

Road Condition Quality Management for Smart Transportation: The Power of GIS

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Abstract

In this century engineers, managers, and decision makers are overwhelmed with statistical data for interpretation of road condition for planning purposes. With new development and recording of digital geospatial data acquired from various geometric-GIS have been a useful tool for data manipulation; it simplifies the way data are visualized and interpreted direct. On the other hand, one of the most important issues on smart transportation is to have a passable road. In order to implement smart transport system, the data in the form of Geographical Information Systems (GIS) is essential. This paper discusses the simplified approach used by Tanzania National Roads Agency (TANROADS) to convert the non-special data collected many years back into Geodatabase to achieve a cost-effective GIS solution. The result was an integrated GIS system for visualization of Roads network and assist in data interpretation and planning. In this way different data such as condition data sets collected in different times were analyzed in GIS to assist decision makers identify part of the network that need attention. The output was used for Quality Assurance of the data including for instance identification of sections with no survey information. Other information such as sections with poor, fair and good condition could be easily identified and this information may be used for different purposes. It is recommended that road implementers may use this method and available non special data to come up with up with cost effective GIS systems for road asset planning and investment decisions.

Keywords: Geospatial data on road management; Web GIS for condition data; data quality management; Smart Road Technology; Road asset management.

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1. Introduction

The modernized smart infrastructure is essential in the arena of city planners to develop more effective highway transportation. It is claimed by [1] that Internet of Things technologies make it possible to develop the smart city roads which easy traffic data become a golden tool in analyzing an environment for installation of smart technologies. The database technology used in TANROADS cannot support multi access and therefore cannot support geodatabase. The data collection for long term planning of transportation. The uses of Geospatial current setting support disjointed GIS; that is, it is not real-time support update on the database to be reflected on GIS directly. Each time the database is updated you need to create a GIS shape file and open using GIS software to reflect the changes in a map. This study provides the solution for the fore mentioned problem.

To start thinking of smart roads the smart Infrastructure must exist first. To have such a smart infrastructure you need to have quality and reliable data collected smartly. GIS is the most prominent tool to assist planers in analyzing road data. Nowadays, public and private agencies have always tried to maintain their infrastructure assets in a good and serviceable condition at a minimum cost [2]. Many factors influence the decision on making road transportation smart. These include serviceability of the existing road assets, availability of funding and design structure of the road. For road infrastructure to be smart, you need to ensure not only the pass-ability of the roads but also road condition in totality as well as prioritization of maintenance and funding [3], [4]. The management decisions on what assets to maintain and when to maintain them should rely on quality and reliable data collection. Widely road assets data has been presented in statistical format or contextual manner making a narrow visualization of the pattern of where things are on the road section. With GIS road assert such as culvert and bridges condition can easily be visualized and associated with maintenance strategy in the decision [5], [6]. GIS can be used to analyze data on axle loading, economic value, road population, and tourism as well as road classification. The GIS delivers powerful spatial analytics, allowing you to discover patterns and gain intelligence to better understand travel behaviors and perform accident analysis [7], [8]. GIS has been widely considered to handle such a diverse range of geospatial data and nowadays it is the game of data visualization for busy planners [9], [10].

Both statistical for economical analysis and GIS tool once well-integrated help decision-makers find the optimum distribution of resources for cost-effectively in maintaining the infrastructure systems [2], [6], [11]. It is a fact that the disjoint database working in a standalone framework cannot be of much help in this arena of Big data. The GIS developer passive that the database should have powerful engine to run GIS information. However, it is claimed by [12] that even MS Access database should be integrated with GIS application to enable management of the roads attribute information. Most common attributes include bridge, roads maintenance of objects, accident, evaluation and classification of object and communication on the roads.

It is claimed in [13], [14] that the road infrastructure management should provide complete life cycle coverage, starting with planning and continuing until replacement or reconstruction. Many studies show that transportation planning is a complex process that carefully requires forecasting of future needs and the study of existing travel patterns in cities [11], [15], [16]. Such a situation forces the developer to innovate on updating their toolkit to accommodate planning.

Therefore, to be of more meaningful roads information from the database should be integrated with the GIS system to yield more intelligence in pavement management.

Railway and highway bridges are an important part of the land transport infrastructure [17]. They represent a major investment for society and an important part of that investment goes to inspection and maintenance [18]. Knowing exactly railway crossing, Road junctions, bridges location, type and size, and even culverts on GIS data can efficiently increase automation and facilitate implementation of smart road technology. Nevertheless, understanding traffic volume is a key for pavement design. With smart road technology safety levels in bridges, junctions, and culvert size are expected to be higher in smart roads than in other parts of the land transport infrastructure. This comes naturally because a failure of a bridge or culvert could have severe consequences in material damage and human lives [19]. As critical assets of the road networks, special attention has been given to bridge structures as well as junctions/intersections where more crushing occurs [19], [20].

Traffic volume on roads not only affects pavement design and road accident but also causes environmental pollution. It is observed in [1] that with IoT sensors, cameras, and radar, data can be analyzed in near real-time and used to improve congested roadways, streamlining traffic flow. Likewise, Data can also be sent to the cloud for long-term analysis, providing critical insight for efforts such as reducing CO2 emissions or improving road conditions. It is also noted in [21] that rapids expansion of the road networks is considered the major factor affecting sustainable development in many countries. Conversely improvement of roads in urban area is the catalyst in increasing automobile manufacturing, vehicle ownership, expansion of road network, and social interaction.

