Integrating Modern Surveying Tools with the Project Team in Nigeria

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Keywords: Modern Surveying Tools, ICT, Professional Recognition, Project Team, Project Delivery

SUMMARY

Over the years in Nigeria, most civil, construction and environmental engineering projects have operationally regarded and treated surveying tools and professionals as mere auxiliary data providers, hence placed outside the box of project teams and implementation strategies. The consequences of this subtle exclusion have been evident in sub-standard project deliveries and short lifespan of infrastructure, across the country. The fact that, all projects initiated by man starts and ends on the earth surface or subsurface suggests that, the lifespan and functionalities of the infrastructure so placed is a function of the physical stability and spatial balance of its host (the earth). This therefore places technical and professional demands for the use of surveying tools and expertise within the framework of project team for the accurate and periodic measurements, spatial representation and management of the project units and area. Most importantly, the rapid technological advances in modern surveying extend beyond measurements to include computing, communications, and geospatial data mapping and modelling. This paper therefore aims at establishing the need for the integration of modern surveying tools with the civil and environmental engineering project teams for rapid and effective project delivery in Nigeria. The paper identified key modern surveying tools for rapid project delivery and justified the need for a balanced project team in modern project tasks and solutions. The benefits of integrating modern surveying tools in all physical development projects were highlighted and strategies for archiving such integration outlined. The paper observed that, project teams work best when there is a balance of primary professional and technical roles, and when team members know and work to their strengths and actively manage weaknesses. The cutting-edge surveying technologies and expertise required for pre-project surveys and mapping, project monitoring (short-term), post-project and as-built surveys (medium term), and project facility management surveys and geospatial database management (long-term) are readily available today; but professional chauvinism and lack of mutual recognition for interoperability have been the bane of sustainable project management in Nigeria. The Surveyors should therefore be included among the project team comprising the Civil Engineer, Architect, Quantity Surveyor, Structural Engineer, Lawyer, etc., in order to discourage the implementation of the surveying contents in projects as supplementary, rather than being considered as core components of projects.

1.0 INTRODUCTION

Surveying is the science of determining the positions, in three dimensions, of natural and man-made features on or beneath the surface of the earth (Schofield and Breach, 2001). These features may be represented in analogue or digital maps, 3D model, plans or charts in order to aid national planning and development. In Engineering projects today, both analogue and digital formats of surveying are being used for planning, design and construction works in a more rapid and accurate manner. The developments in information communication technology (ICT) have changed the landscape of surveying solutions and practice across the globe; thereby creating a total departure from the conventional tedious field data collection and processing to digital data collection, storage, processing, integration and management.

From the 1st Century to date, surveyors have fulfilled the need to mark property boundaries, conduct reconnaissance and make maps for planning (Fosburgh, 2014). As economies and populations grew, surveyors kept up with the increased demands for broader knowledge and higher accuracy, as being witnessed nowadays across the globe.

However, over the years in Nigeria, most projects of civil engineering, construction and environmental engineering contents have operationally regarded and treated surveying tools and professionals as mere auxiliary data providers, hence placed ‘outside the box’ of project teams and implementation strategies. The consequences of this subtle exclusion have been evident in sub-standard project deliveries and short lifespan of infrastructure, across the country; though efforts and claims are made to denigrate these facts. The fact that, all projects initiated by man starts and ends on the earth surface or subsurface means that, the lifespan and functionalities of the infrastructure so placed is a function of the physical stability and spatial balance of its host (the earth). This therefore places huge demand on man to accurately and periodically carry out the measurements, the spatial modeling and the accurate representation of the relevant *project area of interest* (PAOI) for effective project management.

The modern and rapidly growing technology extends surveying beyond just measurement to include computing, communications, and geospatial data mapping and management. These changes have made satellite positioning, earth observation satellite systems and geographic information more accessible, which have placed increased importance on accurate, reliable, timely, high level data integrity, and user-friendly geospatial information. Far beyond the time-honoured practices of property and construction measurement, surveying has grown to include managing, interpreting, analysing and portraying spatial information for better construction project implementation and delivery. Therefore, modern engineering and construction projects must integrate the modern surveying tools to facilitate *standard, accurate, reliable, cost-effective and timely* project delivery. Therefore, this paper seeks to establish the need for the integration of modern surveying tools with the civil and environmental engineering project teams for rapid and effective project delivery in Nigeria.

