RNI: DELENG/2005/15153
Publication: 23rd of every month
Posting: 27th/28th of every month at DPSO

No: DL(E)-01/5079/2023-25
Licensed to post without pre-payment U(E) 28/2023-25
Rs.150

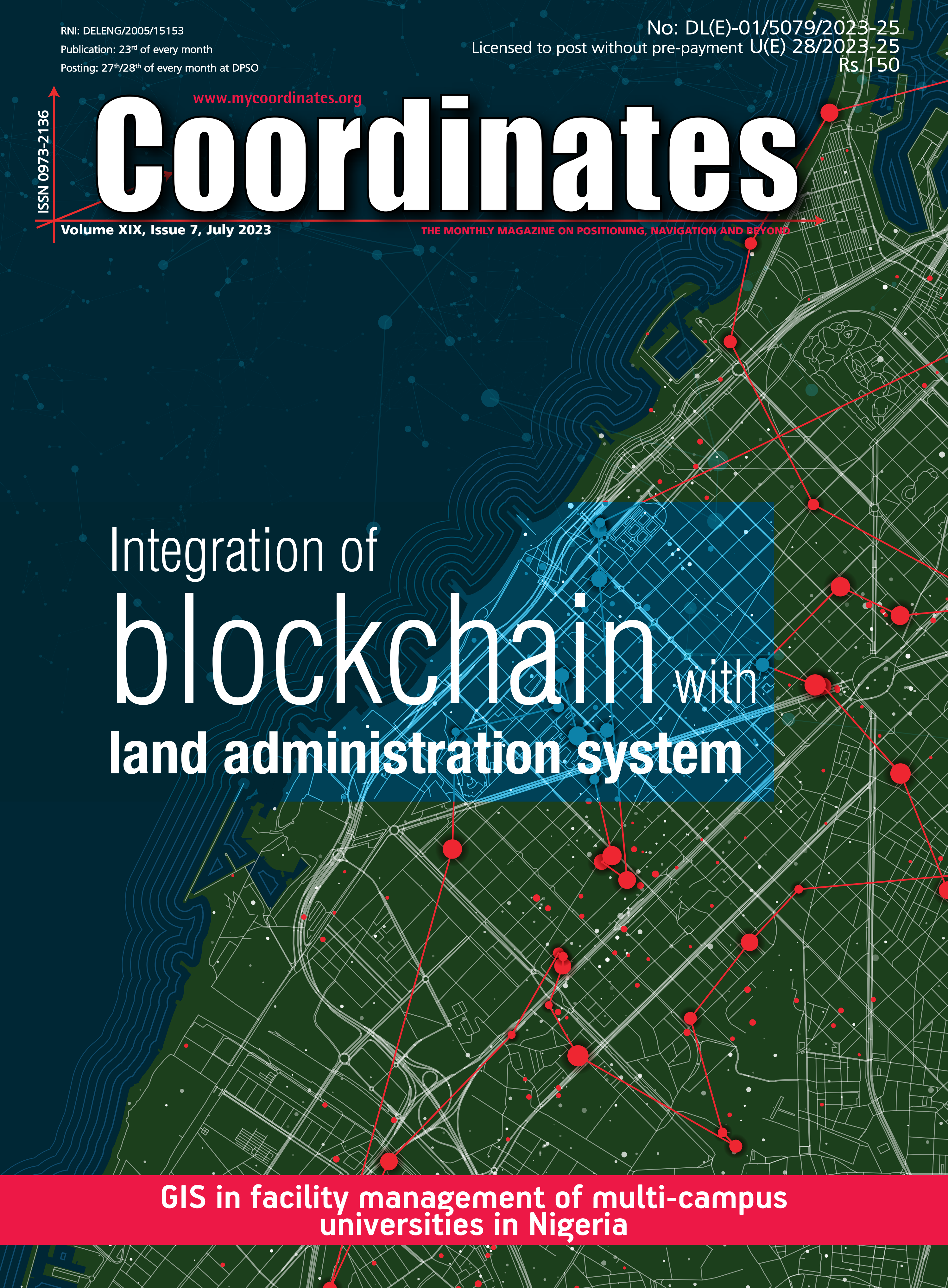
ISSN 0973-2136

www.mycoordinates.org

Coordinates

Volume XIX, Issue 7, July 2023

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND



Integration of blockchain with land administration system

GIS in facility management of multi-campus universities in Nigeria

In Coordinates

10 years before...

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Outdoor mobile field robot navigation

Chung-Liang Chang, Bo-Han Wu and Yong-Cheng Huang
Department of Biomechatronics Engineering, National Pingtung University of Science and Technology, Taiwan, R.O.C.

To ensure safety for the moving vehicle, the proposed vehicle is equipped with a laser range finder to avoid collision. The accelerometer, gyroscopes, and electronics compass are adopted to effectively correct the error of vehicle moving path. The Hallrotary wheel encoders can be combined with GPS to serve as an elementary dead reckoning in order to accomplish vehicle safe navigation through multi-layer fuzzy decision scheme. The proposed platform is designed to receive the multiple sensor data and integrated in multiple microcontrollers based on embedded concept.

GIS in pipeline route selection

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Imtiaz Ahmed Chandio
Assistant Professor, Mehran University Technology Mehran University, Jamshoro, Pakistan

Development of new oil and gas pipeline routes in coming years is inevitable and selection of an optimal route is crucial to the success of any pipeline routing project. An optimal route will minimize economic loss and negative socio-environmental impacts, in addition to enhancing the pipes' sustainability and prolonging its lifespan.

NATIONAL GIS: Setting agenda

Dr Mukund Rao
Adjunct Faculty at National Institute of Advanced Studies, Bangalore Adviser, Karnataka State RS Centre, Bangalore and is also an International Consultant in EO, GIS and Space.

National GIS is an "over-arching system cutting across existing systems" and thus complexity is "core embedded" in its inherent character – after all, integrating human, technological, social, cultural, competitive and temporal dimensions is a difficult task but not impossible.

3D Cadastral complexities in dense urban areas

Tarun Ghawana
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Joao Hespanha
Adjunct Professor, Technology and Management Polytechnic School of Águeda, University of Aveiro, Portugal

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Chief Engineer, East Delhi Municipal Corporation, Delhi, India

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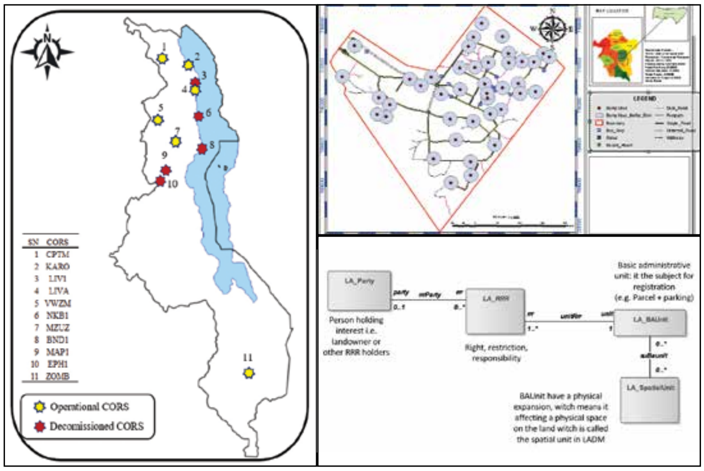
Professor, Delft University of Technology (OTB institute), The Netherlands

Dense urban spaces in developing countries are facing new challenges of land management on technical and institutional coordination level. Delhi and its immediate neighbourhood cities are going through a transformation process for land administration and their cadastral systems. There is an imperative need on land management related organisations and other stakeholders level to understand this rapidly changing scenario of land as a valuable commodity and also as a scarce resource. Cadastral systems need to be designed and supported from three dimensional spatial perspective and contributing for a continuously updated registration system(s).



In this issue

Coordinates Volume 19, Issue 7, July 2023

Articles

Columns

This issue has been made possible by the support and good wishes of the following individuals and companies
Attoumane Tahar, Charles Chisha Kapachika, Francis Gitau, Gervais Mendy, Harvey Chilembwe, Ifeanyi Edwin Ihemeje, John Bosco Ogwang, Kenechi Peter Ifeanacho, Kingsley Chika Chukwu, Mphatso Oscar Soko, Nonso Izuchukwu Ewurum, Robert Galatiya Suya and Samuel Ouya; SBG System, and many others.

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Annual subscription (12 issues)
[India] Rs.1,800* [Overseas] US$100*
*Excluding postage and handling charges

Printed and published by Sanjay Malaviya on behalf of Coordinates Media Pvt Ltd
Published at A 002 Mansara Apartments, Vasundhara Enclave, Delhi 110096, India.
Printed at Thomson Press (India) Ltd, Mathura Road, Faridabad, India

Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

This issue of Coordinates is of 36 pages, including cover.

It feels like being inside an oven,

With erratic temperature setting,

Being roasted – slowly and slowly.

The frequent heat waves engulfing the globe,

From Algeria, China, Morocco to Portugal, Spain, Thailand, the USA…

Will have inevitable multi-dimensional cascading effects

On health, livelihood, agriculture, economy, …

Where poor and vulnerable facing the major brunt.

Moreover, many of us and some of the fellow species,

Might not withstand this prolonged heat disaster and its consequences

And eventually may have to give in.

As the time runs out, are we still wise enough

To reset the temperature button?

Bal Krishna, Editor
bal@mycoordinates.org

Applying Malawi Continuously Operating Reference Stations in GNSS meteorology

In this paper, the ZTD estimation approach and the evaluation of results from the GPS measurements are presented

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Abstract

Global Navigation Satellite System (GNSS) signals in the L-band are affected by the non-dispersive neutral atmosphere. Regardless of their center frequency, the L-band code and phase observations are affected by the same measure of delay. GNSS receivers play a significant role in quantifying the zenith tropospheric delay (ZTD) from satellite signals. Malawi has a Continuously Operating Reference Stations (CORS) network which was established to support research in geophysical geodesy and geodynamics. However, the quality of the observations tracked by the CORS has never been tested in terms of its meteorological application. In this paper, the ZTD estimation approach and the evaluation of results from the Global Positioning System (GPS) measurements are presented. The optimal approach of precise point positioning (PPP) was used to estimate ZTD from one-week datasets which were collected from six CORS monuments distributed in the northern and southern regions of Malawi. In addition, the zenith wet delay (ZWD) and zenith hydrostatic delay (ZHD) were also estimated to determine their respective contributions to the total delay in all the stations. Alongside the meteorological parameters, the positioning repeatabilities were also established for all stations. Results indicate that the averaged ZTD, ZWD, and ZHD can reach as high as 247mm, 47 mm, and 199 mm, respectively. The minimum ZTD, ZWD, and ZHD for the stations can drop to as low as 220 mm,

24 mm, and 181 mm, respectively. This indicates that the ZHD contributes to more than 90% of the total delay at the stations. For the positioning performance, there was no obvious disparity in the latitude (less than 0.5 cm), longitude (less than 1 cm), and ellipsoidal height repeatabilities (less than 1.5 cm). Thus, the results clearly demonstrate that the Malawi CORS network may be used for GNSS-based meteorological applications using the available geodetic receivers. However, for high-precision meteorological applications, Malawi may consider densifying the available network with geodetic-grade receivers.

Introduction

Global Navigation Satellite System (GNSS), which comprises Global Positioning System (GPS, for the USA); Global'naya Navigatsionnaya Sputnikova Sistema (GLONASS or Russian Global Navigation Satellite System); BeiDou Navigation Satellite System (BDS, for China), and Galileo (for Europe), has revolutionized positioning, navigation, and timing (PNT) services. Other than PNT applications, GNSS has also extended its roles in meteorology (Gutman and Benjamin, 2001; Shoji, 2009; Kiyani et al., 2020) and weather studies (Gutman et al., 2004; Rahimi, Mohd Shafri and Norman, 2018).

In GNSS meteorology, satellite observations can be tracked with low-cost receivers such as smartphones with a single frequency (Pesyna et al., 2014; Krietemeyer et al., 2018) and a multi-frequency (Paziewski, 2020; Uradziński and Bakuła, 2020) tracking capability. These gadgets act as an alternative to employing reference stations, such as the International GNSS Service (IGS) or the Multi-GNSS Experiment (MGEX) stations, established by agencies, institutions, or countries. In their geographical positions, the stations may be installed alone or co-located with other space geodetic techniques such as Very Long Baseline Interferometry (VLBI); Satellite Laser Ranging (SLR); Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS); water vapour radiometers (WVR) or tide gauge stations. In both single and multi-purpose CORS networks, ZTDs can be estimated from the tracked GNSS (Bevis et al., 1992; Alshawaf et al., 2017), VLBI (Heinkelmann et al., 2007; Balidakis et al., 2018); SLR (Pollet et al., 2014); DORIS (Teke et al., 2013), and WVR (Bock et al., 2010) observations.

The estimated ZTD is a sum of the components including the zenith wet delay (ZWD) and the zenith hydrostatic delay (ZHD). The ZWD is directly related to ground pressure within the spatial region, whereas the ZHD is linked to the amount of water vapour in the atmosphere. The troposphere, being the first layer of the atmosphere, is influenced by the total refractivity, which is a function of temperature, pressure, and water vapour partial pressure (Essen and Froome, 1951). Furthermore, the quantity of precipitable water can be determined from the available water vapour in the atmosphere which tends to be proportional to ZWD (Hurter and Maier, 2013).

The measurement and monitoring of physical variables such as pressure, temperature, and humidity using GNSS signals is of profound significance to regional and short-term weather forecasting (Awange, 2011). On the other hand, the existing CORS networks need to accommodate a considerable density of stations to achieve ZTD of improved spatial resolution (Zhao et al., 2018). ZTDs have commonly been estimated from phase observables (Bevis et al., 1992) or combined code and phase (Ahmed et al., 2016; Zhao et al., 2018). As a consequence, ZTD estimates are derived from double differences (DD) or precise point positioning (PPP) techniques (Zumberge et al., 1997). The resultant ZTDs derived from PPP are consistent with the global reference system implied by the fixed global GNSS ephemerides. On the other hand, ZTDs estimated from the DD technique are biased by a datum offset depending on the baseline lengths in the CORS network.

