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Research Article

GUIDELINES FOR ROUTE AND ROAD SURVEYING PRACTICES AND REGULATIONS IN SUDAN

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ABSTRACT

This research aims to present guidelines to regulate the practice of route survey work by standardizing routes field surveys, processing, quality control, and procedures related to highway surveying works to be carried out by relevant authorities in Sudan. As well as to improve the quality harmonization and provision of geospatial data, that, aid engineering design, construction, and decision-making processes. By establishing a comprehensive executive regulation for implementing the Sudan Survey Works Organization Act, to regulate all routes corridor surveying and mapping performed by the public and private sectors, as, there is a growing awareness of the importance of geomatics activities and measurements on the Earth's surface in space and time, and their usage in design and construction, as well as in observing, and mapping the changes. This means that geospatial data must be captured on time, with more accuracy, and in more detail. One of the main objectives of this paper is to highlight the current situation in Sudan, the degree to which route surveying standards are used, and the problems and errors that arise from not using the standards, taking road surveying practice as a case study. Thus, the investigations mostly traced survey works in all phases of road establishment, starting from route selection, feasibility studies, and engineering designs and ending with the construction and as-built drawings.

Keywords: ASWOA, SSA, WGS84 ITRF2008, GNSS, UTM, DEM.

INTRODUCTION

Route corridor selection and road feasibility and detailed engineering designs must be based on the performance and engineering characteristics, including the consideration of topographic geometry, and the full range of economic, social, environmental, and other relevant factors involved. One of the important engineering characteristics is the issuing of road surveying executive regulations for implementing the Sudan Survey Works Organization Act (ASWOA). These are to regulate and standardize all route corridors and design surveying and mapping performed by the public and private sectors and should be in line with international best practices. The objectives of the executive regulation are to include surveying and mapping activities together with the regulation and control of the surveying profession, and monitoring of all activities related to surveying work in Sudan. This study is also meant to assess the existing road surveying practices, to outline the required route survey standards and specifications required to be developed, as well as the procedures, regulations, and methods of implementation using a new approach coupled with international best practices [1], [2]. Here, road construction surveys were considered as a case study to determine what standards exist and how widely they are used in Sudan. Starting with the road project's initial studies, route selection, reference control points and benchmarks, survey equipment and all required means to achieve the required accuracy, adopting the Quality Control (QC) and Quality Assurance protocols, in feasibility studies, engineering designs, construction and implementation stages and to overcome most of damages arising from applying no standardized survey criteria and their effect on society and the environment, as well as their financial impacts and losses that occur in the road sector.

The paper also, intended to reflect the importance of unifying survey standards and specifications used in Sudan by various stakeholders and to propose the executive regulation legalization in all aspects of the SSWO Act [20]. the methodology to be adopted for the development and documentation of the executive regulations, standards, and specification is to identify, the key stakeholders, professional experts, policymakers, decision-makers, professional surveyors, and end-users, as well as the tools used for their intervention. The authors also reviewed the organizational aspects related to how surveys are carried out, the analysis needs to shift to who is carrying out these activities to ensure that the required standards and specifications are met.

The need also, identified for the Sudan Survey Authority to have control over all survey providers (whether they supply data directly or indirectly to federal or state governments) translates into the objective of organizing the Surveyors' trade and unifying regulations (legislation, policies) with regards to the survey activities. To reach this objective, the following aspects need to be investigated and documented in the routes and roads surveying executive regulations, such as education, degrees, and professional experience; surveyors Licensing and registration, and companies Licensing and registration.

MAIN SUDAN ORGANIZATIONS INVOLVED IN ROAD SURVEY ACTIVITIES

Sudan National Highway Authority and state infrastructure departments are developing major highways and road projects that necessitate surveying works and geospatial information collection, such as roads, bridges, highways, railways, highways, and feeder road infrastructures. For each of the phases of their major works (Master Plan, design, implementation, supervision, and execution), the Planner, the Designer, the Owner, the Engineer, and the Supervisor will have to rely on standardized surveys and geospatial data collection and processes. These geospatial data are the result of survey data capture using standard field survey works procedures, measuring equipment, and processing software [17] and [18]. These data, can also, be the input or the output of geospatial databases, each of the roads stakeholders maintain, and of the shared SSA database. Currently, in Sudan, these survey works may not necessarily be standardized as it has been carried out in the absence of a regulated framework common to all the entities concerned. The targeted common framework should have several components, such as:

- Juridical components, as a law, which defines who is in charge of the reference systems, the positioning infrastructure, and the official and legal standards and by defining who is entitled to carry out the road surveys [3].
- Technical components, through the shared acceptance of the given land and marine spatial references, positioning infrastructure, aerial photography, and processing and standards, including Fedic and international best practices of highway and road surveys.
- Economical component, the development of activities that served many sectors, taking into consideration the social economy and environmental impacts.

The paper tried to identify and formalize the current surveying needs, and to ensure that all survey works carried out or delivered for the various Sudan organizations are realized by trained, competent, and qualified surveyors. The authors then studied and examined in detail the existing standards and procedures, those of which, are related to SSA and those shared by the stakeholders.

Applying the principles on which this approach is based, the authors worked closely with SSA and the National Highway Authority to investigate all the existing road survey activities and programs that relate in any significant way to surveying works and geospatial information and services. For drafting applicable survey standards and specifications in Sudan, meetings are to be organized with all relevant government and private entities, as shown in Table(1), to agree on the related road survey standards and specifications and the method of their implementation, to have a clear view on what stakeholders' interactions are involved, concerning road surveying activities.

Table 1: List of main SSA Main Routes Corridor stakeholders

ENTITY	Full Name	ENTITY	Full Name
SSG	Sudan States Governments	MOA	Ministry of Agriculture
SCAA	Sudan Civil Aviation Authority	MOF	Ministry of Finance
NEA	National Environment Authority	MOT	Ministry of Transportation
MOIWR	Ministry of Irrigation and Water Resources	MOM	Ministry of Mining
SSPC	Sudan Sea Ports Cooperation	MOG	Ministry of Oil and Gas

The state infrastructure departments are responsible for the consistency between the Federal national highways and the State's Road networks, as well as the detailed planning and plans' approvals. In such cases, upon completion of some projects, a certain part of the infrastructure remains under the authority of entities, whilst another is "delivered" to the State Infrastructure Department or National Highway Authority to be in charge of their maintenance. This maintenance relates to the corridors and the road surfaces, assets, and services.

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SUDAN GEODETIC AND GEOSPATIAL REFERENCE SYSTEM

The Sudan geodetic and geospatial Reference System [19], should be considered to be a consistent national reference frame and coordinate system that specifies the official control points coordinates throughout the territory of Sudan as well as how these values change with time. Specifically, the needs identified are to define units, geodetic reference, elevation reference[11], and geoid reference. The Sudan geodetic and geospatial Reference System is also consisting of the following components, tables 2 and 3:

- A consistent, accurate, and up-to-date international and state boundaries and shorelines.
- A unified Geodetic Reference frame and Network for all utility infrastructures.
- The unified network of permanently marked Geodetic Control Points and Benchmarks.
- A set of accurate models describing dynamic geophysical processes affecting spatial measurements [23].

