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Establishment of Continuously Operating Reference Stations (CORS) in Zimbabwe

An exploration of stakeholders' readiness in adopting the CORS technology

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ABSTRACT

Advances in Global Navigation Satellite Systems (GNSS) have revolutionized the geospatial industry around the globe. Recently, the Government of Zimbabwe realized the need to adopt GNSS- Continuously Operating Reference Stations (CORS) for boundary mapping of farms to ensure security of tenure. In order to fully utilize the proposed CORS network there is need to ascertain the readiness of stakeholders involved in the land delivery value chain. This study was conducted to evaluate the perceptions of Zimbabwean geospatial practitioners concerning CORS and their readiness to adopt the technology. The readiness of stakeholders was evaluated based on their level of awareness to the CORS technology, access to GNSS equipment compatible with CORS, prior experience with CORS and skills on manipulation of CORS data. Data were gathered in the form of questionnaires and focus group discussions. The study showed positive results in terms of access to GNSS equipment and level of awareness to CORS, where more than 50% of the participants responded positively. However, in terms of frequency of use and preparedness of stakeholders to upgrade their GNSS equipment to become compatible with CORS technology, the results were discouraging.

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1. INTRODUCTION

In the last decade, advances in GNSS technology have enabled many national mapping agencies to abandon conventional surveying instruments such as theodolites in favour of CORS (Stone, 2006). Nowadays, the use of CORS has permeated various application domains around the world (Roberts et al., 2004; Calais et al., 2006; Liangke, Lilong and Chaolong, 2012) mostly due to their pronounced advantages over traditional survey equipment such as greater speed in carrying out surveys, less dependence on clear lines of sight or strength of figure considerations (Snay and Soler, 2008; De Moegen, Hill and Cairns, 2018). Recently, Africa has realised the importance of establishing a continent-wide CORS network for socio-economic prosperity and initiatives such as the African Geodetic Reference Frame (AFREF) have been vital in motivating member states to adopt a unified geodetic reference frame allowing seamless use of CORS across the continent (RCMRD, 2016). When the AFREF project was established in 2005 by the Committee for Development Information- Geo-Information of the United Nations Economic Commission for Africa (UNECA) (RCMRD, 2016) its main objective was "to unify the horizontal and vertical geodetic reference systems, datum and references frames in Africa in support of the ideals of the New Partnership for Africa's Development".

In order to realize this goal, the AFREF initiative works to encourage African governments, through their respective national mapping agencies, to modernize their national geodetic networks by using modern GNSS technology leading to the establishment of CORS networks. In response to the AFREF initiative, a number of African countries (e.g. South Africa (Vorster and Koch, 2014), Egypt (El-Tokhey et al., 2017) and Nigeria (Naibbi and Ibrahim, 2014)) have, through different institutions already started installing networked geodetic-grade GNSS receivers in various locations. These networked GNSS receivers (CORS) provide a reference framework to support acquisition of high-quality spatial data for use in surveying, construction, mining, agriculture and other allied fields. In addition, the CORS technology as envisaged by national mapping agencies in Africa will expedite the establishment of Spatial Data Infrastructure.

In South Africa the adoption of CORS, first proposed in 1997, was motivated by the need to expedite their land reform process and other land-related activities (Vorster and Koch, 2014). Over the years the CORS network (TRIGNET) has developed substantially and currently consists of 64 operational base stations spread over the entire country (Malservisi et al., 2013). Since ten years ago, Nigeria has installed and densified their CORS network, NIGNET, through the Office of the Surveyor General of the Federation in collaboration with SEGAL (Jatau et al., 2010). This project was initiated in line with recommendations from UNECA through its Committee on Development, Information Science and Technology (Naibbi and Ibrahim, 2014) and received support of the Presidential Technical Committee on Land Reform (Ojigi, 2015). NIGNET is tied to the International Terrestrial Reference System (ITRS) and contributes directly to the AFREF project