Malawi has a local CORS network purposefully established to support geophysical and geodynamics studies (Shillington et al., 2016). The studies rely on a limited number of CORS monuments, the majority (91%) of which are geographically located in the northern part of the country. While the Malawi CORS network offers such research benefits, the possibility of using the existing CORS monuments in GNSS meteorology has been overlooked. In GNSS meteorology, PPP is one of the optimal techniques requiring only a single geodetic receiver to estimate meteorological parameters. Taking advantage of such a versatile approach, ZTD, ZHD, and ZWD are estimated for the CORS network in Malawi for ten days in this paper. This is achieved not only to demonstrate the feasibility of using Malawi's CORS network in the estimation of meteorological parameters, but also to establish the overall positioning repeatability performance for the individual stations.

Estimation of meteorological parameters

The PPP Technique

As the GNSS signal propagates through the atmosphere, it is delayed by the ionosphere. Typically, GNSS dual-frequency phase and code observables are combined to eliminate first-order ionospheric propagation delays. Hence, the ionosphere-free (IF) combinations of the dual-frequency GPS phase and code observations between satellite and receiver can be formulated as in Leick et al.(2015):

$$\left.\begin{aligned} \varphi_{r,f}^{s} &= \rho_r^s + \Delta t_r^s + m_f.ZTD_r^s + M_{r,f}^s + \lambda_{\varphi,f} N_{r,f}^s + \epsilon_r^s \\ P_{r,f}^{s} &= \rho_r^s + \Delta t_r^s + m_f.ZTD_r^s + M_{r,f}^s + \varepsilon_r^s \end{aligned}\right\} \quad [3.1]$$

with

$$\left.\begin{aligned} \Delta t_r^s &= c(\delta t_r - \delta t^s) \\ \rho_r^s &\equiv \| \mathbf{x}^s - \mathbf{x}_r \| = \| (x^s, y^s, z^s)^T - (x_r, y_r, z_r)^T \| \end{aligned}\right\} \quad [3.2]$$

where $\varphi_{r,f}^{s}$ denotes the IF phase combination between GPS signals such that f = L1 and L2 signal frequencies; $P_{r,f}^{s}$ denotes the IF code combination between GPS L1 and L2 signals; ρ_r^s denotes the geometrical range between s and r such that (x^s, y^s, z^s) is the satellite position whereas (x_r, y_r, z_r) is the receiver position; Δt_r^s denotes the satellite (δt^s) and receiver (δt_r) clock offset from the GNSS time; c denotes the vacuum speed of light; ZTD_r^s denotes the signal path delay due to the neutral atmosphere (troposphere). Here, it is worth noting that the unknown wet part of the tropospheric delay is expressed as a product of the ZTD and a mapping function (m_f) relating to the zenith delay; $M_{r,f}^s$ denotes the multipath; $\lambda_{\varphi,f}$ denotes the IF combination of the carrier-phase wavelengths; $N_{r,f}^s$ denotes the non-integer ambiguity of the IF phase combination; ϵ_r^s and ε_r^s and denote the phase and code residuals, respectively.

From [2.1], the satellite coordinates and clocks can be fixed by applying the precise GNSS orbits and clock parameters. Thus, the estimable parameters for [2.1] are the receiver position coordinates, which are also the CORS geographical positions (x_r, y_r, z_r) in this paper; the CORS receiver clocks (δt_r); ZTD and the float IF phase ambiguities $(N_{r,f}^s)$. Applying least squares or Kalman filter approaches, the estimated parameters R can be expressed as

$$R = \left[x_r, y_r, z_r, \delta t_r, ZTD, N_{r,f}^s\right] \quad [3.3]$$

Estimation of water vapour from GPS observations

In GNSS meteorology, the ZTD expressed in [2.3] can either be assimilated into numerical weather models or be converted to precipitable water vapour (PWV) using surface pressure models. As indicated by Hurter and Maier (2013), the conversion of ZTD into PWV can be achieved using simple atmospheric models. The satellite signal is delayed by free electrons and air density as it propagates through the troposphere. The refractivity (N) of the troposphere can be expressed as in Thayer (1974),:

$$N = 10^6(n-1) \quad [3.4]$$

where n denotes the refractive index. The tropospheric refractivity can be split into hydrostatic (N_{dry}) and wet components (N_{wet}), and can be related to meteorological parameters such as temperature, partial pressure of water vapour, and dry gases as formulated in Hofmann-Wellenhof et al. (2008):

$$\left.\begin{aligned} N &= N_{dry} + N_{wet} \\ &= k_1.\frac{p-e}{T} + k_2.\frac{e}{T} + k_3.\frac{e}{T^2} \end{aligned}\right\} \quad [3.5]$$

with

$$\left.\begin{aligned} k_1 &= (77.604 \pm 0.014)K\ mbar^{-1} \\ k_2 &= (64.79 \pm 0.08)K\ mbar^{-1} \\ k_2 &= (3.776 \pm 0.004)10^5 K^2\ mbar^{-1} \end{aligned}\right\} \quad [3.6]$$

where T denotes temperature in degrees Kelvin (K); p denotes the partial pressure of dry gases in millibars (mbar); denotes the partial pressure of water vapour in mbar; e and k_i (i=1,2,3) denotes the empirical constants as determined by Thayer (1974),

Estimation of zenith tropospheric delay

The troposphere delays the signal and can be described as an integral to N in the zenith path (z) from satellite s to receiver r as:

$$\triangle = 10^{-6}\int_r^s Ndz \quad [3.7]$$

where $\triangle$ denotes the signal delay. Therefore, the integrals of N in the zenith direction are referred to as the ZWD and ZHD. Substituting the integrals of N in [2.7] leads to

$$\triangle = 10^{-6}\int_r^s N_{dry}dz + 10^{-6}\int_r^s N_{wet}dz \quad [3.8]$$

Depending on the satellite elevation angle, the total tropospheric delay in the slant path can be mapped to the zenith direction. Taking the mapping function into account, [2.7] can be expressed in terms of ZWD and ZHD with respect to the satellite elevation angle (E) as

$$\triangle = ZWD.(m_w.E) + ZHD.(m_h.E) \quad [3.9]$$

where m_w and m_h denote the wet and hydrostatic mapping functions, respectively. Thus, having mapped tropospheric delay to the zenith direction, the ZTD parameter is readily estimated as an integral, as in Wilgan et al., (2017):

$$ZTD = 10^{-6}\int_z Ndz \quad [3.10]$$

Also known as the zenith total delay (ZTD), the ZTD is related to N of the troposphere as indicated in [2.10].

Estimation of zenith hydrostatic delay

While the ZTD can be estimated as integral [2.10], the ZHD can also be extracted from it by using the Saastamoinen model (Saastamoinen, 1972) as expressed in Davis et al. (1985):

$$ZHD = \left.\frac{0.0022768\mathrm{m/hPa}p}{1 - 0.00266\,cos(2\phi) - 2.8.10^{-7}m^{-1}h}\right\} \quad [3.11]$$

where p denotes the surface pressure observed at the receiver position; ϕ denotes the station latitude in radians; h denotes the orthometric height in kilometres. The ZWD has a poor predictive characteristic as compared to the ZHD (Bevis et al., 1992). Since the ZTD is simply the sum of ZWD and ZHD, the modelled ZHD in [2.11] is used to estimate ZWD:

$$ZWD = ZTD - ZHD \quad [3.12]$$

Characteristics of the Malawi CORS network

Decommissioned CORS network

Malawi briefly recorded GPS single-frequency observations from CORS monuments between March and May in 1997 in

Table 1: Initial CORS monuments in Malawi.

Monument	Recording Period From -To	Latitude	Longitude	Height [m]	Location Remarks
BND1	DOY: 103-104	-11° 55′ 18.84″	34° 10′ 44.04″	531.4	Lake Malawi, Nkhata-Bay
EPH1	DOY: 111-113	-12° 10′ 33.60″	33° 27′ 54″	1292.5	Embangweni, Mzimba District
LIV1	DOY: 116-117	-10° 35′ 42.36″	34° 6′ 23.76″	1305.3	Livingstonia, Rumphi District
MAP1	DOY: 090-092	-12° 6′ 34.56″	33° 38′ 30.12″	1646.8	Hill Top, Mzimba District
NKB1	DOY: 126-127	-11° 37′ 0.12″	34° 17′ 0.60″	532.8	Nkhata-Bay District

Table 2: Station characteristics for Malawi CORS network.

Monument	Livingstonia	Mzuzu	Karonga Airport	Chitipa	Vwaza Marsh	Zomba
Marker	LIVA	MZUZ	KARO	CPTM	VWZM	ZOMB
Latitude	-10° 36' 49.32"	-11° 25' 30.36"	-9° 57' 14.76"	-9° 42' 4.68"	-11° 10' 31.08"	-15° 22' 32.88"
Longitude	34° 06' 25.56"	34° 00' 21.24"	33° 53' 43.80"	33° 15' 46.80"	33° 34' 27.84"	35° 19' 30.36"
Height	1359.50 m	1261.24 m	513.80 m	1285.60 m	1113.30 m	972.63 m
Receiver	TRIMBLE NETR9	TRIMBLE NETR8	TRIMBLE NETR8	TRIMBLE NETR8	TRIMBLE NETR8	TRIMBLE NETRS
Antenna	TRM57971.00	TRM59800.00	TRM57971.00	TRM57971.00	TRM57971.00	TRM59800.00

five different geographical locations. In all the five stations, GPS observations were logged using a TRIMBLE 4000SSI geodetic receiver equipped with a TRM29659.00 antenna. Operated by the East Africa 1997 campaign, the average data recording periods for the receivers are summarized from initial to the final day of year (DOY) in Table 1.

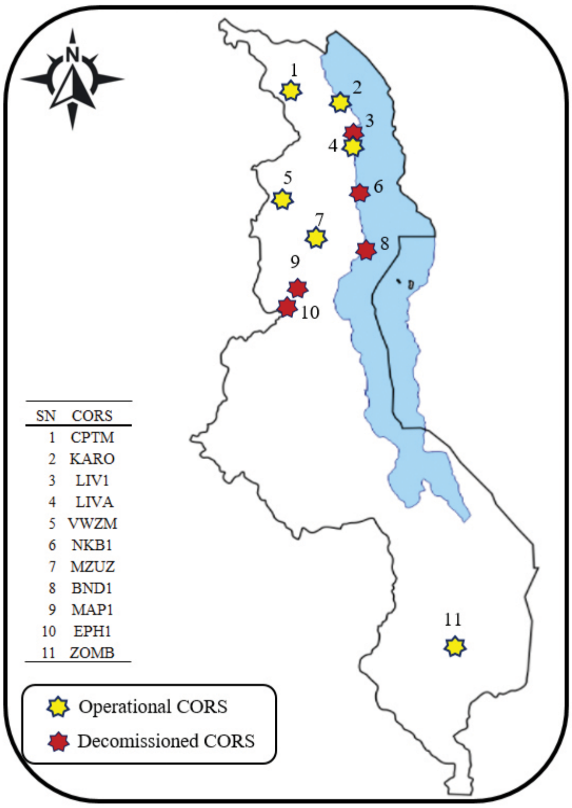

Figure 1: Distribution of CORS monuments in Malawi.

Since the initial campaign, another CORS station has been installed in Malawi in 2008 by the Department of Land Surveys and funded by Hartebeesthoek Radio Astronomy Observatory (HartRAO) Space Geodesy Programme of South Africa. The CORS was installed at the top of the Home Affairs and Department of Human Resources building (Capitol Hill) in Lilongwe City (AFREF, 2008). This station (not included in Table 1) was specifically installed as part of African Reference Frame (AFREF) to support satellite positioning by GPS in Malawi. In this paper, the CORS stations that were constructed in 1997 have been termed "decommissioned CORS" (refer to Figure 1).

Operational CORS network

Recently, a new CORS network has been initiated by the Malawi Rifting GPS Network (MRGN) and the Africa Array GPS Network (AAGN) in Malawi. Currently, Malawi has six operational CORS monuments. Four of the CORS (Livingstonia, Vwaza Marsh, Karonga, and Chitipa) are operated by MRGN, and the other two (Mzuzu and Zomba) are operated by AAGN. The station characteristics for the operational CORS network in Malawi are summarized in Table 2. Figure 1 depicts the distribution of the CORS network in Malawi.

Experimental datasets and processing

The GNSS datasets for the stations used in this paper (Table 2) were obtained from the University NAVSTAR Consortium (UNAVCO) at https://www.unavco.org/. UNAVCO is sponsored by the National

Table 3: Summary of the processing scheme.

Parameter	Setting
Observable	IF code and phase, Equation [2.1]
GNSS Datasets	GPS constellation
Frequency	GPS L1 and L2
Elevation Mask (Cut-off)	7 °
Sampling Interval	15 Seconds
Orbits and Clocks	IGS Final (300 seconds)
Satellite Phase Center Offset (PCO)	igs14.atx
Satellite Phase Center Variation (PCV)	igs14.atx
Receiver Phase Center Offset (PCO)	igs14.atx
Receiver Phase Center Offset (PCV)	igs14.atx
Tropospheric Mapping Function	Vienna Mapping Function (Boehm et al., 2006a)the b and c coefficients of the continued fraction form for the hydrostatic mapping functions have been redetermined. Unlike previous mapping functions based on data from numerical weather models (isobaric mapping functions (Niell, 2000
Zenith Hydrostatic Delay (ZHD)	Saastamoinen, Equation [2.11]
Zenith Wet Delay (ZWD)	Global Mapping Function (Boehm et al., 2006b)based on data from the global ECMWF numerical weather model. The coefficients of the GMF were obtained from an expansion of the Vienna Mapping Function (VMF1
Weighting Scheme	Elevation-dependent
Phase wind-up	Corrected (Wu et al., 1992)
Relativistic effect	Applied with respect to the IERS convention 2010 (Kouba, 2009)the International GNSS Service (IGS

Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) to provide free services to support research worldwide. In order to test the Malawi CORS network on GNSS meteorology, ten days of GNSS observations spanning from DOY 001 to DOY 010 in 2016 were downloaded from UNAVCO. Due to data unavailability in the first constructed CORS monuments, only the geodetic stations in Table 2 were considered.

All the necessary PPP corrections according to Kouba (2009) were applied. The processing parameters are summarized in Table 3. The ZTD was estimated using Equation [2.10] whereas the ZHD was modeled using [2.11]. The water vapour refractivity is responsible for most of the wet delay and it was estimated using [2.12]. The estimated quantities of ZTD, ZHD, and ZWD for the selected days were compared. Finally, the standard deviation was used to express the positioning repeatability of the CORS monuments.

