Accelerating Labor and Cost Efficiency in Fit-for-Purpose Data Collection Programs Through Easy-to-Use, Interactive Software and as-a-Service GNSS Positioning

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SUMMARY

The volume of undocumented land parcels worldwide is estimated in the billions. In Uganda alone, there are currently an estimated 15 million unregistered land parcels that current cadastral government authorities estimate will take Ugandan surveyors 1,000 years[1] to legally register. To register these billions of undocumented parcels, we need to collect a lot more data in a lot less time, and at a lower cost. New approaches are needed. This paper discusses how flexible and easy-to-use field data collection software, together with scalable, as-a-service GNSS positioning can increase labor and cost efficiency, community involvement, and overall project flexibility, in line with fit-for-purpose (FFP) objectives.

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1. INTRODUCTION

The volume of undocumented land parcels worldwide is estimated in the billions. In Uganda alone there are currently an estimated 15 million unregistered land parcels that current cadastral government authorities estimate will take Ugandan surveyors 1,000 years[1] to legally register. To register these billions of undocumented parcels, we need to collect a lot more data in a lot less time, and at a lower cost. New approaches are needed. This paper discusses how flexible and easy-to-use field data collection software, together with scalable, as-a-service GNSS positioning can increase labor and cost efficiency, community involvement, and overall project flexibility, in line with fit-for-purpose (FFP) objectives.

2. TRADITIONAL CADASTRAL APPROACHES

A major obstacle in accelerating systematic land registration efforts is the use of traditional, high accuracy, and relatively expensive land surveying techniques.[2] Land professionals often capture land information with the highest accuracy, top-end, technical solutions and follow rigid regulations for accuracy. These overall approaches and results may well be seen as the end target, but may not be required to deliver the basic requirements of Land Administration needed to support the UN Sustainable Development Goals (SDGs). Alternative approaches cannot provide all the benefits of traditional high accuracy surveys, but they can supplement these efforts, and provide material benefits in the interim. Considering the timelines of the SDGs and the scarcity of resources available (staff, equipment budget, trainers, training sites, etc.), other approaches to field collection need to be found.

Traditional survey techniques are often point-oriented. The connection of points to adjacent boundaries and the direct acquisition of person-related data and land information are typically not captured. Moreover, recorded boundaries, as well as personal and land information, must be combined from different media and digitized. This process is time-consuming, requires additional manpower and typically produces redundancies, errors, ambiguities or missing data that are only discovered very late in the system of record.

Among the methods to record land rights and ownership, many are pure form-based methods. In the field, these are either completely analog or recorded using form-based data collection software. Both methods are insufficient for FFP in terms of speed, accessibility and relation to the geographic environment.

To accelerate the process of field data collection, tools are needed that do not necessarily follow traditional approaches. Furthermore, it is important that the application of these tools and the expected results are appropriate for the social, environmental, and legal context of each specific land administration project.
Accuracy, a key aspect of a field data collection effort, should be understood as a relative issue. Taking into account local conditions and the social environment, the selected FFP acquisition solution should optimize minimum required accuracy for the particular context, and maximum data collection speed. A field solution must fit into a jurisdiction's social and legal context, which defines the accuracies, methods, and tools that are suited for land survey. Ideally, these should align with the elements of FFP: Flexible, Inclusive, Participatory, Affordable, Reliable, Attainable, Upgradable.
Many solutions currently available in the market do not meet these requirements, or do so only partially, because they were designed for other purposes. Organizations pursuing large-scale systematic land survey efforts are, therefore, often faced with the challenge of finding a truly FFP solution.

3. TOOLBOX FOR SUCCESSFUL ACCELERATION OF FFP DATA COLLECTION PROCESS

Registering the billions of undocumented land parcels worldwide, in a meaningful time frame, requires new approaches. Many of the products currently available in the market are suboptimal and insufficient for fit-for-purpose field data collection. With a toolset that leverages existing technologies and is focused on the FFP approach, the process of capturing land rights and land parcels can be accelerated.
We identify the following four key field data collection elements.