Recently, Zimbabwe recognized CORS technology as an integral component for the prompt acquisition of spatial data. Consequently, the country engaged the EU and UNDP to fund the process of establishing CORS in the country. Initially, five GNSS CORS will be established primarily focusing on expediting the process of boundary mapping of farms to support security of tenure thus ensuring food security (Trukhachev, Ivolga and Lescheva, 2015) in line with the Sustainable Development Goals (Griggs et al., 2013; UN, 2016). Having realized the urgent need for establishing CORS in

Zimbabwe, the readiness of the stakeholders and institutions which use geospatial data is yet to be evaluated. Although the primary rationale for establishing CORS in Zimbabwe was motivated by the need to regularize the land reform program to ensure tenure security, it is apparent that other stakeholders besides cadastral surveyors will use this technology. It is against this background that this study seeks to determine the readiness of key stakeholders involved in the acquisition and consumption of spatial data to adopt CORS.

2. METHODS AND MATERIALS

Since the establishment of the Department of the Surveyor General (DSG) in 1930, Zimbabwe has established a geodetic control network consisting of 2,550 trigonometrical beacons which forms the basis of land survey and mapping in the country (Bradford and Gauld, 1952; Lugoe, 1990). The trigonometric beacons were first established through the extension of a triangulation network conducted by Alexander Simms in 1901 with geodetic coordinates of the established points referred to an origin point where latitude, Φo = 17o50'25.440'' South and longitude, Λo = 31o02'19.000'' East, with an azimuth to Mt. Hampden, αo= 273o13'48.456''. This network, which spanned the western part of the country, was extended by Captain Gordon eastwards between 1928 and 1936. These two triangulation campaigns established most of the present-day primary control points in the country. The ellipsoid currently used in Zimbabwe is the Modified Clarke 1880 while the Gauss projection is used in recording cadastral survey measurements. Regarding the vertical component, reference is made to the Arc 1950 datum.

This study involved identifying key stakeholders, participating in focus groups as well as completing questionnaires. This enabled us to fill the information gap in the Zimbabwean literature on CORS, which at present is non-existent. Primary data was collected through open-ended questionnaires and focus group discussions with stakeholders involved in the provision and use of geospatial data. To identify the major stakeholders, we reviewed membership lists of the main Professional Geomatics bodies in the country. Lists of all registered surveyors, surveyors-in-training and survey technicians practising in the country were obtained from the DSG, while a register of all recognised geospatial institutions (and practitioners) was availed by the Survey Institute of Zimbabwe (SIZ). In recognition of the fact that the list from SIZ may have not been exhaustive, we supplemented it with data on alumni from academic institutions offering Geomatics programmes.

As is common with most survey designs (Merry et al., 2016) we gave assurance to all potential respondents of anonymity with regard to their contributions. This assurance of privacy may have been partly responsible for the good response rate achieved with the questionnaires, in contrast to the relatively low response rate usually associated with mail-based surveys (Dillman, 1991). The questionnaire focused on six aspects namely: (i) access to GNSS equipment, (ii) application domain of the practitioner, (iii) frequency of use of GNSS equipment, (iv) awareness to the concept of CORS, (v) competence in operating GNSS equipment and (vi) perceived utility of CORS by various stakeholders.

Focus group discussions were held as part of a stakeholders' workshop to review the interim report of a UNDP consultancy on the establishment of CORS in Zimbabwe. Workshop participants were organised into three thematic groups, based on their fields of practice and expertise. The following thematic groups were established: (i) Policy Framework & Structural issues, (ii) Human capacity and

sustainability issues and (iii) Technological and infrastructural issues. A total of 52 workshop attendees participated in the group discussions and distribution of group members was approximately uniform.