1.1 Objectives of the Paper

The Objectives of this paper are to:

i. Identify key modern surveying tools for rapid project delivery in Nigeria
ii. Justify the need for project teams in the modern project tasks and solutions
iii. Establish the need for modern project team to integrate modern surveying tools in Nigeria
iv. Recommend strategies to adopt in the proposed integration.

2.0 MODERN SURVEYING TOOLS

The developments in ICT have improved the tools and techniques for surveying solutions and practice across the globe, and have repositioned the discipline of surveying and geoinformatics in the main stream of sustainable national development and inter-disciplinary or multi-level relevance globally. Today, the understanding and applications of surveying and geoinformatics requires huge inputs of computer science and information technology. In this section, some key modern surveying tools required for rapid project delivery are identified and briefly discussed.

2.1 Location-Based Information System (LBIS) with GNSS

Over the years in Nigeria, lack of adequate land titling and record systems have been serious problems; hence the need to set up modern and robust surveying tools for geodetic and computing capability needed to develop and support location based information system. Between 2008 and to-date, the Office of the Surveyor General of the Federation (OSGoF) has established about 15 permanent Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) to provide the framework for positioning and geospatial data for the AFREF Project, the National Land Reform Initiative and the Surveying and Engineering projects across Nigeria. In Nigeria today, field crews use similar GNSS receivers to capture Cadastral/Land information. In rural areas, handheld Global Positioning System (GPS) receivers measure property and ownership boundaries to an accuracy of 1-meter. For property in higher-value urban areas, survey-grade GNSS receivers collect data to centimeter precision.

Figure 1: State-of the Art GNSS CORS Infrastructure in Nigeria (Ojigi et al, 2011)

2.2 GNSS-Activated Construction Machines

New technologies and changing demands are driving a paradigm shift in modern surveying. Rapid technological development extends modern surveying beyond measurements to include computing, communications, geospatial data mapping and modeling.

The advent of machine control system (Fig.2a), a surveyor's function has radically changed to supporting construction through planning processes used by construction organisations, and as a geo-data manager, the construction site surveyor creates or verifies the digital terrain and design models used by the heavy machines. Additional activities include work to ensure that machines accurately create the desired design, managing on-site communications, monitoring individual machine performance, and providing input into the project's building information model (BIM). Also, the Trimble Integrated Surveying Equipment (fig.2b) combines RTK GNSS with robotic Total station, to instantly make results available to the user(s) in the appropriate coordinate system on site.

Figure 2: (a) GNSS-Activated Leveling Bulldozers: (b) Trimble Integrated surveying combines robotic total station with RTK GNSS (www.trimble.com)

2.3 Electronic Total Station (SmartStation/SmartPole) and Electronic Theodolite

Surveying by *SmartStation* and *SmartPole* have revolutionalised spatial mapping; such that, with *SmartStation* the entire survey is carried out by and controlled from the total station. While with *SmartPole* (Fig. 3b) the entire survey is carried out by and controlled from the pole. The SmartPole Total Station is remotely controlled, hence only one operator is required. Measurements can be angles and distances from the total station and/or RTK. SmartPole is ideal for robotic total stations and provides total flexibility. Whichever system that is used (including fig. 3a), the time saving, speed of work, cost-effectiveness, and increased profits are ensured.