- Software-Application
- Data-Collector / Handhelds
- GNSS-Hardware
- GNSS Correction

3.1 Software-Application

3.1.1 FFP Challenge

It is currently difficult to find software that adequately addresses the needs of FFP data collection efforts. The existing solutions are often pure survey software or pure form-based GIS software. The strict focus on either pure surveying or GIS acquisition makes these software solutions inefficient and complex for a FFP initiative with cadastral specific data models and workflows. Both tend to focus on field measurement of point and feature positions, and do not readily accommodate workflows that combine field measurements with remote sensing data. While FFP Land Administration promotes use of aerial and satellite information to accelerate cadastral data collection, ultimately this data must be supplemented by field survey and attribute data collected with stakeholders on the ground. An optimal FFP solution must support this combination of source data.

Survey-specific software applications are designed for and highly effective in the recording of measured points and the recording of accuracies using surveying methods. These methods and tools are designed for trained surveyors and are not designed for capturing attributes or land parcel geometries. While one can use any of the available survey-specific software products to create rudimentary attributes and geometries, this functionality is not the strength of these applications.

GIS applications for mobile use, on the other hand, are strong in capturing attributes and forms. However, these solutions have weaknesses in measuring, controlling GNSS antennas, and generating geometries. In fact, many GIS field applications can only store a single coordinate per attribute form.

The capture tools currently available in survey and GIS software, in general, are not designed to capture land parcels, boundaries, their attributes, and property rights. The rudimentary database, graphical support, and geometry tools included in these products are insufficient. In addition to lacking sufficient capture tools, the above solutions often do not allow the possibility to edit attributes or geometries such as boundaries. This encumbers users from efficiently building cadastral survey data sets particularly when using a combination of remote sensing and ground survey data. Using software that does not align with FFP principles, objectives, and the needed domain models severely limits the possibility of community engagement and easy scalability. These solutions do not help to accelerate the FFP process. In many cases, stakeholders make do by using several point solution software products in parallel and must subsequently integrate the data. This leads to additional work, slower progress, data compatibility issues, complexity, and increased sources or error.

3.1.2 FFP Solution

The software application is one of the most important, if not the most important, technologies for FFP land administration. Software connects the user and data such as aerial images with methods of acquisition and technologies such as GNSS. Furthermore, it collects and refines the data collected from the user and then forwards it to the System of Record.

As a guideline, the Land Administration Domain Model (LADM) or the Social Tenure Domain Model (STDM), a 'specialization' of the ISO-approved LADM, should be supported by the collection software used. This means that the software and its database must be able to handle spatial and non-spatial objects and establish relationships. For example, " 'People – land' relationships can be expressed in terms of persons (or parties) having social tenure relationships to spatial units. Parties are persons, or groups of persons, or non-natural persons, that compose an identifiable single entity. A non-natural person may be a tribe, a family, a village, a company, a municipality, the state, a farmers´ cooperation, or a church community. This list may be extended, and it can be adapted to local situations, based on community needs."[5]

The user interface must be simple, easy-to-use, interactive, and map-based. It should be able to easily capture coordinates, geometries, as well as GIS attributes. The software should be as flexible as possible in the order and type of recording; the user should decide whether to record parcels sequentially as objects, for example, or to start with points for the boundaries or to begin with the parcel owner information. Coordinates and geometries must be visible in the map-based software and must be fully interactive and editable. For orientation and as base data, base maps, data sets, aerial images and WebMapServices (WMS) must be digitally available in the field. Thus, even the non-professional field user has a good overview and receives an intuitive map-based acquisition.