A total of 143 questionnaires were administered and yielded a response rate of 62.23% (n = 89 respondents). Survey participants identified themselves as operating in one of seven main industries namely Cadastral surveying (52.81%), Construction/Engineering surveying (11.24%), Mining (10.11%), Geographical Information Systems (GIS) (8.99%), Academia/Research (8.99%), Agriculture (5.62%) and Forestry and Wildlife (2.24%) (Figure 1). Although most respondents identified themselves with the Cadastral surveying industry, it is important to note that most cadastral surveyors can be involved in other related geospatial industries. A registered Land Surveyor primarily undertakes cadastral survey work but can also be contracted for engineering survey projects. However, an engineering surveyor is not authorised to undertake cadastral surveys since Cadastral surveying is regulated by law and therefore requires registration with the Council of Land Surveyors.

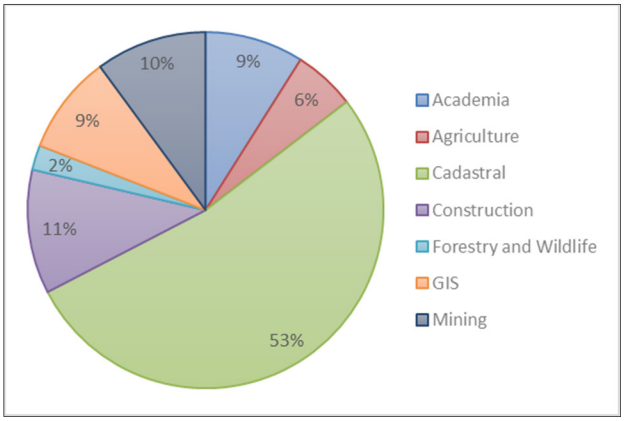

Figure 1: Key stakeholders utilising GNSS in Zimbabwe.

The frequency of use of GNSS equipment varied across the identified sectors, although no sector overwhelmingly responded always or never (Table 1). While approximately 37% of the total number of respondents across the different industries always use GNSS and 28% often use it, only 15% admitted to having never been exposed to GNSS equipment in their work environment. The remaining 20% seldom utilize GNSS equipment in their respective areas of specialization.

Responses regarding stakeholders' awareness to the concept of CORS showed that the highest level of awareness to the concept of CORS lies within the Cadastral surveying group (93.62%), followed by Academia (75%) (Figure 2). In contrast, the groups with the least awareness were Construction (30%) closely followed by Mining (33.33%) and Agriculture (40%). However, when combined, a significant number of all respondents (71.91%) had either heard or read about CORS. Although approximately 6% of all respondents admitted to having previously worked with CORS data, only 2% had actually worked on a CORS network in their respective domains, all being Cadastral Surveyors. All of the respondents who indicated working experience with CORS had done so in neighbouring countries such as on South Africa's TRIGNET.

Table 1: Frequency of use of GNSS by industry (per cent of respondents).

Type of industry	Frequency of use of GNSS equipment			
	Never	Seldom	Often	Always
Cadastral Surveying	10.63	19.15	27.66	42.56
Mining	33.33	11.12	22.22	33.33
Agriculture	20.00	40.00	20.00	20.00
GIS	12.50	37.50	12.50	37.50
Forestry and Wildlife	-	-	50.00	50.00
Academia	12.50	25.00	25.00	37.50
Construction/Engineering	20.00	10.00	50.00	20.00

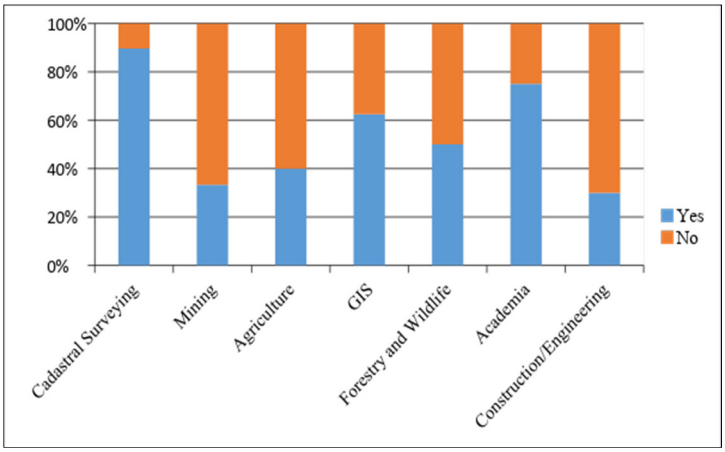

Figure 2: Level of awareness to the concept of CORS among stakeholders.