It is concluded in [22]-[24] that road network affects social networking and interaction, while social life is widely affected by transportation facility available in the cities. Other studies also conclude the same that the expansion of road transportation results in the increase of vehicle ownership, energy use, and higher emission levels, increasing congestion, ever more complex and intrusive road networks, a vehicle-based society, and inefficient usage of available resources [25]-[27]. The use of GIS in such situation is unavoidable. It is observed by [25]-[28] that GIS has thus focused on three main goals: acquiring geographic information, studying geo-objects and their relationships, and exploring advanced geographic rules that determine planners' spatiotemporal behavior.

1.1 The role of GIS system in building smart road infrastructure

GIS is a computer system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data related to positions on the Earth's surface [29]. GIS has been recognized as an important tool for geospatial data application decision support and planning analysis [30], [31]. Since maps can make better understanding compared with a verbal sentence or statistical data, GIS provides great capacity for applications about geospatial data [30], [31]. Nevertheless, GIS can be used as a tool in both problems solving and decision-making processes, as well as for the visualization of data in a spatial environment [32]. On the other hand, geospatial data can be analyzed to determine the location of features and relationships to other features, knowing where the most and/or least of some feature exists, Measuring the density of features in a given space, understanding what is happening inside an area of interest and what is happening nearby some feature or phenomenon, and classifying on how a specific area has changed over time and in

what way [12], [33], [34]. GIS application appears to be a rational choice for the manipulation and analysis of transportation infrastructure information [2]. This technology can be used in different areas such as scientific investigation, disaster management, traffic management, resource management, environmental impact assessment, asset management, cartography, archaeology, infrastructure management marketing, urban planning, public health and epidemiology, defense, airline route planning, and many other areas. GIS has become more popular in transport engineering. A more comprehensive pavement management models require a diverse collection of road-related data, which can only be achieved with GIS [35]. Furthermore, GIS can also vastly improve the quality of the Decision-making process by allowing better coordination of maintenance and Rehabilitation activities of different infrastructure assets [2]. Apart from that, the GIS-based system can offer the best understanding of pavement design, in terms of improved management of the road transport network and infrastructure [36]. To arrive at Smart Road, planners need to have a systematic process for site identification, and the deployment of treatments based on sound research rather than opinion-based infrastructure development [37].

1.2 Smrt roads infrastructure

It is argued by [38]-[40] that Smart roads use the IoT devices to make driving safer, more efficient, and in line with government objectives. Smart roads combine physical infrastructures such as sensors and solar panels with software infrastructure like AI and big data.

The study by [41], [42] show that, smart road technologies embedded in roads can improve visibility, generate energy, communicate with autonomous and connected vehicles, monitor road conditions, and more. Furthermore, the study by [42] show that Smart roads will bring about greater automation, higher energy efficiency, lower cost, improved public safety, cleaner air, a greener environment, less traffic congestion, fewer accidents and fatalities, and hence improve the overall quality of lives of city residents.

It is claimed in [41] that smart road phenomenon will no longer be viewed as static infrastructures but rather an 'intelligent grid', fully aware of the situation, context, and the environment. Smart roads will also be 'end-to-end', meaning it will not only benefit the city residents but also the city leaders and operators [43]. It is asserted by [42], [43] that with the improvement of technology residents will be able to interact with the smart transport entity through their mobile phones while city operators will be able to monitor traffic and environmental conditions remotely but attentively, responding promptly on a demand.

It is predicted by [43] that as smart roads progress towards realization, more research and development efforts will be needed in the area of personal mobile, and software applications to help citizens realize the full benefits of future smart transport. As shown in Fig. 1, the future will have a greater inter-mix and embedment of ICT and transportation. Therefore, pavement management decisions need to integrate diverse spatially referenced data, including condition surveys, construction history, skid resistance measurements, traffic counts, and construction and maintenance records [12].

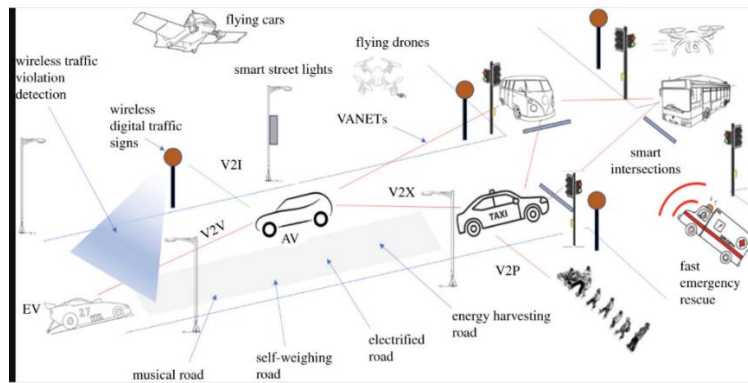


Fig. 1. Future of smart transportation source: [43].

1.3 Core value of web-based GIS

The development of internet technology makes it possible for data communication between the Web servers and client [31]. Web and the GIS are ever-evolving technologies and embrace the great potential for public use, allowing wider involvement in environmental decision-making [7]. The information can be shared and transferred from one place to another around the globe with users making choices for access to geography-related information. The integration of GIS and the internet further makes the geospatial information be in touch by users at anytime and anywhere [44].

It is stated in [2] that the distributed nature of the infrastructure asset also makes infrastructure management an excellent ground for the use of emerging Web-based information technologies. These technologies allow efficient inputting, accessing, and analyzing of information remotely from geographically distant locations. Currently, several applications have been developed based on GIS technology for the management of traffic, road conditions, and environment and safety data [45]. Web Based GIS applications are tools that allow users to control, interact, evaluate, keep, manage and exhibit all kinds of geo-spatial data, as well as edit data through the web map and operations outcome visualization [46], [47].