Figure 3a: Electronic Total Station, Theodolite and Laser Levels for Precise Engineering Surveys

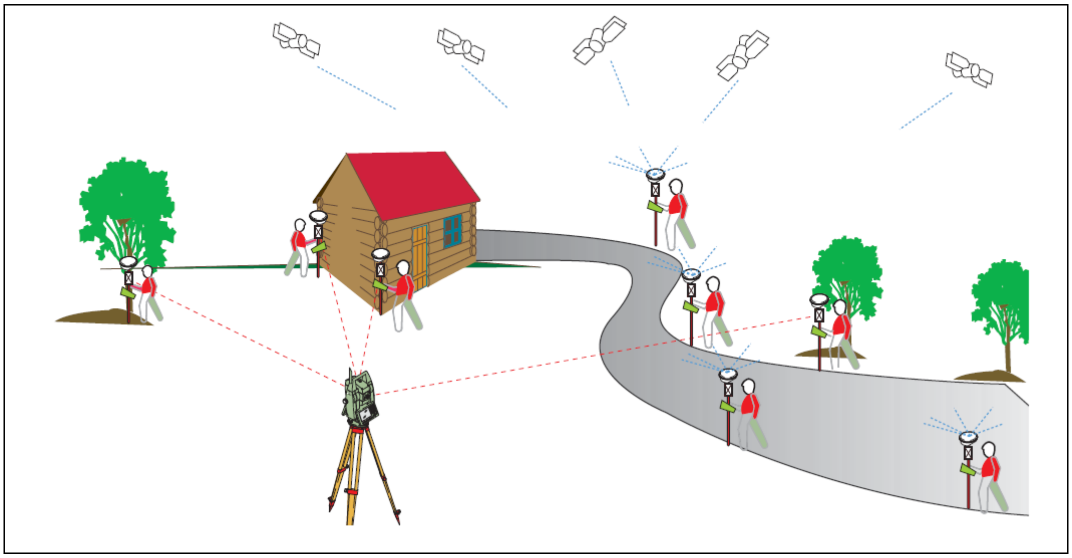

Figure 3b: An Illustration of Surveying with SmartPole (Source: Leica Geosystem (n.d))

2.4 Hydrographic Mapping and Charting Vessel

Field surveys take place regularly on our territorial waters, especially for higher-risk, higher-priority coastal areas of the country. Tools of modern hydrographic surveying now include modern multi-beam sounders, the Global Navigation Satellite System-based Positioning System, and other devices (fig. 4). The vessel has communication facilities for data dissemination to central hydrographic data repositories. However, old methods using lead lines and triangulation can still come in handy where necessary or integrated.

It is now a fact that, the use of survey vessel extends beyond hydrographic surveys to specialised service areas such as environmental protection and monitoring, mine countermeasures, Port and Harbor security, Oil theft and bunkering surveillance, etc. These services are possible for the surveyor because of the availability of modern and standard payload sensors made up of dual frequency side scan sonar with Interferometric bathymetry, video camera, navigation sensors and optical backscatter sensors on-board the modern survey vessels.

Figure 4: Hydrographic Charting Vessel (http://www.hydrosurveys.net/surveys.htm)

2.5 Real Time Kinematics (RTK) Observations of Positions of Interest with GNSS

In traditional GNSS carrier phase positioning, the **integer ambiguity** which is known to be the number of full cycles between the receiver and the transmitting satellite at the time the receiver begins to track the signal at the initial epoch or the number of wavelengths between the satellite and the receiver during the travel time of the signal is not known. As a result of this unknown **integer ambiguity**, the position fixing is less accurate. As a solution, the RTK concept in modern positioning allows the integer ambiguity to be determined computationally through the processing of GNSS carrier phase data, and by implication provides the user with more accurate and reliable position fix (centimeter level positioning).

The principle of Network RTK begins with all reference stations within the RTK Network continuously streaming satellite observations to a central server running Network RTK software. The aim of this is to correctly measure the correlated errors for a region, to predict their effects for users. Errors are estimated using information from more than one reference stations so their effect is significantly reduced compared to the single reference station approach. In figure 5 the data in network mode will require four (4) or more stations for the same area of interest to determine the position of a user. The advantage of this approach is the significant reduction of costs of infrastructure. The architecture in figure 5 includes densification of the reference stations, and the need to establish regional data processing and back-up system.