On the specialist areas where respondents are currently using GNSS equipment, Topographical surveying and GIS mapping was by far the most common application (100%) across all sectors (Table 2). The second most popular application among the respondents was Cadastral surveying (52.81%), although this was obviously directly related to the number of respondents who had earlier on identified themselves with the Cadastral surveying industry (Figure 1). Other GNSS applications identified by the respondents were Engineering surveying (38.20%), Mining and stockpile surveying (30.34%), Navigation and machine guidance (20.22%) and Control densification surveys (14.61%).

Access to GNSS equipment by stakeholders was also evaluated. It was observed that 69% of the respondents indicated that their organisations owned at least one or more GNSS set (Figure 3). On the other hand, 14% of the respondents indicated that they outsource and 11% personally owned GNSS equipment. However, 6% responded that they do not own any GNSS equipment either personally or within their respective firms. The effective proportion of respondents with reasonable access to GNSS equipment either through ownership or outsourcing was 94%.

Table 2: Application domain of GNSS

GNSS Application	Response (%)
Cadastral surveying	52.81
Densification of control	14.61
Engineering/Construction surveying	38.20
Navigation/Machine guidance	20.22
Topographic surveys/GIS Map update	100.00
Mining/Stockpile surveying	30.34

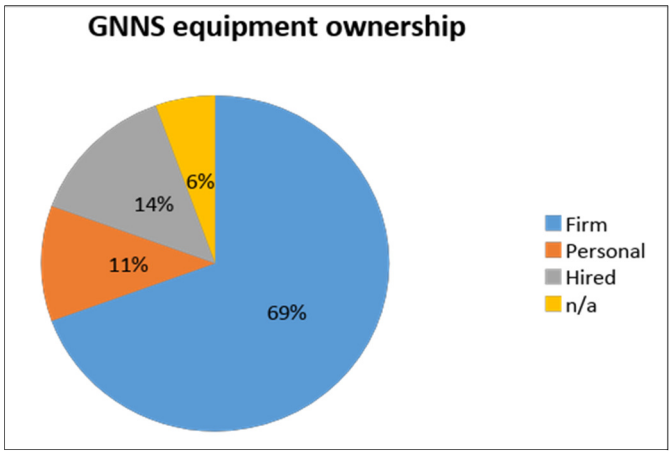

Figure 3: Access to GNSS equipment by stakeholders

We also investigated the level of preparedness of the respondents to upgrade their existing GNSS equipment to that compatible with CORS. The responses varied widely across different groups, with 47.19% of all respondents totally agreeing to upgrade. Although only a few (11.24%) did not agree to upgrade, 26.97% were not sure whether they would upgrade – which is approximately half of those who totally agree. As shown in Figure 4 most of the respondents who totally agree to upgrade are in Cadastral surveying (68%) and Academia (50%), while most of those who do not agree are in Construction (33%) and GIS (22%). Most of those who responded not sure are in Forestry and Wildlife (50%) and Mining (44%). None of the respondents from Forestry and Wildlife either totally agreed or did not agree to upgrade.