According to IGI Globle [48] “Web-based GIS is based on a type of distributed information. This set of technological services is part of a communication structure between the GIS server and the client. Their relationship is expressed through URLs and HTTP. Spatial data access, advanced mapping, and spatial analysis are the most common type of analysis options in Web-based GIS”. A Web Based GIS Should be able to carry out any task that a standalone desktop GIS application can do, but should be accessed remotely through the web [49]. Most current Web-GIS applications are focused on environmental studies with fewer applications on infrastructure monitoring and management [31]. Web GIS application plays an important role in environmental monitoring, bridge management, and public administration since it provides GIS functionality through the Web. It also helps timely maintenance for an appropriate bridge since it allows the responsible authority to access and visualize bridge conditions distantly and effectively [50], [51].

The GIS delivers powerful spatial analytics, allowing the authorities to discover patterns and gain intelligence to better understand travel behaviors and perform accident analysis. It can significantly directly or indirectly reduce the number of accidents on roads. It brings intelligence in planning, proper selection of pavement, innovation in maintenance,

increasing safety, and other road assets [8], [52]-[54]. Similarly, Smart Road Technology aims at improving transportation, health vitality, and living standards.

In order to arrive at good planning, selection of pavement type, improved safety and decide on maintenance strategy [12], [55]. The pavement management needs to integrate diverse spatially referenced data including surveys, construction history, skid resistance measurements, traffic counts, and construction and maintenance records [12]. The contribution of this paper is found on the methodology of converting non special database into geodatabase.

2. The Approach in Integrating the Roadmentor With GIS System

The TANROADS Road network database, popularly known as the Roads Maintenance Management System (RMMS) has been developed many years ago when the GIS technology was not much being used. Initially the database was targeted for storing the road network data and use it for maintenance planning and programming. Currently, although the system continues to maintain the same functionality it is being used for diverse applications other than maintenance planning and programming. The system is also being used for investment planning and it has been integrated with other decision support tools such as Highway Development and Management too (HDM-4) for long planning of road maintenance. The current RMMS system have been integrated with GIS using an interface (GeoGIS) that connect to the RMMS and convert any set of selected data into a shape file that can be opened and viewed using standard GIS software. The challenge with this integration is that it is not real-time. Each time the RMMS database is updated you need to create a GIS shape file and open using GIS software in order to reflect the changes in a map. This process is a bit lengthy, though it serves the purpose of mapping. To alleviate this TANROADS team of Roads Management Systems formed team of experts in cooperation with RMMS Software Programmer to investigate and implemented the more effective system of integrating RMMS database with GIS. The adopted process enable viewing the RMMS data in a GIS map directly from the RMMS database and perform all GIS analysis using GIS application using data from the RMMS database. This enables the GIS view to be updated simultaneously as the database is being updated. The process involved converting the RMMS which was non special database into Geodatabase while maintaining format of the RMMS database.

2.1 Methodology for converting the RMMS database into Geodatabase

The GeoDatabase is any database with special representation capability. The GeoDatabase can show its features in GIS maps and the map is updated as you update the database. The RMMS database was integrated with GIS through the GeoGIS interface. The challenge with this integration is that it is not real-time. Each time the RMMS database is updated you need to create a GIS shapefile and open using GIS software to reflect the changes in a map. This process is a bit long, though it serves the purpose of mapping. To alleviate this, multi-disciplinary effort was required. The TANROADS formed a team of experts in cooperation with RMMS Software Programmer to investigate and implement the more effective system of integrating the RMMS database with GIS. The adopted process enabled viewing the RMMS data in a GIS map directly from the RMMS database. The process involved converting the RMMS, which was a nonspecial database into a personal GeoDatabase while maintaining the format of the RMMS database. We took advantage of the GeoGIS interface for creating the shape file of the entire network and convert the shapefile into feature class directly.

The Geodatabase is any database with special representation capability. The Geodatabase has ability to show its features in GIS maps and the map is updated as you update the database. The conversion must ensure that all roads and road sections are correctly defining, coded (numbered) in the non-special database (RMMS). The conversion of RMMS into Geo Database involves three steps and that are as follows:

- Create the shape file of all the roads sections using any appropriate means including digitizing, using GIS interfaces, etc.
- Create route layer of roads/sections in Arc GIS
- Convert route layer back RMMS Database and restore relational database capabilities with other non-special tables of the RMMS.

The advantages are taken of the GeoGIS interface for creating the shape file of the entire network. The Arc GIS was then used to convert the shape file into feature class. The process is summarized in Figs. 2,3, and 4 and are summarized as follows:

- Use Arc Catalogue to create a Personal database called Roadmentor.mdb (The main RMMS database)
- Import the Feature class in Personal database as feature class (multiple). The feature class referred here is the shape file for all roads here it is called (HighwayOrdnance)
- In Arc Map Create Route (Linear Referencing>Create Route) from the shape file, i.e HighwayOrdnance for RMMS Geodatabase.

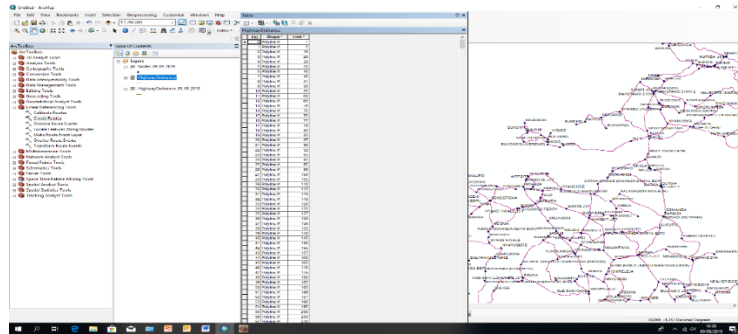


Fig. 2. Route layer highway ordnance.

