A WEBGIS APPLICATION FOR THE MANAGEMENT OF THE ETHIOPIAN ROAD NETWORK SYSTEM

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ABSTRACT

A well maintained database system for the Ethiopian roads network would play a significant role in the road maintenance, traffic safety, mobility management, environmental and socio-economic planning, etc. This paper addresses the design and development of software system called Ethiopian Roads Network Information System (ERNIS). ERNIS is a web application which incorporates geographical information (WebGIS) that is used for gathering, updating and working with the national roads network data for Ethiopia. Using this system, road agencies and other stakeholders can add new road data in the system, update existing roads information, and investigate the maintenance and other requirements of road networks, etc. by remotely accessing the central database through a web browser. Geographical Information System (GIS) data of the roads' physical location, the towns each pass through, the rivers they cross, location of bridges on the road and other geographical features accompany each road segment data. The development of ERNIS followed the model-view-controller (MVC) framework and it was implemented using open source components for the various parts of the system. The system has been configured at the School of Civil and Environmental Engineering and in the Office of the Road Fund. It was tested and is found to be functional that requires populating it by appropriate data, which would be the next step.

Key words: *Road Network, ERNIS, WebGIS, Open-Source, OpenLayers, Web Application, GeoServer*

INTRODUCTION

The roads infrastructure is an important part of a country's economy and the social wellbeing of its population. Ethiopia's roads network is estimated to be 85,966 km with a density of 78.20 km per 1000 people [1,2,3]. Some of these roads are part of the "Trans-African-Highways" [4], showing further significance of the roads network for the cross-border transportation. Though exact figures could not be obtained, a significant addition to the network has been made in recent years through various government initiated programs.

A well-functioning digital roads network data on all levels of the country's roads is a basis for having an intelligent system with regard to road maintenance, traffic safety, mobility management, environmental and socio-economic planning and many other issues. This kind of standardized, updatable and quality-assured digital road network data does not exist in Ethiopia. With the complexity of road maintenance and traffic safety management tasks as well as the rising number of newly constructed roads nationwide, it is high time that such a centralized roads database information system is developed and utilized.

This paper presents the details of a project undertaken to develop a web application for the capturing and processing of roads-network and related information in Ethiopia.

THE ETHIOPIAN ROAD NETWORK INFORMATION SYSTEM

The Office of the Road Fund (ORF) is responsible for the financing of road maintenance works and road safety measures of all roads in Ethiopia. ORF manages the budget allocation and checks for the proper utilization of the allocated fund.

The existing working situation within ORF is, however, handled manually except for some digital documentation using Excel and Word. There is no organized road network database and recording system for road inventory and maintenance. Keeping proper road section and road network database, road condition data, maintenance history, budget information and so forth are not systematically organized and computerized. The office has no well-developed mechanism to check and ensure the proper utilization and fair distribution of budgets among regions. It has no ways to prove that maintenance programs have been prepared based on reasonable and justifiable priority among roads and sections.

In order to have reliable road network data under different jurisdictions and evaluate the proper

utilization of funding, the ORF has identified the need for the development of Ethiopian roads network database system and consequently involved the School of Civil and Environmental Engineering of the Addis Ababa University. The first phase of this project is the development of Ethiopian Roads Network Information System (ERNIS), a software system that enables to capture, store, analyze and display all possible road segment related data in Ethiopia. The author is part of the team formed for this purpose and leads the design and development of the software system in this project.

ANALYSIS, DESIGN AND DEVELOPMENT

System Architecture and Functionalities

A thorough review of the requirements of the ORF led to the use of a web application for ERNIS in which users can access and update (if privileged) the information stored in the database system by using web-browsers and visiting the designated ERNIS website (see Fig. 1). Thus, users of the system are not required to install any kind of software apart from having an up-to-date web browser and an internet connection.

ERNIS is designed to be composed of a number of autonomous components, each of which is required for manipulating a specific aspect of the system database. One of the components is the "access control sub-component" that provides system users to have differing capabilities and rights. For example, selected staff of the ORF may have full access to the system. With this privilege, one can designate other users of the system and perform any modifications or additions to the existing data. Selected staff of Road Agencies, on the other hand, will have rights to add or update road segment information within their jurisdiction. Still other registered users from the public may have read-only access to some of the data in the system.