Table 2: Sudan Geodetic and Geospatial Reference System

Horizontal Reference System	ITRF2008 epoch 2008.0	Geodetic Control points
Vertical Reference System	Alexandria or Port Sudan vertical datum	National benchmarks, Stakeholders' benchmarks, WGS84 ellipsoidal height + Sudan geoid
Gravimetry Reference System	GSN71	Reference Gravity Stations

Table 3: Parameters for UTM zones 34, 35, 36, and 37

Zone	34 north	35 north	36 north	37 north
Central Meridian (λ_0)	21° East of Greenwich	27° East of Greenwich	33° East of Greenwich	39° East of Greenwich
Latitude of Origin (φ_0)	0°	0°	0°	0°
UTM Scale Factor (k_0)	0.9996	0.9996	0.9996	0.9996
False Easting (E_0)	500,000 m	500,000 m	500,000 m	500,000 m
False Northing (N_0)	0 m	0 m	0 m	0 m

COMMON DEVELOPMENT PROCESS

A common frame of work has to be considered through the general routes and roads development process in Sudan, at the planning and design stages for creating plans and designs, using software that generates an output set of coordinates in a given reference system (horizontal reference system, vertical reference system, projection). To understand what the needs and expectations fulfilled by the route and road survey business processes are the mission of the SSA and State Survey Departments and the road departments needs to be revisited to understand what the axes of their mandates are. Here the following four major axes can be identified:

- Ensuring consistency in terrestrial land planning
- Implementation of the planning policies such as town and urban planning.
- Management of the urban space (cadastre, utilities, corridors, routes)
- Protection of the people and properties (marine)

SSA and Roads Stakeholders Terrestrial needs

Considering the SSA objectives concerning road surveying and geospatial information, to identify the needs, the business processes, land, and topographic surveys are to be reviewed. Based on the existing road survey business process the following can be identified:

- Densification and maintenance of SSA and its stakeholders Positioning Infrastructure
- Computation and adaptation of vertical control, including a gravimetric geoid model
- SSA and Stakeholders demarcation, setting out and construction surveys
- Stakeholders Routes surveys
    - Corridor surveys
    - Road surveys
    - SSA Base map creation and update by land topographic surveys and/or aerial and satellite imagery surveys

SSA Stakeholders' needs and expectations

After analyzing the information obtained from the relevant routes and road stakeholders, it can be drawn that the common ground in terms of needs and expectations of the stakeholders from SSA, federal and state government entities is the reliable reference data, which is particularly true in the case of the stakeholders involved in roads and utility management services. As far as the SSA is concerned, its needs and expectations from the stakeholders mainly consist of all organizations is to use the same references, as this is the only way to ensure consistency of the datasets in use (WGS84 ITRF2008 epoch 2008.0 for the horizontal reference system and Alexandrea/or Port Sudan for the vertical datum).

EXISTING BUSINESS PROCESSES AND SURVEY PRACTICES

In the analysis of the existing practices for road survey across the business processes (Figure.1) identified, it has been studied how the surveying activities are carried out at the level of the federal and state governments as well as the stakeholders and private sector organizations, terms of land surveys, the establishment of the methods and specifications used to assess whether the required accuracies can be met.

All survey activities fall under the responsibility of the SSA and survey Departments at state governments, whose mission is to ensure:

- Managing the surveying processes, the detailed planning surveys, and the division of urban uses as well as the issuance of surveying policies and relevant rules [6].
- Management establishment, distribution, updating, and maintenance of geospatial data.
- Issuance of building and wall construction layouts [21].
- Management of paths and segments of different service lines.

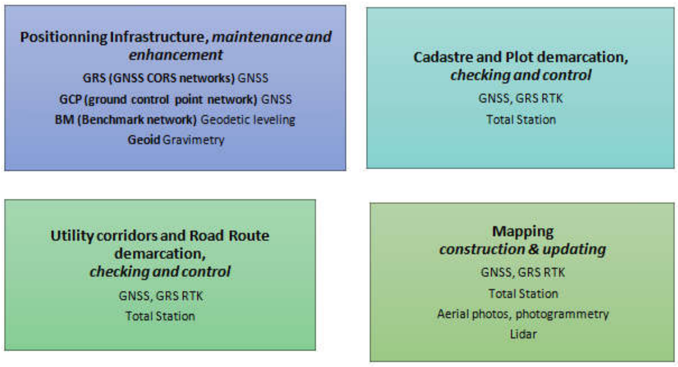

Figure. 1: Existing route survey business processes and survey practices

The overall responsibility of SSA is:

- Establishing and maintaining national Geodetic Ground Control Point Networks [3].
- Supervision of GNSS Reference Station using CORS, Maintaining and Running
- Providing boundary demarcation surveys [12].
- Carrying out federal geomatics and surveying activities [16, 21]
- Providing technical support and services in all surveying and geospatial-related matters
- Producing fundamental geospatial data in base maps and integrated geospatial information.

Utility Control

Corridor survey datasets are of interest because they include many elements critical to the public and private infrastructure, and provide services in the daily life of citizens. The reliable functioning of the increasingly complex, inter-connected, and inter-dependent utility infrastructures [16], [17], including roads, electricity, water, and gas supply systems, wastewater systems, and communications, is vital for the security, economic prosperity, and social well-being of the nation. The utility (service) corridor represents the area above and below ground where utilities reside. It is an area of highway right of way designated or any part of the land used or intended to be used for the location of utilities, either public or private.

The state governments in Sudan, are not directly in charge of all utilities, which are under the responsibility of authorities and/or companies in charge of electricity, gas, irrigation, street lights, sewage, communications, and fiber cable. These authorities and companies have their survey units with their surveyors and/or sub-contractors. However, certain mechanisms are to be set in place between them and the state governments, as they should require from them:

- The corridor site dedicated to the road or utility;
- The approval of routes setting out and design;
- The approval after work of the as-built

In the above phases, the SSA and the survey departments of the state government must be in charge of supervising and checking the surveying, mapping, and demarcation processes and the measurements of the corridor routes as well as as-built drawings. Corridor surveys are meant to measure the coordinates of certain features in the field or stake out given coordinates in the field. All coordinates must be in the Sudan geodetic and geospatial Reference System [19]. Utilities may include Electricity, Gas, Irrigation, Street lights, Sewage, Water supply, and drainage [18]. The utility data sets contain: Utility point device features located along utilities; utility line features involved in the transmission and distribution of oil, gas, electric, or telecommunications commodities; and polygon "plant" features involved in the generation, treatment, refining, or storage of oil, gas, or electric commodities.

TOPOGRAPHIC MAPPING AND BASE MAP UPDATING

The base maps are established and maintained by the SSA and provide to all stakeholders through the Sudan National Base map System [18, 20], the appropriate geospatial data needed to accomplish their missions. These data have been continuously improved and updated. So, the base maps fall under the responsibility of SSA, which already, has initiated the unification of the geospatial models and the specifications of the base map. Traditionally, aerial surveys have been used in Sudan, mostly for large and medium-scale mapping. So far, UAV airborne and Lidar mapping started to be used for road surveys by the public and private sectors.