- Reconstruct the routing table (HighwayOrdnance) in Roadmentor.mdb to include all fields of the standard HighwayOrdnance table.

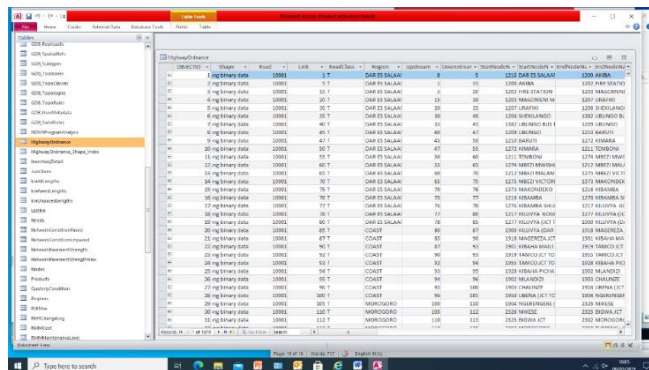


Fig. 3. Rebuilding of new database.

- Showing other features of the database along with the route file

The final physical database design of the RMMS specified the changes in database attributes that require both relational database and GeoDatabase retrieval. In the case of RMMS, others data except nodes were shown as route events along the route line with the link used as Route Identifier. The event was shown for instance as located **FROM.... N TO....M** along the link route that is linear feature, or as a point feature using a distance from the start of the link or by coordinates. This requires modification of the existing tables to contain the fields that will store the additional featured required by arc Map data for each data row. For the case of RMMS, among others, the highway ordnance tables were modified to include fields to facilitate locating features along the line highway ordnance route. This effect required the modification of the following object inventory details, network condition paved and unpaved, bridges culvert, junction, and nodes.

- Adding other base map layers to make the map presentable

The final base layer was added to the highway ordnance. The resulting map after showing other route events and adding base map layers looks as shown below.

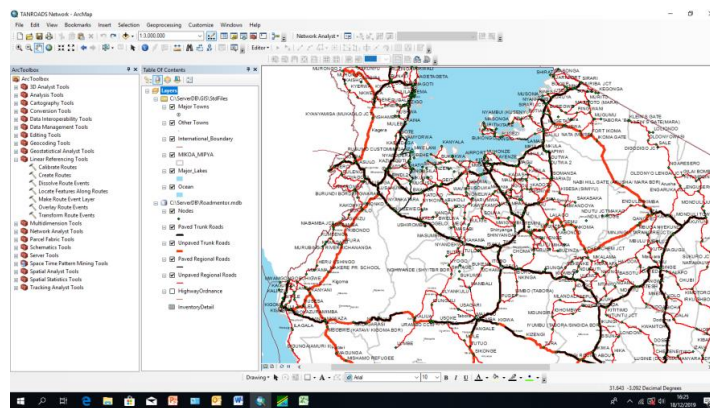


Fig. 4. Adding the base layer.

2.2 Prototyping with WeBGIS

Until to date, the RMMS system uses a jet engine that cannot allow multi-user interaction. Therefore, the change of backbone database becomes necessary to allow Web GIS. In the prototype of web server GeoServer with PostGreGIS were configured. The GeoServer is an open-source platform for publishing spatial data and interactive mapping applications. It was used as a spatial data server. It allows to creates map images from spatial information stored in digital format. It can handle both vector and raster data. GeoServer renders map tiles according to specifications provided by the Web Map Service protocol.

When a layer is configured in GeoServer, its data such as images for the map are saved using what's called the URL endpoint. It's a link for where the application requests the images and creates the map. The server takes care of it and makes the visual information available via that endpoint.

2.3 Mapping technology

Mapping technology is the most important part of every web-based GIS application, which allows displaying data in the form of maps [56]. There are three ways in which visualization functionality is implemented; static map renderers, slippy maps, and flash mapping. The slippy mapping technique was used because it can provide dynamic and interactive maps. Slippy maps are faster to load because they can load up only the tiles that a user wants to see, while static maps load all the tiles at once [56]. Therefore, the lippy mapping technique can minimize computational time, processing power, and memory resources.

3. Results and Discussion

3.1 Status of road network and inventory

The national road covers almost 36,257.97 km where the paved road is about 10,666 (29.42 %) and the unpaved road is 25,591 (70.58%) as shown in Fig. 5. However, according to the RMMS data set, the development trends in the last three years, that is June 2018 to September 2020, indicate that the paved road increased by 8.27 % while the unpaved road decreased by 3.08% national wise. Fig. 6 shows GIS for the Inventory network. The inventory details indicate that about 10,155 km is a bituminous road while 24, 718km is Gravel Road and about 1419 km is earth road.



Fig. 5. Paved and unpaved road network.

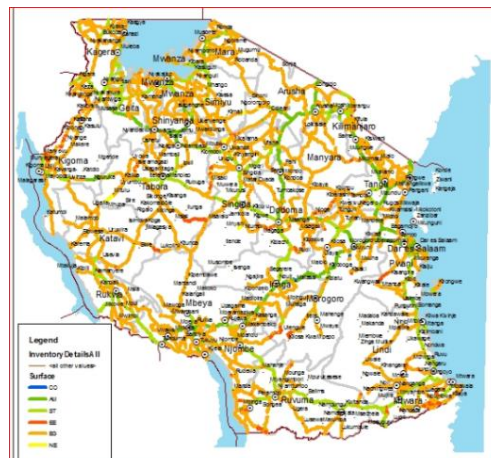


Fig. 6. Inventory road network.

