An Analysis of Data Handling Techniques in Zimbabwe

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SUMMARY

Land information forms an integral part of any Land Administration System hence the need to discuss issues pertaining to spatial data capture and lodgement. Data capture techniques have evolved from the traditional land surveying using chains and plane tables to more current sophisticated methods such as the use of GPS, Lidar and Satellite imagery. It is however important to note that the techniques in use differ from country to country though often similarities are noted. At the same time, it is logical to promote methods which enable efficient execution of the data acquisition or field work process as well as the subsequent processing while keeping costs at a minimum and maintaining quality. A complete land administration system requires all land to be demarcated and registered and as such relies on these techniques. The boundary surveys in Zimbabwe are incomplete and thus there is no seamless cadastral database available. Land surveys in Zimbabwe are based on the use of total station traverses as the major data acquisition technique and there are set standards which regulate the operations. GPS use for cadastral surveys has been restricted within the Surveyor General's office while there has not been significant progress in the utilisation of photogrammetry and satellite imagery for mapping. This paper discusses the current collection and processing techniques for cadastral, topographical and other spatial data as well as newer or more sophisticated technologies that are being implemented in other nations. This study concludes with recommendations for improving the land survey data collection process in Zimbabwe.

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1. INTRODUCTION

Boundary surveys encompass the determination, identification, delineation and reporting of boundary lines relating to a land parcel. The end result is a map (cadastral layer) which can have other supporting textual information such as the subject and rights attaching to the defined parcels. Cadastral surveys find their roots in ancient Egypt where there was use of traditional land surveying techniques, namely the chain and compass. This innovation was towards determining the extent of all parcels and the rights attaching them. The establishment of parcel boundaries also ensured a peaceful community as it minimized boundary disputes. History has shown nations fighting over land as well as tribes within a nation engaging in territorial war in order to acquire more land. The Egyptians carried out boundary relocation surveys for farming fields along the Nile after the river flooded. The advent of Total Stations and other sophisticated data acquisition techniques such as GPS have revolutionised the way in which boundaries can be determined. On the other hand, information and communication technology (ICT) has facilitated more efficient processing of raw field data into the final product.

Zimbabwe has been conducting a land reform program since 1980 which was fast-tracked in the period 2000 – 2005. In this regard, the subdivisions in these resettlement areas are not surveyed yet the new settlers are supposed to be issued 99 year leases while the land has been unalienated (Paradzayi 2007). This makes the need for boundary surveys crucial to determine what has been allocated (the land parcels), how much (area or acreage) and to whom (the land owner) for the proper cadastral or land administration documentation. On the other hand, communal land that is administered under customary law by chiefs is not surveyed into individual property units yet 70% of Zimbabwe's population dwells in such land. It is also necessary to find inexpensive ways to map communal lands and record the land rights attaching so that they are also part of the national cadastre. This information is valuable for input in the land administration system for better land management. The Surveyor General's Department (DSG) is the custodian and supplier of base data in Zimbabwe however, most of the data is still in analogue format (EIS 2000). The status of the control network in Zimbabwe is sufficient to accommodate the nation-wide surveys and currently the whole country is mapped up to 78 % on 1:250 000 and 24% coverage on 1:50 000 map sheets (Lugoe 1990). The DSG supplies topographic maps at scales 1:50000, 1:100000, 1:250000 and 1:500000 for the whole country with larger scale topographic maps available for urban and tourist resort areas (EIS 2000). The national trigonometrical system was instituted in 1897 such that all surveys can ideally be tied to the national geodetic system (Philip et al. 1992). Land in Zimbabwe is private, state, communal and municipality owned. Technically, Zimbabwe as a whole has been surveyed to demarcate boundaries for the administrative authorities and this is at provincial, district and municipality levels. The farms, wildlife parks and communal areas are surveyed but only the outline boundaries. Individual subdivisions of these large units of land to correspond to individual right holders are yet to be done.