Confidence level

In the recent past, the scale of the produced route or road layout documents dictated the required accuracy. The relation between the map scale(Table 4) for example and the target accuracy is to be established by the common rule of the 1/10 mm. On a scale of 1: 1 000, one-tenth of mm on the map represents 10cm on the ground, in which one used to have a target and expected accuracy of less than 10cm, this is less true as GIS replaces printed documents..

Table 4: The traditional relationships between map scale and accuracy

Scale of map	Tenth of mm	Target Accuracy at One Sigma
1: 1000	0.10 m	8 cm
1: 5,000	0.50 m	16 cm
1: 10,000	1.00 m	80 cm
1: 25,000	2.50 m	2m

In route/ road specifications the trend is to ask for the maximum achievable accuracy regardless of the actual identified needs. One of the goals of the paper was to clarify and highlight the level of confidence associated with the accuracies, and to understand whether it was one sigma level, or 95% level [12, 17]. This is an important issue since the multiplying factors (Table 5), to change from a one-sigma confidence level to a 95% confidence level are usually given as:

Table 5: Confidence level multiplying factor

1.96	if one-dimensional (vertical)
2.45	if two-dimensional (horizontal)

Practically, it can be found that some of the required accuracies were not realistic, given the techniques and methods used in the field. For instance, one cannot get a 3 cm accuracy from a total station survey based on ground control points established with GNSSRTK [13]. The purpose of control surveys is to provide a uniform framework of reference for the coordination of all surveying activities within a given area. They consist of horizontal and vertical controls [7], which require fundamentally different methods of establishment, although some control points may be common to both control networks. The basic rule is that the accuracy of the control should be superior to that of the surveys it coordinates. Different types of surveys produce different types of data, which are stored in different layers of the GIS. As a result, the accuracy associated with the data becomes very important since, when the different layers are superimposed and overlaid, one has to keep in mind the different accuracies involved.

UTM projection

The Sudan Survey Authority adopted the UTM projection, which is based on the Transverse Mercator projection. The UTM properties [1], [2], and [11], are the Grid Scale factor is 0.9996 along the central meridian of the zone (Figure.2). The scale is deliberately reduced so that the mean scale of the entire area is more correct, the origin of E coordinates is the equator and the N coordinates is the central meridian (+500 km). The grid scale factor increases as going away from the central meridian reaches a value of 1 and then increases beyond a value of 1 (at constant latitude). Along the same meridian, the scale factor decreases when latitude increases [23].

The distance measurement correction that the surveyor should use with the total station is composed of:

- Correction of the prism target used
- Meteorological correction (temperature and atmospheric pressure)
- Reduction to ellipsoid (scale factor caused by topography). Also known as the Elevation factor or Orthometric Height scale. It depends on ellipsoidal height and mean radius of curvature of the earth
- Linear distortion due to the projection

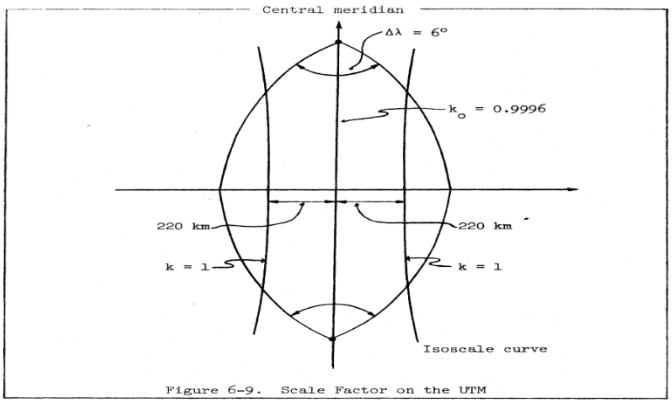

Figure 2: Scale Factor on the UTM

The total (combined) scale factor is the product of all scale factors. The issues related to the projection, scale factor, and linear distortion, have a direct impact on the surface of the plots and engineering works. The legal surface of property generally refers to a computerized surface relative to the legal projection used. GNSS processes transform plan cartographic coordinates in GNSS coordinates and vice-versa. Each distance measured on the field is normally corrected by the scale factor to be “drawn” on the projected map; otherwise, the demarcation is wrong because the scale factor is not negligible when the accuracy requested is equivalent to the error in distance measurement due to the value of this scale factor.

To sum up, all surveying entities, and particularly, the state governments, utility stakeholders, and GIS users should realize that [14]:

- The surface of a plot or a piece of land is always computed with the legal projection used whatever the scale factor of the legal projection is. For example, in any place, when the legal projection is changed, means that the total surface of the area, say the agricultural land used will change.

- UTM Projection is a “conformal” map projection preserving angles locally, but not “equal-area” i.e. not preserving areas [9].
- Therefore, if all the surfaces of properties in the State government are computed following the legal projection of Sudan, nobody can dispute the surface of his land in front of the court.
- For the UTM Zone projection, the scale factor value is 0.9996 at the central meridian of the zone. There are two meridians with a value equal to 1, one West and the other East of the central meridian of the zone
- The linear distortion varies according to the variation of the value of the scale factor.
- For surveys using measurement of angles and distances (Total Station), a correction shall be applied to the distance measurement to be able to “draw” the results of the survey in a projection map.
- The correction is called “scale factor”. Nevertheless, for the modern total station, this correction includes prism correction, temperature correction, pressure correction, altitude, and linear distortion due to the projection used. With UTM Zones 34, 35, 36, and 37, all the corrections are almost negligible compared to the linear distortion.
- If this correction is not correctly applied on the field, the demarcation is wrong. A specific procedure has to be devised and followed on the field to check that issue.
- For GNNS measurement, the process of transforming projection coordinates to GNSS coordinates takes into account the projection parameters.

Quality Assurance/Quality Control

One of the key aspects related to the organization of a survey is how Quality Assurance and Quality Control are handled. Generally, two approaches are possible: Process-oriented (Quality Assurance) and Result-oriented (Quality Control).

The approach used by the state government about quality may not be quite qualified as result-oriented, as the Quality Control carried out after the handing over is limited to checking the formats. In the rare instances where attempts to check the accuracy are made. The major risk identified in terms of Quality Assurance lies precisely in the surveying functioning model used, and its uncontrolled ramifications. The survey pattern can be reproduced several times as each of the entities meant to execute the survey. It is nearly impossible to assess the qualifications of the surveyors who carry out the survey. Therefore, the state government has in the end very little control over the quality of the results they are being delivered, other than this Quality Control on handing over which is not carried out in depth. Quality can have different interpretations (Table 6), depending on where is the quality in the production and usage life cycle of the reference data.

The ISO 19157:2013 standard does not specify how to measure the differences between a dataset and a universe of discourse. It defines a taxonomy of the various kinds of differences that are usually measured [12], those various kinds of differences being called quality elements and sub-elements. It also describes how to identify whether these elements and sub-elements apply to one given dataset, how to create additional elements and sub-elements, and how the reporting of quality assessment should be performed. The data quality elements described by the ISO 19157:2013 are: a. Completeness b. Logical consistency c. Positional accuracy d. Temporal accuracy e. Thematic accuracy and f. Usability.