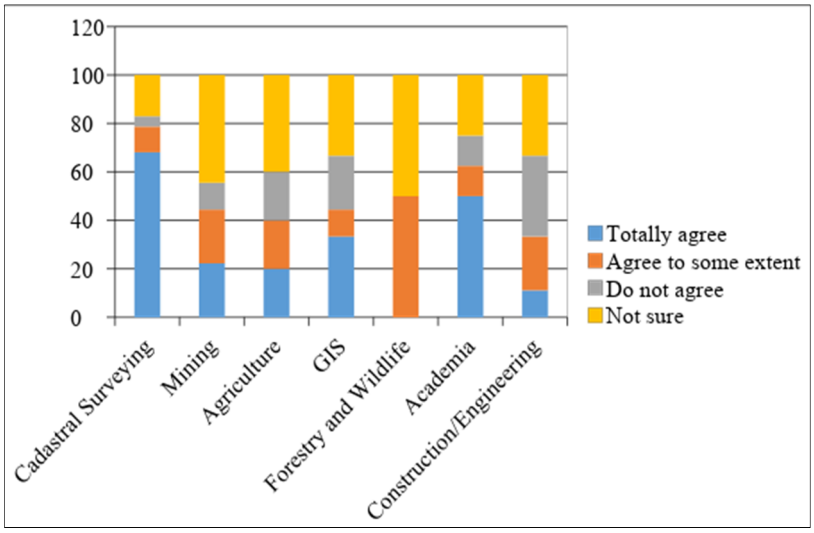

Figure 4: Preparedness to upgrade GNSS equipment

Responses pertaining to the preparedness of stakeholders to subscribe to a paid Real-Time Kinematic (RTK) service also varied considerably across the different industries. The majority of stakeholders responded either totally agree (49.44%) or not sure (24.72%). Table 3 shows how the majority of those who totally agree are, as expected, from the Cadastral surveying industry (65.95%), closely followed by those in Academia (62.50%) while all respondents from the Forestry and Wildlife group were not sure. A considerable proportion of all respondents (22.47%) agreed to some extent while very few (3.37%) did not agree to subscribe to the service.

Table 3: Preparedness to subscribe to RTK service by industry (per cent of respondents).

Type of industry	Preparedness to subscribe to RTK service			
	Totally agree	Agree to some extent	Do not agree	Not sure
Cadastral surveying	65.95	25.53	2.14	6.38
Mining	22.22	11.11	22.23	44.44
Agriculture	-	40.00	-	60.00
GIS	37.50	12.50	-	50.00
Forestry and Wildlife	-	-	-	100.00
Academia	62.50	25.00	-	12.50
Construction/Engineering	30.00	20.00	-	50.00

By combining responses from the different sectors, we observed that most respondents (83.15%) required training in setting up and operating the equipment, followed by training in post-processing and software (79.78%). A significant portion of the respondents also expressed the need for training in CORS theory (75.28%) as well as data formats and exchange protocols (69.66%). The 83.15% that require training in setting up and operating equipment consists of all respondents in the cadastral survey, mining and forestry and wildlife industries as well as 75%, 60%, 50% and 25% from the GIS, agriculture, Construction and Academia sectors respectively (Table 4).

Table 4: Training requirements by stakeholders (per cent of respondents).

Type of industry	Theory	Setting up and operating equipment	Post processing and software	Data exchange and formats
Cadastral surveying	91.45	100.00	100.00	85.11
Mining	100.00	100.00	100.00	77.78
Agriculture	100.00	60.00	100.00	100.00
GIS	25.00	75.00	37.50	12.50
Forestry and Wildlife	100.00	100.00	100.00	100.00
Academia	-	25.00	12.50	12.50
Construction/Engineering	60.00	50.00	40.00	60.00

On the focus group discussions, within the Policy Framework & Structural issues group emerged the need for a consolidated government policy on land information management which would act as a fundamental legislative instrument. The group also highlighted the need for the DSG to engage other institutions such as the Postal and Telecommunications Regulatory Authority (Potraz), Ministry of Defence, power utility companies and mobile network providers to ensure that the implementation of the CORS network is successful. Another concern was the need to amend the Land Survey Regulations to accommodate GNSS and other emerging technologies such as drones for Cadastral surveying. Although it was noted that another UNDP consultancy on the amendment of the Survey Regulations was in progress, the group expressed the need for a deliberate collaboration of the two consultancies leading to an inclusive, all-encompassing solution to the country's Land Administration challenges.