Results and discussion

The estimated ZTD

Using GPS datasets for ten days (DOY 001-010) of the year 2016, the ZTDs were estimated for the Malawi CORS network. Figure 2 depicts the ZTD-PPP derived time series for CTPM, KARO, LIVA, MZUZ, VWZM, and ZOMB CORS monuments.

As can be seen from Figure 2, the estimated ZTDs for CTPM, LIVA, MZUZ, VWZM and ZOMB are consistent and within the same range of approximately 212 cm to 232 cm. However, KARO has the maximum estimated ZTD, reaching up to 250 cm on average. For the selected 10 days, the highest total delay for KARO is attributed to the large contribution of the ZHD (Table 4). The highest ZTD for 10 days simply indicates the high refractivity of dry gases in the troposphere for the KARO station. This is, on the other hand, caused by an increase in average atmospheric pressure, as demonstrated in Figure 2, reaching up to 950 mbars.

The estimated ZWD

The ZWD was derived from the difference between ZTD and ZHD and the associated time series for the estimated ZWD are shown in Figure 3 and the computed numerical values are

Table 4: Comparison of estimated ZTD, ZWD and ZHD from GPS observations.

CORS	ZTD [cm]	ZWD [cm]	ZHD [cm]
LIVA	220.04	38.65	181.40
MZUZ	220.67	37.23	183.44
KARO	246.68	47.19	199.49
CTPM	221.35	38.43	182.92
ZOMB	223.77	34.27	189.50
VWZM	225.18	38.66	186.52
Max	246.68	47.19	199.49
Min	220.04	34.27	181.40

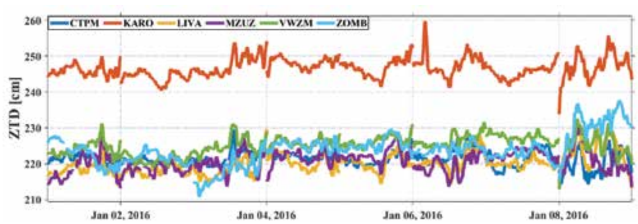

Figure 2: Comparison of estimated ZTD time series for the selected days.

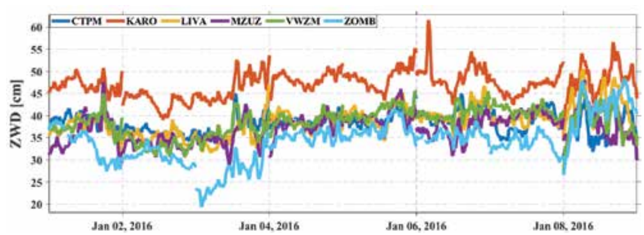

Figure 3: Comparison of estimated ZWD time series for the selected days.

presented in Table 4. From Table 4, it can be demonstrated that ZHD contributes to almost 90% of the total delay. This is evident from the numerical values between ZWD and ZHD. To better distinguish between the variations in the estimated meteorological parameters, the mean ZTD, ZWD and ZHD is illustrated in Figure 3. What is apparent is that ZOMB has the minimum ZWD of about 34 cm. This can also be verified from Table 4 and the least wet delay may be attributed to a higher influence of water vapour refractivity in the troposphere (Yuan et al., 2019). This can be explained better by comparing water vapour refractivity with the average atmospheric pressure of about 903 mbar for the selected days (Figure 4). On the other hand, LIVA CORS has the least atmospheric pressure, namely only about 864 mbars (Figure 5).

Positioning performance

In situations where the visible number of satellites is small, the overall positioning performance declines. For the determination of the ZTD described above, knowledge about the tracked satellite vehicles (SVs) at each CORS is thus necessary.

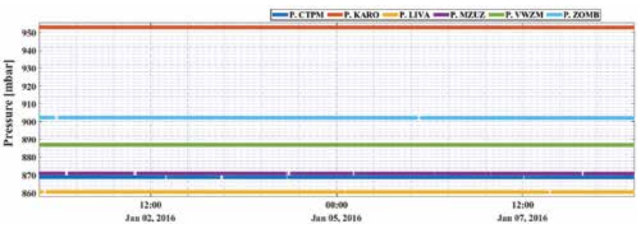

Figure 4: Pressure as estimated from GPS observations from Malawi CORS.

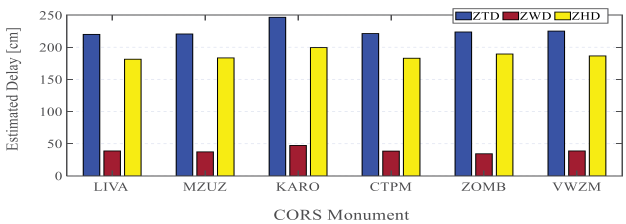

Figure 5: Estimated ZTD, ZWD and ZHD from GPS observations.

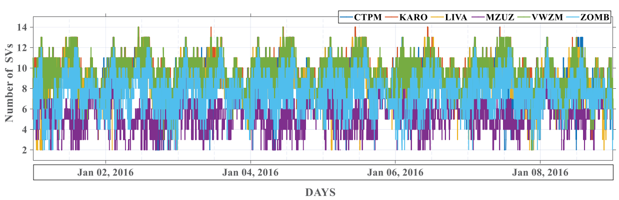

Figure 6: Average number of observed satellites at the CORS stations

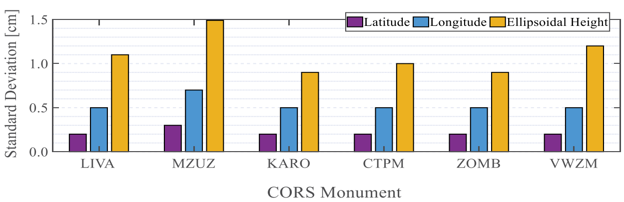

Figure 7: Standard deviations for the estimated positions.

Hence, for the selected days in this study, the visible SVs are illustrated in Figure 5. As can be noticed from Figure 6, at least ten GPS satellites were observed on all the selected days. As indicated in Suya (2019)convergence time and Positional Dilution of Precision (PDOP, this number of tracked satellites is more than enough for the estimation of parameters by PPP.

To assess the effect of the estimated ZTD on positioning performance, the positional stability of the CORS stations during the sampled period was examined. This was performed by computing the standard deviations between the estimated coordinates and the *a priori* coordinates. The estimated coordinates and their associated standard deviations that express the CORS 3D positioning repeatability for the six stations are presented in Table 5. The geodetic coordinates in Table 5 are referenced to the local geodetic datum of the World Geodetic System 1984 (WGS – 84).

Moreover, the standard deviations in latitude, longitude, and ellipsoidal height have been expressed as σ_{Lat}, σ_{Long} and σ_{Elev}, respectively. The standard deviations for the positioning repeatability in Table 5 were computed at a 95% confidence interval and have been expressed in centimetre for convenience and plotted in Figure 6. The positioning repeatabilities demonstrate obvious variability in the station coordinates, especially in the height dimension. For the Mzuzu station, the standard deviation in the height component can reach as high as 1.49 cm. From Figure 6, there is no obvious difference in the standard deviations for latitude and longitude except for Mzuzu CORS. Based on the selected days, the positioning performance in all the dimensions may satisfy geodynamics studies. Considering the number of days investigated in this study, these repeatabilities are insignificant.

Conclusions

Malawi CORS are commonly used for geophysical and geodynamics studies. This paper attempted to estimate the meteorological parameters from the operational CORS network using the PPP technique. Ten days of GNSS datasets from DOY 001 to 010 in 2016 were used to estimate the ZTD, ZWD, and ZHD, including coordinate repeatabilities for the six CORS monuments. Results indicate that the mean ZTD, ZWD, and ZHD can reach as high as 247cm, 47 cm, and 199 cm at the Karonga CORS monument, respectively. This was attributed to the high atmospheric pressure of about 903 mbars for the experimented days. On the other hand, the minimum ZTD, ZWD and ZHD for the stations can drop to as low as 220 mm, 24 mm, and 181 mm at the Livingstonia CORS monument, respectively. The reduced values were attributed to low pressure at the Livingstonia CORS monument. The study also indicates that the ZHD contributes to more than 90% of the total delay in the stations. In the case of positioning performance, there was no obvious disparity in the latitude (less than 0.5 cm), longitude

Table 5: Averaged coordinates for the stations.

	LIVA	MZUZ	KARO	CTPM	VWZM	ZOMB
Latitude	-10° 36′ 49.32″	-11° 25′ 30.36″	-9° 57′ 14.76″	-9° 42′ 04.68″	-11° 10′ 31.08″	-15° 22′ 32.88″
	-10° 36′ 49.3981″	-11° 25′ 30.3488″	-9° 57′ 14.9230″	-9° 42′ 04.7836″	-11° 10′ 31.0985″	-15° 22′ 33.0268″
	± 0.002 m	± 0.003 m	± 0.002 m	± 0.002 m	± 0.002 m	± 0.002 m
Longitude	34° 06′ 25.56″	34° 00′ 21.24″	33° 53′ 43.80″	33° 15′ 46.80″	33° 34′ 27.84″	35° 19′ 30.36″
	34° 06′ 25.3948″	34° 00′ 21.4142″	33° 53′ 43.6944″	33° 15′ 46.8008″	33° 34′ 27.9871″	35° 19′ 30.4878″
	± 0.005 m	± 0.007 m	± 0.005 m	± 0.005 m	± 0.005 m	± 0.005 m
Height [m]	1359.500	1261.240	513.800	1285.600	1113.300	972.630
	1359.552	1261.219	513.838	1285.54	1113.312	972.627
	± 0.011 m	± 0.015 m	± 0.009 m	± 0.010 m	± 0.009 m	± 0.012 m

(less than 1 cm), and ellipsoidal height repeatabilities (less than 1.5 cm). Therefore, the results clearly demonstrate that the Malawi CORS network may be used for GNSS-based meteorological applications using the available geodetic receivers. This study used datasets for a few days to fully quantify the meteorological parameters. Therefore, a similar study may be conducted with datasets spanning the whole period of a year or more. Furthermore, for high-precision meteorological applications, Malawi may consider densifying the available network with geodetic-grade receivers for the robust estimation of meteorological parameters.

Acknowledgement

The authors gratefully acknowledge UNAVCO for the CORS GNSS observation datasets used in this project. The satellite clocks, orbits, and all other PPP datasets were retrieved from the IGS (http://www.igs.org/).

Software

Data processing was done in an in-house software developed by the first author.

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The paper originally publsihed in South African Journal of Geomatics, Vol. 11. No. 2, August 2022 is republished with authors' permission.

A proof of concept of the integration of blockchain with an ISO 19152:2012 based land administration system

In this paper we proposed a model and a Proof of Concept imple-mentation on how to integrate blockchain technologies to land administration system that relies on ISO 19152:2012 Land Adminis-tration Domain Model

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Abstract

In recent years, we witnessed extensive study of the integration of blockchain technology in Land Administration System. It is believed that it would enhance transparency and trust. Besides, since 2012 and the publication of the ISO 19152 Land Administration Domain Model we have evidence of it increasing adoption as the de facto domain model to use when creating new Land Administration System or refactoring existing one. To allow a broader implementation of blockchain technology in Land Administration System, we propose to blend those two trends to create a system that would integrate major technological advancement (blockchain) with international standards on effective land administration.
Merging these two techniques have the potential to create a Fit-For-Purpose land administration framework that would meet land administration requirements while improving transparency. The main contribution of this paper is the proposition of a Proof of Concept of integrating blockchain technology in a land administration system based on the ISO 19152 Land Administration Domain Model

Introduction

The United Nations Land Administration Guidelines [30] state that land is the *ultimate* resource because without it life on earth isn't sustainable. It also has an important impact on the economy, in fact, at least 25% of the nation's Gross Domestic Product(GDP) can come through land [30]. For instance, in most sub-Saharan countries, the agricultural sector contributes between 25% and 40% of the GDP [39]. Adding to this direct implication there is an increasing contribution of land in other economic sectors such as tourism, nature conservancies, oil and mineral revenues.

However land is a litigious subject and its administration faces many challenges. In order to lessen the burden, the organization in charge of its administration relies upon various information systems.

Building such a system is a tedious task, therefore to ease the process, an international ISO, namely ISO 19152 Land Administration System(LADM), has been proposed and is used as the basis for new systems. As there is evidence of the adoption of LADM by more and more countries [17], it is only a matter of time before most countries wishing to build new land administration system, or even refine existing one, base those systems on the standard. Information Technology integration in land administration can improve the effectiveness of its procedures, by making the process simpler, cheaper, faster and more transparent[41].

The impact of the usage of Global Positioning System (GPS) and Geographic Information System (GIS) technology for cadastral and land use mapping is arguably the best example of how technologies can improve land administration[40, 41]. Blockchain is one such technology. It is a disruptive one which has the potential to revolutionize the way value is stored and exchanged [26]. The introduction of blockchain technology in land administration would allow to add some much-needed transparency [2, 21, 36]. Land administration system of developing country would benefit the most [29], as in most of those countries, we notice a loss of trust in land administration offices.

Given the existence of a standard upon which Land Administration System(LAS) can be built around and it increasing adoption[5, 17]; And witnessing the growing evidence, through diverse studies[2, 26, 29, 37], that the land administration would largely benefit from an introduction of blockchain technology. We propose in this paper to pose the bases of implementation of blockchain on a land administration system that is built upon LADM (ISO 19152:2012).

This work is structured as follows: After this introduction, in section 2 we first introduce some basic knowledge regarding Land Administration System and the standard mentioned above. Then we review the literature on integration of blockchain technology in LAS. In section 3 we describe our designed model and it Proof of Concept (PoC) implementation. We further give, in section 4, a comprehensive discussion around transaction handling, the type of blockchain that we deemed suitable, the identity management layer and further subjects that require specific investigation. The last section concludes this paper.

Background and related work

Background: LAS and LADM

Land administration is best defined as the process of recording and disseminating information about the ownership, value and use of land and its associated resources, further includes restrictions and responsibilities related to rights, land value, land use and impact of development processes[30]. Stig Enemark [4] states that land management can be subdivided into three main components: Land Policies, Land Information Infrastructures, and Land Administration Infrastructures in support of sustainable development. The operational functions of land administration include [30]:

- Land tenure — it is the way in which right in land is held, it determines how rights are secured and transferred;
- Land value — it encompasses the valuation and taxation of land and properties;
- Land use and planning;
- Land development in regard of infrastructure and utilities implementation.