Table 6: Interpretation of quality in different phases of production

Phase	Quality documentation	Goal for quality	Quality method	Level
Before production	Specification -> quality model	Define quality requirements	Investigation of customer requirements	Feature type level
During production	Database-> Process history	Meet the specification, Record the expected quality to the database	Inspection	Feature instance (e.g. dates, positional accuracy)
After production	Metadata, Test reports	Measure conformance to quality requirements	Evaluation, Reporting	Dataset level

Regarding Positional accuracy [8], to be able to evaluate the data quality of a dataset, a subset of this dataset must be compared to « true positions ». To simulate true positions, one must measure again with a technique at minimum twice as accurate (a compromise between cost and accuracy). The following quantities are examples of the data quality measures for the data set (ISO19157:2013) among more than 50 existing [12]: Standard deviations of residuals; Mean value of positional uncertainties; Mean value of positional uncertainties excluding outliers; Number of positional uncertainties above a given threshold; and Root means square error.

OUTLINES OF ROUTES SURVEYING REGULATION, STANDARDS AND SPECIFICATIONS

The routes and road Surveying regulations, standards, and specifications aim to organize and implement road surveying works in Sudan by the best international practices. In this regard, the objectives of these regulations require management and control of the survey profession and control of all activities related to road survey work.

The SSA and the National Highway Authority shall undertake together, the following tasks and functions:

- Creating a register to register the persons licensed to practice surveying work in Sudan.
- Determining the standards, foundations, and technical specifications for surveying works, the spatial reference system, the coordinate system, and all regulations.
- Preparing the provisions regulating the practice and ethics of the survey work profession.
- Registering and striking off surveyors and surveying companies.
- Preparing support mechanisms to enable building and strengthening the capabilities of information systems and geospatial maturity among the entities associated with road and routes corridor utilities.
- The National Highway Authority has the right to delegate some powers under these regulations or to seek the assistance of whomever it deems appropriate to it, and this includes any of the federal government agencies, states or private institutions under an agreement to be concluded for this purpose, the rights and duties of its parties are determined in a manner that achieves the public interest and the application of the articles of the regulating law.
- Permanent registration with the Sudan Engineering Council and SSA is a condition for practicing the surveying profession.

- The executive regulation determines the period of validity of registration, how to submit and renew registration applications, and the conditions and the required documents.
- Duties and obligations of surveyors: to execute surveying works following the adopted national and international standards and specifications.
- Obtaining the authority's approval for any survey or field photography work.
- Compliance with the decisions issued by the Authority regarding the practice of a profession and surveying.

Routes feasibility studies

A feasibility study contains a detailed analysis of what's needed to complete a proposed road project. The investigation may include a description of the new product or venture, a market analysis, the technology and labor needed, and the sources of financing and capital. The road feasibility study involves surveys and geospatial information [12] related to:

(a) The Prospective of the Economy: includes the population, the economy (Overall Performance), Average Annual Agricultural Production, The Industrial Sector, The Services Sector, Basic Infrastructure [4], Foreign Direct Investment, Income, and Consumption Predictions. The project area: Determine the study area, reviewing all available reports, maps, studies, and other information in the study area, including acquiring relevant satellite and aerial imageries, climate, hydrology, water courses, and rainfall, land use, and vegetation cover, population, and socioeconomic, agriculture and animal productions.
(b) Traffic Study: include the Problems Related to the Estimation of the Current Level of Traffic, analysis of the traffic count, the Observer traffic count; the Demand for Transport and Traffic Projects; Road Transport Costs, Vehicle Operating Costs (VOC) and Time Saving Costs: include Vehicle Prices, Fuel and Oil Prices, Tyres Prices, Fuel Consumption per Unit/Kilometer, the estimated benefits.
(c) Route Selection: Identification of Alternative Routes and Comparison of Alternatives, Define the selection factor for the path.
(d) Soils and geophysical investigation and materials
(e) Road Construction and Maintenance cost and economic evaluation and risk analysis.

Detailed engineering design

Detailed engineering design means the preparation of actual detailed engineering designs, plans/drawings, and bills of quantities or cost estimates, supported by design analysis and calculations, brochures, catalogs, and technical specifications. The quality of such designs may largely depend on the comprehensiveness and quality of the surveying works.

The goal of the detailed design stage is to develop the sketch design into working drawings and specifications suitable for construction purposes. During this stage, it will be expected to review the project and cost plan regularly and provide advice if the cost appears to be increasing. The detailed engineering design surveys for highways [10] will be carried out as:

(a) Reconnaissance survey: To verify the area and features shown on the topographic map or in Google images, and to assess the general character of the area in the field to determine the most effective way to conduct detailed studies, the survey team may use a very simple tool in the field such as an analog scale, a barometer...etc., to gather additional information
(b) Topographical Survey: includes satellite image review and preliminary route alignment, field visit to check the route alignment, Benchmark installation, benchmark leveling, detailed survey, data processing, and computations of coordinates and elevations.
(c) Route identification and optimization: In this case, the contour map of the location of the targeted road is studied by the Survey team, explaining on it the main features of the area such as rivers, hills, valleys, existing roads ... etc. (base map). The contour interval ranges depending on the nature of the area. A thorough study of the map allows for one or more visualizations of the target road path, taking into account the design parameters. Depending on the conditions of the topography or obstruction, the road route can be modified to maintain the permitted gradients.
(d) Preliminary survey: In the preliminary survey, all necessary physical data, topographic details, drainage details, as well as soil details are collected so that alternative alliances can be surveyed. In addition, it compares different widths in light of the requirements for a good alignment. Also, to estimate the quantity of excavation materials and other constructional aspects, and to work out the cost of alternative routes.
(e) Final location and detailed surveys: In the road alignment surveys, the alignment should be transmitted to the ground using a GNSS device, while primary and secondary control points should be established on the ground and at the center line, according to the topography of the earth, and engineering requirements.
(f) A detailed survey included readings along the route at intervals from 25 to 100 meters, depending on the nature of the area, as well as drainage measurements.
(g) Cross-sections are taken every 20 m on flat terrain and every 10 m on rolling terrain, or as required by the specification and the CBR value of the soil along the alignment of the pavement design. The data during the detailed survey should be elaborate and complete for preparing detailed plans, designs, and estimates of the bills of quantities.
(h) Hydrological and geological survey: The main objective of this investigation is required for the hydraulic design of the road drainage system. Information about the hydrology of the study area, the valleys/water courses that intersect the road, and their hydrological and hydraulic characteristics are collected to calculate the most important design parameters. Depending on this, the drainage structure's type and size are determined.
(i) Soil and materials survey and investigation will be conducted for the selected route, and bridge crossings at the valleys and shores. The survey of locally occurring construction materials is essential to identifying their quality, and locations, and estimating their quantities. A sampling of representative materials will be analyzed by laboratory tests.
(j) Geometric design: The principal geometric features are the road cross-section and horizontal and vertical alignment. The use of engineering design standards achieves three goals. First, it provides minimum levels of safety and comfort for drivers by providing appropriate viewing distances, friction coefficients, and road area for vehicle maneuvers; second, it provides a framework for economical design; and third, it ensures consistency of alignment. The design criteria must consider environmental road conditions, traffic characteristics, and driver behavior. Generally, the design criteria considered during the design will be: right of way and roadway features, vehicular characteristics, traffic pattern, number of lanes, widths and shoulder type and width, design speed, maximum and minimum grade, maximum super elevation, sight distances, vertical and

horizontal curves characteristics, and normal crown of the surface.