A FFP field software should provide simple tools for data acquisition, both a digitizing function as well as precise GNSS measurements. It is important to recognize that remote sensing techniques and ground survey techniques both play a critical role in efficient FFP cadastral data collection. The solution must allow for seamless integration of remote imagery data, ground survey data, and non spatial attribute data from surveyors, trained data collection crews, and an engaged community. Precision and accuracy should not depend on the software but on the GNSS infrastructure, so that the application is upgradeable, depending on budget, requirements, user and availability of GNSS. For the round-trip data workflow from the system of record into the field collection software and back again, the chosen field software must provide a solution. Ideally, the field solution offers not only standard GIS interfaces but also the opportunity to create tailor made integrations.
An easy-to-use and mostly graphical way of working supports the community engagement approach. The application should be coupled with a flexible subscription. In this way, it is possible to react flexibly to an expansion of the field crews, periodic events such as the rainy season or even community engagements. The costs for the software and its maintenance remain scalable and can be related to the project time and the number of crews.

One solution that fits these criteria is the Trimble Penmap for Android application. An easy-to-use, interactive, field data collection software with map-based graphics and tools for FFP. The solution allows for seamless integration of aerial remote sensed positions, low accuracy positions from a smartphone or tablet, higher accuracy positions from external GNSS, and non-spatial attribute and tenure data. As an Android based software application, Penmap enables bring-your-own-device (BYOD) data collection efforts. This makes it easy to scale up the number of field crews with data collection solutions while remaining cost-effective.

3.2 Data-Collector / Handhelds

3.2.1 FFP Challenge

Large-scale parcel data collection efforts typically utilize expensive, professional-grade handhelds and tablets that require a high initial investment and complex procurement process for the desired number of users. Currently, there are three major operating systems for field data collection, Apple iOS, Microsoft Windows, and Google Android. While Apple includes its operating system on a variety of hardware devices, these devices are comparably expensive and there are no ruggedized versions. In addition, Apple iOS has the smallest market share of the three, which limits community engagement opportunities where community members help collect data with their own devices. While Windows OS is available on a variety of platforms, very few lightweight and affordable tablets or smartphones exist.

3.2.2 Data-Collector / Handhelds, FFP Solution

With the Android OS platform, users have many opportunities to use devices as data collectors. Android OS claims to have over 2.5 billion users[3], or around 80% market share.[4] Available Android devices include smartphones, tablets with a larger screen, and ruggedized devices optimized for in tough field conditions. In addition, Android devices are very well suited for data acquisition in the field due to their graphics and processor performance. Due to the large number of manufacturers on the market, Android systems are comparatively inexpensive. In a FFP project, the advantage is that potential users can use their own Android devices (BYOD) or the Fit-For-Purpose initiative can procure the appropriate system for the respective field crew.

For example, they may procure a tablet with a larger display for a crew member who will be helping community members negotiate their boundaries. BYOD, Android OS, and the integrated GNSS chips of a smartphone combined with a map-based field application form a cost-effective, powerful solution to cover general boundaries and equip many crews.

3.3 GNSS-Hardware and GNSS-Correction

3.3.1 FFP Challenge

Traditional parcel data collection efforts typically utilize the same GNSS hardware used in professional surveying applications. While the receivers are highly precise, very fast, and achieve the maximum accuracy, this solution is also relatively expensive and not scalable. They are also dependent on complex and/or expensive solutions for GNSS corrections.
For GNSS positioning, accuracy is dependent on the combination of the receiver capabilities, and the GNSS Correction source. Traditional GNSS Correction sources include CORS (Continuously Operating Reference Station) networks, base-rover radio based RTK GNSS solutions, and GNSS post-processing. If a CORS and mobile communications networks are available, they can of course be used. While setting up a CORS network is certainly useful and greatly expands a region's infrastructure, this can be expensive and time consuming. If a CORS network is unavailable or cannot be established, other methods for GNSS correction, such as post-processing or base-rover workflows, can be used. However, these then require additional process, procedures, software products, or hardware, thus resulting in higher costs and increased complexity. Moreover, these workflows cannot be easily automated and with post-processing the GNSS position is not visible in real-time corrected in the field software. Post-processing and base-rover are easy to handle for experienced users but, in FFP initiatives, not all users are prepared to take on the added complexity and extra steps in the process.
In order to use the described methods for GNSS correction, comparatively expensive GNSS receivers are required. Projects usually procure a fixed number of systems, which means deciding for the duration of the project on the appropriate accuracies, the number of crews that can be equipped with GNSS measurement equipment and the workflow to GNSS correction.
Besides the burden on the budget, there are no possibilities for variation, scalability and further development in the course of the initiative.
As an alternative, some projects opt for low accuracy consumer grade GNSS receivers. While this approach can save on cost, there is no ability to vary the level of accuracy as may be required for specific points, parcels, or applications (ex.; an urban vs. rural boundary).