Within the Human capacity & System Sustainability group it was deemed imperative that DSG personnel be adequately trained on CORS as the spear-headers of the project. Specific training requirements were identified as (i) Technology overview of CORS and (ii) Land survey functions. All other potential users would subsequently be trained by DSG instead of outsourcing. The group proposed the establishment of a Continuous Professional Development programme through stakeholder institutions such as SIZ to keep CORS users abreast with the latest trends in CORS and GNSS technology. There were also strong calls for stakeholders in Academia to spearhead restructuring of their respective curricula to include training on CORS technology at both diploma and degree level. Finally the group recommended a balance between ensuring financial sustainability and increasing uptake of the technology by a wide range of stakeholders through (i) incorporating the Ministry of Finance as financier and making both the post processed data and RTK services free, and (ii) introducing a pay-as-you-go service in partnership with mobile telephone companies in which a nominal fee would be paid by users.

The last group discussed Technological and infrastructural elements of the proposed CORS and agreed that the initially proposed five CORS should be distributed in a manner consistent with the locations of the majority of A2 farms in the country. Ideally, adjacent stations should be within 50km

to 70km of each other (NGS, 2005). However, the group stressed the need to first model atmospheric conditions in order to locate more optimum stations. Another important recommendation was the need for strategic partnerships with mobile telephone companies and data providers to enable the creation of an efficient GNSS data delivery service and a RTK correctional service (Rizos, 2007).

3. DISCUSSION AND CONCLUSION

The use of internet to administer questionnaires proved to be effective in collecting primary data from the geographically dispersed respondents. However as noted in Merry et al. (2016) internet based surveys have some limitations. Some of the contact lists obtained during compilation were out dated and sometimes contained names of certain individuals who were known to have died. Moreover, some of the emails given were organisational emails and would not work in the case that the individual would have changed companies prior to the survey. Another factor contributing to coverage error in the sampling process is uneven access to the internet by the survey population (Couper, 2000; Dillman and Smyth, 2007). Zimbabwe does not yet have uniform internet coverage, and a considerable size of the population relies on internet access from their respective workplaces. This limited the engagement of a considerable number of individuals particularly those using personal emails and do not have internet access at home. Considerable efforts were made to minimise non-response error by making follow-ups to questionnaires issued. For some participants who were in Harare, we managed to make informal individual visits to their workplaces to either physically administer questionnaires or to make a follow up on unreturned ones. One factor that also contributed to non-response error was the concern on anonymity (Albuam and Oppenheim, 1993). Although we gave assurance of anonymity to potential respondents, we suspect that most of the non-responders were concerned that their responses would be used to directly compare technical capabilities of competing companies.

Harmonious to the fact that the majority of the stakeholder population is comprised of cadastral surveyors, the highest response rate (88.68%) was achieved within this group. Since the main thrust behind the proposed establishment of CORS is to facilitate farm surveys, obviously there was greater motivation among cadastral surveyors to participate in the survey since they are the main players. To limit measurement error, we carried out internal testing of the questionnaires prior to administering. The respondents' contact list was supplemented with data from academic institutions after realising the potential existence of unregistered geospatial practitioners who were likely to be overlooked. However, we acknowledge the fact that the final contact list used may not have been entirely representative of the actual population (i.e. the entire list of stakeholders in the country), a factor well-known to contribute to sampling error (Dillman, 1991).