2. CURRENT SURVEY DATA COLLECTION TECHNIQUES IN ZIMBABWE

Data handling refers to the collection and processing techniques or methodologies and technologies used for the capture, processing and lodgement land surveying data. Currently, boundary surveys are carried out using total stations as the main data acquisition instrumentation. Total stations are used for about 90% of the boundary surveys carried out in Zimbabwe. This is the most common technology available at the disposal of the majority of land surveyors. It is also the only (recent and continually developing) technology which has standards and specifications for the examination of survey records submitted by the surveyors at the DSG. The DSG has legislation regulating the calibration and use of total stations in cadastral surveys. Other sources of data for carrying out surveys are existing topographic maps and previous survey records from archives at the Surveyor General's Department. The surveyors however, have to physically visit the DSG for the data searches because the data is in analogue format and there is no mechanism for ordering the data online and having it sent by courier to their work places. Photogrammetric images have minimal use as a technique of acquiring data for boundary surveys since most of them are out-dated and there have been no aerial survey missions to date. The last aerial images date back to 1979, and thus are not fit to provide up-to-date information of current state of land.

It is still common to find theodolites in use for simple beacon relocation and replacement surveys. Theodolites are still being utilised in 'running lines' during a land subdivision exercise where beacons for individual properties sharing some outer liner boundaries are placed. The monumentation of these beacons usually comprise of 12mm iron pegs in concrete. GPS as a data capturing technique is used in carrying out rural land surveys, although not yet adopted for subdivision surveys and related cadastral surveys like property consolidation surveys in urban areas. This is due to the cadastral regulations requirement that demands millimetre accuracy in boundary surveys within urban areas. For class A, B, C and D surveys (see Table 1), the degree of accuracy required differs hence the use of GPS without millimetre accuracy in class C surveys. GPS technology has been adopted due to its time and cost effectiveness with respect land survey field work. This was done to be able to cope with the increased demand of land transactions on the farms allocated for redistribution. The use of GPS among private surveyors is only upon instruction from the Surveyor General office and for class C surveys.

The major proportion of boundary surveys namely subdivision and consolidation surveys are carried out using total station since the use of GPS is not yet standardized and regulated for examining by the Surveyor General's Office. Today the total area surveyed is approximately 70% of the total lands in Zimbabwe. Of the total area surveyed, approximately 40% are fixed boundaries established by total stations and GPS while 30 % are general boundaries. In many high density suburbs only block surveys are in existence which is accompanied by general boundaries which demarcate individual parcels within a specific block. No legislation and standards have been set to regulate the appropriateness and use of GPS as both a land surveying data collection technique and as a mapping technology. The current land survey records have not been updated to include the calibration of GPS equipment.

Survey Class	Allowable Misclosure (metres)	Class Description
Class A	$0.005\sqrt{(0.0075f+0.000\ 15f^2)}$	Refers to surveys to determine the position of town survey-marks;
Class B	$0.02\sqrt{(0.0075f+0.000\ 15f^2)}$	Surveys in townships, other than surveys of high-density developed townships; and Survey operations in high density developed townships
Class C	$0.03\sqrt{(0.0075f+0.000\ 15f^2)}$	All surveys on rural land
Class D	$0.25+0.03\sqrt{(0.0075f+0.000\ 15f^2)}$	Refers to surveys carried out by photogrammetric methods.
*Where "**f**" is the sum of the traverse distances, expressed in metres.*		

Table1: Survey classes: Source- Second schedule of land survey regulations

2.1 Land Surveying Standards

The current standards which are set to define the acceptable quality of survey work are rigid because they do not accommodate or are not applicable to the recent technologies such as GPS despite the fact that GPS itself is being employed in farm surveys. There is an issue of double standards which are applicable to the use of GPS because the survey examining board claims not to have standards to examine GPS produced cadastral work while GPS is recognized in the boundary surveys of rural areas. GPS is not used in boundary surveys of urban areas due to need for preserving the millimetre accuracy in class A and B surveys. The practicality of placing property boundary monuments at a millimetre level accuracy is also questionable considering that 12mm iron pegs are in use. Photogrammetric surveys are recognized by law although not currently employed for demarcating cadastral boundaries.