3.3.2 FFP Solution

Modern GNSS hardware and GNSS correction services are available today as a combination on demand, this represents an “as-a-service GNSS positioning” solution that is ideally suited for FFP Land Administration applications.
The on-demand capability, in combination with field software that supports this approach, Android BYOD flexibility and an antenna technology which fits FFP, brings flexibility and scalability to the most budget intensive part of the data collection solution. The lower cost hardware associated with on-demand positioning allows a larger workforce to be equipped with GNSS. A subscription model provides the ability to vary the required accuracy and number of users as needed for specific periods of time. Satellite delivered GNSS corrections are also available through subscription. There are some limitations in availability depending on region, but in general, these services can provide variable levels of accuracy as needed to meet specific project needs.

Trimble Catalyst is such an “as-a-service GNSS positioning” solution, it brings worldwide and configuration-free access to Trimble GNSS positioning and correction services. This positioning concept also includes a lightweight, low cost antenna that easily connects to the smartphone.
As it works in connected and offline conditions it fits great for FFP efforts. The subscription-model offers flexibility to adjust the service on demand. It also gives the flexibility to scale the accuracy. Depending on the region and infrastructure, the user can choose between different accuracy levels from meter to centimeter.
In regions where a higher accuracy is required, but not yet supported by improved GNSS infrastructure, the GNSS CORS network structure can be expanded or techniques such as base rover or post-processing can also be used. However, these measurement methods again require additional hardware, software and expertise or training.
If better precision or faster initialization is required, higher-accuracy GNSS receivers can be used for part or all of field positioning as needed. These devices can be used through the same field software maintaining consistency and simplicity for the overall project.

4 IMPLEMENTATION

The 4 elements for data collection must be brought together for effective implementation. This also includes training, technical expertise, support and customizing if necessary.

4.1 FFP Challenge

The products and workflows used in a FFP effort must meet the diverse needs of the wide variety of stakeholders that must operate and understand these products and workflows. The more difficult and less intuitive the field data collection application is to use, the more difficult it will be for users to adopt it. Terms, phrases, and routines that are familiar to professional land surveyors can present major hurdles for users in FFP initiatives.

Part of the implementation of a FFP effort is the combination and integration of the different components. This involves installation, configuration, training, and support, including setting up the GNSS correction services and data. Establishing the data workflow from the office to the field and from the field to the system of record are major challenges, especially when all elements come from different providers. For users, the question then becomes who is responsible and can help if there are questions or problems with the setup.

4.2 FFP Solution

A very important aspect of solution acceptance is to examine the social and legal context in the respective region and to listen to local experts. Together with these local experts, a training methodology must be developed in addition to the recording, data and measurement methodology. The training concept should cover social aspects as well as measurement techniques, GNSS methods, and legal requirements.