In order to manage all those aspects, many systems are used to create an integrated system for the land administration offices. Those systems are comprised by at least a Cadaster component (often backed by a GIS) and a land tenure, registry-like, solution [13]. Those two components may be loosely coupled or strongly integrated. The Land Administration Domain Model or ISO 19152:2012 is the first successful standard in land administration. It attempts to conciliate social drivers and technology design approaches by providing global standardized vocabulary for land administration. It emphasis that the main characteristic of land tenure is the reflects it has of a social relationship regarding right to land which leads to a certain relationship, legally recognized, between people and land. This means that there's a registration component of the mentioned right for it to have legal meaning [16]. The LADM focuses on the part of land administration that deals with rights, responsibilities and restriction affecting land(and what is above and below) and the geospatial components[16, 24]. At its core LADM is an abstract, conceptual model comprised of three packages, and one subpackage:

- Administrative package: comprised of the basic administrative units (BAUnit) which is the subject of registration; the Rights, Restriction and Responsibilities (commonly addressed as the RRR) on a BAUnit.
- Party package: contains the classes used to represent the people and organization linked to RRRs
- Spatial units package: used to represent the physical expansion of the BAUnit, the parcels, building (their legal space) or utility networks.
- Surveying and representation subpackage: comprised of spatial sources, geometry and topology(spatial representation) classes

The main classes of each package are related to each other through association which give a coherent model (Fig. 1 gives an overview of those relationships). Fig. 2 is an example of how instances of the main classes on Fig. 1 relate in a use case. In this case the instance of *LA_BAUnit* to register is called the *Wayne Manor*, the owner is *Thomas Wayne* represented by the *LA_Party* instance. It relationship with the *LA_BAUnit* is represented with the instance of *LA_Right* of type ownership. In the overview diagram (Fig 1), the class *LA_Right* wasn't visible. It is a subclass of *LA_RRR* which is itself an abstract class. The last class involved is *LA_SpatialUnit* it is the physical extension of the manor. The additional information it provides here is the area of the manor. To go one step further we could use the *Surveying and Representation* subpackage's classes to represent its geospatial extension.

In many aspects, the standard approach only allows a rather general description, for instance in the case of interests in land, it's classifying them as right, restriction or responsibility. These RRR can be classified according to short code lists.The code lists enables us to distinguish, for example, if a right is an ownership rights or a leasehold; if a restriction is a servitude or maintenance of waterways[16]. The LADM is, therefore, a very good basis for designing and structure information system. It flexible nature by design allows for adaptation to national context. This is done through ISO

19109: Generic Feature Model concepts mainly by *specialization of feature class* to add additional attributes, operators, and associations; *creating new data types* for complex attribute like *address; Refinement of code list* fixing the possible values of a feature class attribute. A specialized model to a national context is commonly addressed as a *country profile*. The standard provides in it annexes some of those country profiles as examples.

Therefore, most countries willing to base a system upon LADM, proceed in creating country profiles of the LADM. They would have, among other objectives, to define the specific RRR applicable to that country by specialization of the main RRRs classes; Redefine the various code lists to be compliant to their laws and regulation on land administration; Review the attributes of each class and add new attributes when needed; Extend BAUnit and spatial unit classes to create new specific ones as per local land administration services requirements.

It is worth noting that the standard is in revision phase[23] for its second edition. In this process it is planned, among other major changes, to add guidelines on how to create a country profile and on how workflow would be implemented[22, 23]. According to [23], the use of a transaction model supported by blockchain technology will be likely discussed. The United Nations initiative on Global Geospatial Information Management, through it Framework for Effective Land Administration—FELA[5], refers to the LADM as a standard for land administration, thus giving it a broader acceptance as the de facto domain model.

Literature review

The application of blockchain technology in land administration, although relatively young and in its early stages have had its fair amount of study.

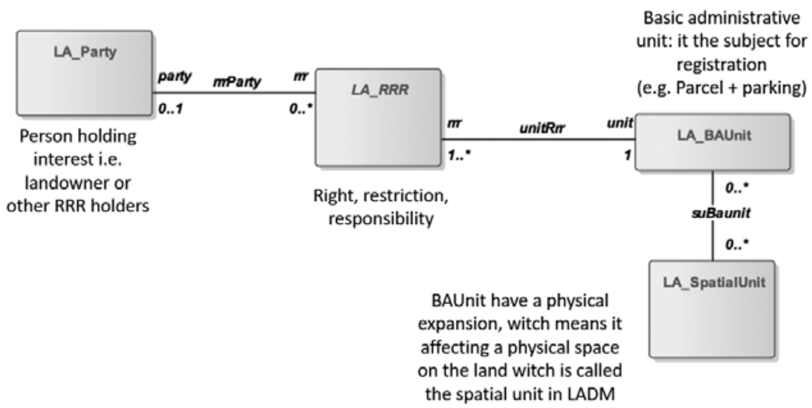

Figure 1: LADM core components overview and relationship. Inspired from [16]

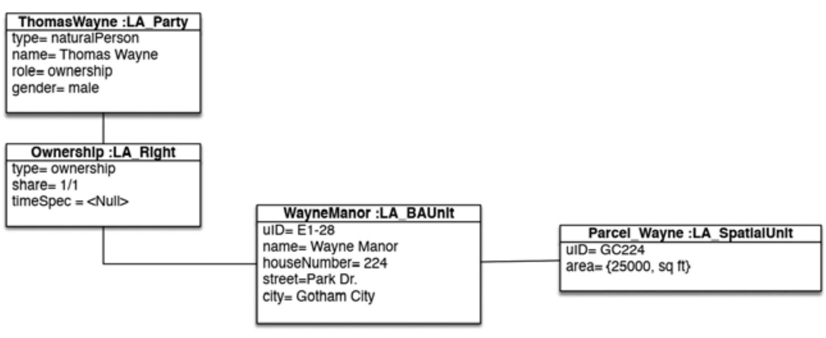

Figure 2: LADM object relationship in an ownership registration[16]

Among the literature we find a lot of case study piloted by government or land administration authority. The first such project is believed to be the joint effort of Honduras's government and Factom to create a pilot project for using blockchain technology in land administration[21]. The proposed implementation is based on Factom blockchain solution which is *anchored* on Bitcoin blockchain [34]. Anchoring in another blockchain is usually done by inserting the hash of the state of the blockchain or of independent block as a transaction on another one. This anchoring method allows the anchored blockchain to inherit part of the trust of the anchor blockchain. This method is believed [32] to allow keeping sensitive data private while removing the trust needed in the administrator of the blockchain.

A similar albeit different method is used by Ubitquity and the Municipality of Pelotas, Rio Grande do Sol, for the Brazilian pilot project [9]. Ubitquity proposed a cloud Colored Coins based solution with Bitcoin as the underlying blockchain solution. It's worth noting that although in this pilot Ubitquity solution was configured to work with public BitTorrent solution, it's supposed to support referencing data stored on IPFS (InterPlanetary FileSystem) or a centralized storage.

The republic of Georgia NAPR (National Agency of Public Registry)[12, 32] who associated with Bitfury Group will move, in the second stage of the project, to using a Bitfury developed blockchain solution called Exonum anchored on Bitcoin blockchain. However, in the first stage of the pilot, which was successfully conducted between April 2016 and April 2017, the focus was guaranteeing safety and non-repudiation of the property title document[32] using Bitcoin blockchain. The Sweden case study which associated Lantmatriet (The Swedish Mapping, cadaster and land registration authority), Telia company, ChromaWay, Kairos Future, Landshypotek Bank and SBAB, [19, 20] was evaluated to save over 100 million euro of taxpayer money per year. This was achieved by enabling smart contract in key land tenure processes (such as sale registration, transfer of ownership and mortgage registration) which eliminate a lot of paperwork and significantly reducing fraud.

Other government initiatives namely, the city of Dubai, the Indian state of Andhra Pradesh[38] or the Chicago Cook County Recorders of Deeds in Davidson County (Tennessee, United States of America)[36] have been studied.
Other studies that are pilots by academics on the application of blockchain on land administration add up to those reports and gives a deeper study of the implications. In a nutshell, we can distinguish three approaches on the integration of blockchain technology on land administration.

Document validation layer. - In this case only the document needing the highest level of security is encapsulated on a transaction and submitted to the blockchain. It was the case for the land title in the phase 1 of the pilot project of the Republic of Georgia [12, 32].

Add-on. - When using this approach, the blockchain is used to enhance the transparency of the existing system. It is added on the system as a way to keep data safe from tempering by adding another layer of protection of transactional data either by adding it finger-prints or actual data on the blockchain. It is the method adopted by Kombe and al.[18] for the integration on the Tanzanian LAS called Integrated Land Management Information System (ILMIS). In this case they proposed to add the fingerprint of the transaction on ILMIS to Factom blockchain. Actually, the ILMIS solution is built upon Innola solution[27], who has worked on the integration of Factom blockchain on their LAS solution[2]. To do so they added a step on the usual workflow named *sign and seal dataset* which once executed submit to Factom network the fingerprint of the core attributes of the transaction.

Rebuild around blockchain. - Another solution is to integrate blockchain at the core of all land transaction. With this approach the sole focus is to take advantage of all the benefits that would come with a blockchain-based application. The implementation proposed in [38] using Hyperledger Fabric and IPFS for document management would be one such implementation. To a certain extent, the distributed architecture with the use of dApp proposed by [33] is an analogous strategy.

The potential benefits of blockchain technologies for land administration are summarized by [1] as follows:

- We could gain transparency, eliminating fraud and doubles sales, easy information access, and enhanced high participation by all stakeholders. Thanks to the *decentralization* nature of blockchain technology.
- Through smart contracts, blockchain has the potentiality of eliminating corruption, reducing the possibilities of human error.
- Through consensus mechanism we could have better data quality, accuracy and integrity.
- Through it distribution property and decentralization, a blockchain-based LAS would benefit security and resilience enhancements.
- Thanks to it immutability property coupled with a well-designed consensus mechanism, we could enhance trust.

Blockchain application in land administration has a huge potential which explains why there's government initiative on conducting pilot projects on it application on a controlled area. However, our literature review showed that there is little to no knowledge on how the blockchain integration will be done on a LAS that is based upon LADM. LAS being quite complex system, we argue that there is a risk of missing some of the components of a LAS if we don't consider the existing LAS solution. Among the existing LAS solution, the adoption of LADM based can only grow. As a matter of fact, even some of the prebuilt existing system as ESRI's ArcGIS for Land Administration and Bentley GIS platform[24], are compliant to it. This study is meant to fill that gap, providing the first step of such an implementation. Given that Blockchain itself is not suited for storing huge amount of data. This approach shall provide ways to deal with off-chain data even in the case where the integration of blockchain technology is done through a complete rebuild.

Proposed model design

Blockchain transactions

Before creating blockchain transaction payload, it is important to define what is considered as a transaction on the LAS. Land administration rely upon legal framework. This framework establish among other things: How BAUnit must be created; How land surveying must be performed; How land ownership can be transferred; How mortgage and liens are created against a property; How they're claimed; Etc. Those operations are the natural land administration transaction. The ISO 19152:2012 standard doesn't specify how transactions or process workflows would be handled. The studied LASs (Innola's[15], Sogema Technologie eLand[11], and ESRI's ArcGIS for Land Administration) relies on workflow engine for that purpose. If we take a look back at the data representation of an ownership case in the LADM (Fig. 2) we can see that while it represents how data would be stored, it doesn't provide additional information regarding whether it recording/registration followed the mandatory process. In order to integrate blockchain technology, transaction should be hard-wired on the system therefore we proceeded by first adding to the core classes of LADM a minimal transaction handling.

Almost all the LADM core classes inherit from Versioned Object (LA_Source being the major exception). The Versioned Object is an abstract class that is responsible of the management of the evolution of the various land component whether it be RRR, BAUnit or Party instances. It allows history management[24]. As the VersionedObject is in charge of providing history and lineage support, we argue that this integration of transaction should be done through it.

As we can see in the proposed model (Fig. 3) transaction will also be associated with the AdministrativeSources(through it LA_Source specialization). This class has an important role on transaction handling, as noted on the standard [16], an administrative source can be the document that describes the rights, restrictions or responsibilities held by a party and affecting a basic administrative unit. The added transaction instance will serve as an anchor for the blockchain transaction. It is apparent that the blockchain transaction should encapsulate at least all the major association of an instance of TransactionInstance : the BAUnit; the RRRs associated to that specific BAUnit version; the party associated to those RRRs; the spatiaUnit(s) and the administrative sources that result or initiated that transaction. In addition, the proposed *BL_Transaction* class has a processKey attribute which can be used, with its counterpart workflowProcessInstanceId of *BL_TransactionInstance*, to keep information about the root land administration process type. In the case of the integration of an external workflow manager like Camunda BPMN Engine, jBPMN or ArcGIS Workflow Manager, these fields could be leveraged and serve as anchors.
Using that model allows us to store all off-chain data, which would be the bulk majority of them(document, party information, condominium declaration. . .), with a direct link to the actual transaction in the blockchain.

Proof of concept implementation

To demonstrate the proposed model we built a Proof of Concept implementation. The implementation can be subdivided into two major components :

- The blockchain network: We used Hyperledger Fabric(HLF) [7] as the blockchain layer. This component has at its core the network where the smart contracts are deployed. We bootstrapped a three organization network with two peer organizations serving as anchor peer and one orderer organization. It's similar to the *HLF test network* [7]. We wrote a java-based smart contract to allow blockchain data creation and querying the ledger state. The smart contract approval policy and transaction endorsement policy were majority based.
- The LADM based LAS is a Java-based application with an angular front end. It is built to be run on a docker container for easier demonstration. The connection to the HLF network is done through a gRPC connection to the Fabric Gateway. It uses the identity of one of the organizations to interact with the smart contract on the network. For the sake of simplicity, not all subclasses are implemented in this PoC. For instance, RRR subclasses are implemented as Single Table Inheritance.