It is observed in Fig. 7 that paved roads increase by 8.27% while unpaved roads decrease by 3.08%. The decrease of the unpaved road is estimated at $y = 407.6x + 26839$ while the increase is estimated at $y = 407.6x + 9418$.

The above status of road development is common to many developing countries. The same situation is noted by [12] and it is claimed that even in the capital city, not all roads are paved and some paved one are not in good condition. Paved road network sometimes remains unchanged in length or surface for two or more decades while vehicle fleet are double, population are tripled and human activity is highly increased. It is common in developing country to found many parts of the road to have poor condition with extensive cracking, potholes, bleeding, and rutting. Nevertheless, lacks of intelligence in annual maintenance strategy results in permanent surface water as a result there is a widespread loss of grilles coverage drains, leading to blockage of the drains themselves. In such a situation GIS tool for intelligence in decision-making for pavement is avoidable.

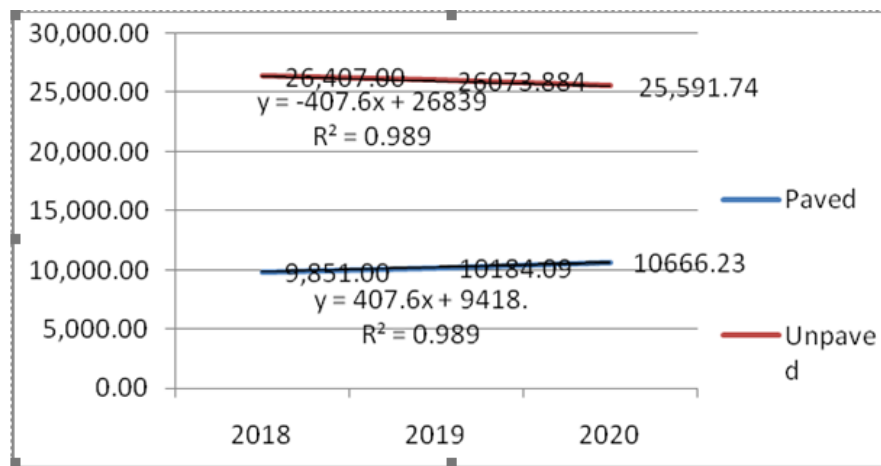


Fig. 7. Road network growth in 2018-2020.

3.2 Discover patterns and gain intelligence using GIS

The below is the status of the condition of the unpaved road of Singida and Dar es Salaam as of September 2020. From Fig. 8 it is observed in Singida region that most of the unpaved roads, which were surveyed in 2019/2020, were in fair condition, few kilometers were in good condition, and poor condition scattered around the network. The same is observed in Dar es salaam region in Fig. 9. With the map in Fig. 10, it is easier to identify other features like AADT, ESAL, culverts size and position, skid resistance measurement, work history, committed road section, and all inventory features of the road section. With the support of GIS visualization planners can reduce the challenges of ascertaining smart roads in a road section. However, sections of unpaved roads with good and fair conditions may suit some future of Smart Roads. GIS analytics can help the manager to identify the pattern in the road network and gain intelligence in the plan for smart road technology. The essence of GIS, in this case, is to identify that section with a recent survey to allow decision on the area that needs maintenance. With the constrained budget, the planner can have a narrow decision on which area to inject money and which in particular can remain on a waiting list.



Fig. 8. GIS for singida unpaved road network.



Fig. 9. GIS for Dar es salaam unpaved network condition.

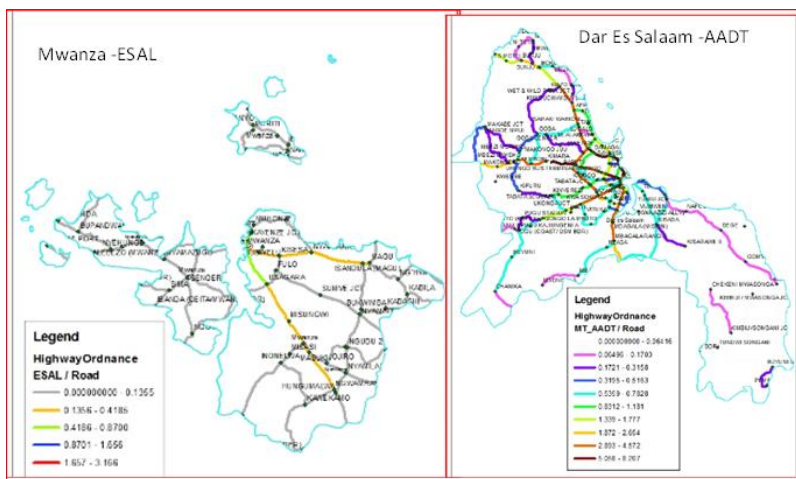


Fig. 10. ESAL data in Mwanza and traffic volume in Dar es Salam.