Figure 1 System Architecture of ERNIS

Other components are also designed to manage separate information related to each Road Segment including the geometry, pavement, road-condition, road-maintenance, traffic, terrain and surrounding climate data.

Furthermore, GIS data of the roads' physical location, the towns each pass through, the rivers they cross and other geographical features are designed and implemented, so that associated digital map could be displayed for each road segment selected. Road GIS data have been gathered from various local and international sources including the United States Geological Survey (USGS) [5] and Google Maps [6].

In order to avoid software license related costs from the project, a design decision was also made to employ appropriate free and open-source software components in the development and implementation of ERNIS.

Database Design and Implementation

The data structure of ERNIS is organized in forty four different tables to capture all possible attributes associated with each road. Table 1 shows the "Road Segment" table, the one containing the basic data of a road-segment such as its start and end nodes, length, construction date, class and standard, construction cost, etc.

Table 1: The Road-Segment Table

Attribute	Data Type	KEY	Comment
roadId	char (20)	primary key	Road ID
roadName	char (50)		Road name
urbanRurl	list		Where the road segment is located (Urban/Intercity)
Zone	char (20)		Location
Wereda	char (20)		Location
startNode	integer	foreign key	Start Node ID
endNode	integer	foreign key	End Node ID
startChainage	double		Start chainage
Length	double		Length
constructionDate	Date		Date of construction (in dd-mm-yyyy format, Eth. calendar)
functionClass	list		Functional Classification (Trunk, Link, Main Access, Collector, Feeder, Unclassified)
designStandard	list		Design standard (DS1-DS10) & Unclassified
Surface	list		Road Surfacing (Asphalt Concrete, Surface Treatment, cement concrete, brick, coble stone, Gravel, Earth)
laneCount	integer		No. of lanes
bridgeCount	integer		No of bridge structures
culvertCount	integer		No of culvert structures
Financer	char (20)		Construction Financer
Consultant	char (20)		Design Consultant
Contractor	char (20)		Contractor
Supervisor	char (20)		Supervisor
constType	list		Construction Type (Labour Based/Machine Intensive)
Cost	double		Construction Cost (Birr)
History	text		Short History (If any)

The national, regional and city road agencies identified as the primary users of the system and programmed in the current implementation of ERNIS are depicted in Table 2.

Table 2: Road Agencies Table

Agency		Key	Agency		Key
National	ERA	ERA	City Road Agencies	Addis Ababa	AACRA
				Diredawa	DDCRA
Regional Road Agencies	Afar	AFRRA		Adama	ADCRA
	Amhara	AMRRA		Awasa	AWCRA
	Benshangul	BGRRA		Bahrdar	BDCRA
	Gambela	GMRRA		Gondar	GNCRA
	Hareri	HARRA		Harar	HACRA
	Oromiya	ORRRA		Jimma	JMCRA
	SNNP	SNRRA		Kombolcha	KOCRA
	Somale	SMRRA		Mekele	MKCRA
	Tigray	TGRRA		Shashamane	SHCRA

The ERNIS data structure is implemented in the open source database management system called PostgreSQL[7]. Together with the software component that adds support for geographical objects (PostGIS), PostgreSQL is found to be the appropriate choice for the development of such a web application which incorporates geographical features (WebGIS)[8].

The ERNIS database tables and their relationships are created using the Structured Query Language (SQL); few SQL statements to create some of the ERNIS database tables and Type is shown in Fig. 2 as a sample.

```
/* Road agencies table */
CREATE TABLE road_agencies (id serial NOT NULL primary key,
                        agency char (6) unique,
                        region char (30),
                        agency_type char (20),
                        full_name char (50));
/* ERNIS users table */
CREATE TABLE users (id serial NOT NULL primary key,
                        first_name char(20),
                        last_name char(20),
                        organization char(50),
                        telno char(20),
                        email char(20),
                        user_name char(15),
                        password char(100),
                        remark character(255),
                        agency char (6)  references road_agencies (agency) on
                                        update cascade);
/* Design standards as a list of Characters */
CREATE TYPE designS AS ENUM ('DS1', 'DS2', 'DS3', 'DS4', 'DS5', 'DS6',
                        'DS7', 'DS8', 'DS9','DS10', 'Unclassified');
```