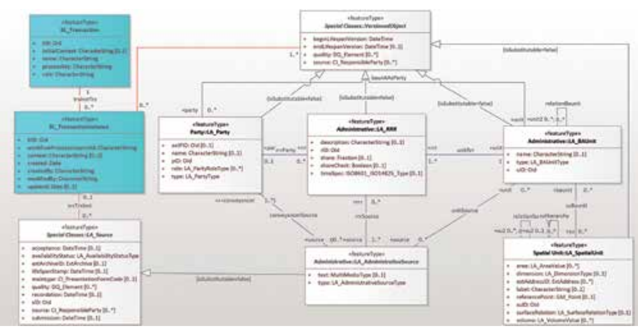

Figure 3: Minimal transaction handling in LADM. Added classes are in blue

When the data creation process is over on the web-based LAS, We added a *seal method* that submits the transactionInstance to the blockchain (Fig. 4)[1].

In listing 1 we present the payload of the transaction. Here we choose to add to the blockchain asset only the ids as anchor for relevance to the proposed model. Further discussion is needed to decide the constitution of the payload(refer to section 4.3).

Figure 4: Transaction submission to the blockchain layer

Listing 1: The registered blockchain asset

```
{
  "txInstanceID": "9a549784-4efa-4e27-87e9-e38179e1319b",
  "baUnitID": "4ce7b68d-9bff-4d96-b4df-57bca81a9dc7",
  "owner": "Mendy",
  "sources": ["10a443eb-1696-49bd-837e-6add89dce482"],
  "appraisedValue": 13000,
  "rrr": [{
      "rrrId": "3c277d68-f12c-4a3d-8308-b8842ee73798",
      "partyIds": ["b6449a64-46f2-4bdc-94c2-7f2be84a249b"]
    }]
}
```

Discussion and further working items

In this section we'll discuss the various propositions made in the previous section (3). It's meant to give insight in how our study relates to other propositions and highlight major remaining research problems in blockchain application to land governance.

Scope of application of the proposed model

The proposed model is based solely on core LADM classes, this allows it to be used in any LADM based system provided that the change and history management are handled through the versionedObject abstract class. However, we believe that some of the countries that have LADM based LAS, have implemented a different way of handling change. This is based on the change handling framework presented for Serbia [33] although Serbia has developed a LADM country profile [31]. This model and its PoC implementation are the major contributions of the present paper as we haven't found in the literature any such proposition.

Around the choice of the blockchain platform

The choice to use a permissioned blockchain network like Hyper-ledger Fabric is based on the need for such a system to be easily adopted by the stakeholders. Besides, public blockchain like Bitcoin and Etheureum, that would bring the most trust to the application, have a fluctuating transaction cost. This adds a volatility to the land-related transactions that could already be expensive as mentioned in the introduction. Many others proposed the use of this platform [8, 28] for implementing blockchain-based LAS or mentioned it as an alternative approach to their proposed blockchain technology [2, 33]. In fact, the flexible permission management can help compliance to the existing legal framework while adding transparency. One other important characteristic of HLF that emphasis its flexibility is the supports of three consensus mechanisms: solo(for test scenarios), Raft (Crash Fault Tolerant) [7] and custom Byzantine Fault Tolerant (BFT) based on BFT-SMART[3, 35] that can be leveraged to implement the most suitable mechanism for a LAS. HLF also supports multiple languages for smart contract and gives various SDK (Node.js, Java, Go and Python) for developers to work with. This gives such an implementation a smoother integration to existing platforms.

Besides Hyperledger Fabric is well suited for implementation model where there's a hard requirement on identifying participants or to be compliant to regulations such as Know-Your-Customer (KYC)[7]. In fact, while the land transaction themselves are not always financial transactions, land is a taxable property and as such it is mandatory to know who owns which piece of land. We also considered the usage of a private Ethereum network, Factom blockchain, Hyperledger Burrow and cloud blockchain implementation like Quorom.

On blockchain transaction payload

We have identified the various objects that would comprise the blockchain transaction but further studies are required to choose how they would be encapsulated. In fact, at a high level the maximum transaction payload would be comprised of the objects on their JSON format in the blockchain, which would allow maximum accessibility and distribution of those data. The minimum payload would contain the ids and the fingerprints of the objects involved on the transaction. While this approach seems the most in line with the idea that blockchain shouldn't serve as a storage but rather as transaction ledger, we could argue that they would be performance and security issues in the case of relying on existing data store as presented by [14].

We propose an add-on implementation model to integrate blockchain support on LADM based LAS. To do so we expanded the LADM based model with transaction support. While it could be argued that we could forge the transaction and submit to the blockchain network without this addition, we deemed this approach more convenient. These table serving as anchor, the LAS is made *aware* of the blockchain integration. Bear in mind that element being added as part of the transaction are versioned object and the system have to expand effort to keep track of the history. Then this anchor allows us to rebuild the history.

Blockchain technology and identity management

Our study focus on integrating blockchain support to LADM based LAS, it is obvious that we will need flexibility on the identity management and blockchain technology. LAS being themselves permissioned system, we propose to use Hyperledger Fabric (HLF) platform.

Hyperledger Fabric identity management relies on public key cryptography. In practice Certificate Authority (CA) would emit certificates for each actor and nodes that need to access or perform any operation on the ledger. Those issued certificates will be used to leverage permission and grant access to the various actions on the LAS. Some CA Server, such as the built-in Fabric CA, can be configured to rely upon existing identity provider services such as an internal LDAP (Lightweight Directory Access Protocol). We suggest this approach for the Land Administration Office Department employee's identity handling.
Other major stakeholders in the land administration are organized as orders(e.g., surveyors and conveyancers). Therefore their member are all known individuals. Each group could have its own CA accepted in the blockchain network.

As for citizens, we can divide them in two groups depending on the type of operation they perform. On one hand, we have people that would need to query the state of the ledger, they could do so through a designed portal. The portal would act as an authenticated entity and forge the query impersonating the citizen thus preserving anonymity while accessing public data. On another hand, we have the various holders of RRRs on a BAUnit these would need to be enrolled and have their digital identities (pair of keys) emitted. How exactly should the enrollment take place can be expanded to the broader question of identity in a smart city.

For transparency reason, we propose to add at the application level (or smart contract level), a notification through mail or SMS to all the RRRs holders if a transaction occurred on the associated BAUnit thus allowing them to lodge a complaint if needed, as proposed by Indian Andhra State government implementation[6].

dApp access to off-chain data

The add-on approach has some drawbacks. One of the major drawbacks of such an integration is the opposite model of implementation between a distributed application architecture and a classical web application architecture. The verification of transaction through the blockchain will be an added burden on the existing servers [14] of the LAS.

In this case, the data that comprise the transactions in the blockchain are stored on the database and other sorts of traditional storage like EDMS (Electronic Document Management System). This further expand the questions regarding how off-chain data will be referenced on the blockchain transaction and if the storage of those data should evolve to be available from the various blockchain nodes.

On process workflow and smart contract

One of the non-addressed requirements in this implementation is the one regarding the usage of smart contract. As mentioned above 3.1 many major modern LAS handle process through workflow engine. Most of the process could be handled with the help of smart contract as proposed by many studies before [19, 28, 29]. We propose a progressive migration to smart contract. As the BPMN 2.0 processes embedded in the workflow engine are created with the help of the various stakeholders, rather than building the smart contract from scratch we could leverage Caterpillar methodology[25]. This method relies upon many technological layers. One of the most important one is the BPMN-to-solidity compiler which translates the standard BPMN model to a solidity smart contract. This approach still requires further investigation.

As we can see through this discussion while we give the bases of implementation, many requirements and implementation questions still need to be addressed. Including but not restricted to:

1. How will data stored off-chain and referenced as part of the transaction payload be referenced and retrieved?
2. Will these off-chain data need to be distributed as well or can we keep them on a central storage?
3. Are the existing data stores from existing LAS suitable for such a system?
4. How will the geographical data be handled on the blockchain transaction will it be stored as GeoJSON using protocol like FOAM[10] or other method?

Conclusion

In this paper we proposed a model and a Proof of Concept implementation on how to integrate blockchain technologies to land administration system that relies on ISO 19152:2012 Land Administration Domain Model. This model is to be implemented directly to the core LADM therefore it can be used on any LADM based LAS providing that they rely on the versioningObject for the history management. In the process of assessing the model, we listed a number of requirements to be addressed in order to implement blockchain backed LAS. In future works, we plan to investigate on how to use smart contract alongside workflow manager 4.6. We also plan to study how geographical data will be handled in such a system. Those upcoming studies are designed as building bricks of a blockchain-based LAS alternative to traditional solution .

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ICBTA2022, December 16–18, 2022, Xi'an, China

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Industry invited to bid for low-Earth orbit satnav demo

While GNSS will remain a fundamental backbone, for Positioning, Navigation and Timing (PNT) services to go on improving into the future, a new element will be required. ESA's LEO-PNT satellites, approved at last year's Ministerial conference, will test out this concept in practice, with a mini-constellation of at least ten satellites, placed in orbit a matter of hundreds of kilometres above the surface of Earth – as opposed to the 23 222-km-distant Galileo satellites.

ESA has now launched the Invitation to Tender (ITT) calling European companies to join this endeavour. The ITT covers all aspects of ESA's LEO-PNT Orbit Demonstrator, including the space and ground segments, system engineering aspects, operations, launch, the test user segment, experimentation, and service demonstration in representative user environments.

Combining medium- with low-Earth orbit constellations on a multi-layer basis should represent a significant step forward. Medium Earth orbit was initially selected for GNSS constellations because a couple of dozen satellites at this altitude can deliver global coverage. In addition, with less of a distance to cover down to Earth, the signals from these additional LEO-PNT satellite signals can reach places where today's satnav signals cannot reach. And by adopting novel navigation techniques and a wider range of signal bands the satellites can address various specific user needs, such as more rapid position fixes, increased precision, resilience and signal penetration. *www.esa.int*

Signal Authentication Service

The Cabinet Office, Japan is developing a signal authentication service that can confirm whether a signal received by a GNSS receiver is actually a signal transmitted from a positioning satellite or not. The service will be launched in the fiscal year 2024.

This service uses digital signature authentication technology to provide a mechanism for verifying the authenticity of positioning signals. Specifically, the QZSS control station generates digital signature data using the private key. The digital signature data is included it in the positioning signal information (navigation message), and it is distributed it via the QZSS. The user (GNSS receiver) verifies whether or not the navigation message has been tampered by performing arithmetic processing using the public key obtained in advance, the received digital signature data, and the navigation message (hash value).This makes it possible to confirm that the positioning signal is authentic.

This mechanism enables users to perform secure positioning using only positioning signals transmitted from real positioning satellites.

GIS in facility management of multi-campus universities in Nigeria

A case for solid waste management in university of Nigeria, ENUGU campus. The dynamics in demographics certainly demand more proactive approaches in solid waste management

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Abstract

Solid waste management has posed serious environmental threat and challenges over the years especially in developing countries. There seems to be poor solid waste management system in Nigeria universities with University of Nigeria not being an exception. This study examined the effectiveness of the waste management system through automation of the system using Geographical Information System. Data was collected through direct field observation using Geographical Positioning System and IKONOS for image data of University of Nigeria, Enugu Campus. A geodata base was created and several spatial analysis was performed using ArcGIS 10.5.

Introduction

Solid waste is an inevitable by-product of man's activities. As the population increases so will the rate of waste generation increase. Hence, solid waste management becomes paramount. The dynamics in demographics certainly demand more proactive approaches in solid waste management. No doubt, challenges in management of solid waste is a global phenomenon, however, Global South has more issues with solid waste management. Nigeria, a well-known developing country in West Africa is no exception to this. The challenges in solid waste management in most developing countries has increased in recent times due to increases in population, industrialization, urbanization and globalization (Butu et al, 2013). Municipal solid wastes are generated from various sources and are stored in bins and dumpsters that are placed at various designated areas for collection by the management agency.

Solid waste is solid or semi-solid materials resulting from human and animal activities that are useless, unwanted or hazardous (Huang, 2008). Solid wastes are refuse which are useless, unwanted or ill- discarded materials that arises from man's daily activities. It should be properly disposed of. Waste can be classified on the basis of source of generation and type (Muniu et al, 2017). The classifications based on source include: residential, commercial, institutional, municipal, industrial and agricultural. On the other hand, the classifications based on type include: garbage, ashes and residues, combustible and non- combustible, bulky wastes, street wastes, biogradable and non-biodegradable, dead animals, abandoned vehicles, construction and demolition waste, farm waste, hazardous wastes and sewage waste.

Tertiary Institutions have enormous challenges dealing with solid waste. This is more so due to population surge in the admissions year by year. The case of University of Nigeria is further visible with the multi-campus operated by the Institution. The University has the following Campuses:

i. Nsukka Campus
ii. Enugu Campus
iii. Ituku Ozalla Campus
iv. Aba Campus

The locations of the dumpsters/ waste bins, prompt evacuation of the bins and distances of the bins from buildings are basic environmental challenges.

Recourse to the provisions by the Nigerian Universities Commission (NUC) and Nigerian Environmental Standards and Regulations Enforcement Agency (NESREA) revealed that emphasis was on adequate provisions of the waste bins/dumpsters. No guidelines or stipulations on distances from buildings for instances. Furthermore, the need for route optimization in placement or location of the dumpsters necessitated an automated approach to the solid waste management in our tertiary institutions. The use of sensors will also ensure timely evacuation of the waste once an alert is received.

A lot can be achieved through automation of the solid waste management in our tertiary institutions. University of Nigeria, a foremost Federal-owned tertiary institution in Nigeria has no official geodata base for its solid waste management. This paper thus makes a case for improved solid waste management in University of Nigeria, Enugu Campus by automation of the system through creating a geodata base for solid waste management and spatial analysis thereafter. The aim of this paper is to examine the application of GIS in determining the spatial location and distribution of the solid waste dumpsters in University of Nigeria, Enugu Campus with a view to achieving a more efficient and effective solid waste management system.