Fig. 10 indicates the Map of Mwanza and Dar es salam. The Map designate use of GIS to discover a pattern of AADT in and ESAL data. The Annual Average Daily Traffic (AADT) is a measure used primarily in transportation planning, transportation engineering, and retail location selection. Traditionally, it is the total volume of vehicle traffic or road for a year divided by 365 days. It is a standard measurement for vehicle traffic load on a section of road, and the basis for most decisions regarding transport planning, or to the environmental hazards of pollution related to road transport. One of the most important uses of AADT is to decide on structural design aproprite for road section. In that sense, the road section with higher traffic volume may be suitable for the installation of smart road technology. With RMMS, the GIS planner was able to visualize areas with a higher volume of traffic during planning. The AADT is a source of computing equivalent to single axle load (ESAL) which saves the purpose of establishing a damaged relationship for comparing the effect of exle carrying different loads. The author advocate that pavement management decisions need to integrate diverse special referenced data, including past and current condition survey, works history, committed works, Annual daily traffic, road age of deterioration, as well as ongoing works on the roads. GIS Technology offers an appropriate tool to handle such kind of information. New Geo Database allows dynamic changes of the data and reflects the changes on the map immediately making the system to be of more user-friendly and allows in-time decision-making process. AADT contributed much on arriving at economic factors and such contributed requires focuses on the survey data processing to determine Cost-effective maintenance and planning to reduce traffic collision.

The magnitude of traffic accidents is very high in some parts of Africa. Smart technology for roads with wireless digital traffic signs and roads that detect traffic violations can save people's lives not only on paved roads but also on unpaved roads too. It is observed by [57] [57] that road traffic collisions, which include an incident with pedestrians, vehicles, and animals, are currently the eight bigger killers in the world. The reports by [57] indicate that many as 14 million people are killed every year about one every 23 seconds while another 20 m to 50 m are injured but survive, often with the life-changing disability. Many countries need strategies to reduce the number of road traffic-related collisions in the community save lives by responding better to collisions when they occur, and enable people who have been affected by road traffic-related trauma to cover and continues living healthy and productive lives. The current installation of the loop counter in some part of trunk roads (Maping in bagamoyo road) does not only reveal the paten of vehicle classification but also over speeding on the roads. It is observed in Fig. 11 that there was high speed between 13pm and 17 pm with maximum at 14 pm which was recorded at 100km/h. Father analysis indicates that short vehicle class were the ones with higher speed on the roads.

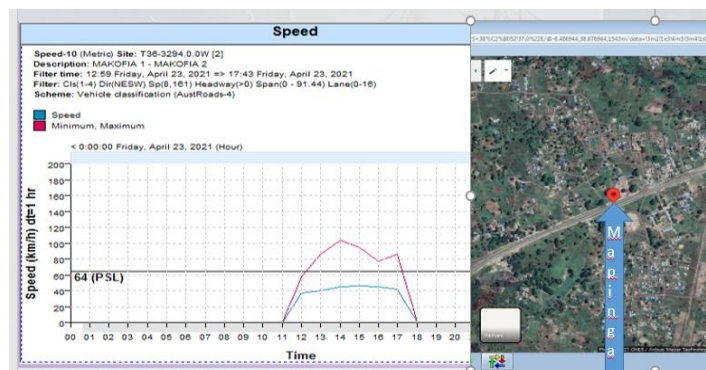


Fig. 11. Over speed on the roads.

GIS information is an important aspect in deciding on road maintenance funding. Fig. 12 indicates the GIS pattern of a bridge in the Mbeya region. Bridges remain one of the cornerstones in roads assert as they allow people and animals to go in their daily activities without having to negotiate a busy road, a dangerous railway line, or a fast-flowing river. Bridges and junctions are prone to the accident due to road crossing and the abstraction of view of the vehicle coming from different directions. We can argue that bridges and roads are as important to your health as what is in your medicine cabinet. The economic impact of bridges can be easily realized when there is a bridge failure. Bridges is a critical component of transportation infrastructure [33]. When a bridge closes economic activities slow or grounded to a complete halt. Worldwide, road and its asset have a remarkable economic and social impact on society [4].

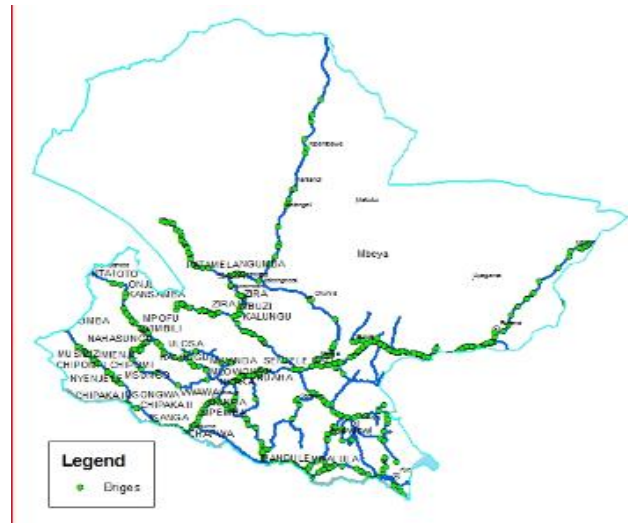


Fig. 12. Bridges location in mbeya regional network.

3.3 WebGIS

Web-based GIS applications can be as simple as presenting a simple map of the world to front-ending complex spatial analyses of spatial distributions and processes. GIS-enabled web applications can utilize many technologies and database platforms, the choice of which can impact the performance of the web application. MS-Access is not the software of choice for a GIS application built around millions of records because the software has not been developed to handle very large amounts of geographically referenced data efficiently. An important consideration in software selection is the speed of response that is database response time as users may expect the result of GIS analysis to be produced in real-time [56]. These requirements choose mapping, database, and development technologies and standards are very important. GeoServer with PostGreGIS application can be of relevance in mapping, database, and development technologies that are required to be used in developing high-volume web-based GIS applications. Fig. 13 indicate a web-based prototype. With web GIS, multiple users can have an online quarry. The user could quarry base Map feature or Patten of the Road Network.

An important part of any web-based GIS application is its mapping or visualization technology to multiple users, which makes it possible to show data in the form of maps. The popularity of web-based mapping applications, therefore, arises in the wide dissemination of software that makes it easy for users and developers to publish map data at glance.

