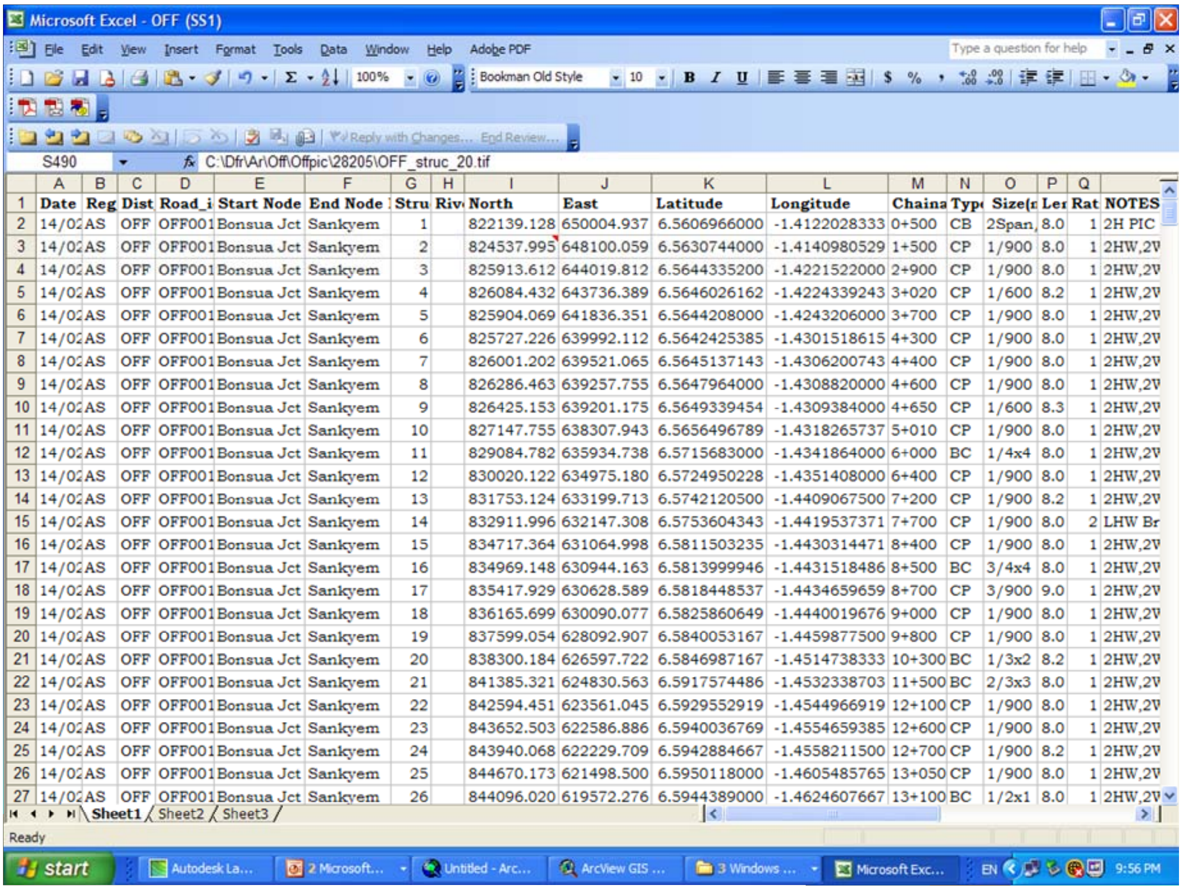
DATE:	REG	DIST	ROAD_NO	START_NODE	END_NODE	START_CHAN	END_CHAINA	START_CHAI	END_CHAIN(	FU	EN	ROA	PAV	S_U	TOP	ROU	C
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	0.000	1.000	0.000	3281	I	E	6.3	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	1.000	2.000	3281.000	6562	I	E	6.3	U	G	H	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	2.000	3.000	6562.000	9842	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	3.000	4.000	9842.000	13123	I	E	6.3	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	4.000	5.000	13123.000	16404	I	E	6.3	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	5.000	6.000	16404.000	19685	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	6.000	7.000	19685.000	22966	I	E	6.3	U	G	H	G	G
14/2/05	ASH	OFF	OFF001	Bonsua Juncti	Sankyem	7.000	8.000	22966.000	26247	I	E	6.3	U	G	H	G	G
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	8.000	9.000	26247.000	29527	I	E	6.3	U	C	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	9.000	10.000	29527.000	32808	I	E	6.3	U	C	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	11.000	12.000	36089.000	39370	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	12.000	13.000	39370.000	42651	I	E	6.3	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	13.000	14.000	42651.000	45932	I	E	6.3	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	14.000	15.000	45932.000	49212	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	15.000	16.000	49212.000	52493	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	16.000	17.000	52493.000	55774	I	E	6.3	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	17.000	18.000	55774.000	59055	I	E	6.0	U	G	R	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	18.000	19.000	59055.000	62336	I	E	6.0	U	G	M	G	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	19.000	20.000	62336.000	65617	I	E	6.0	U	G	M	F	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	20.000	21.000	65617.000	68897	I	E	6.0	U	G	R	F	P
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	21.000	22.000	68897.000	72178	I	E	6.0	U	G	R	P	P
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	22.000	23.000	72178.000	75459	I	E	6.0	U	G	R	F	F
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	23.000	24.000	75459.000	78740	I	E	6.0	U	G	M	G	G
14/2/05	ASH	OFF	OFF001	Bonsua Junctic	Sankyem	24.000	24.500	78740.000	80380	I	E	6.0	U	G	M	G	F
14/2/05	ASH	OFF	OFF002	Pewodie Juncti	Pewodie	0.000	1.000	0.000	3281	A	P	5.0	U	C	R	P	P
14/2/05	ASH	OFF	OFF002	Pewodie Juncti	Pewodie	1.000	1.300	3281.000	4265	A	P	5.0	U	C	R	P	P