There are specifications for the levels of accuracies that are obtainable from a given total station due to the varying least counts and or precision. The Surveyor General's office has the mandate to calibrate all the equipment used by surveyors for cadastral work. All equipment is tested against the established baselines to determine the scale factor to be applied on measured distances. The survey governing board has the authority to recommend on the technology to be used when performing certain survey tasks. As a quality control measure, all cadastral survey work undergo rigorous scrutiny or examination, which takes considerable time of approximately 34% of the total time in carrying out a boundary survey (Chimhamhiwa and Lemmen 2001). The surveyor general can also regularly visit the site to check on the consistency between the documented information and the field work thus checking the quality of the survey work. It is a requirement that the survey records are submitted in paper format even though it is possible to acquire and process data digitally which is another setback for technological innovation and the migration from hard copy to computerized Land Information System. The survey regulations board (SRB) also prescribes the monumentation, survey documents to be submitted and their contents as well as the structure of the contents of the records.

2.2 The Processing and Lodgement of Surveying Fieldwork

There are basically 4 major software packages in use in Zimbabwe namely SURPAC, Vcad, Micro-station and AutoCAD. SURPAC, a product from South Africa, is particularly useful in carrying out all surveying computations based on least squares adjustment programs up to the preparation of survey diagrams and general plans. It also has options for accepting observation files in ASCII, text (.txt) and other formats which facilitates the use of total stations. However, to some extent, total stations are not being used to their full capacity since the issue of digital lodgement has not been discussed in Zimbabwe. The survey records to be submitted for examination involve a check list comprising of an instruction to survey the property in question, a field-book, traverse and subdivision calculations, a work plan, coordinate list and a general plan or survey diagram showing the extent and boundaries of the surveyed land among other documents. All these documents need to be submitted in paper or hard copy format. In the case where the survey has been carried out using a total station, some of these calculations are done internally using the inbuilt total station software. However, these have to be redone using SURPAC software on a personal computer platform for the sake of submitting survey records. As a result, there is duplication of work and effort in as far as the lodgement of survey records is concerned.

This surveyor also has to manually book the observations during fieldwork instead of just automatically storing the measurements for downloading into the processing software. Measurements stored may only assist in checking for blunders on the field-book as the surveyor records the observations or in checking traverses as the fieldwork commences. AutoCAD, Vcad and micro-station are being employed for preparing survey diagrams, topographic maps and general plans. Surpac is tailor made for Southern Africa such that all coordinate computations always result in positive values with clear discrimination of X and Y coordinates shown by their magnitudes. It is suitable for the Gaussian Coordinate System with the zero degrees south orientation which is employed in cadastral surveys in Zimbabwe. However, the surveys on this system require transformation parameters in order to fit on GPS surveys carried out based on a different ellipsoid model.

Digital lodgement offers the option to download coordinates calculated and stored in the total station as well as observations as recorded during the surveying field work. This would then only require generating a general plan using draughting software. This package can be sent by electronic mail or in form of a compact disk or other digital storage media for examination at the Surveyor General’s Department. This reduces the costs in printing and storage of documents while attempting to realise the convenience brought forth by information and communication technology utilisation. This, in future speeds up the creation of digital cadastres at municipality (Kurwakumire 2007), regional and eventually national level as land information will already be available in digital form. The use of GPS has also not been spared from this hard copy document lodgement issue while at the same time having no quality assurance standards available (Paradzayi et al. 2007). The digital lodgement issue can be viewed simply as a matter of software and data formats. The regulating body, namely the SRB, can decide on usable formats such as txt and ASCII for observation and coordinate files as well as dxf, shp, jpeg and bitmap for graphics. With respect to GPS, the main issues are calibration and the appropriate field procedures that need to be adhered to during cadastral surveys. There is no need for diagrams and calculations generated using computer software to be printed and with the advent of the use of digital signatures and the internet the surveyor can compile all his office- work and lodge it electronically for examination. This is time saving even in cases when the surveyor has to carry out data searches as he can access information through the internet.

2.3 The Need for Change in Land Surveying Standards

The existing set standards were established to maintain and monitor the level of accuracies in carrying out boundary surveys and the specifications stipulated total stations as standard equipment for such tasks. In order to improve the existing cadastral surveys, particularly boundary surveys, there is need to define the standards in such a way that they can be applicable to new technology (Craig and Wahl 2003). The standards should be unambiguous, usable and simple while not compromising the quality of work to be produced. The suggested standards should be flexible so as to allow room for changes.