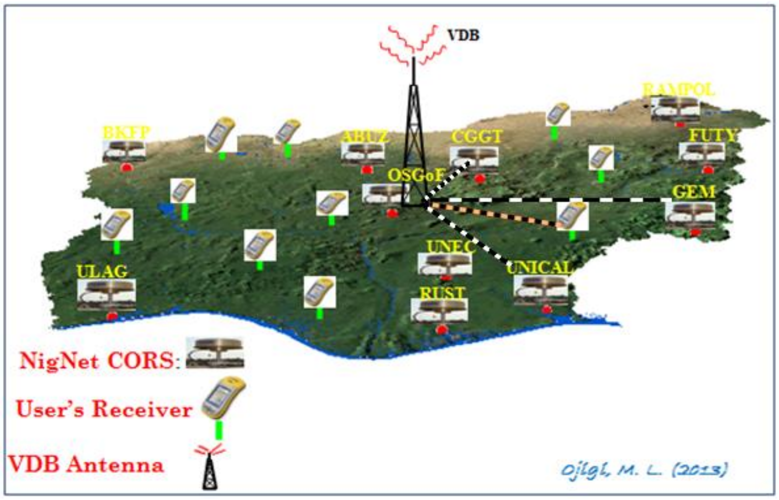

Fig.5: Centralized Network RTK data processing Model for Nigeria (Ojigi, 2014a)

From field observations, only major construction and large engineering firms in Nigeria imbibes GNSS technology with differential GPS receivers in which measurements on the satellite signals are taken simultaneously at two stations and differenced. One of the receivers is set up at a known point and is termed the reference; the other receiver is set up at an unknown point and is termed the rover, and the position of the rover is obtained relative to the position of the reference.

2.6 New Aerial Sensors and Solutions with UAV and LiDAR

Mobile mapping systems utilise video and LiDAR imaging combined with position data from GNSS and inertial systems (Fig.6a and b). Airborne systems continue to improve as well, with aerial cameras and scanners supported by positioning systems for navigation, flight management and georeferencing. The data from these high-speed, multi-sensor systems are fused and made available to GIS, design and other applications.

In addition to traditional photogrammetry and terrain modeling, information from the mobile systems is today being used for feature extraction, asset management and maintenance operations. For example, the railway project in Nigeria can use mobile mapping to collect information on the condition of its track, signals and other assets and management. Airborne imaging has taken an important step forward with the emergence of small, unmanned aerial vehicles (UAV) for aerial photography. Using very small, lightweight aircraft flying at low altitudes, the UAV captures high-quality images over small and medium areas. GNSS provides navigation and georeferencing. The images are processed with traditional photogrammetry techniques to produce orthophotos and digital terrain models, which provide timely, low-cost imagery for Project Management. The Nigerian project team is yet to come to terms with these innovations.

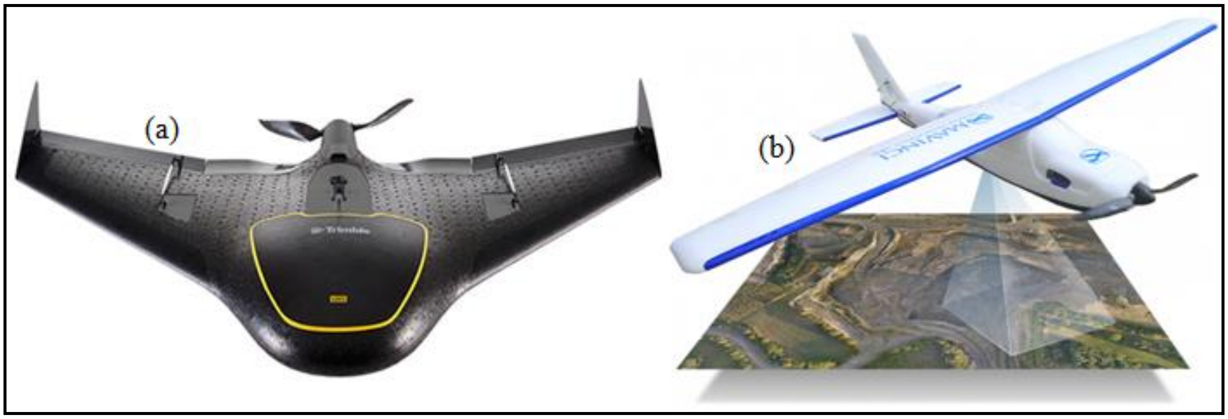

Figure 6: (a) UAV for Aerial Surveys (b) SIRIUS PRO Terrestrial Laser Scanner (http://www.geo-matching.com/products)