During training, the data flow must also be kept in mind, transferring the data digitally whenever possible. Base maps, aerial photos, and general information should flow smoothly and easily into the field application. After field acquisition, measurement data, land information such as geometries, points, attributes, additional information, photos, etc. should be exported digitally and made available to the System of Record. Another key aspect of the implementation is alignment of the coding, database model, and graphical design with the domain model in use.
It should be noted that a completely digital workflow can only possibly be realized with a tailormade interface. The implementing organization should therefore discuss the possibility of individualizing software and data transfer with the providers from the beginning. Of course, the solution, the training, and all documents should be available in the local language. It needs to be ensured that all elements of the FFP field data collection also fit together. This can be ensured by testing or by suppliers who offer all or several parts of the solution and can assure compatibility. In addition to compatibility, support, on-site experts, and maintenance of the solution elements can be critical criteria for implementation.
A holistic solution from one supplier offering components, service, maintenance and support brings benefits to an FFP Project. A provider with stability and scale provides the certainty of further development of the solution for the entire project duration and beyond. With as a service (aaS) models, maintenance and support is already ensured for project duration. Providers that offer comprehensive solutions can also offer advantages in scalability, such as bundling subscriptions if necessary or generating user statistics. If we talk about nationwide cadastral campaigns, this can decisively improve the administration and control effort.

5 DATA COLLECTION PROCESS

We have now brought together and implemented all the elements of the FFP solution. The data collection process is the challenge that will now be accelerated.

5.1 FFP Challenge

Prescribing specific workflows is difficult because, from a remote location, the definition may not follow the local requirements. The data collection process in many software products is very rigid and inflexible. Strict application sequences must be followed to achieve a result. This makes it difficult to use in FFP efforts, and the strict workflows make the solution suboptimal for local conditions. In non-graphical software products, the result is not displayed as a graphic, in the process of capturing boundaries and parcels the user is not able to see the result of the data collection in the field. Furthermore, in many workflows, the participation of owners, residents, and municipalities cannot be realized.

5.2 FFP Data Collection Process

The optimal workflows for FFP initiatives are ideally very flexible, automated, and customizable. To achieve this, the user could have different approaches for the data acquisition of a parcel, its attributes, and ownership. He could first talk to the owner and record this data. He could digitize the parcel based on aerial photos. Where required, he could measure points of the parcel and walk the boundary with the owners. The corner points that he has captured can be connected automatically by the software or manually to form the parcel as an object.

The surveyor cannot always walk all points of a parcel in the field in order. Often he must follow the topography and therefore break the sequence. Boundaries always have relationships to neighboring parcels and rights holders, so a boundary could still change after negotiations with the involved neighbors, where the surveyor needs the tools to edit geometry and rights data on site.
These possibilities represent only a small selection of possible local conditions.
Another possible process could be to capture "general boundaries" through community engagement, community members identify their properties on aerial or satellite imagery in the FFP field software. This process is comparatively quick and requires little prior knowledge. In a further step, the "general boundaries" become "fixed boundaries" by being recognized by the involved parties, and where applicable, improving the boundaries with better accuracies e.g. by GNSS measurements or adjusting them to the locality by using simple edit tools.
Involving the stakeholders community members, residents and owners in the process of recording and transparent recording via visual graphic software builds trust and the possibility of participation.
The data capture workflows should have the flexibility to map these situations easily and collaboratively. Certainly, the collected data must follow the data model and it is the task of the software to support this and to provide guidance to the user with all flexibility.

If possible, recurring tasks such as imports, exports, and reports should be standardized and automated. Just like measurement routines, these should be integrated into the workflow so that standards are set and the user only has to initiate the measurement. Settings or measurement data evaluation should be automatically predefined by the software as a workflow. The GNSS hardware, as well as ruggedized professional handhelds, can be flexibly deployed in fit-for-purpose initiatives if possible. Where greater performance, robustness, or accuracy is required, the requisite hardware can be added. For applications where no GNSS or even a normal consumer tablet is sufficient, costs and resources should be kept to a minimum. In many instances there are time periods driven by regional weather conditions (e.g. winter, rainy season) where no data collection takes place or only with very reduced crew numbers. In this case, it is preferable to have a subscription-based solution to ensure that one only pays for the project time. When the correction data, software, and related accuracy levels are available via subscriptions, this flexibility and scalability can be used in FFP initiatives. Higher accuracy for urban areas, lower accuracy for rural areas, no correction data if not needed, etc. The subscription services levels can be broken down to the respective crews, different tasks, or the respective project status in different areas of the FFP initiative.