Fig 1: Copy of road Inventory form (RS1)

4.3.2 Structures Survey Form SS1

Columns

- Date -District Code- -Road No- -Start Node Name-
- -End Node Name- -Structure No- -River Name- -GPS Northings-
- -GPS Eastings- -Chainage (km+m)- -Structure Type (eg. BC,SB,CP)-
- -Size (mm)- -Length (M)- -Condition Rating (1-5)- -Notes-



Microsoft Excel - OFF (SS1)

S490 | C:\Dfr\Ar\Off\Offpic\28205\OFF_struc_20.tif

	Date	Reg	Dist	Road_i	Start Node	End Node	Stru	Riv	North	East	Latitude	Longitude	Chaina	Typ	Size(r	Ler	Rat	NOTES
2	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	1		822139.128	650004.937	6.5606966000	-1.4122028333	0+500	CB	2Span,	8.0	1	2H PIC
3	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	2		824537.995	648100.059	6.5630744000	-1.4140980529	1+500	CP	1/900	8.0	1	2HW,2V
4	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	3		825913.612	644019.812	6.5644335200	-1.4221522000	2+900	CP	1/900	8.0	1	2HW,2V
5	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	4		826084.432	643736.389	6.5646026162	-1.4224339243	3+020	CP	1/600	8.2	1	2HW,2V
6	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	5		825904.069	641836.351	6.5644208000	-1.4243206000	3+700	CP	1/900	8.0	1	2HW,2V
7	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	6		825727.226	639992.112	6.5642425385	-1.4301518615	4+300	CP	1/900	8.0	1	2HW,2V
8	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	7		826001.202	639521.065	6.5645137143	-1.4306200743	4+400	CP	1/900	8.0	1	2HW,2V
9	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	8		826286.463	639257.755	6.5647964000	-1.4308820000	4+600	CP	1/900	8.0	1	2HW,2V
10	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	9		826425.153	639201.175	6.5649339454	-1.4309384000	4+650	CP	1/600	8.3	1	2HW,2V
11	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	10		827147.755	638307.943	6.5656496789	-1.4318265737	5+010	CP	1/900	8.0	1	2HW,2V
12	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	11		829084.782	635934.738	6.5715683000	-1.4341864000	6+000	BC	1/4x4	8.0	1	2HW,2V
13	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	12		830020.122	634975.180	6.5724950228	-1.4351408000	6+400	CP	1/900	8.0	1	2HW,2V
14	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	13		831753.124	633199.713	6.5742120500	-1.4409067500	7+200	CP	1/900	8.2	1	2HW,2V
15	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	14		832911.996	632147.308	6.5753604343	-1.4419537371	7+700	CP	1/900	8.0	2	LHW Br
16	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	15		834717.364	631064.998	6.5811503235	-1.4430314471	8+400	CP	1/900	8.0	1	2HW,2V
17	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	16		834969.148	630944.163	6.5813999946	-1.4431518486	8+500	BC	3/4x4	8.0	1	2HW,2V
18	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	17		835417.929	630628.589	6.5818448537	-1.4434659659	8+700	CP	3/900	9.0	1	2HW,2V
19	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	18		836165.699	630090.077	6.5825860649	-1.4440019676	9+000	CP	1/900	8.0	1	2HW,2V
20	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	19		837599.054	628092.907	6.5840053167	-1.4459877500	9+800	CP	1/900	8.0	1	2HW,2V
21	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	20		838300.184	626597.722	6.5846987167	-1.4514738333	10+300	BC	1/3x2	8.2	1	2HW,2V
22	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	21		841385.321	624830.563	6.5917574486	-1.4532338703	11+500	BC	2/3x3	8.0	1	2HW,2V
23	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	22		842594.451	623561.045	6.5929552919	-1.4544966919	12+100	CP	1/900	8.0	1	2HW,2V
24	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	23		843652.503	622586.886	6.5940036769	-1.4554659385	12+600	CP	1/900	8.0	1	2HW,2V
25	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	24		843940.068	622229.709	6.5942884667	-1.4558211500	12+700	CP	1/900	8.2	1	2HW,2V
26	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	25		844670.173	621498.500	6.5950118000	-1.4605485765	13+050	CP	1/900	8.0	1	2HW,2V
27	14/02	AS	OFF	OFF001	Bonsua Jct	Sankyem	26		844096.020	619572.276	6.5944389000	-1.4624607667	13+100	BC	1/2x1	8.0	1	2HW,2V