The specific objectives are:

i. To find out the various locations of the dumpsters/waste bins in UNEC
ii. To carry out spatial analysis for route optimization, suitability of the dumpsters location among others
iii. To develop geodata base for the waste dumpsters in UNEC

Literature review

Conceptual review

Concept of Geographical Information System

Geographic Information Systems (GIS) are a powerful set of computer-based tools used to collect, store, manipulate, analyze and display spatially referenced information (Burrough & McDonnell 1998; Rusko et al, 2010; Yogesh, 2018). GIS is a computerized system that combines spatial and descriptive data for mapping and analysis (Brooker, 2002). GIS are a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986). Geographical Information System is any system that captures, stores, analyzes, manages, and presents data that is linked to location (Akankpo, & Igboekwe, 2012). GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Environmental Systems Research Institute, 1990). Technically, GIS is a system that includes mapping software and its application to remote sensing, land surveying, aerial photography, mathematics, photogrammetry, and geography. (Akankpo, & Igboekwe, 2012).

One of the main strengths of a GIS is its ability to integrate different types of spatial data. GIS provides facilities for data capture, data management, data manipulation, analysis, and the presentation of geographical data (Arnoff, 1989; Rusko et al, 2010). GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (Environmental Systems Research Institute, 1990). From the foregoing, we define GIS as a computerized tool that is used to collect, store, manage, manipulate, transform, analyse, update, display and retrieve geographical data in a quick and efficient manner in other to aid analysis and decision making.

Solid Waste Management (SWM)

Waste management involves the collection, transportation, processing, disposal, management and monitoring of waste materials (Coker et al, 2015). SWM is the control of generation, storage, collection, transfer, transportation, processing and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations (Yadav, 2015). SWM basically includes the storage, collection, transfer, transportation, disposal, and treatment of solid waste which includes recycling of organic waste, thermal treatment techniques, recovery of recyclable products and landfilling (Sharholy et al, 2008). In its scope, SWM includes all administrative, financial, legal, planning and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants (Tchobanaglous et al., 1997). SWM is made up of many drivers that can be used to reduce the volumes of solid waste and this are reusing and recycling materials, composting, and source reduction (Jibril et al, 2012). The main objectives of SWM are the maintenance of clean and hygienic conditions and reduction in the quantity of solid waste (SW), which is disposed of in the sanitary landfill facility (SLF) of the area after recovery of material and energy from it (Ammar et al, 2019).

Empirical review

Review of Studies on the Application of GIS in Educational Institutions

Makinde et al. (2020) examined the use of GIS geo-database for waste management in University of Lagos, Nigeria. Data was retrieved via field observations using GPS, questionnaires and interviews, and Google Earth satellite image data of the University of Lagos. A geo-database was created, and several spatial analyses were performed using ArcGIS 10.6 and MySQL software. The study revealed that the model created could serve as a useful alternative method in managing waste in the University. Arrasyid et al. (2019) developed a space-based geography learning media for high schools in Indonesia. This study used a quasi-experimental design to examine the influence of GIS in geography learning. The study population were social class eleventh graders at SMAN 15 Kota Bandung, Indonesia which is the experimental site as well. The analytical technique used was Kolalogov-Smirnov. The study created and developed a user-friendly GIS system which was able to display data in a variety of formats. The user interface was designed to be simple with such basic facilities as thematic maps, data searching, and data display in various formats. The GIS-based learning media developed showed significant influence on learning achievement of learners.

Lin & Li (2018) developed a campus navigation system in China using GIS. The system included four function modules for map query, campus navigation, campus environment preview and campus profile. The campus navigation function modules accurately provided the school road conditions and building facilities to visitors, helping them to familiarize themselves with the location and information of various types of building facilities on campus and selecting the optimal route. The campus profile function was used to identify and connect properties. Campus environment preview function was used to show the real shot maps of the various facilities on campus. The campus navigation system describes the distribution of campus teaching facilities, living facilities, other buildings, and relative location relationships. Inyang (2018) examined the use of GIS in University of Calabar library. The study traced in-use statistics in the different divisions of the library for a 3-years period which gave the data for study of all the functional areas. Analysis was presented using different types of GIS charts: Lines with markers charts, Radar charts, and a 3-D 100% stacked column chart. The findings revealed that the library use data can be represented using a GIS. When data is accurate, whatever GIS design used for presentation and visualization will be accurate, most times self-explanatory and easy to understand.

Ngunyi & Makokha (2017) examined the application of web GIS in accreditation and monitoring of professional training institutions in Kenya for quality assurance. A survey of user requirements was undertaken. Spatial locations of training institutions were digitized using Google Earth geobrowser. An accreditation geodatabase was designed in ArcGIS, and used to store both spatial and attribute data. The data was then exported to ArcGIS Online where the use of web GIS technology ensured the creation of an Accreditation Web App. The app simplified the accreditation process and offers accreditation officers, students and other stakeholders a web-based GIS enabled solution. It also provides management with the ability to perform market research, and integrate the app with other existing systems in order to enhance efficient use of resources. Al-Rawabdeh et al (2014) built a 3D GIS map and all utility information for Al al-Bayt University campus to improve its data management and to develop methods using 3D spatial analysis for specific applications at the university. The study showed that 3D GIS model expresses terrain features in an intuitive way which enhances the management and analysis of a proposed project through 3D visualization. The 3D GIS model provides access to mapping data to support planning, design and data management. Integration of GIS spatial data with campus organization helps to improve quality, productivity and asset management.

Haghparast et al. (2013) examined the use of GIS in carbon sequestration in Pune University. GIS Arc view 9.2 was used along with field measurements to obtain accurate calculation and interpretation of different layers of ground biomass, soil organic carbon, leaf litter, herb biomass distribution and it was used as a technique for indicating dominant species in the study area and marking hot spots of the project. The study revealed that the Dalbergiamelanoxylon and Gliricidia sepium are the most dominant species in terms of carbon sequestration, whereas species such as Ficusbengalensis and Samaniasaman, Cocosnucifera and Delonixregia were categorized next to this two species. GIS based map showed the location and value of above-ground carbon sequestration for each plot in the study area.

Akankpo & Igboekwe (2012) examined the application of GIS in mapping of groundwater quality for Michael Okpara University of Agriculture Umudike, Nigeria. GIS software ILWIS 2.1 was used to analyze and create groundwater pollution sensitive zone map. Spatial variability maps of different groundwater quality parameters were generated using interpolation operation in the software and were incorporated as data layers in the software for further generation of groundwater pollution sensitive zone map. The effect of various data layers (elevation map, contour lines, and land use activities) on the distribution of groundwater pollution was also studied. The study revealed that GIS software is very useful in the analysis of topographic slope, groundwater table variation and land use activities in the distribution of groundwater pollution.

Ibraheem & Falih (2012) built a GIS based system for Nahrain University that provides information for use on which all aspects of the Pavement Maintenance and Management System (PMMS) process can be built. Twenty three sections was selected along the roadways of Nahrain University and all these sections were found to be in bad conditions. The present serviceability binder (PSI) of these sections ranged between 1 to 4, and most of these sections in the low ranged between 1 to 2. The study revealed that the spatial nature of transportation data makes GIS a logical choice on which to base systems such as pavement maintenance system (PMS). GIS has proved to be an effective tool for integrating, managing, storing, displaying, mapping, querying, and spatially analyzing transportation data.

Donnelly (2010) gave an overview of free and open source (FOSS) GIS software and posed the question of whether libraries and academic departments should consider adopting FOSS GIS. The process of creating a basic thematic map was used to test six FOSS GIS software packages. Each of the individual FOSS GIS packages had their own particular strengths and weakness, and some performed well for thematic mapping. The FOSS packages generally were weaker compared to ArcGIS in terms of support for various projection and coordinate systems, joining attribute data to GIS files, and automatic labelling, but their advantage was that they were free in terms of cost and licensing restrictions. When coupled with plug-ins and helper applications the viability of the FOSS GIS packages increased.

Fisher & Toepfer (1998) surveyed fisheries programmes at 24 US universities about their training in GIS and uses of GIS in fisheries research. The study revealed that on average, 21% to 40% of fisheries faculty and students indicated they occasionally used GIS in their research. The most common fisheries-related uses of GIS were mapping and modelling fish distributions and aquatic habitats, and evaluating the effects of watershed land use on fish populations, communities and habitats.

Review of Studies on Solid Waste Management (SWM) in Tertiary Institutions

Ugwu et al. (2020) examined the waste generated in the University of Nigeria, Nsukka campus using ASTM D5231-92 method. The study revealed that 96.58% of the total waste is recyclable, and has about 51.85% biomass potential. Parvez et al (2019) evaluated SWM at Indian Institute of Technology Roorkee (IITR). Data was retrieved through observations, interviews with staff and students, and documents from the campus authorities. The SWM at IITR was disorganized and incompetent. Lack of awareness and improper collection, imprecise segregation, exposed transportation, inefficient processing and disorganized disposal of solid waste are the major reasons for it. Moqbel (2018) evaluated the SW characterization of the University of Jordan. The study estimated the generation rate of SW generated on campus. The study revealed that 87% of the waste generated on campus may be recycled.

Coker et al (2015) examined SWM in Covenant University. Data was gotten using key-informant interview and personal field observations. Results showed that SW were collected using appropriate waste collection bags and mobile bin positioned at strategic corners of the university premises. The waste materials after collection were segregated into plastics, bottles, nylon and organic materials by scavengers. Ekong & Enefiok (2013) examined waste disposal habits of the students of the University of Uyo. Questionnaire, interview and observation was used to retrieve primary data. The study revealed that the environments where students are accommodated was poor as a result of the indiscriminate waste disposal habits of the university students. Jibril et al. (2012) analysed the Reduce, Reuse and Recycle strategic approach for the awareness amongst the waste generators within Higher Educational Institutions. The study used exploratory research approach relying on secondary data. The study revealed that most of the Institutions and communities do not use 3R s system in managing their waste generated, which threatens the health of human and other living organisms.

Gakungu et al. (2012) examined SWM in 29 public technical training institutions. Students, principals, and officers in-charge of waste management in the institutions were administered with questionnaire and interviewed. Direct observations was also used in the study. The study revealed that the cost of SWM in the institutions was dependent on both the waste generated and the institutional population. Taghizadeh et al (2012) analysed the wastes generated in University of Tabriz. Sampling of waste and determination of waste composition methods was according to standard for determining unprocessed municipal SW composition (ASTM D5231- 92), and waste handling trucks were weighed. The results showed that more than 80% of waste generated could be diverted through waste reduction, recycling and composting activities. Olusegun & Udonwan (2012) analysed the SW materials generated in selected sites in Covenant University, Nigeria. During the 10 weeks study period, solid waste were weighed before their delivery to landfills. The study showed that SW could be managed using landfill system, bio-gasification scheme, recycling, co-incineration, pyrolysis, and gasification system.

Smyth et al (2010) evaluated the waste generated by Prince George Campus of the University of Northern British Columbia (UNBC). Waste haulage and disposal records were obtained through the UNBC facilities department and key informant interviews. The location of interior and exterior waste, recycling and compost receptacles were mapped. The Wilcoxon signed-rank test was used for analysis. The study revealed that more than 70% of waste could be diverted through waste reduction, recycling and composting activities. Malakahmad et al (2010) analysed the SW generated at University Technology Petronas (UTP). Questionnaire was administered to students and staff in the campus. The study revealed that 80% of students and staff were interested to take part in recycling activities only 53% of them have practiced in it and the main reasons were that 75 and 83% of them could not find suitable and enough number of recycle bin, respectively. Up to 80% of produced materials at academic building are recyclable.

Farzadkia et al (2009) investigated SWM in eight teaching hospitals of Iran University of Medical Sciences. Data was retrieved through a questionnaire and direct observation. The results showed that the challenges of SWM in the study area were lack of separation between hazardous and non-hazardous waste; absence of the necessary rules and regulations applying to the collection of waste from hospital wards and on-site transport to a temporary storage location; lack of proper waste treatment; and disposal of hospital waste along with municipal garbage. Vega et al. (2008) evaluated the recycling potential of SW for the Campus Mexicali I of the Autonomous University of Baja California (UABC). The research methodology involved estimate of the daily SW generation; SW sampling and characterization of samples; and data capture and analysis of the amounts and types of wastes generated. It was found that more than 65% of SW are recyclable or potentially recyclable. Dehghani et al (2008) evaluated SW generated in 12 educational hospitals of Tehran University of Medical Sciences. Descriptive, cross- sectional and interviews with the authorities of the healthcare facilities and personnel involved in the management of the wastes was conducted. The results showed that 92% of medical wastes of hospitals were collected by covered-trucks. In 46% of hospitals, transferring of medical wastes to temporary stations was done manually.

Application of GIS in Facility Management (FM)

Mirarchi et al (2018) examined FM processes through end-users' integration and coordinated BIM-GIS technologies. A workflow was defined and designed, in which a FM supporting platform was proposed and characterized, featuring indoor positioning systems to allow end users to send geo-referenced reports to central virtual models. Result showed that the integration of end users in the maintenance processes through smart and easy tools can overcome the existing limits of barcode systems and building management systems for failure localization. The proposed framework allows the identification of every element of an asset including wide physical building elements without requiring a prior mapping; and the entire cycle of maintenance activities is managed through a unique integrated system.

Makinde et al. (2017) created a 2D and 3D visual facility map of University of Lagos. The spatial attributes of the facilities were collected with the aid of total stations. Google earth software was used as source of data to produce 2-dimensional facilities through digitization process. SRTM Digital elevation model image was downloaded from United State Geological Survey website to give the elevation data required for the 3-dimensional representation. All these data were processed with ArcGIS 10.2.1. The 2D and 3D model carried out in this project identified numerous cultural and natural ground features, such as roads, buildings, power transmission lines, lakes, streams, swamps, slopes, trees cleared land, highway names etc. Kang et al. (2016) created a software architecture for the effective integration of BIM into a GIS-based FM system at the Korea Institute of Construction Technology (KICT). The databases which were integrated with the current system for information interoperability, were Excelbased structures constructed for the BIM-based FM of the main building at KICT, and the BIM objects were modeled using the Revit software. For a GIS based FM, the property information was extracted from BIM models and transformed using the ETL (extract, transform, and load) concept. The results show that BG-DI and BIM/GIS integration has benefits such as reusability and extensibility.