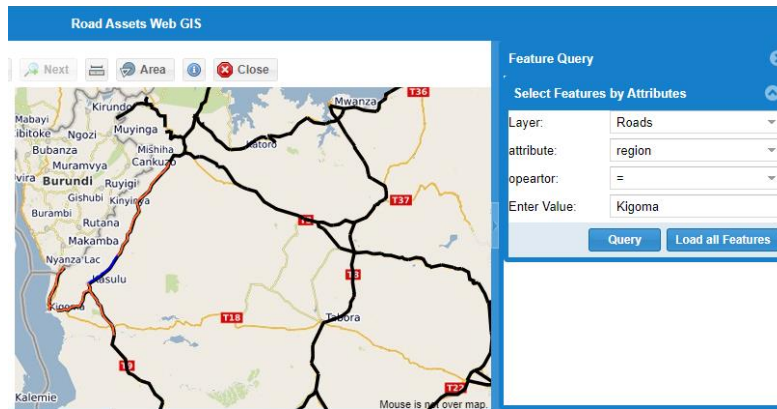


Fig. 13. Online map queering.

4. Conclusions and Recommendations

In this article, we have demonstrated the methodology of integrating non spatial databases into GeoDatabase. This article also gives out that the new simplified GIS system allows users department to visualize the results of database queries and pavement management analyses on a map. As a result, it empowers road planners with intelligence on decision-making for pavement maintenance. Users can view network conditions and economical factors at glance. With GIS other not only road information can be revealed but also traffic volume and over spending. The integrated condition data with graphs, tables, charts, maps is very efficient in helping engineers to communicate with politicians and others stakeholders on issues arising on the roads. Moreover, with GIS those sections with the poor, fair and good condition could be easily identified visually on the map.

It is noted that smart infrastructure is in the front end for improving transportation, human health, and living, which applied, to both paved and unpaved. It is anticipated that future roads will be made intelligent and sign-free. Moreover, they will be safer and commutative such that they will not only support mobility of people and cargos but also enhance other projects such as energy, big data analysis, artificial intelligence as well as smart transportation technologies. It is recommended that in pavement planning the use of GIS should take into account to improve intelligence in planning.

REFERENCES

1. Intel. Smart road start with smart infrastructure, Intelligent transportation. 2020. [Online]. Available: <https://www.intel.com/content/www/us/en/transportation/smart-road-infrastructure.html>
2. Flintsch GW and Medina A. Framework for a web-based intelligent infrastructure asset management system. In Proc. 5th Int Conf Managing Pavements, 2001.
3. Lopez JZ and Alfar I. Universidad Autónoma Metropolitana, " ed: Obtenido de El estres cronico leve impredecible altera el sistema de, 2016.
4. Vitalis N and Ndaji S. Comparative analysis of road financing at operational level in Tanzania. Trans Eng Comput Sci. 2020;1(2):112.
5. Choi Y. PV analyst: Coupling ArcGIS with TRNSYS to assess distributed photovoltaic potential in urban areas. Solar Energy. 2011;85:2924-2939.

6. Díaz-Cuevas P. Developing a wind energy potential map on a regional scale using GIS and multi-criteria decision methods: The case of Cadiz (south of Spain). *Clean Technol Environ Policy*. 2018;20:1167-1183.
7. Miller G and Twining-Ward L. *Monitoring for a sustainable tourism transition: The challenge of developing and using indicators*. CABI Pub, 2005.
8. Newton JN. Spatial temporal dynamics of vehicle stopping behavior along a rustic park road. *Appl Geogr*. 2017; 88:94-103.
9. Li QS and He DP. Application of GIS in highway maintenance management. In *CICTP 2012: Multimodal Transportation Systems—Convenient, Safe, Cost-Effective, Efficient*, 2012, 3132-3137p.
10. Mitchel. *The ESRI Guide to GIS analysis, Volume 2: Spartial measurements and statistics*: ESRI Press, 2005.
11. Fonte J. A GIS-based analysis of the rationale behind Roman roads. The case of the so-called via XVII (NW Iberian Peninsula), 2017.
12. Sitanyiova D and Mužík J. GIS application for managing and maintaining road network in Ulaanbaatar. *Silesian Univ Technol Civil Eng*. 2013, 61-68p.
13. Abaza KA. Back-calculation of transition probabilities for Markovian-based pavement performance prediction models. *Int J Pavement Eng*. 2016;17:253-264.
14. Guler H. Railway asset management system in turkey: A gis application. in *FIG Working Week*, 2004, 22-27p.
15. Chatterjee A and Venigalla MM. Travel demand forecasting for urban transportation planning. *Handbook of Transportation Engineering*, vol. 1, 2004.
16. Morova N. Pavement management systems application with geographic information system method. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, vol. 20, 2016.
17. Maparu TS and Mazumder TN. Transport infrastructure, economic development and urbanization in India (1990–2011): Is there any causal relationship? *Transp. Res. A Policy Pract*. 2017;100:319-336.
18. Skorobogatova O and Kuzmina-Merlino I. Transport infrastructure development performance. *Procedia Eng*. 2017;178:319-329.
19. Cook W. Bridge failure rate. *J Perform Constr Facil*. 2015;29:04014080.
20. Martínez N, Martí Albiñana, JV, and Yepes Piqueras V. Multi-criteria decision making techniques in civil engineering education for sustainability. In *ICERI2018*, 2018, 1p.
21. Grigg NS. *Infrastructure finance: the business of infrastructure for a sustainable future*. John Wiley & Sons, vol. 536, 2010.
22. Atzori L. The social Internet of Things (siot)–when social networks meet the Internet of Things: Concept, architecture and network characterization. *Comput Networks*. 2012;56:3594-3608.
23. Giles-Corti B. City planning and population health: a global challenge. *Lancet*. 2016;388:2912-2924.
24. Jones P and Lucas K. The social consequences of transport decision-making: clarifying concepts, synthesising knowledge and assessing implications. *J Transp Geogr*. 2012;21:4-16.
25. Forman RT. *Road ecology: Science and solutions*: Island Press, 2003.
26. Mattioli G. Transport needs in a climate-constrained world. A novel framework to reconcile social and environmental sustainability in transport. *Energy Res Soc Sci*. 2016;18:118-128.
27. Woodcock J. Energy and transport. *Lancet*. 2007;370:1078-1088.