Sheet1 / Sheet2 / Sheet3

Fig 2: Copy of Structure Condition form (SS1)

4.4 Delivering the Data

From the road inventory survey, a GIS database was established to document the existing conditions along the road which were in the following forms:

- Structures list (Form SS1)
- Detailed roads list (Form RS1)
- Nodes table
- Road Definition table
- Shape file
- GIS Map

4.5 Practical GPS Exercise

Fig. 3: Survey carried out using Toyota Pickup and connected GPS at the back using a four wheel

Fig. 4: Survey carried out using a motorbike and bag packed GPS using two axles due to inaccessibility of four wheels

Fig 5: Accessing broken culvert on the road

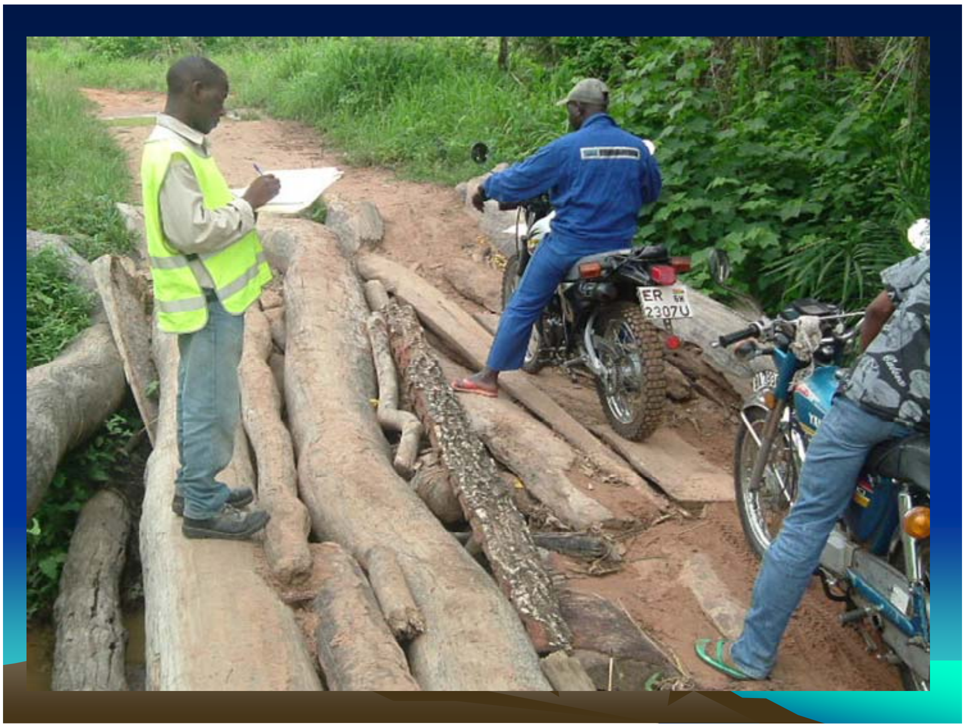


Fig. 6: Filling in of the Road Inventory and Condition Survey Form

4.6 GIS Map

For the purpose of identifying and classifying, the following functions were used:

- Basic functions (editing, display, measurements)
- Overlay.
- Create Polylines to Polylines M.
- Dynamic segmentation
- Raster display and analysis
- Surface modeling.
- Links to other software.