2.7 Geospatial Information Systems (GIS)

GIS is a dynamic management tool that provides a geographic framework to manage and utilise data from a host of sources. A surveyor's involvement in GIS is not limited to just collecting measurements; but also collect and manage attributes about the elements they geo-locate, using sensors and data collection technologies that extend beyond the traditional surveying instrumentation. This is a huge paradigm shift for many surveyors, who necessarily regard position and spatial relationships as primary data. But GIS presents abundant opportunities for a surveyor and entire project team who understands that future success requires them to be a geospatial data professional. A GIS can contain data management, precision and visualisation functionality needed to support traditional surveying and engineering project needs.

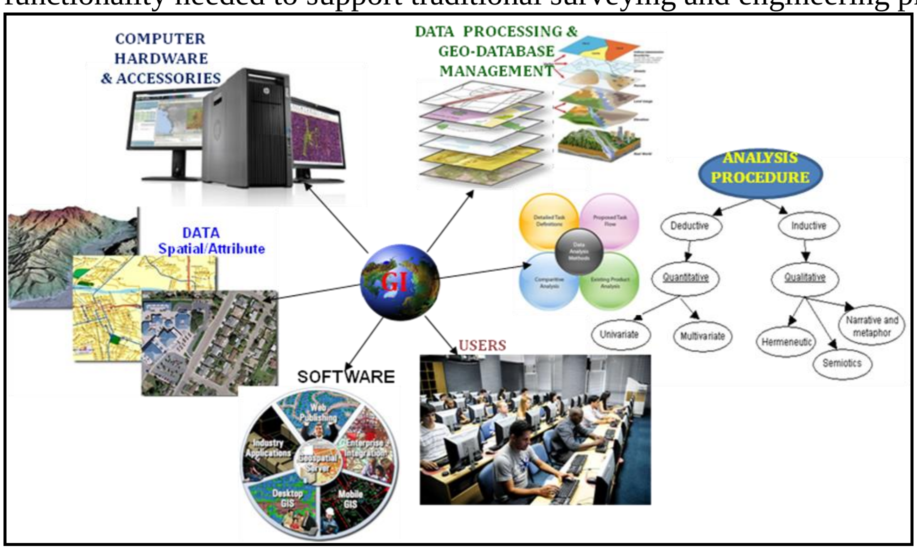

Figure 7: Features of GIS for Rapid Project Delivery (Ojigi, 2014b)

Today, GIS presents business opportunities that include creating, populating and maintaining a GIS and using it to manage cadastral data and information on the natural and built environment. Therefore, given the close relationship between Surveying and GIS, it comes as no surprise that the tools and techniques are on the converging path, and providing a robust solution for construction and engineering project planning, design and implementation across the globe. Figures 7 and 8 provide typical geoinformatics tools and techniques project site information and management.

Figure 8: Rapid Survey Data Collection Tools (Ojigi, 2014b)

2.8 Terrestrial Scanning Tool for As-Built Surveying

Main users of RIEGL VZ-1000 Terrestrial Laser Scanner (Fig. 9a) include surveyors; architects; civil engineers; plant design engineers, archaeologists, etc. Application areas include mining; architecture; as-built surveying; heritage; city modelling. Key distinguishable features of this equipment are echo digitization; online waveform processing; multiple target capability; stand-alone data acquisition; HMI-interface; integrated GPS receiver; laser plummet; inclination sensors; compact; lightweight. The scanned data products by this terrestrial laser scanner are in JPEG; TIFF; RAW formats.