Figure 2 Typical SQL-Statement for ERNIS database

Model – View – Controller

The Model-View-Controller (MVC) framework is a software architecture used in general to separate the data and its presentation for complex web applications, thereby simplifying the development process. The major parts of the software components of ERNIS are development using the MVC programming paradigm, since it enables the clear separation as well as a very good organization of the final software system. The model components represent the database objects, the view components represent what would be presented on the user interface and the controller components are the server side programs responsible for fetching database information and taking care of user actions on the system, i.e, updating the model and/or view components based on the user action, deciding which alternative method of road maintenance is the best option, etc [10]. All programs are developed using the open source general-purpose scripting language that is especially suited for web development (PHP) [9].

WebGIS Implementation

WebGIS is a web-based Geographical Information System that enables to distribute interactive maps via the Internet. Users can handle the maps using a web browser to change the scale, contents and extent of a displayed map.

The map produced by a WebGIS allows the distant user to:

- control display settings (zoom & panning),
- find the position (coordinates) and the meaning of the displayed objects (legend),
- query the map and the database (query),
- combine data from separate sources at different scale and detail, etc.

A number of well-established commercial WebGIS solutions exist in the market [12, 13]. However, the open-source solution known as GeoServer [11] has been adopted for the implementation of the WebGIS solution in ERNIS. GeoServer is an open source software server that allows users to share and edit geospatial data. Designed for

interoperability, it publishes data from any major spatial data source using open standards. GeoServer uses the OpenLayers [openlayers] JavaScript library for displaying map data in web browsers which provides interfaces for building web-based geographic applications similar to Google Maps.

ERNIS USER INTERFACES

The ERNIS user interface is designed and developed as the View component of the MVC framework implemented, and it has the hierarchy shown in Fig. 3.

– Home page
  |– *Login*
    |– *Register*
– Select and View a Road Segment
    |– *Edit a Road Segment*
    |– *Add Road Segment to this Agency*
    – *List Road Segments of this Agency*
  |– View Geometry Data Summary
    |– *View, Edit and Add Horizontal Alignment*
    |– *View, Edit and Add Vertical Alignment*
    |– *View, Edit and Add Cross Section*
    – *View, Edit and Add Earth Work*
  |– View Condition Data Summary
    |– *View, Edit and Add Condition Data*
    |– *View, Edit and Add Paved Road Conditions*
    – *View, Edit and Add Unpaved Road Conditions*
  |– View Climate & Terrain Data Summary
    |– *View, Edit and Add Climate Data*
    – *View, Edit and Add Terrain*
  |– View Maintenance Data Summary
    |– *View, Edit and Add Maintenance Data*
    |– *View, Edit and Add Paved Road Maintenances*
    |– *View, Edit and Add Unpaved Road Maintenances*
    – *View, Edit and Add Maintenance History*
  |– View Pavement Data Summary
    |– *View, Edit and Add Base course Data*
    |– *View, Edit and Add Subbase Data*
    |– *View, Edit and Add Subgrade Data*
    |– *View, Edit and Add Asphalt Surface Data*
    |– *View, Edit and Add Capping Layer Data*
    |– *View, Edit and Add Asphalt Concrete Data*
    |– *View, Edit and Add Asphalt Fine Aggregate Data*
    |– *View, Edit and Add Asphalt Coarse Aggregate Data*
    |– *View, Edit and Add Asphalt Combined Aggregate Data*
    – *View, Edit and Add Asphalt Mineral Filler Data*
  |– View Drainage Structures Data Summary
    |– *View, Edit and Add Cross Drainage Structures Data*
    – *View, Edit and Add Ditches Data*
  |– View Traffic and Road Furniture Data Summary
    |– *View, Edit and Add Traffic Accidents Data*
    |– *View, Edit and Add Accident Severity Data*
    |– *View, Edit and Add Axel Load Data*
    |– *View, Edit and Add Traffic Volume Data*
    – *View, Edit and Add Road Furniture Data*

Figure 3 Hierarchy of User Interfaces

The main webpage of ERNIS is depicted in Fig. 4. It contains all the links to access the various components of the system. The links could only be activated after user login to the system and authentication is completed.