4.7 Overlay

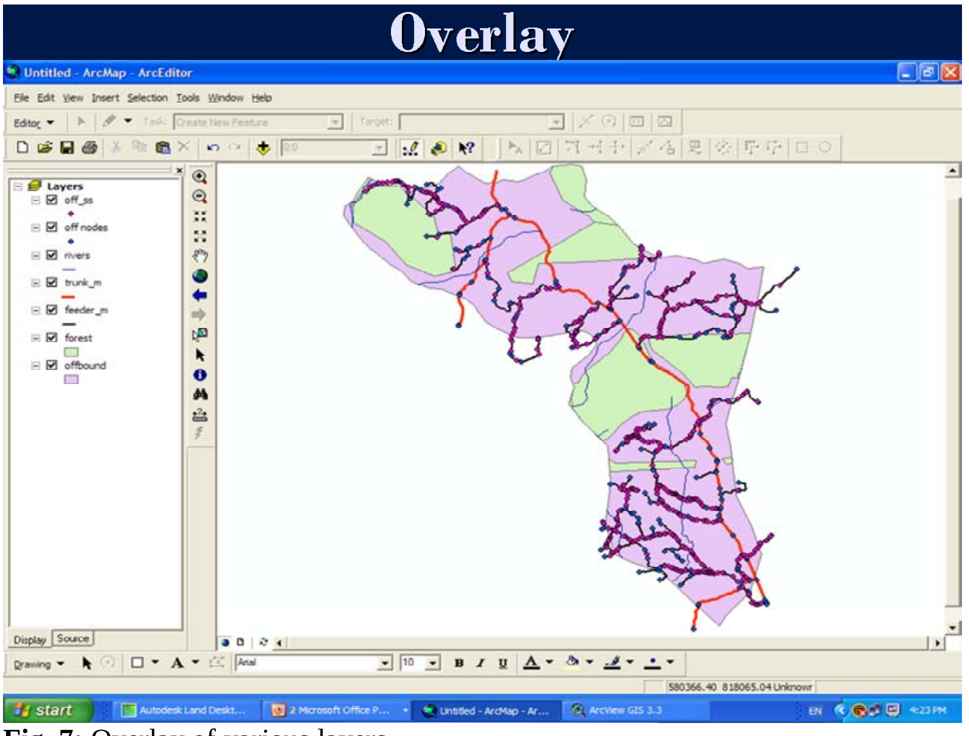


Fig. 7: Overlay of various layers

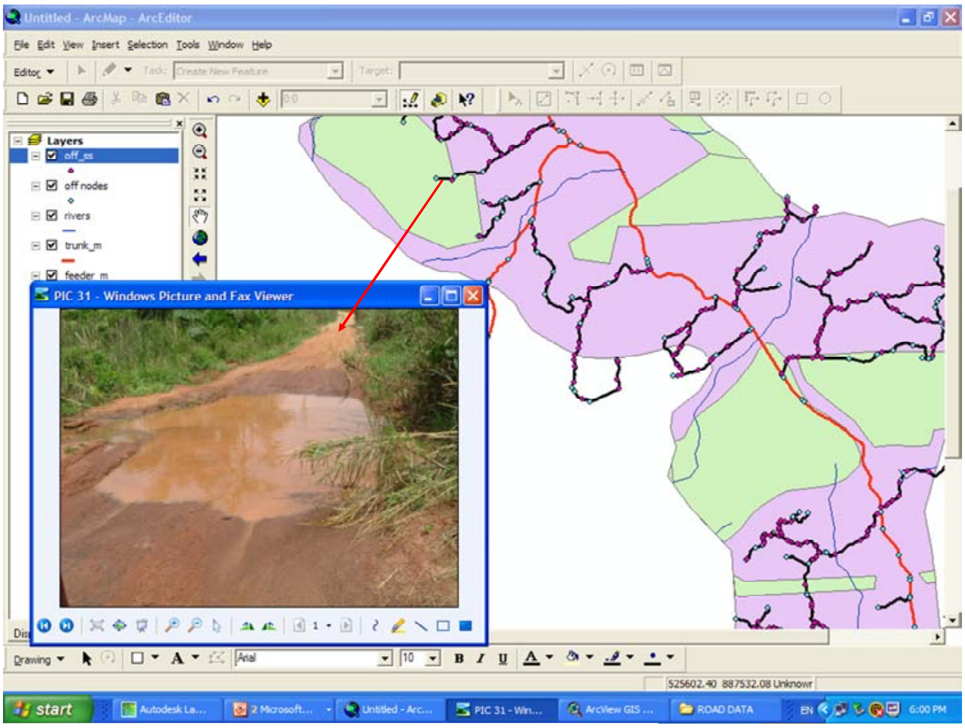


Fig. 8: Road Inventory data linked up with its picture

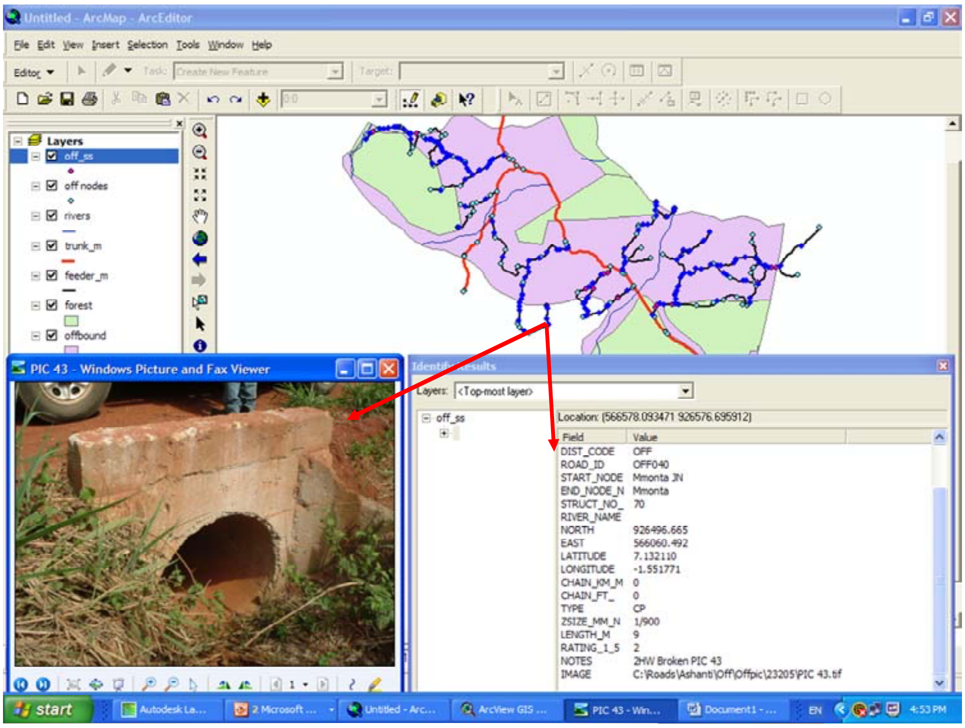


Fig 9: Structure Condition data linked up with its picture

4.8 Dynamic Segmentation

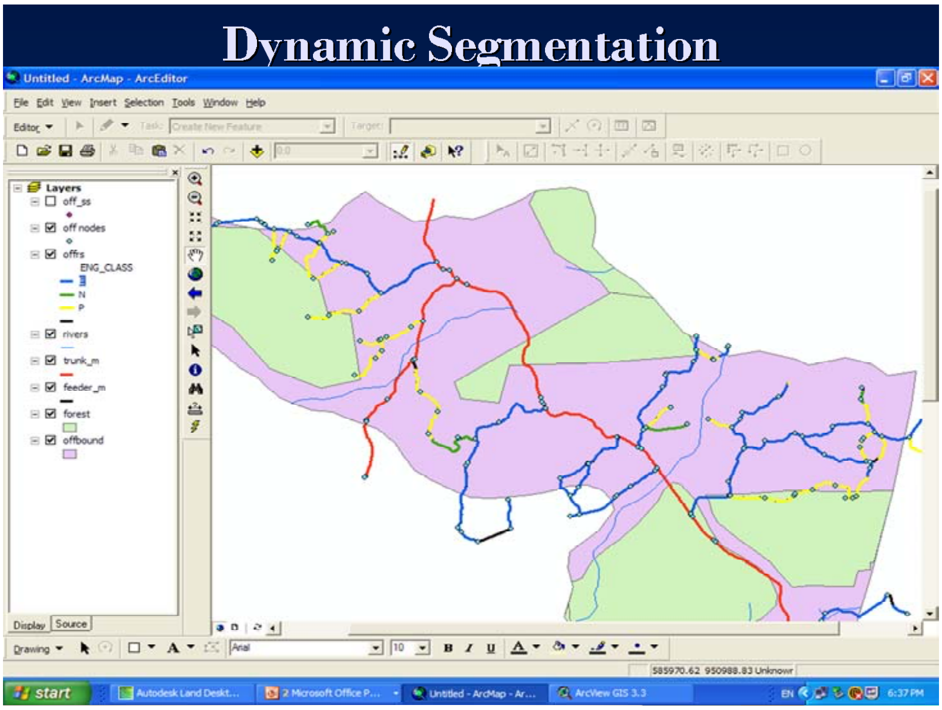


Fig. 10: Dynamic Segmentation generated to accesses Engineered, Unengineered and Partial engineered roads

5. THE WAY FORWARD

5.1 Updating

The developed database can be further supplemented with new information as and when it is available. So, the database keeps on evolving, which is otherwise not possible to compile at one time. The topological information available in GIS database opens the new ways for analyzing the transportation related data for different purposes. Various GIS functionality, the spatial analysis functions and querying capability, are very useful tools for the day-to-day management of the road network by the government of Ghana.

5.2 Engineering

Engineering applications are required which is a relationship between Planning and Management review cycles.

5.2.1 <u>Pavement Management System</u>

GIS is a logical approach for managing the road network in Ghana, thereby analysis of pavement section descriptions and pavement deficiencies collected in pavement condition surveys could be maintained by location.

Also the distribution of maintenance and resurfacing funds may be made on the basis of lane kilometers in a geographic area and corresponding pavement condition ratings. Pavement Management System based on GIS will thus make more equitable distribution of funds and a more visual medium for making such policy decisions.