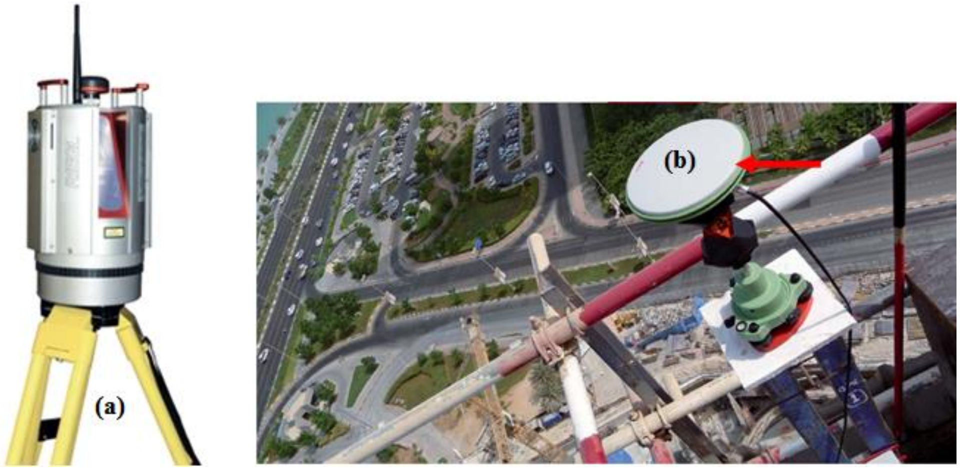

Figure 9: (a) RIEGL VZ-1000 Terrestrial Laser Scanner; (b) Monitoring Vertical Towers with Core Wall Control Survey System (CWCS) (Source**:** van Cranenbroeck (n.d))

Advances in technology have generated considerable interest in the construction of super high-rise and iconic buildings all across the cities of the world, including the on-going World Trade Centre building in Central Business District (CBD), Federal Capital City (FCC) Abuja, Nigeria (Fig.9c); whose monitoring with conventional surveying tools may be challenging; but modern surveying tools such as the Core Wall Control Survey System (CWCS) (Fig.9b), developed and tested by Leica Geosystems provides a unique solution. It uses networked GNSS (GPS and GLONASS) sensors combined with high precision inclination sensors and total stations to deliver precise and reliable coordinates that are referenced to the design frame, and ellipsoids/projections that are not influenced by building movements.

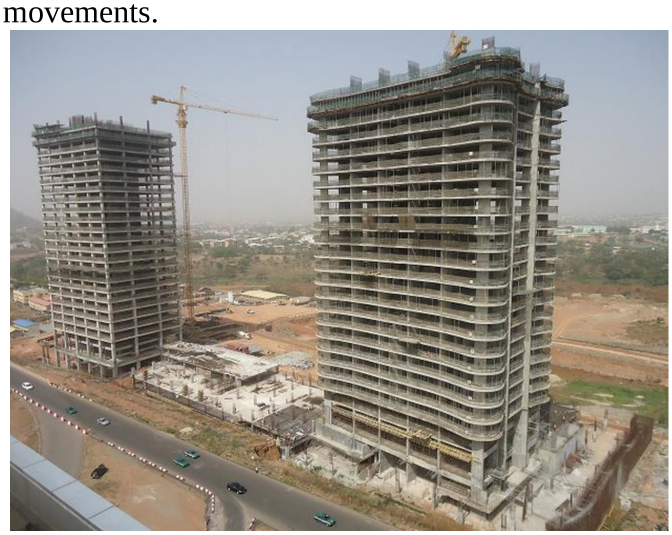

Figure 9c: Abuja World Trade Centre *(Under Construction)*, Central Business District (CBD), Federal Capital City (FCC), Phase 1, Abuja, Nigeria

The Nigerian project team must without delay recognizes these advances in surveying tools and employ them for high quality project deliverables.