Mwaniki & Odera (2014) examined the application of GIS in space management in International Livestock Research Institute (ILRI). A GIS database which integrated spatial and non-spatial data of facilities in ILRI was built. Data obtained from AutoCAD, ArchiCAD and PDF files was geo-referenced, and used to create spatial entities. Non-spatial data was obtained from Excel and PDF files. GIS analyses were then carried out on the data stored in the geo-database. These analyses included determination of the main types of facilities that occupy the organizations' space and their areas; and potential locations for fire assembly points. Finally a web map of the underground and surface facilities was built using features stored in the geo-database. Motuka (2008) developed an integrated GIS of the U-block of the Kenya Polytechnic University College. ArcView GIS and/or ArcGIS, Microsoft Access, and Microsoft Excel, was used to provide operations of data input and conversion. The floor plans (after digitization) and the room-specific data were analyzed using GIS software. From the U-Block database, the study was able to extract information on the amount space available, the department to which some space is assigned, and the maximum number of students a room can accommodate (stations).

An important fact that has emerged from the review of extant related literature is that most previous studies on the GIS application was centered on issues such as space management, facility mapping, carbon sequestration, mapping of ground water quality, management of transportation data, use of library resources, and campus navigation. Only the study of Makinde et al. (2020) examined the use of GIS in waste management; however, the study was domiciled in the University of Lagos. Therefore from literatures available to the researcher no study has examined the application of GIS in solid waste management in the University of Nigeria, Enugu Campus; hence the need for this study to also fill this extant literature lacuna.

Methodology

The primary data include the geographical coordinates of all the dumpsites in the UNEC using hand held GPS while the secondary data used include; administrative boundary maps (Ancillary data).

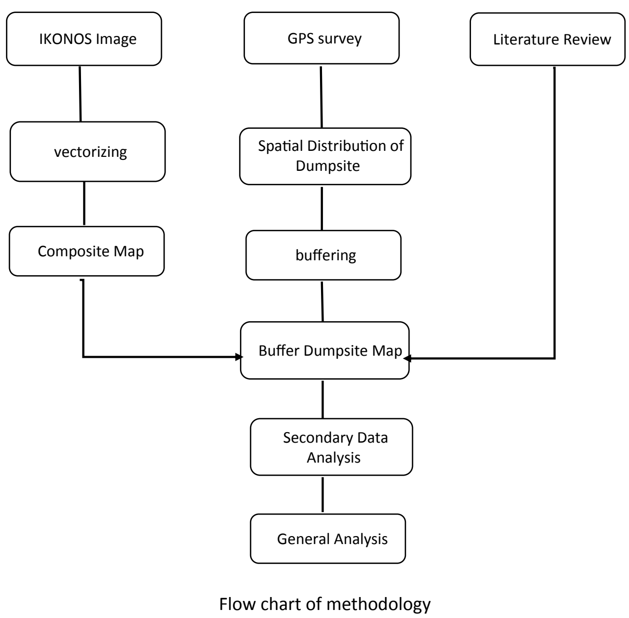

Figure 1: Flow Chart of Methodology

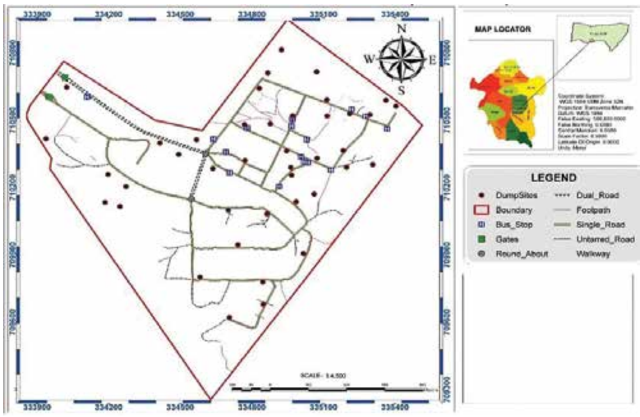

Figure 2: Map Showing the Location of Dumpsters in the Study Area
Source: Department of Land Surveying and Geoinformatics Geographic Information System (GIS), University of Nigeria Nsukka.

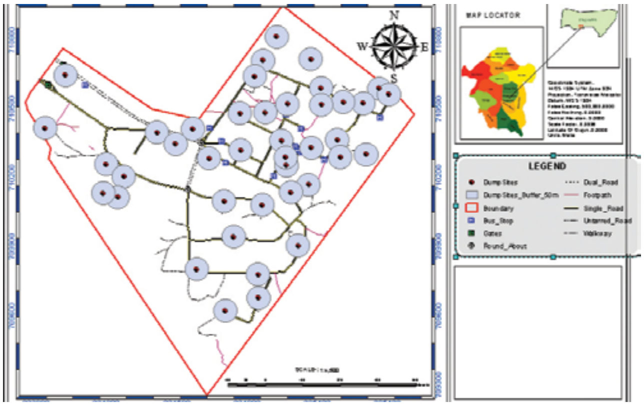

Figure 3: Map Showing the Proximity of Dumpsters
Source: Department of Land Surveying and Geoinformatics Geographic Information System (GIS), University of Nigeria Nsukka.

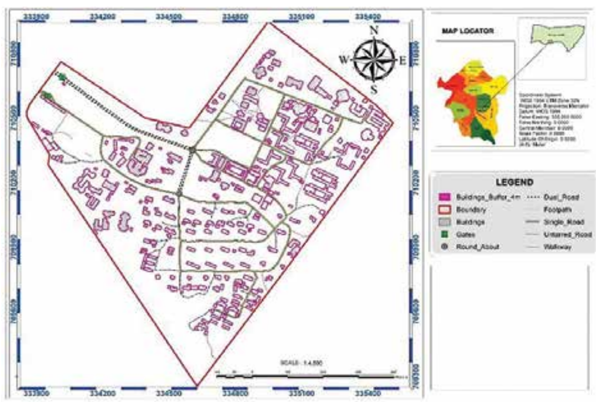

Figure 4: Map Showing a Buffer of Placing Dumpsters Within 4m Radius
Source: Department of Land Surveying and Geoinformatics Geographic Information System (GIS), University of Nigeria Nsukka.

The methods adopted for data collection were: Field survey was conducted using handheld GPS, GARMIN 78sC to obtain Geographic Coordinate of dumpsites located within UNEC. Secondly, high resolution Image (IKONOS) covering UNEC was used to extract and produce the Composite Map. Data was analyzed in ArcGIS 10.5 in Windows OS environment.

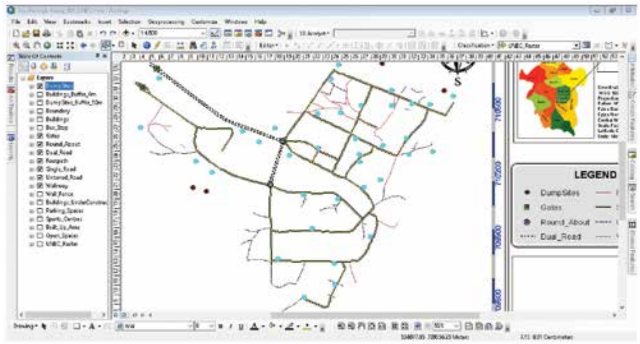

Figure 5: Proximity of Dumpsters to Road Side
Source: Department of Land Surveying and Geoinformatics Geographic Information System (GIS), University of Nigeria Nsukka.

Figure 6: Map Showing the Suitability Analysis for Siting a Dumpsite
Source: Department of Land Surveying and Geoinformatics Geographic Information System (GIS), University of Nigeria Nsukka.

Results and discussion

Geospatial analysis of the waste management facilities, reveals a total of 41 dumpsters and 2 major waste collection points (Located behind Lady Ibiam Hostel and Ojukwu Hostel) were identified in the University of Nigeria, Enugu Campus and mapped. The resulting feature layer was used to develop a waste collection system. It was observed that there were more dumpsters located in the Northern part of the university when compared to the other parts. This could be because of the high population of people occupying that axis of the university. The administrative offices of the university and guest house are in this section of the university, while the Southern side are where the staff quarter is located

The proximity of the dumpster was assessed. It was observed that within 50m radius, certain areas on campus had their dumpster filled up and litters around the dumpster. A proximity analysis was performed of dumpsters to buildings on campus. It was observed that most of the buildings do not have any dumpster located within 4m. Places such as Lady Ibiam and some Bus stop had its closest dumpster within about 10m and it was filled up. Others were CEMAC, Faculty of law areas of the campus.

Thus, it is suggested that dumpster should be placed at least 4m of every building on campus for proper waste management.

An analysis was performed to identify the location of dumpsters along the roads, to assess the ease of pedestrians disposing their waste on campus. We observed that the most of the major roads in UNEC did not have sufficient roadside dumpsters.

We observed that there are currently two major dumpsites on campus: the first one (which is the main one) is located behind Lady Ibiam while the second is located behind Ojukwu and Manuwa Hall or residence. Waste is moved from first dumpsite to the second for sorting and some form of recycling. Suitability analysis was applied to assess the location of one of these two dumpsites (Lady Ibiam), and it was observed that the dumpsite behind the Lady Ibiam fell within the 500m buffer even the one behind Ojukwu and Manuwa Intercepted with the Lady Ibiam at Buffer of 500m. It is recommended that this dumpsite should be relocated based on health reasons or the university should provide a way of daily disposing of waste generated.

Conclusion

This study created a GIS database model for waste management in the University of Nigeria, Enugu Campus. It incorporated the use of GIS and GPS methods of survey to solving the management of waste. Spatial analysis was performed, and maps created. The maps created can be used as a decision support tool to enhance the current management system. Furthermore, this research can serve as a primary beacon with which another research can be founded upon. The research ends up providing us spatial location of waste bin located in university of Nigeria Enugu Campus and its proximity to each other, buildings (offices, library, classroom, hostels and Guest houses) roads and so on. Their spatial locations will help in further research, decision making and was well as having analysis on its effects to proximity to either Buildings or road.

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Saudi Arabia charts the first-ever coastal tourism map of Red Sea

Tourists traveling to The Red Sea Project can expect better mobility and accessibility options as Saudi authorities are developing the Kingdom's first geographical navigation map that charts the scope of marine tourism in the coastal area.

The Saudi Red Sea Authority and the General Authority for Survey and Geospatial Information have partnered with 19 government agencies to develop the first-ever coastal tourism map of the Red Sea.

The new map will serve as an introductory guide to government agencies, allowing better identification of avenues to boost coastal tourism in the Red Sea.

By building the navigational map, appropriate legislation requirements, governance and digital solutions, the committee will present the map to the Council of Economic and Development Affairs and Council of Ministers for approval. *www.arabnews.com*

CompassCom releases upgraded telematics platform

CompassCom Software has released Version 8.2 of the CompassCom GIS-centric hybrid telematics platform that can be deployed on premises or in the cloud for real-time asset tracking and comprehensive fleet management. The new version offers enhanced ease of use and more robust analytics and reporting functionality for safer, more efficient and secure fleet operations. It has been developed on Esri ArcGIS technology supports JavaScript 4.0. *www.compasscom.com*

New capabilities for carbon assessment in iTwin experience by Bentley

Bentley Systems has recently announced the new carbon assessment capabilities in iTwin Experience to enable infrastructure professionals to seamlessly quantify carbon reduction opportunities in their projects.

In 2022, Bentley developed an integration service in the iTwin Platform to automate the process of generating embodied carbon reports for infrastructure projects via One Click LCA and EC3. Reports are initiated using the iTwin Platform and then viewed in One Click LCA or EC3. Now, iTwin Experience provides a ready-to-go, bi-directional integration with EC3, enabling carbon assessments to be visualized in a digital twin without the need to write code. *www.bentley.com*

New collaboration for advance seafloor mapping technology

Monterey Bay Aquarium Research Institute (MBARI) has joined forces with 3D at Depth. This partnership aims to revolutionize seafloor mapping by developing an advanced subsea Lidar system.

Imaging the structure of the deep seafloor is crucial for comprehending the biology and ecology of the largest living space on our planet. However, only approximately 20% of the ocean floor has been mapped at a resolution suitable for scientific study. Over the past decade, MBARI has collaborated with 3D at Depth to develop innovative tools utilizing Lidar technology for seafloor mapping. *www.mbari.org*

$500 million to tackle biodiversity loss, climate change

The GEF (Global Environment Facility) has announced a US$1.4 billion fund to rapidly tackle environmental crises around the world, including biodiversity loss and climate change. The program aims to directly benefit 14 million people globally, over half of whom will be women disproportionately impacted by planetary crises.

In the UNDP-GEF Partnership, more than US$500 million will be deployed across 88 countries, in particular Least Developed Countries and Small Island Developing States. As lead agency for the fund's Blue and Green Islands Integrated Program, UNDP with support from United Nations agencies and development partners, will help countries to use the resources to address intense environmental and socio-economic shocks faced by people on frontlines of nature loss and the climate crisis. UNDP will also help to operationalize GEF's Small Grants Programme, a key channel for supporting local communities, indigenous people and youth on environmental stewardship. *www.undp.org*

Esri releases Land Cover Map

Esri, in partnership with Impact Observatory, has released a global land-use/land-cover map of the world based on the most up-to-date 10-meter Sentinel-2 satellite data for every year since 2017. Following the latest 2022 data released earlier this year, the artificial intelligence (AI) model for classification has been improved, making the maps more temporally consistent. *www.esri.com*

Saudi geospatial authority to align with UN framework

Geospatial studies, map production and marine surveys in Saudi Arabia will soon be on par with global standards as the Kingdom is set to align its projects with the UN framework in this pioneering field. According to the Saudi Press Agency, the General Authority for Survey and Geospatial Information (GASGI) participated in the inaugural meeting of the international advisory committee of its UN counterpart between April 20 and 22 in Deqing, China.

During the meeting, the Kingdom presented the experience of the GASGI in developing a national strategy in line with global standards prescribed by the UN's Global Geospatial Knowledge and Innovation Centre Framework.

This integrates location information to plan cities, build infrastructure, develop disaster management strategies and manage natural resources such as green spaces, water and minerals. *www.arabnews.com*

EgSA & Chinese LASAC Collaboration

The CEO of the Egyptian Space Agency(EgSA), Dr Sherif Sedky, has formally entered into a MoU with the Chinese Land Satellite Remote Sensing Application Centre (LASAC). The primary objective of this agreement is to enhance Egypt's access to remote sensing data, providing valuable insights for informed decision-making in crucial areas. Additionally, the MoU aims to facilitate adequate training opportunities to improve Egypt's ability to extract actionable intelligence from the obtained data. *https://africanews.space*

Voyager Space Signs MoU with ISRO and IN-SPACe

Voyager Space announced the signing of a MoU with the Indian Space Research Organization (ISRO) Department of Space and the Indian National Space Promotion and Authorization Center (IN-SPACe) to explore opportunities for the utilization of ISRO's Gaganyaan crewed spacecraft to service Starlab, a first-of-its-kind, continuously crewed, free-flying space station.