As stated by (Craig and Wahl 2003) there has to be a compromise between costly and time consuming scientific perfection and low accuracy methods that are economical. Craig and Wahl (2003) also explain that current technology enables accuracies approaching better scientific precision for less cost. Therefore GPS should be introduced to all sectors of cadastral surveys including boundary surveys. Exceptions could be in land that is of higher economic value that would require millimetre accuracy such as properties in the central business district. Reasonable accuracies should be adopted to improve efficiency in carrying out boundary surveys because they are economical. The standards should be product rather than technology driven.

2.4 Current Staffing

The surveying fraternity in Zimbabwe has a mixture of traditional surveyors produced in the mid 1990s and the fresh blood who graduated between about 5 to 11 years after the turn of the century. There are two universities offering training for Surveying and Geomatics namely Midlands State University and the University of Zimbabwe. There are about sixty registered land surveyors in Zimbabwe with some among this figure practicing in neighbouring countries or internationally. In this respect, the country is understaffed of licensed land surveyors as there was also a mass exodus to neighbouring countries like South Africa for greener pastures during the period 2000 - 2008. Thus the few licensed land surveyors in the country have not been capable of coping with the pressure of land subdivisions and farm surveys. The new data capturing technologies that are emerging are not popular to traditional land surveyors. In this manner, the new surveyors have an appreciation of the new technology and their capabilities while at the same time the experienced surveyors want to hang on to the traditional methods. Thus organisations like the Surveyor General's office may be reluctant to change certain specifications so that they protect the old surveying techniques and the traditional land surveyors. However, new technologies always require training and staff development workshops and that is how their benefits can be realised.

3. TECHNOLOGICAL BOTTLENECKS

It is time consuming to carry out boundary surveys using total stations as compared to GPS, photogrammetry or satellite imagery. There is more involving field-work which often requires chopping trees which has a negative effect on the environment and traditional surveying techniques require more manpower in the field. However robotic total stations can reduce manpower needed as only one person can do the survey in the field. Total stations cannot measure through densely forested areas therefore vegetation clearance is needed to clear the line of sight unlike airborne systems such as photogrammetry. As the technology in use requires the placement of beacons as monuments, this presents extra cost as some of the set-up stations during the traverse require monumentation, something not required with GPS use. However, in the Zimbabwean context iron pegs are affordable as well as the cement itself for monumentation so the extra costs are considered negligible or worth taking. Although this can be economically expensive, placing monuments is an appropriate measure to avoid boundary disputes as neighbours would have a tangible evidence of their respective boundaries. These iron pegs also stay for more than a century in the ground which is historical data that can be used in the future surveys.

The current legislation does not support the assigning of preliminary boundaries. General plans only show existing surveyed parcels. So in case where new boundaries are to be assigned, a field reconnaissance and survey is mandatory. Aerial photographs and satellite images that contain more detail of the area under consideration can be technically used to assign preliminary boundaries since also, a general over view of the whole area is provided. This reduces the time needed to carry out the survey as the reconnaissance can be done in office, or general boundaries can be assigned on the map for the purposes of land registration. As an alternative to field surveys, high precision photogrammetric images can be used to pre-mark the boundaries in case where huge portions of the land are to be surveyed at once (Larsson 1991). However, in the developed world, technological developments have been a driving force in changing the face of the spatial information world. In this respect, GPS technologies have revolutionised the traditional surveying discipline (Enemark 2001). The continuous developments in photogrammetry, remote sensing can also not be ignored.

4. MODERN TECHNOLOGIES

Over the past decade, there has been a rapid improvement in many surveying related data capturing technologies. The world has seen many satellite positioning and navigation, remote sensing and other earth observation satellites being launched into space. This includes the GALILEO project for a positioning and navigation system for Europe but with worldwide coverage in the same manner as GPS and GLONASS. Technologies such as radar and Lidar have gradually gained acceptance and are now useful in many applications. Photogrammetry has evolved from the traditional practices to close range photogrammetry useful for cadastral applications and even the use of oblique images through pictometry (Lemmens et al. 2007). In this discussion we concentrate on photogrammetry, satellite imagery and GPS in a view to show how these technologies can improve boundary mapping in terms of time, cost and the manner in which they can complement current traditional methods.