28. Lü G. Reflections and speculations on the progress in geographic information systems (GIS): A geographic perspective. *Int J Geogr Inform Sci.* 2019;33:346-367.
29. Kundapura S. Assessment of changes in wetland storage in gurupura river basin of Karnataka, India, using remote sensing and GIS techniques. In *Water Resources and Environmental Engineering II*, ed: Springer, 2019, 57-68p.
30. Qiu-Shi LI and He DP. Application of GIS in highway maintenance management. In *Proc Twelfth COTA Int Conf Transportat Professional*, Beijing, China, 2012.
31. Liu X. Dynamic risk assessment of drought disaster for maize based on integrating multi-sources data in the region of the northwest of Liaoning Province, China. *Nat Hazards.* 2013;65:1393-1409.
32. Farag HN. Pavement-management maintenance system using geographical information system for Asphalt pavement roads. *J Civil Eng Res.* 2020;10
33. ESRI. *GIS Solutions for Highway and Roadway Management*, 2011.
34. U. Madison. *Mapping and Geographic Information Systems (GIS)*. Accessed: Mar. 6, 2021. [Online]. Available: <https://researchguides.library.wisc.edu/GIS>
35. Acquah P and Fosu C. Implementation of geographic information system application in the maintenance management of roads in Ghana: a case study of roads in Kumasi Metropolis. *Amer J Geogr Inform Syst.* 2017; 6:90-102.
36. Jaro TSRDI and Iguisi MPE. Development of GIS-based road transport information management system for adamawa central, Adamawa State, Nigeria. *Development.* 2015;5.
37. Austroads. *Austroads' Guide key factor in more than halving road casualties in Thailand case study.* 2019.
38. Amico GD. Understanding sensor cities: Insights from technology giant company driven smart urbanism practices. *Sensors (Basel).* 2020;20:2-3.
39. Konstantakopoulos C. A deep learning and gamification approach to improving human-building interaction and energy efficiency in smart infrastructure. *Applied Energy.* 2019;237:810-821.
40. Yingli Wang LE. The use of ICT in road freight transport for CO2 reduction – An exploratory study of UK's grocery retail industry. *Int J Logistics Manage.* 2014;26:1-29.
41. Hossain E. Application of big data and machine learning in smart grid, and associated security concerns: A review. *IEEE Access.* 2019;7:13960-13988.
42. vrioerpe. *Smart Road Technology: Digital Highways Of The Future.* 2020. [Online]. Available: <https://vrioerpe.com/en/smart-road-technology-digital-highways-of-the-future/>
43. Toh K. Advances in smart roads for future smart cities. *Proc Royal Soc A, Meth, Phys Eng Sci* vol. 476, 20190439p, 2020.
44. Curtis MD. Analyzing the diffusion of geospatial technologies as instructional tools in high school geography education. *Semantic Scholar.* Semantic Scholar, 2015.
45. García-Pérez S. Environmental assessment at the urban level combining LCA-GIS methodologies: A case study of energy retrofits in the Barcelona metropolitan area. *Build Environ.* 2018;134:191-204.
46. Jeong, JS. Planning of rural housings in reservoir areas under (mass) tourism based on a fuzzy DEMATEL-GIS/MCDA hybrid and participatory method for Alange, Spain. *Habitat Int.* 2016;57:143-153.

47. Herráez P. A GIS-based fire spread simulator integrating a simplified physical wildland fire model and a wind field model. *Int J Geogr Inform Sci.* 2017;31:2142-2163.
48. Global. IGI Global. *Sort.* 2018;20:100.
49. Mushonga HT. Development of a web based GIS for health facilities mapping, monitoring and reporting: A case study of the Zambian Ministry of health. *South Afr J Geomat.* 2017;6:321-332.
50. Bodner A. Simulation-based decision support for systems engineering experience acceleration. In *Proc 2012 IEEE Int Syst Conf SysCon, 2012*, 1-6p.
51. Wade JP. The architecture of the systems engineering experience accelerator. In *INCOSE Int Symposium, 2012*, 1806-1820p.
52. Boulos MNK. Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom. *Int J Health Geogr.* 2004;3:1-50.
53. Shah SAR. Road safety risk evaluation using gis-based data envelopment analysis—Artificial neural networks approach. *Applied Sci.* 2017;7:886.
54. Yona M. Data science and GIS-based system analysis of transit passenger complaints to improve operations and planning. *Transport Policy.* 2021;101:133-144.
55. Feighan K. Recent developments in pavement management on Irish national roads. In *9th Int Conf Manage Pavement Assets, 2015*.
56. Adnan M. *Developing efficient web-based GIS applications.* 2010.
57. SRA. Preventing and responding to road traffic related trauma. 2021. [Online]. Available: <https://saferoadsafrica.com/>



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