3.0 THE PROJECT TEAM

A project team could be described as a group of professionals with relevant expertise who have been tasked with collectively completing a project. A project team is to perform and to deliver specific projects according to time, cost, quality and benefit expectations (Roberts, 2013). Each team member typically has a specific set of deliverables that will help the team complete the project (Fig. 10a). Teams work best when there is a balance of primary roles and when team members know their roles, work to their strengths and actively manage weaknesses (British Council, n.d).

Figure 10: (a) Illustration of the importance of Team members' expertise in Project Delivery; (b) Project Team Thinking Together (Source: http://www.ehow.com)

Examples of projects that require project team include:

i. *Road and rail construction,*
ii. *Mass housing project,*
iii. *Drainages and flood control,*
iv. *Dams and bridges,*
v. *Dredging and pipeline,*
vi. *Stadia and parks,*
vii. *Telecommunication and power transmission projects,*
viii. *Jetties/harbor and ports,*
ix. *Underground tunneling and mining of solid minerals,*
x. *Exploration and exploitation of oil and gas, etc.*

Attempts to belittle or denigrate the tasks of some team members in a project team often lead to sub-standard project completion and delivery. In Nigeria and many parts of Africa, poor constitution of project team is one fundamental reason for poor quality construction works and non-effective project delivery over the years. Therefore, a project team imperatively should be groups of consultants working towards a common goal; hence must think together (Fig.10b). Regardless of where the project team members come from, the goal is the same: to complete the project successfully.

3.1 The Need for a Balanced Project Team

A robust project team is needed for the following reasons amongst others.

i. When team members use their skills and knowledge together, the result is a stronger union that can fulfill its project mission;
ii. People working together can sustain the enthusiasm and lend support needed to complete the work of each program.
iii. Civil and environmental engineering in the face of ever dynamic development in science and technology are more complex; hence require comprehensive approach to delivering complete and effective results;
iv. Need for interdisciplinary approach for multi-dimensional solutions is a key requirement in modern science and technology
v. If there must be speed and precision to a well thought out civil and environmental engineering project vision, many relevant hands and opinions are imperative (*the more, the merrier*)

It's therefore important to note that, the skills of the project team must be tendered and listened to; they must be questioned and tested, believed, respected and cherished, offered and nurtured to grow; must be shared and assimilated, and wisely adopted with best practice for attaining the most desired results.

4.0 STRATEGIES FOR THE INTEGRATION OF MODERN SURVEYING TOOLS

Modern environmental and engineering challenges require inter-disciplinary solutions; meaning expertise from relevant fields must be harnessed towards effective project deliverables. There is a paradigm shift from ***'I can do it alone; to, we can it together'***. Notably today, the advances in technology have brought about the need for collaborations for robust solutions. In order to effectively integrate the modern surveying tools with the project team, the following strategies are necessary:

1. The efficient use of modern surveying tools such as Global Navigation Satellite System receivers, Mobile GIS and location based information system, Electronic Total Station and Terrestrial Laser Scanner, Laser Levels, 3-D Sounding Boats and Vessel, etc should be emphasized at the following stages of projects:

   i. Pre-project surveys and mapping (for planning and design)
   ii. During-project surveys and mapping (monitoring)
   iii. Post-project surveys and mapping (As-built surveys in medium term)
   iv. Maintenance surveys and Geospatial Database Management (long-term).

2. Secondly, professional Surveyors or Geomaticians should be among the project team alongside the Quantity Surveyor, Civil Engineer, Architect, etc. This should discourage the implementation of the surveying contents in a project as supplementary part of project, rather than being considered as one of the core components.

3. Spatial measurements and database on land information, geographic information; marine and hydrographic information, subsidence and ground deformation (x, y, z) over time should be adopted and integrated into the mode of project operations for robust project delivery and maintenance. Deformation surveys can provide not only the geometric status of the deformed object, but also information on its response to leading stress. This provides a better understanding of the mechanics of deformations and the checking of various theoretical hypotheses on the behaviour of a deformable body. Examples of deformation surveys include the following:
4.
   i. The monitoring of ground deformations due to mining exploitation,
   ii. Withdrawal of oil or underground water, or
   iii. Construction of large reservoirs and engineering structures;
   iv. The monitoring of accumulation of stress near active tectonic plate boundaries;
   v. Checking of the stability of large or complex structures (e.g. hydro-electric dams, stadium structure, high rise building, etc).