Figure 1: 1:5000 Maps Series from Photogrammetric Stereo-plotting

4.1 Photogrammetry

Photogrammetry is an old technology, but one that has been in continuous development over the years to the extent of data being processed almost in real time when digital photogrammetry is employed. Photogrammetry has gained popularity in surveying and mapping over the years through the use of orthophotos and stereo images. Photogrammetry can be used as a low cost data acquisition technique for large areas where total station is not economical because of mainly the time and human resources it requires. Also it is a requirement to carry redundant checks on beacons visible from different stations when using total station. Overlapping images in photogrammetry can be used to get redundant information about a point at minimum time. This would enable the efficient mapping of general boundaries in rural land, which if complimented by the proper land administration policies, also support land adjudication. Aerial survey data will remain an asset to the department as it useful in creating digital elevation models (DEM), updating topographic maps and even in planning surveys. Surveying with total stations can then be restricted to urban land while photogrammetry makes its way to rural land.

Adopting aerial photography in cadastral mapping can revive the photogrammetry section at the Surveyor General's office. The DSG in Zimbabwe owns a complete set of photogrammetric equipment including analogue stereo-plotters for processing aerial photographs (Philip et al. 1992; EIS 2000). The department was previously creating 1:5000 map series digitally for urban areas using aerial photographs (see Figure 1). Photogrammetry was once utilised for archaeological purposes for example at Great Zimbabwe and Khami Ruins for conservation of cultural heritages (Rodrigues and Mauelshagen 1987).

4.2 Global Positioning Systems

GPS is a satellite based system used to determine 3-dimensional positions on the earth's surface though it's also useful as a navigation tool. GPS use is time saving since there is no need to change instrument stations and orienting as is done with total stations. Once you initialise and start the survey then all measurements including a few reference marks can be measured for the site calibration. It is however common practice to change the base and check the beacons of the parcel to enable the use of rigorous least squares computation software and checks. However, acquiring a GPS is a long term investment in Zimbabwe and orders have to be made through South Africa as there is no agent selling the equipment within the country. Zimbabwe has an extensive triangulation network comprising of primary, secondary, and tertiary trigonometrical beacons (see figure 2).

The quaternary beacons are also useful for orientation purposes though an instrument cannot be set over them as there are usually antenna masts on towers and booster stations for mobile networks. Such a dense network would be useful when introducing GPS infrastructure as the existing monuments can be used. The trigonometrical beacons are placed on high ground (normally mountain tops) for visibility but this may ensure the travelling of signals without disruption for GPS. GPS surveys can be employed countrywide so long as there are adequate reference marks to enable the use of differential positioning. GPS use in form of handheld GPS is increasing in various public sector and non governmental organisations (EIS 2000) who deal with forestry, environment impact assessment and geological applications. This is because the Surveyor General's Department does not have a complete digital topographic layer for Zimbabwe while various organisations require the data. GPS, on the other hand, offers the organisations an easier and cheaper data collection method while they only concentrate on mapping the features most relevant to their applications.