6 CONCLUSION

It is possible to accelerate data acquisition in the field.
To speed up data acquisition in the field, there are already solutions and components that are very well suited to the needs of FFP. In general, these solutions are flexible, scalable, configurable and collaborative. It turns out that these solutions are now more affordable than traditional cadastral survey methods due to flexible subscriptions and scalable hardware components. With that toolset more crews can collect more data, in less time, at a lower cost per field crew.
Trimble, as a leader in geospatial technology, offers a strong solution with Penmap Android software, on demand GNSS technology such as the Trimble Catalyst, and its multiple upgrade capabilities. With Trimble's expertise and development power, an FFP initiative can deploy solutions that are reliable and effective, even over the life of an initiative and beyond.
We strongly believe that the available geospatial technologies that can accelerate FFP Land Administration have not been harnessed to their full potential. Through deeper collaboration between Geospatial technology providers and our industry and government partners, we can move the needle for Land Administration in support of the UN SDGs.

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ACRONYMS

aaS: as a Service

BYOD: Bring your own device

CORS: Continuously Operating Reference Stations

FFP: Fit For Purpose

GNSS: Global Navigation Satellite System

LADM: Land Administration Domain Model

RTK: Real Time Kinematik

SDG: Sustainable Development Goals

STDM: Social Tenure Domain Model

WMS: WebMapServices

BIOGRAPHICAL NOTES

Markus Koper, Sales Application Engineer at Trimble

Markus Koper is a sales application engineer at Trimble. He is working on Trimble Land Administration software products and software integration projects. Markus started in surveying with a 3-year education in land surveying in 1998. Afterwards he started studying in Bochum. After finishing his engineering degree in survey at Bochum University of Applied Sciences in Germany, Markus started as a sales engineer at Trimble. Today, Markus is working as a sales application engineer for Trimble Land Administration.

Andy Wickless, Strategic Marketing Director at Trimble

Andy Wickless is the Strategic Marketing Director for Trimble's Land Administration division. He leads the development of the division's long-range strategic plan as well as related strategic initiatives. He has more than 20 years of experience in strategic planning, go-to-market strategy, growth strategy, opportunity analysis, market segmentation, competitive benchmarking, market due diligence, process redesign, and roadmapping. Prior to Trimble, he worked in marketing and business consulting in the technology and energy sectors. He holds a Bachelor of Science in Business Administration and a Bachelor of Arts in Spanish from the University of Kansas as well as a Master of Business Administration from the Wharton School of Business of the University of Pennsylvania.

Martin Westers, System Designer and Project Manager at Trimble

Martin Westers is a system designer and project manager at Trimble. He is working on Trimble Land Administration software products and software integration projects. After finishing his engineering degree in survey at Jade University of Applied Sciences in Germany, Martin started as an application engineer at Trimble. After managing the Trimble Survey Manager and Spectra Precision Field Surveyor software, he takes over the product management of the GEOgraf A³ cadaster software. The GEOgraf A³ product family was designed and developed for the German private surveyors. It supports the whole cadaster update process (office and field).

Today, Martin is working as a system designer and project manager for Trimble Land Administration. He is focusing on designing end-to-end solutions for enterprise customers based on the Trimble product portfolio. Combining off the shelf products with additional customization´s and system integration allows him to deliver customer-satisfying solutions.

His long background within the cadaster and GIS software development area is his key for successful system integrations in international Trimble Land Administration projects.

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