(k) Pavement design: Determination of Cumulative Equivalent Standard Axles, Sub-grade Strength, and Deigned Thickness of Pavement.

(l) Drainage Structure: From topographic and hydrological data, a structural system is to be designed and constructed to facilitate the passage of khors (streams) or drains under the road embankment. Then it will decided, in conjunction with the hydrology investigations, the most suitable hydrological structures needed for the selected alignment, and design of drainage structures including the Culverts and Bridges.

(m) Road construction surveys: Land surveying plays a crucial role at the start of any construction project. An engineering survey is required before the finalization of alignment.

ROAD SURVEY DATA AND METHODOLOGY (CASE STUDY)

Study area and the Survey work

The study area (Figure 3) was located at Buttri Extension Road (Located north of ElGazeiraState-Alkamilinlocality).The total length of the road is 725 m.

Figure 3 Study Area (Source Google Earth)

Road alignment mainly includes the placement of the center line of a highway/road. The road was selected with its characteristics based on the lowest cost, the shortest route, and the purpose for which the road was built. The factors that also influence the choice of route location are traffic, land use, the existing transportation system, terrain topography, geology, and socioeconomic and environmental impacts. Usually, routes are selected by using a base topographic map, or satellite images of the area, to overlay all survey points, important features data, relationships with surroundings and mobile tracks, county routes, and city-street, and other relevant geodetic control signs. To choose the appropriate route in terms of location, services, and cost, a Google image was used to help in route determination during the field visit to the area. On-site, survey work was performed according to the specifications in the terms of reference including the following activities:

(a) Control Survey was started in the project area by identifying the existing control points and benchmarks, followed by;

(b) Route identification and optimization (route selection).

(c) Establishment of reference control points: As there was no control points were available on the site, temporary GNSS observations were conducted to establish two control points at CP1 and CP2 (Table 7), to determine the coordinates and the ellipsoidal height as a reference for all other datasts surveys (Table 8).

Table 7: Cartesian coordinates control points

Point	Easting (m)	Northing (m)	Elevation (m)	Code	Remarks
CP1	467474.250	1709571.730	393.243	CP	Observation Control Point
CP2	467251.557	1709561.260	392.518	CP	Observation Control Point

(d) Double Leveling for the control points or GNSS Height (h= ellipsoidal height) to be observed and converted to orthometric height (H). To determine the orthometric height from ellipsoidal heights, the geoid separation (N)is given by:
$H=h-N$

(e) Detailed survey works for the center line of the route with cross sections covering15 m. left and 15m right from the route axis.

(f) Detailed survey works for water courses.

(g) Detailed topographical surveys for features collection and to be drawn on the layout map.

(h) Fixing of intersection points along the centerline of the selected route axis.

(i) Intensive cross-section survey works have been carried out for the water courses including wadi, khors, and existing drains.

(j) Processing of surveys, data analysis, and drawings.

The equipment used in the field survey work activities composed of a complete set of Trimble R8 dual frequency DGPS Receivers Base and rover, high power pacific crest radio long range; and the automatic Level NA2 Leica complete set with two stave. The software used were the GPS and automatic leveling software, in addition to Surfer 19.1 and Excel 2013 were also used. The Autodesk's Civil 3D is used for road geometrical design purposes and to plan, design and manage land development, water and transportation requirements. Civil 3D is well known software and widely used on a variety of both large and small infrastructure projects, such as construction area development, road engineering, river development, dams, embankments, and many others.

Table (8) sample of final points coordinate data

No.	Easting (m)	Northing (m)	Elevation (m)	Code
1	468047.314	1709283.271	393.287	CP
2	468014.963	1709260.189	393.106	CP
3	468019.801	1709259.887	393.249	PL
4	468012.347	1709273.991	393.110	CRV
5	468016.13	1709274.589	393.262	PL
6	468015.378	1709280.405	393.140	PL
7	468011.368	1709280.089	393.042	CRV
8	468012.229	1709277.158	393.102	C.T.DOOR
9	468009.725	1709293.02	393.061	CRV
10	468011.691	1709295.544	393.089	CRV
11	468014.177	1709295.717	393.235	PL
12	468008.366	1709255.715	392.669	PO1
13	467249.263	1709566.282	393.319	PO2
14	467335.454	1709569.092	392.358	PO3
15	467355.324	1709566.11	392.371	C.PIPE
16	467423.255	1709564.517	392.487	PO4
17	467969.744	1709554.455	391.759	PO5
18	467250.147	1709562.882	393.203	EDG
19	467250.219	1709561.574	393.209	T
20	467249.529	1709559.803	392.455	B
21	467249.558	1709549.944	392.224	GI
22	467265.772	1709549.322	392.272	GI
23	467285.473	1709549.001	392.236	GI
24	467296.187	1709549.335	392.252	GI
25	467310.813	1709548.676	392.261	GI

Longitudinal Section

In a longitudinal section, elevations are determined along a fixed route, such as a ground profile along a road's centerline. The longitudinal sections are deduced and designed from the axes in the horizontal plane, and they are of two types: Longitudinal sections of the natural land, the Profile Surface (ground level) represents the natural land levels of the axis. The design of longitudinal sections (design level), represents the levels of the road axis design. This is done according to the established standards(Figures 4 and 5), which, include horizontal and vertical geometry design (Figure 6), horizontal curves, and vertical curves for the consideration of safe driving conditions.