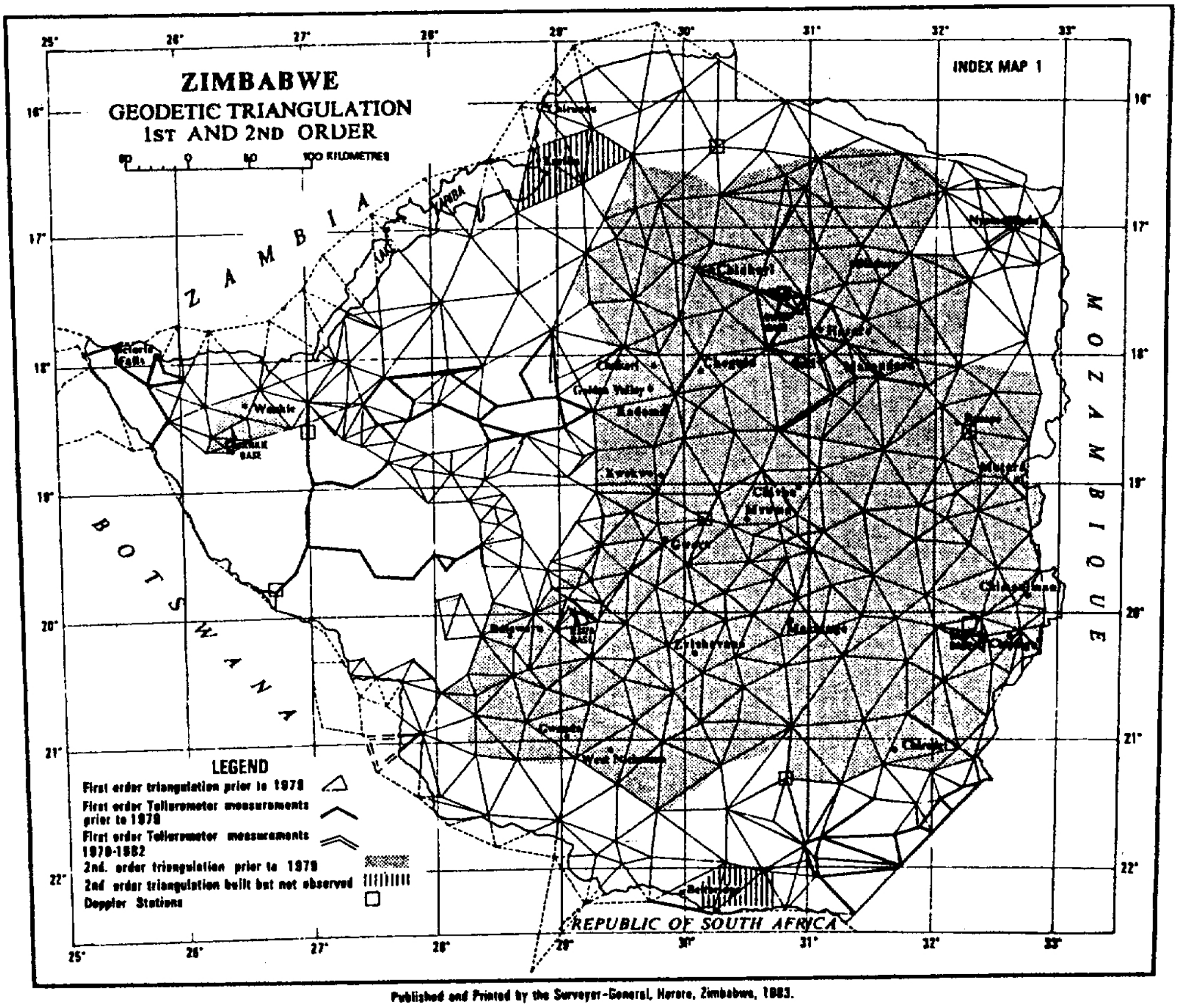

Figure 2: The triangulation network: *Source- (Lugoe 1990)*

4.3 Satellite Imagery

This technology entails the use of satellite images to acquire real world data though in this discussion emphasis will be on surveying and boundary mapping. The ground sampling distance (GSD) of satellites has improved significantly over the last decade especially as more high resolution satellite continue to be launched into space. Ikonos, Quickbird, Orbview 3 and Worldview 1 are some of the most important as they are useful in most cadastral applications due to the spatial resolution of 1m and less. Satellite images are a low cost data acquisition method in which data of the whole country can be determined. At the same time, the data will not be needed all the time for the purposes of surveying and mapping. A nation does not need to own a satellite but can purchase the data from the licensed vendors as of when they need it.

Satellite images enable the updating of topographical base maps for the whole country in a short period of time. Most of the work is basically ground truthing, quality assessment and other processing office work. Another advantage offered is the provision of data in digital form which can be overlain with existing layouts to determine areas requiring retracement surveys. The ground sampling distances (GSD) of Quickbird of 0.62m (Topan et al. 2006) and Worldview 1 (GSD 50cm) are particularly useful for most cadastral work as smaller parcels can be mapped with a minimum standard deviation in the general boundaries. Quickbird offers as low as 17 United States dollars (USD) per square kilometer at a resolution of 60 cm[1] while 1m resolution IKONOS imagery can be obtained for 35 USD per square kilometer[2] depending on the vendor. This means an area measuring 300 hectares of land requires 3 sets of IKONOS satellite images in theory costing 105 USD as compared to the thousands of USD required for the field survey by total station. However all the aforementioned satellites are quite useful in extracting buildings and mapping general boundaries for rural land. The Surveyor General's Department in Zimbabwe supplies SPOT data at 1:100000 in both analogue and digital formats (EIS 2000).