The objective is to jointly study the potential use of ISRO's Gaganyaan spacecraft to provide crewed flights to the Starlab station. Furthermore, Voyager and IN-SPACe will seek additional collaboration opportunities with various stakeholders within the Indian space ecosystem, including research institutions, commercial entities, and government agencies.

Artec 3D collaborates with Leica Geosystems

Artec 3D has introduced the Artec Ray II, a highly precise 3D Lidar scanner specifically designed for digitizing large objects and spaces with exceptional speed and accuracy. The new scanner is the result of a collaborative effort between Artec 3D and Leica Geosystems, part of Hexagon. The Artec Ray II is capable of capturing a complete dome in just 1.7 minutes, achieving a 3D point accuracy of 1.9mm from a distance of 10m. These features make it an ideal solution for generating digital twins of extensive objects and complex scenes.

SHI tests autonomous navigation system on container ship

Samsung Heavy Industries (SHI) has claimed an industry first with the verification of its autonomous navigation technology on a container ship sailing between South Korea and Taiwan.

The company installed its remote autonomous navigation system (SAS) and smart ship system (SVESSEL) on a 15,000 TEU class large container ship built at its Geoje shipyard. Fom June 26 to July 1, the vessel departed from Geoje and passed Jeju Island to Taiwan, demonstrating its autonomous navigation technology by operating about 1,500km to Kaohsiung Port. The demonstration included integration of advanced autonomous navigation technologies such as AIS, radar, camera sensors and sensor fusion.

Konux uses AI, IoT for railway infra optimization

Konux has been building out a SaaS business powered by proprietary sensing hardware and AI that drives a predictive maintenance software-as-a-service(SaaS) play which is upgrading railway infrastructure. Its mission is to drive digitization and transformative change atop rail travel, using AI plus IoT to add intelligence to fixed rails by capturing real-time data on what's happening on and to the railway network.

The company is using deep tech methods and stress-tested connected hardware to gain visibility into the loads and forces railway lines are accommodating day in, and day out; measuring vibration through the tracks to pick up anomalies that may signify failures incoming, then presenting its probabilistic analysis of what's going to happen to the infrastructure over the next few months. Its AI-driven predictions were developed to a 90% accuracy standard, per Bonnifield. *www.konux.com*

Drone security solutions for civil airports

Aircraft are designed to withstand the impact of a small number of small birds entering the engines or colliding with the fuselage or windows. However, the unauthorized launch of large birds or, even worse, metallic electronic drones near airports can cause serious damage and lead to aircraft accidents or system failures, posing risks to flight safety. Bel Trading & Consulting Ltd offers automated drone suppression systems as part of its arsenal to create safe corridors for aircraft in proximity to airports. These systems have been successfully deployed and are in operation in various airports across Asia and Europe. Comprehensive solutions have been used, including interference jammers disrupting communication between the drone operator and the drone itself, as well as GPS positioning suppression systems for drones. *beltrading.net*

DroneAcharya and KMITL partnership

DroneAcharya Aerial Innovations Limited, announced its partnership with King Mongkut's Institute of Technology Ladkrabang (KMITL) in Thailand.

The main goal of this partnership is to launch an innovative Drone School and Drone Centre of Excellence at KMITL campus, which will provide a variety of drone and GIS – related training programmes. This center will also enable the faculty, students and industry experts to collaborate and work on projects and develop innovative solutions through DroneAcharya's Industry Experts and Technical knowhow.

Drone-based land parcel mapping in India

The Geospatial organizations Allterra and NeoGeo, collaboratively won the drone-based Land Parcel Mapping contract through an open tender process from the Karnataka government. The project covers an area of 68,000 SQ. KM. and 10 complete districts in Karnataka – Gadag, Koppal, Kodagu, Chamarajanagar, Chikkamagaluru (Chikmagalur), Vijayapura (Bijapur), Yadgir, Raichur, Bidar, Kalaburagi (Gulbarga). Both companies have chosen Aereo (formerly Aarav Unmanned Systems) as their technology partner for this project.

This work envisages deployment of approximately 60 survey-grade PPK drones to capture high-resolution images to generate maps with a resolution better than 5 cm per pixel. At full scale, the fleet of drones will be mapping an approximate area of 1,75,000 acres in a single day on an average. *www.thehindu.com*

Chennai gets India's first Police Drone Unit

Greater Chennai Police, in India, established a 'Drone Police Unit' to assist cops in aerial surveillance. This is going to help in case of large gatherings, real-time checking of vehicle registration data, and spotting of suspects.

A total of nine drones under three categories are available in this unit: Quick Response Surveillance Drones (6), Heavy Lift Multirotor Drone (1), and Long Range Survey Wing Place (2). All these drones are equipped with built-in artificial intelligence (AI) capabilities and can be operated up to a distance of 5-10 km from the ground station.

India's DGCA signs MoU with EASA for UAS

The Directorate General of Civil Aviation (DGCA) India has signed MoU with the European Union Aviation Safety Agency (EASA) for cooperation in Unmanned Aircraft Systems and Innovative Air Mobility.

This MoU will focus on collaboration on unmanned aircraft and innovative air mobility between the civil aviation authorities.

It would include cooperation in the areas of development of certification standards and environmental standards and related requirements for the certification and use of unmanned aircraft systems and innovative air mobility operations.

This includes licensing of personnel, training, air traffic management and infrastructure, including Unmanned Aircraft System Traffic Management (UTM) standards and services.

The MoU will also ensure regular information sharing between the two authorities on the technological developments and research in this area and their respective outreach strategies to reach relevant stakeholders. *pib.gov.in*

XTEND partnership with ModalAI

XTEND and smart devices has announced a multi-layered partnership with ModalAI, Inc., the leading Blue UAS Framework manufacturer of autonomous drone and robotics technology. The partnership will see XTEND make available their XOS operating system on ModalAI's technology, and XTEND's range of revolutionary human-guided autonomous drones become tightly fused with ModalAI's VOXL® 2 Autonomous AI Autopilot, supercharging both sets of users' ability to complete advanced robotics missions successfully.

IIT Kanpur develops AI-enabled Kamikaze Drones

The Indian Institute of Technology, Kanpur, has developed an indigenous version of the Kamikaze drone. The suicide drone can carry up to 6 kg warhead for up to 100 km. The indigenously developed drones are also capable of neutralising enemy targets even in the absence of GPS support.

The drone is 2 meters long and has a foldable fixed-wing design. It can also be equipped with cameras and infrared sensors. The drones can be launched from a catapult or canister launcher. The battery-operated UAVs can deliver a payload of up to 100 km in 40 minutes, providing a boost to the offensive capabilities of the armed forces.

Terra Office Workflow and ArcGIS Pro integration

Trimble has released Terra Office add-in for Esri ArcGIS Pro. It is a new product in Trimble's Terra Office suite of desktop solutions for integrating Trimble TerraFlex® field data collection software with GIS systems of record.

With a streamlined user interface, the new add-in for ArcGIS Pro allows a customer to connect TerraFlex workflows directly to their ArcGIS environment from within ArcGIS Pro, Esri's desktop GIS application. An ArcGIS Pro user can now create and manage TerraFlex geospatial data collection projects without leaving the ArcGIS environment. *www.trimble.com*

GMV tests lunar rover at unprecedented speeds

GMV is conducting field tests as part of RAPID (Robust and Semi-Autonomous Platform for Increased Distances), a space robotics project run by the European Space Agency (ESA).

The Moon has been and continues to be the next step in human exploration. Water, along with other volatile and lunar materials such as regolith, metals, and rare earth elements (REE), present potential resources that can sustain human and robotic exploration sustainably on the Moon, the Solar System, and beyond. The lunar poles, in particular, are of great interest for exploration but present harsh environmental conditions with very low temperatures (below 30K/-243 degrees Celsius) and challenging lighting conditions. *www.gmv.com*

Rohde & Schwarz collaborates with Qualcomm

Rohde & Schwarz, in collaboration with Qualcomm Technologies, will conduct a broad range of NB-IoT over NTN tests that address the many challenges inherent to satellite-based non-terrestrial networks that use geosynchronous orbit (GSO) and geostationary orbit (GEO) constellations. The test set covers time and frequency synchronization from prolonged delays and the Doppler effect, low signal-to-interference-plus-noise ratio (SINR), power saving mechanisms, satellite ephemerides, GNSS acquisition and more.

These tests will be a validation tool for Qualcomm Technologies' latest NTN chips, the Qualcomm® 212S and Qualcomm® 9205S. R&S CMW500 Protocol Testing Framework scenarios and the R&S CMW 3GPP Release 17 NTN IoT protocol enabler on a single R&S CMW500 wideband radio communication tester will help engineers assess their NTN NB-IoT devices powered by Qualcomm Technologies' NTN chips under realistic conditions. The R&S CMW500 wideband radio communication tester emulates GSO and GEO satellite base stations in combination with the R&S SMBV100B, which generates GNSS signals. Establishing a real-time, comprehensive connection with the simulated GSO/GEO satellite network lets engineers test relevant signaling and RF scenarios in line with 3GPP Release 17. *www.rohde-schwarz.com*

ComNav's GNSS receiver

As a high-precision integrated GNSS positioning and heading receiver, the A200 can track all existing and planned constellations — including GPS, BSD, GLONASS, Galileo, QZSS and SBAS - providing high-precision positioning and heading data for users. It is equipped with a K823 GNSS module. It also features 1,226 channels. The A200's third generation IMU delivers fast initialization and ensures the output of heading during temporary GNSS signal loss. The built-in data link has low power consumption and a long working range. It also can be upgraded to a super-long-range data link module. *comnavtech.com*

NextNav announces new European Commercial Testbed

NextNav has taken the first step toward providing a resilient 3D PNT capability in Europe, opening a new commercial testbed for its Pinnacle technology in France. This is the company's first European testbed for the high-accuracy vertical location technology and will be located in the Paris area. Pinnacle offers precise floor-level vertical location—which is critical for emergency responders who need to quickly find victims. The terrestrial-based system provides accurate 3D PNT for emergency services, logistics, telecommunications and other sectors that rely on precise positioning and timing but are vulnerable to GPS interference. *nextnav.com*

U-blox releases two GNSS positioning modules

U-blox has released two modules based on the u-blox F9 high-precision GNSS platform. The low-power NEO-F9P supports precise navigation and automation of moving industrial machinery, and the ZED-F9P-15B provides customers in the mobile robotics market with an L1/L5 option in addition to the L1/L2 bands.

Both the modules feature concurrent reception of GPS, Galileo, and BeiDou; multi-band L1/L5 real-time kinematic; short convergence times; and reliable performance. *www.u-blox.com*

Northrop Grumman's new airborne navigation system

Northrop Grumman Corporation has conducted a successful flight test of its advanced airborne navigation solution, Embedded Global Positioning System (GPS) / Inertial Navigation System (INS) Modernization, known as EGI-M. It is the first time that EGI-M, equipped with an M-Code capable receiver, has been tested in flight. *northropgrumman.com*

Leica Geosystems introduces Leica CountryMapper

Leica Geosystems, part of Hexagon, introduces the Leica CountryMapper, extending the hybrid sensor portfolio with the most efficient solution for large-area imaging and LiDAR mapping.

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5-7, September 2023
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www.expouav.com

ION GNSS+ 2023
11-15 September
Denver, Colorado, USA
www.ion.org

European Lidar Conference (ELC)
13 – 15 September
Cluj-Napoca, Romania
https://enviro.ubbcluj.ro

DroneX Trade Show & Conference 2023
26-27 September
London, United Kingdom
www.dronexpo.co.uk

October 2023

FIG COMMISSION 7 Annual Meeting 2023
2-4 October
The Netherlands
figcommission7@fig.net

Asian Conference on Remote Sensing (ACRS 2023)
30 October to 3 November
Taipei, Taiwan
https://acrs2023.tw

Intergeo 2023
10-12 October
Berlin, Germany
www.intergeo.de

November 2023

Trimble Dimensions 2023
6-8 November
Las Vegas, USA
www.trimble.com

GoGeomatics Expo
6-8 November 2023
Calgary, Canada
https://gogeomaticsexpo.com

The Smart GEO Expo 2023
8 to 10 November
Gyeonggi Province
Republic of Korea.
www.smartgeoexpo.kr/fairDash.do

18th International Conference on Location Based Services (LBS 2023)
20-22 November
Ghent, Belgium
https://lbs2023.lbsconference.org

The Pacific GIS and Remote Sensing Conference
27 November - 1 December
Suva, Fiji
https://pgrsc.org

December 2023

Ramon GeoInt360
4-5, DEC 2023
Tel Aviv, Israel
www.geoint360.com

The CountryMapper collects foundational geospatial data simultaneously, enabling the generation of highly accurate data products to support a wide variety of customer applications. It makes full use of Leica Geosystems' unique expertise in combining industry-leading imaging and LiDAR sensor modules into highly efficient hybrid airborne systems.

Spirent unveils Simulation Systems and PNT Testing Tools

Spirent Communications demonstrated its latest GNSS simulation solutions and positioning, navigation and timings (PNT) testing tools at the Spirent GNSS Connect 2023.

Spirent has been working with government, automotive, unmanned aerial vehicles (UAVs) manufacturers, and military organizations to help understand the threats to GPS and other satellite navigation systems and address them through the use of sophisticated testing and measurement. *www.spirent.com*

RIEGL, Schiebel Cooperating on UAV-Based Airborne Scanning

RIEGL Laser Measurement Systems GmbH and Schiebel have completed the integration of a high-end laser scanning system, the RIEGL VQ-840-G topo-bathymetric LiDAR sensor, on the Schiebel CAMCOPTER® S-100 Unmanned Air System (UAS).

The compact topo-bathymetric laser scanner was designed for use in a variety of maritime and hydrographic environments. The LiDAR sensor payload system is controlled remotely via a data link, which is crucial for the integration into the S-100 system.

The scanner is controlled by using the onboard software "RiACQUIRE-Embedded" via the available data link; data acquisition and laser safety are also monitored. Once the survey is completed, the raw data seamlessly integrates into the RIEGL data processing workflow. *www.riegl.com*


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