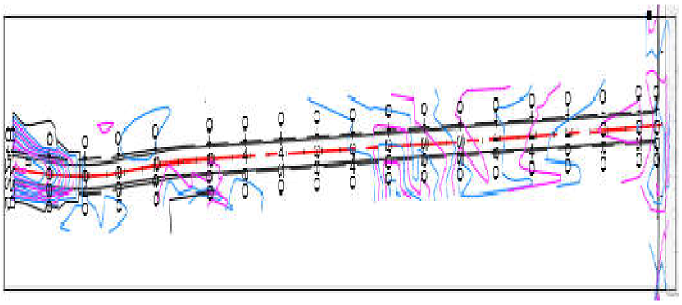

Figure 4 Longitudinal section Contour Map

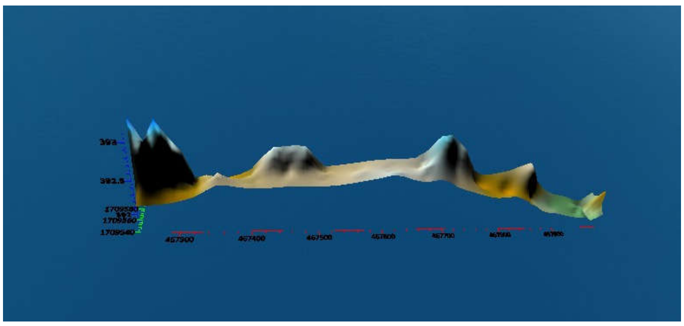

Figure 5 Road Corridor 3D Digital Elevation Model

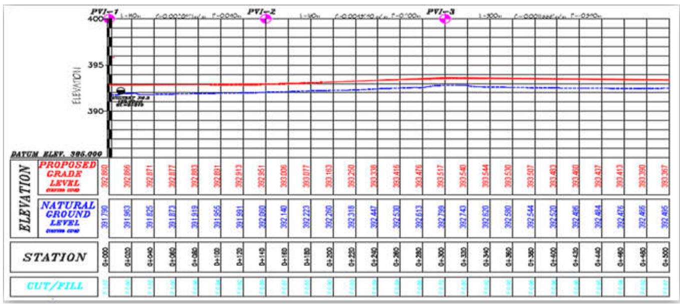

Figure 6: Geometrical layouts of the Road Longitudinal Section (Profile)

Cross-section surveys

The orientation of the cross-sections is determined so that it is perpendicular to the longitudinal path and at the same points chosen to represent the longitudinal section. Wedges are placed and numbered at the specified points of the cross-sections and are usually marked when changing the slope of the earth's surface. These points are marked with their designation if they are to the right or left of the center line.

The cross-section of the road (Figure 7) can be considered as a representation of what can be seen, if the excavator digs a trench across a road, showing the number of lanes, their width, and their intersecting slopes, as well as the presence or absence of shoulders, curbs, sidewalks, drains, ditches, and other road features. The cross-section layers are Sub Grade, Base Course, Sub Base, and Wearing Course. These sections are separated according to the type of land and the required level of accuracy.

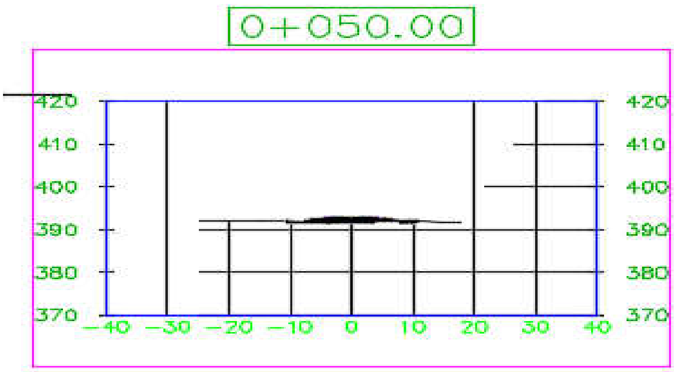

Figure 7 Sample of road Cross section layout

Typical cross sections (Figure 8) are a graphical representation of existing conditions or work to be performed within the station limits of a roadway. A typical cross-section represents the predominant section of the roadway and shows the major elements. Cross-section elements considered in the design of streets and highways include the surface type, side slopes (1:3), pavement slopes (1.5%), lane widths, shoulders (1m.), roadside or border, curbs, carriageway (3.5 m.), and medians. The cross-section layers are Sub Grade, Base Course (0.15 m.), Sub Base (0.20 m.), and Wearing Course (0.05 m.).

Earthwork computation

The earthworks computation aims to quantify the volume and the costs to be considered as a basis for negotiation and contracting. In recent years, the process of calculating quantities has evolved into an existing and it has become a specialty by itself. Three main factors influence the process of calculating quantities: Cross sections; the Nature of the Earth in the surrounding area; and the design line.

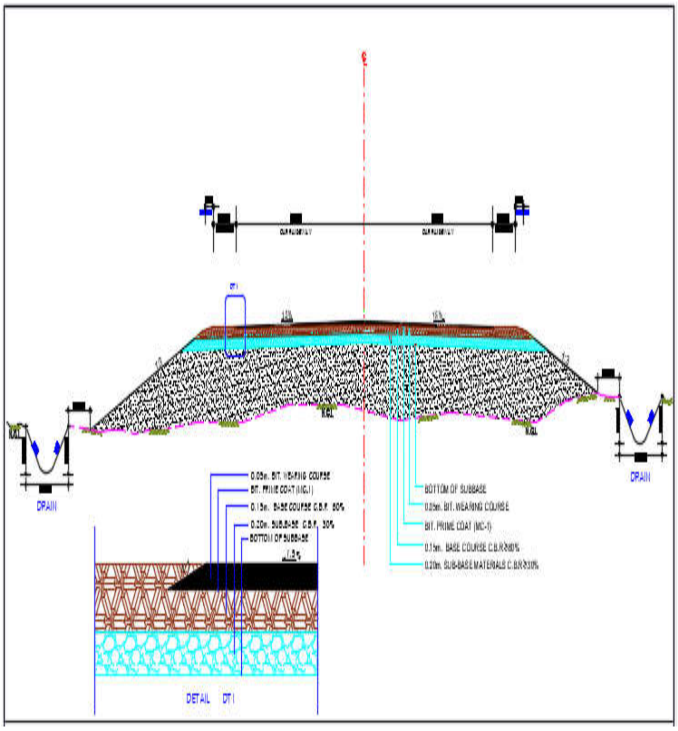

Figure.8 Typical Cross-section

Road as-built drawings

Road as-built drawings include a detailed plan (Figure 9); Digital elevation model (DEM) (Figure 5); longitudinal Section (Profile); Cross sections (every 50 m.);Typical Cross section and box and pipe culverts sections.

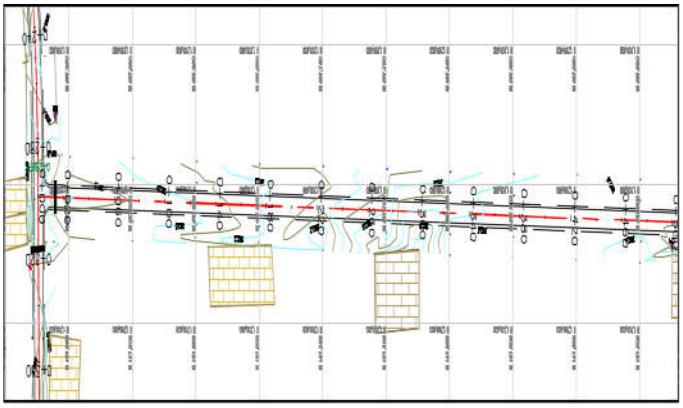

Figure 9 Road Corridor plan

Cases of Earth Work Computation

Case (1): Calculating the quantities volume (cut and fill) in cubic meters (Table 10) taking measurements every 25m (Table 9). and every 5m to the left and right of the center line.