5.2.2 Bridge & Culvert Maintenance

A major benefits derived from GIS use in Ghana will be in obtaining bridge & culvert information through general query capability. Example includes bridge & culvert condition surveys, sufficiency ratings, functionally deficient bridges & culverts, posted capacity distribution, clearness etc. Through relational database, bridge & culvert maintenance engineers could access important information like average daily traffic, as well as system and functional classification from planning and research maps.

5.2.3 Traffic Engineering

- Congestion management systems using GIS can start with the highway base maps and attribute databases used for long range transportation planning in urban areas.

- These regional base maps will provide the framework for identifying and monitoring congestion in real time in critical corridors from a regional perspective.

5.2.4 Safety Management

The analysis of accident data coupled with roadway features and characteristics, traffic volumes, bridge inventory and other data and the geographical presentation of this information in GIS environments will be very useful to develop safety management system.

Inventory files such as traffic signals, narrow bridges and railroad crossings could be analyzed more efficiently using GIS.

6. CONCLUSION

GIS have come to stay and there is no doubt that is a an efficient and effective tool in the Transportation Infrastructure Planning of the transport industry .There is an urgent need to organize the existing database compatible to GIS environment and suggest various other new data items, which are considered useful for better planning and management.

If GIS technology is exploited to its fullest extent in Ghana it will completely revolutionize the decision making process in transportation engineering. The huge amount of information related to transport infrastructure in Ghana could be put together for its most efficient utilization in planning, design, construction, maintenance and management of the transport system.

BIOGRAPHICAL NOTES

Stephen Yao Fiatornu has over nine years experience in various aspects of Geodetic, Mining and various Engineering works and over five years experience in all aspects of Integrated Map and Geo-information Production. His areas of specialization include ground control survey, road survey, route location, and GIS Standard Facility Development. Mr. Fiatornu is an expert in Geographic Information Systems and serves as a consultant to a number of firms undertaking GPS related Surveys including Geotech Engineering, Mobitel, Tarkwa Mines, Bogoso Gold Ltd, Town and Country Planning, Feeder Roads Department and Survey Department. His in-depth knowledge in Geographic Information System is an asset in helping some companies, district assemblies and chiefs in their efficient execution of all aspects with regard to revenue generation. He has worked extensively in Ivory Coast and Senegal helping client to develop GIS Database. His involvement in assisting the Feeder Roads in their Pilot Roads Inventory in the Northern Region has added value to the GIS section.
Mr. Fiatornu serves as a resource person for seminars focused on imparting knowledge on modern trends. He is currently the head of GIS/GPS section of Geo-Tech Systems Limited.

CONTACTS

Stephen Yao Fiatornu
Head GPS/GIS Section
GEO-TECH SYSTEMS LIMITED
P. O. BOX 14727
27 Samora Machel Road
Asylum Down
Accra
GHANA
Tel. + 233 21 245945 / 226049