4.4 Remarks

The initial costs of setting up infrastructure of an aerial survey department are quite high. Since there is a dense network of control points, surveyors would invest in GPS so that they employ differential GPS (DGPS) for surveying field work. Photogrammetry is also quite important in as far as mapping large areas efficiently is concerned, but this dependent on the availability of up-to-date aerial photographs. Satellite images end up being the most economic method but quality issues still come into play in terms of the type of boundaries to be mapped, in this case, general boundaries. The detail on satellite images is usually affected by altitude and haze plays its part in deteriorating the visual appearance. Due to the pros and cons of different technologies, each technology ends up with its own area where it can be best applied. Application of technology in different areas may be depended on physical operation or the accuracy of the method. It is however common to use a combination of the technologies, for example GPS and Total station in the same survey. In an open area GPS will be very useful but in vegetated or built-up areas the total station may prove to be very appropriate as GPS suffers from multipath and loss of initialisation. In the light of this we recommend the continued use of total station while extending the use of GPS to private surveyors. The Surveyor General has the responsibility for nationwide mapping so can utilise satellite images to map rural areas and update small scale topographic maps.

5. CONCLUSION

The high accuracy standards are required for cadastral surveys are impeding the use of relatively low cost technologies for mapping boundaries. This results in little or no improvement in the land surveying process at a nationwide scale. This is worsened by the available legislation which only takes into account of the old technology while not incorporating new technologies. The question of accuracy on the boundary surveys is another point of discussion in which the nation may need to implement reasonable accuracy standards

[1] http://old.mfb-geo.com/pic/pdf/EURIMAGE_qb_FAQ.pdf *(Accessed 16/01/2012)*
[2] http://www.landinfo.com/satprices.htm *(Accessed 16/01/2012)*

in certain areas to ensure the creation of a complete nationwide Land Administration System. This is achievable basing on a complete coverage of the whole country in terms of surveying and mapping and this is what the country should aim at. There is need for a trade off between accuracy requirements and the costs for carrying out the demarcation exercise and whether or not it is necessary to have fixed or general boundaries. The direct benefit for a complete cadastral layer is the platform for land adjudication upon which there can be secure tenure on land thus making the land more economic and the costs of survey and other services can then be recovered. The employment of Photogrammetry, Satellite images and GPS as alternatives will greatly speed up the boundary mapping surveys. This should be coupled with an investigation into the cost-benefit analysis of implementing newer data capturing techniques. A proposal in the implementation of GPS infrastructure as well as the acceptance of the use of GPS in all classes of surveys should also be considered.

6. RECOMMENDATIONS

6.1 Proposed for a new or revised Geodetic Datum

The geodetic system provides a country with the basis for managing all geographical or spatial activity (Bevin 1999). Adopting new datums or revising old ones may be necessary for introducing modern technologies such as GPS. Zimbabwe uses the Gauss Coordinate System based on the modified Clarke 1880 ellipsoid. At the same time, the survey regulations have been stagnant since 1979 such that they fail to appreciate the employment of new methods in field data collection. GPS uses the WGS 84 ellipsoid which is also a global coordinate system. This means that, all information collected with GPS on WGS 84 is compatible and can be easily integrated. Zimbabwe still has a lot of surveys (cadastral, engineering and topographical) and it might be necessary to adopt GPS with its datum and then transform the existing information to WGS 84. Countries also often revise the local systems which they use simultaneously with WGS 84 for field surveying. Netherlands has recently modified the parameters of the RijksDriehoekMeting (RD) datum in order to improve the positional accuracies. The problem faced is whether to maintain the old datum and design transformation parameters to convert coordinates from the GPS datum to the local datum or the vice-vesa.

6.2 Use of General Boundaries for Cadastral Surveys

The concept of general boundaries employs features such as hedges and walls as boundaries. These are captured using high resolution satellite imagery such as QUICKBIRD and IKONOS or through close range photogrammetry. The boundary line work is then captured with GIS software such as ArcGIS after the images have been rectified and geo-referenced. The layer of polygons resulting from this exercise is contains the cadastral boundaries. This technique can be employed in mapping communal lands or the resettlement areas. It can provide a low cost but effective solution to surveying these areas.

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