Table (9) case (1) Calculating the quantities volume of the cut and fill in m3

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	8.74	0.91	0.00	0.00	0.00	0.00
0+025.00	7.68	1.56	205.16	30.96	205.16	30.96
0+050.00	7.27	1.63	186.77	39.92	391.93	70.88
0+075.00	7.05	1.59	178.94	40.29	570.87	111.17
0+100.00	6.55	1.95	169.99	44.28	740.87	155.45
0+125.00	6.44	2.06	162.38	50.12	903.24	205.57
0+150.00	3.34	3.53	122.27	69.88	1025.51	275.45
0+175.00	5.94	2.04	115.97	69.56	1141.47	345.00
0+200.00	6.36	1.79	153.76	47.82	1295.23	392.82
0+225.00	7.71	0.91	175.95	33.77	1471.18	426.60
0+250.00	6.20	1.92	173.91	35.38	1645.08	461.97
0+275.00	6.87	1.57	163.42	43.54	1808.51	505.51
0+300.00	3.71	3.27	132.32	60.46	1940.83	565.97
0+325.00	6.75	1.27	130.82	56.74	2071.65	622.71
0+350.00	7.44	1.27	177.38	31.68	2249.03	654.39
0+375.00	7.59	1.23	187.82	31.20	2436.86	685.59
0+400.00	7.50	1.26	188.57	31.15	2625.43	716.74
0+425.00	7.17	1.46	183.38	33.99	2808.80	750.73
0+450.00	7.05	1.32	177.77	34.75	2986.57	785.47
0+475.00	7.26	1.17	178.83	31.17	3165.40	816.64

Table (10) case (1) Total volume of cut, fill and cumulative in m3

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+500.00	5.88	2.28	164.27	43.19	3329.67	859.84
0+525.00	5.98	2.31	148.34	57.49	3478.01	917.33
0+550.00	4.77	2.85	134.49	64.59	3612.49	981.92
0+575.00	6.50	1.40	140.96	53.10	3753.46	1035.01
0+600.00	6.47	1.44	162.17	35.56	3915.63	1070.57
0+625.00	7.00	1.52	168.51	36.91	4084.14	1107.48
0+650.00	7.83	0.65	185.49	27.03	4269.63	1134.51
0+675.00	1.25	1.76	113.50	30.06	4383.13	1164.56
0+700.00	0.12	6.13	17.08	98.54	4400.21	1263.11
0+725.00	0.00	0.00	1.50	76.59	4401.71	1339.70
0+725.30	0.00	0.00	0.00	0.00	4401.71	1339.70

Case (2): Calculating the quantities volume of cut and fill in cubic meters, taking measurements with intervals of 25m along the centerline, and every 10m to the left and right of the center line (Table 11). An initial point is generated automatically by the surface estimate value 1.

Table (11) case (2)): Calculating the quantities volume of cut and fill in m3

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+500.00	3.90	2.81	136.54	51.60	3288.26	907.77
0+525.00	5.85	2.35	121.91	64.56	3410.17	972.33
0+550.00	4.75	2.86	132.56	65.12	3542.72	1037.45
0+575.00	6.02	1.77	134.65	57.78	3677.37	1095.23
0+600.00	6.24	1.72	153.27	43.59	3830.64	1138.82
0+625.00	6.43	1.80	158.44	43.79	3989.07	1182.61
0+650.00	6.49	0.92	161.53	33.93	4150.60	1216.54
0+675.00	0.39	3.61	86.05	56.55	4236.65	1273.10
0+700.00	0.45	5.00	10.52	107.63	4247.17	1380.72
0+725.00	0.00	0.00	5.64	62.56	4252.81	1443.28

Case (3): Calculating the quantities volume (cut and fill) of the table.12,taking measurements every 50m (estimate value 2).

Table (12) Case (3) Calculating the quantities and volume of cut and fill in m3

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	8.75	0.91	0.00	0.00	0.00	0.00
0+050.00	6.93	1.62	392.07	63.33	392.07	63.33
0+100.00	6.55	1.95	337.11	89.26	729.17	152.59
0+150.00	3.34	3.53	247.27	136.92	976.44	289.51
0+200.00	6.37	1.79	242.70	132.97	1219.14	422.48
0+250.00	6.20	1.92	314.18	92.73	1533.32	515.21
0+300.00	3.71	3.27	247.83	129.77	1781.15	644.98
0+350.00	7.44	1.27	278.85	113.46	2060.00	758.44
0+400.00	7.50	1.26	373.57	63.23	2433.57	821.67
0+450.00	7.05	1.32	363.75	64.61	2797.32	886.28
0+500.00	5.88	2.28	323.33	90.17	3120.64	976.45
0+550.00	4.77	2.85	266.47	128.43	3387.12	1104.89
0+600.00	6.62	1.42	284.80	106.75	3671.91	1211.64
0+650.00	8.00	0.65	365.53	51.53	4037.45	1263.17
0+700.00	0.16	5.92	204.10	163.97	4241.54	1427.14
0+725.30	0.00	0.00	2.07	74.87	4243.61	1502.00

Case (4): Calculating the quantities and volume of cut and fill (Table.3) in cubic meters, taking measurements every 100m (estimate value 3)

Table (13) Case (4) Calculating the quantities and volume of cut and fill in m3

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	8.60	0.91	0.00	0.00	0.00	0.00
0+100.00	6.55	1.95	757.89	142.93	757.89	142.93
0+200.00	6.39	1.68	647.11	181.32	1405.00	324.25
0+300.00	3.71	3.27	505.08	247.49	1910.08	571.74
0+400.00	7.23	1.26	546.91	226.69	2456.99	798.43
0+500.00	5.88	2.28	655.50	177.35	3112.50	975.78
0+600.00	6.62	1.42	625.06	185.11	3737.56	1160.89
0+700.00	0.16	5.92	339.21	365.99	4076.76	1526.89
0+725.30	0.00	0.00	2.07	74.87	4078.83	1601.75

For comparison purposes of the previous results, the confidence level was calculated by using:

Confidence level = (the estimated value / actual value) %.

the equation above shows if it falls within the limits of acceptable quality, the permissible confidence level is 95%, and therefore the quality acceptance limit is 5%.

Table (14): Comparison (1): between actual value (case 1) and estimate value 1 (case 2)

Station	Actual value		Estimated Value		Compression %	Compression %
	Fill Volume	Cut Volume	Fill Volume	Cut Volume	in Fill Volume	in Cut Volume
0+000	0.00	0.00	0.00	0.00	0.0	0.0
0+025	205.16	30.96	214.32	25.87	104.5	83.6
0+050	186.77	39.92	203.51	30.67	109.0	76.8
0+075	178.94	40.29	188.30	34.93	105.2	86.7
0+100	169.99	44.28	169.17	43.71	99.5	98.7
0+125	162.38	50.12	154.64	54.43	95.2	108.6
0+150	122.27	69.88	135.97	73.08	111.2	104.6
0+175	115.97	69.56	127.67	74.80	110.1	107.5
0+200	153.76	47.82	143.48	55.57	93.3	116.2
0+225	175.95	33.77	164.73	40.41	93.6	119.7
0+250	173.91	35.38	169.75	40.77	97.6	115.2
0+275	163.42	43.54	165.28	46.31	101.1	106.4
0+300	132.32	60.46	130.25	62.44	98.4	103.3
0+325	130.82	56.74	128.21	58.19	98.0	102.6
0+350	177.38	31.68	165.21	37.29	93.1	117.7
0+375	187.82	31.20	171.79	39.38	91.5	126.2
0+400	188.57	31.15	177.38	38.13	94.1	122.4
0+425	183.38	33.99	180.34	35.62	98.3	104.8
0+450	177.77	34.75	182.63	32.51	102.7	93.6
0+475	178.83	31.17	179.09	32.08	100.1	102.9
0+500	164.27	43.19	136.54	51.60	83.1	119.5
0+525	148.34	57.49	121.91	64.56	82.2	112.3
0+550	134.49	64.59	132.56	65.12	98.6	100.8
0+575	140.96	53.10	134.65	57.78	95.5	108.8
0+600	162.17	35.56	153.27	43.59	94.5	122.6
0+625	168.51	36.91	158.44	43.79	94.0	118.6
0+650	185.49	27.03	161.53	33.93	87.1	125.5
0+675	113.50	30.06	86.05	56.55	75.8	188.1
0+700	17.08	98.54	10.52	107.63	61.6	109.2
0+725	1.50	76.59	5.64	62.56	376.0	81.7