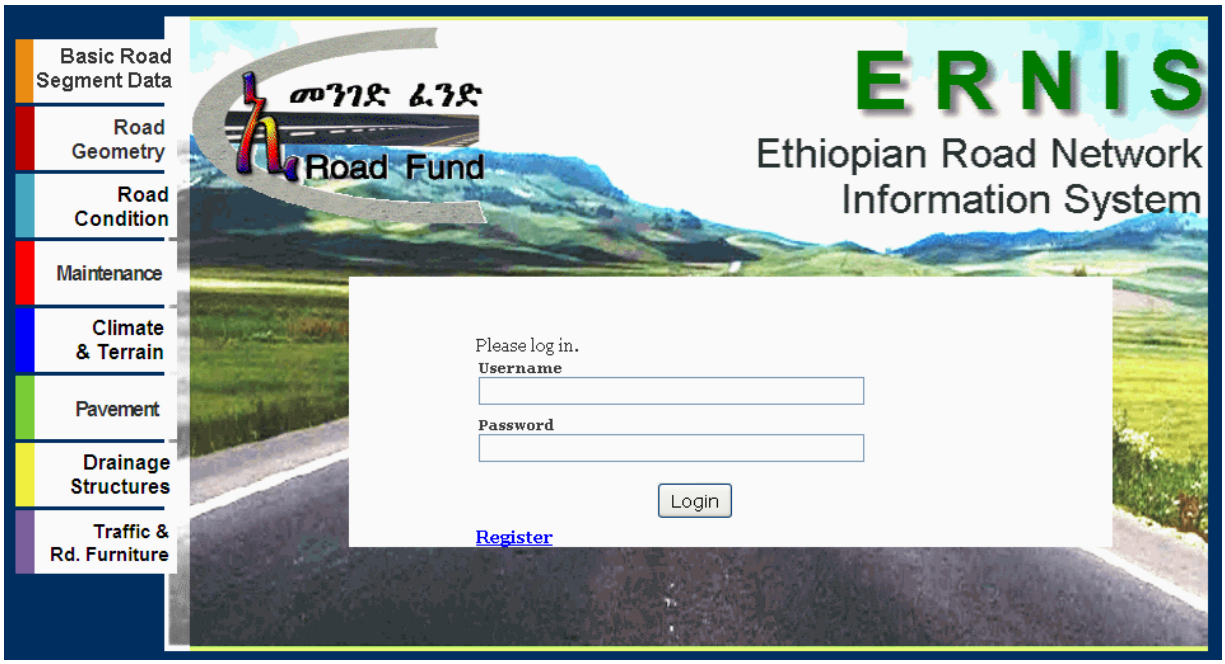

Figure 4 Front page of ERNIS & the Login Screen

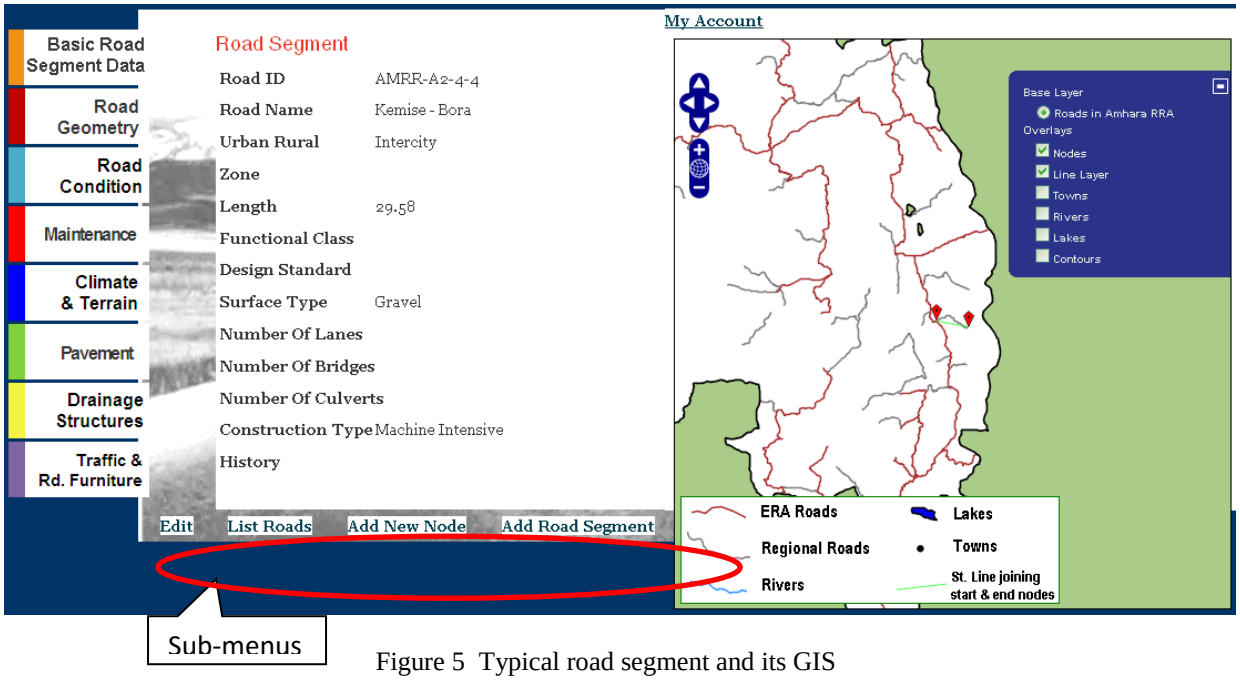

Figure 5 Typical road segment and its GIS

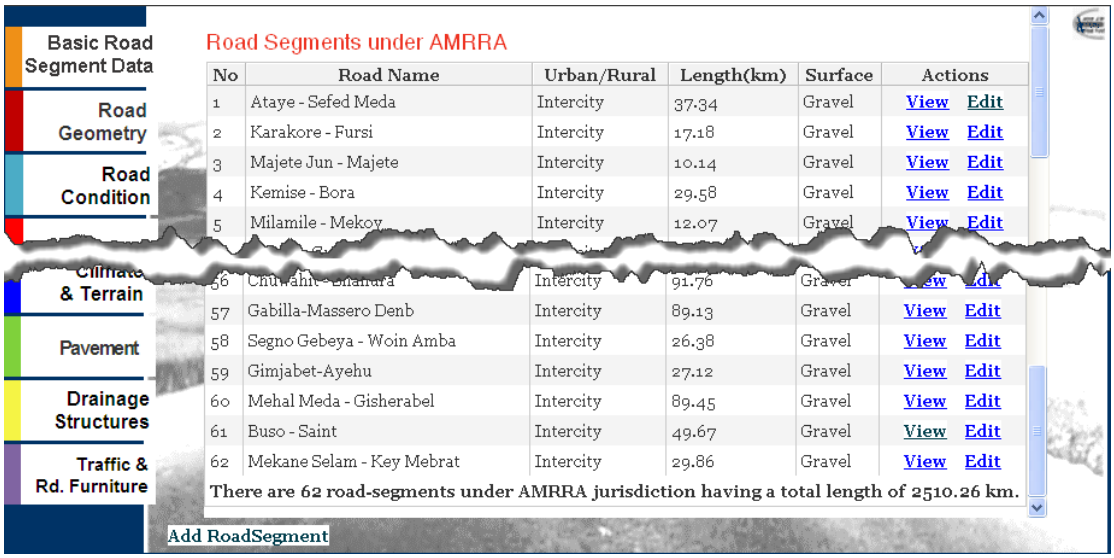

Figure 6 List of roads under a given Roads Authority

CONCLUSION AND RECOMMENDATION

A WebGIS application called ERNIS has been designed and developed for collecting, updating and working with the nation's roads network data. The user interfaces that are developed enable users to seamlessly communicate with the system.

Data collection and updating of ERNIS at the national level is resource intensive in nature. Hence, it is recommended that this task is conducted by dividing the national network into different zones and involving road agencies and possibly universities in the regions, under the coordination and supervision of the ORF.

With the understanding that the roads infrastructure of a country is the backbone of its economy and the social wellbeing of its citizens in general, and noting the magnitude of public investment made in the road sector of Ethiopia in the past decade or so in particular, it is believed that the presented software will play a crucial role in roads data acquisition, data analysis, policy making and policy implementation.

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