   Properly designed and properly analyzed deformation monitoring schemes of engineering projects provide essential information on the actual state of the deformation and may give advance warning of imminent structural failure (Chrzanowski, 2011; Chrzanowski and Szostak-Chrzanowski 2010; Ojigi, 2010).
5. Building collapse cases across Nigeria today are not all as results of poor construction materials; but due to ground subsidence in the project vicinity leading to micro-geodetic axial deformation (x, y, z,) of structures over a period of time (t_o). These phenomena are measurable with modern surveying tools such as Differential Global Positioning System (DGPS) in Real Time Kinematic (RTK) mode and Terrestrial Laser Scanner, Laser Levels, and high precision Electronic Total Station.
6. In view of the current advances in information communication technology, which have in several ways narrowed the professional gaps hitherto, the built environment professional must deliberately create a more inter-operable platform for interdisciplinary interactions and roles for effective delivery of projects in Nigeria.
7. Capacity building of members of the project team in moderate handling and use of key modern surveying tools in order for them to appreciate the requirements and need for employing such tools.

4.1 Benefits of Integrating Modern Surveying Tools with the Project Team

The following benefits are accruable to effective integration of modern surveying tools in project implementations

i. Improved accuracy in the job quantities (location based information) and delivery;
ii. Cost-effective and speedy delivery of project;
iii. Assurance of project quality and longevity
iv. Enhances professional collaboration and inter-disciplinary expertise
v. Ensure consistency with the global best-practice in modern solutions to project implementation and delivery
vi. Support sustainable digital mapping and applications, and enterprise geospatial information system for project planning, design, implementation and delivery

5.0 CONCLUSIONS

The developments in information communication technology (ICT) have in modern times changed the landscape of surveying solutions and practice; thereby creating a total departure from the conventional tedious field data collection and processing to digital data collection, storage, processing, integration and management systems.
Surveying technologies and ICT will continue to evolve to deliver best accuracies in measurements and spatial information development and communication for the project manager. This paper has outline some major modern surveying tools for efficient planning, design, implementation and monitoring of construction and environmental engineering projects, and justify their adoption and integration with other project tools and team for effective project delivery. The paper went further to suggest key strategies for the integration of modern surveying tools and techniques and identified their inherent benefits to project management.

Modern ground-based, airborne and mobile mapping systems have significant hardware and software capabilities for improving the standard, accuracy, reliability, cost-effectiveness and timeliness of project delivery ten times over the conventional approach. All that's required is for the project management team to structurally create a more inter-operable platform for interdisciplinary interactions and roles of relevant experts and tools for effective delivery of civil engineering, construction and environmental engineering projects in Nigeria.

As ICT advances, clients also become increasingly sophisticated; hence they expect and drive the surveyor and entire project team to deliver higher levels of information, analysis and robust solutions. On the other hand, the technological advances in acquiring and applying measurements enable the surveyors to perform as the geodata managers, and by selecting and blending techniques of geomatics and data management technologies, the surveyor can structure an optimal geospatial solution that help the project team for effective project delivery in Nigeria. Therefore, these modern tools and expertise should be injected into the operations of various project teams for cost-effective, qualitative and reliable deliverables in our national project tasks.

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He is a member of many professional organisations such as Nigerian Institution of Surveyors (NIS), Nigeria Association of Geodesy (NAG), EIS-Africa, African Association of Remote Sensing of the Environment (AARSE), IEEE/GRSS, and Geoinformation Society of Nigeria (GEOSON). He is married to Mrs. Mary Ebule Ojigi and they blessed with three children.

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He is also a practising Surveyor with over eighteen years experience. Dr. Chima Ogba is happily married to Mrs. Barida Ogba and they are blessed with four lovely children.