Table (15) Comparison (2): Between actual value (case 1) and estimate value 2 (case 3)

Station	Actual value		Estimated Value		Compression %	Compression %
	Fill Volume	Cut Volume	Fill Volume	Cut Volume	in Fill Volume	in Cut Volume
0+000	0.00	0.00	0.00	0.00	0.0	0.0
0+050	391.93	70.88	392.07	63.33	100.0	89.3
0+100	348.93	84.57	337.11	89.26	96.6	105.5
0+150	284.65	120.00	247.27	136.92	86.9	114.1
0+200	269.73	117.38	242.7	132.97	90.0	113.3
0+250	349.86	69.15	314.18	92.73	89.8	134.1
0+300	295.74	104.00	247.83	129.77	83.8	124.8
0+350	308.20	88.42	278.85	113.46	90.5	128.3
0+400	376.39	62.35	373.57	63.23	99.3	101.4
0+450	361.15	68.74	363.75	64.61	100.7	94.0
0+500	343.10	74.36	323.33	90.17	94.2	121.3
0+550	282.83	122.08	266.47	128.43	94.2	105.2
0+600	303.13	88.66	284.8	106.75	94.0	120.4
0+650	354.00	63.94	365.53	51.53	103.3	80.6
0+700	130.58	128.60	204.1	163.97	156.3	127.5

Table (16): Comparison (3) between actual value (case 1) and estimate value 3 (case 4)

Station	Actual value		Estimated Value		Comparison %	Comparison %
	Fill Volume	Cut Volume	Fill Volume	Cut Volume	in Fill Volume	in Cut Volume
0+000	0.00	0.00	0.00	0.00	0.0	0`0
0+100	740.86	155.45	757.89	142.93	102.30	91.95
0+200	554.38	237.38	647.11	181.32	116.73	76.38
0+300	645.60	173.15	505.08	247.49	78.23	142.93
0+400	684.59	150.77	546.91	226.69	79.89	150.35
0+500	704.25	143.1	655.5	177.35	93.08	123.93
0+600	585.96	210.74	625.06	185.11	106.67	87.84
0+700	484.58	192.54	339.21	365.99	70.00	190.09

From Tables 14, 15, and 16, it can be realized that flat areas may be treated differently from the undulated areas, i.e. table (10) shows the computation at the changes of 0+100.

Table (17) Station Chain age (00+100)Fill and Cut volumes (in m3) in a Flat Area

Comp. No	Actual value		Estimated Value		Compression %	Compression %
	Fill Volume	Cut Volume	Fill Volume	Cut Volume	in Fill Volume	in Cut Volume
1	169.99	44.28	169.17	43.71	99.5	98.7
2	348.93	84.57	337.11	89.26	100.0	89.3
3	740.86	155.45	757.89	142.93	102.30	91.95

From the contour map, as shown in Figure 4, and the 3D DEM (Figure 5), it can be seen that the area in which station 00+100 is located is semi-flat. The comparison in Table 17, showed that the level of confidence in the permissible limits in case 1 is higher than that in case 2, while case 3 is lower than that in case 2. From these comparisons, it can be concluded that flat areas do not require convergent measurements i.e. measurements are to be taken for longer distances to shorten the time and to minimize the cost. Table 18, also illustrates the computation at the chain ages of 0+700 in an undulated area.

Table (18) Station chain age (00+700) Fill and Cut volumes (in m3) in an undulated area

Comp. No	Actual value		Estimated Value		Compression %	Compression %
	Fill Volume	Cut Volume	Fill Volume	Cut Volume	in Fill Volume	in Cut Volume
1	17.08	98.54	10.52	107.63	61.6	109.2
2	130.58	128.60	204.1	163.97	156.3	127.5
3	484.58	192.54	339.21	365.99	70.00	190.09

The area in which station 00+700 is located is undulating as shown on the contour map. From the comparison (Table 11), it can be seen that the confidence level is not appropriate for all cases, from which it can be concluded that undulating areas require close measurements to attain the required accuracy. Therefore, the balance between accuracy and cost is what would be considered in road and highway engineering. Based on the results obtained in the case study, the following recommendations can be drawn:

(a) Standardizing the way how surveys are to be conducted, by applying all survey standards, specifications, quality control, survey laws, regulations, and guidelines.
(b) The standards should be clear, usable, and simple, without compromising the quality of the road work and its product.
(c) Always identify standards, reference coordinates, and technical specifications for survey work, spatial reference systems, coordinate systems, and all necessary survey data regulations that are to be followed in the field of survey work.
(d) There must be a compromise between high-precision, expensive scientific methods, and low-precision economical methods.
(e) Creating a survey accuracy matrix to allow the classification of surveys based on the type, the technique employed, and the accuracy achieved.
(f) Commitment to adhere to the specified designs during implementation to avoid costly mistakes caused by design flaws.

CONCLUSIONS

This paper aims to outline the executive regulations, survey standards, and specifications required for the implementation of highway and road regulations for organizing all surveying work activities in Sudan. The paper presents conceptual guidelines to be used to regulate the survey work practice and standardize the field surveys, processing, quality control, procedures, and processes related to survey work which are to be carried out by the relevant authorities and stakeholders in Sudan. The conceptual guidelines are meant to improve the quality and harmonization of geospatial data required for highway design and asset management as well as decision-making processes. The targeted standards and specifications may include, the reference frame, projection, coordinates systems, and the guidelines and specifications that must be followed in the highway field survey work. The paper also highlighted the importance of developing survey regulations, standards, and specifications for routes and road surveys, as well as establishing the procedures and survey guidelines.

The case study is applied in the field of road surveying to evaluate and apply survey standards for route selection, road design, and for calculating excavation and backfill volumes. The results indicated volume differences based on the adopted criteria. From the results, the specifications of the cross-sections and distances between sections can be established at intervals between 50 to 100m in flat areas and intervals of 25 m in undulated areas, taking measurements on both sides of the road (left and right) from the center line of the road, every 5 to 10 meters, based on the terrain.

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