At first glance the level of awareness to the concept of CORS of the stakeholders across different industries (71.91%) seems good. However, in each of the industries Mining, Agriculture and Construction there is less than 50% of respondents who were aware of the concept of CORS. This trend partly explains the results obtained on the willingness of respondents to upgrade their GNSS equipment to that compatible with CORS. As observed in Figure 4, most of the respondents who either do not agree to upgrade or are not sure are from the Construction, Agriculture and Mining industries. Regarding willingness to upgrade GNSS equipment, responses of stakeholders from the same industries seem to be influenced largely by the fact that they were not aware of the concept of

CORS to begin with. It thus seems logical for them to be reluctant to agree to upgrade to GNSS equipment compatible with CORS. These observations also tally with results obtained on the training requirements, at least for the Mining and Agriculture industries where there were overwhelmingly large numbers of respondents requiring training in CORS Theory and Post processing of CORS data. Relatively much fewer respondents from the Construction industry seemed eager to obtain training on CORS, as shown in Table 4. The same can also be said for the results regarding preparedness to subscribe to a RTK correctional service. Most respondents who do not agree or are not sure could have responded this way because of limited knowledge of the CORS technology.

Results on the frequency of use of GNSS equipment by the different stakeholders indicate that the majority of the stakeholders still rely on the more traditional alternative equipment such as total stations and automatic levels for field surveys. For the Cadastral Surveying this low uptake of GNSS can be partly attributed to the continued reliance on pre-colonial Land Survey Regulations of 1979 which are still being used thirty-eight years after independence (Paradzayi et al., 2007; Kurwakumire and Chaminama, 2012). These regulations do not clearly prescribe the appropriate procedures to be adopted when using GNSS for different types of cadastral surveys thereby inhibiting its frequent use.

As a result, not many cadastral surveyors frequently use GNSS in their work, although on overall a good number (52.81%) eventually use it for cadastral surveys, and fewer still (14.61%) use it for control densification surveys. This observation is further supported by results on the most common application domains where stakeholders are using GNSS. It is quite apparent that the most popular area of application of GNSS, Topographic surveying/GIS mapping, is an application common to all geospatial practitioners in their professional careers. As shown in Table 2 all respondents, including Cadastral surveyors admitted to using GNSS for this application, probably because this application domain is not regulated by law and can be carried out by almost anyone with the technical knowhow.

The fact that less than half of all respondents totally agree to subscribe to a RTK correctional service provided it is paid for, can be linked to the various application domains identified as commonplace across the various industries. From the application domains identified the only domains to which a CORS RTK service would have the most impact are Navigation/Machine Guidance and Engineering/Construction surveys. All other application domains can be performed quite well even without this service, i.e. through static methods and post processing.

4. CONCLUSIONS

This paper has explored the perceptions and readiness of stakeholders in the Zimbabwean geospatial industry on the adoption of CORS. In order to guarantee the full utilisation of CORS technology in revolutionizing land administration in the country, it is important that the relevant authorities in the land delivery value chain be adequately apprised on the readiness of the major stakeholders. These insights should be used as a framework to design and implement a robust training programme for all players in the geospatial industry. Awareness campaigns, through professional bodies should be made to educate stakeholders on the utility of CORS in the timely acquisition of quality spatial data. For the system to be maintainable it needs to be self-sustainable and not rely exclusively on external funding. Thus, a consistent stream of revenue must be guaranteed, preferably through subscriptions to CORS data and services. In addition to potential system users being adequately apprised on the benefits of CORS, they should also be encouraged to migrate from traditional surveying equipment

and field techniques. One strategy to achieve this would be to review the country's Land Survey Regulations and incorporate guidelines which accommodate emerging spatial data acquisition tools and methods. The Academic sector would complement this by reviewing and modernizing its curriculum.

5. ACKNOWLEDGMENT

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7. KEY TERMS AND DEFINITIONS

Continuously Operating Reference Station (CORS): a network of reference stations that provide a virtual base station that allows users to access long-range high-accuracy Network RTK corrections

Geodesy: science which deals with the methods of precise measurements of elements of the surface of the earth and their treatment for the determination of geographic positions on the surface of the earth

Land reform: The various processes involved in altering the pattern of land tenure and use of a specified area