Lessons learnt in reviewing technologies utilised to improve capacity and the spatial integrity of the "One Map Project" in Indonesia or other Fit-For-Purpose Land Administration Systems.

Ian HARPER, Australia, Virgo Eresta JAYA, Indonesia, Sofyan khairul ANWAR, Indonesia

Key words: Fit-For-Purpose, Digital cadastre, 3D Cadastre, Adjustment

1. ABSTRACT

Fit-For-Purpose (FFP) solutions have provided cost effective ways to build a title database. Modern spatial technologies, particularly the latest imagery options, provide new tools to upgrade the spatial integrity of existing FFP databases.

FFP outcomes prepare a strategic digital map of land ownership and other Rights, Restrictions and Responsibilities (RRRs) for the benefit of more efficient land administration and title security for land owners. One challenge is in the detail and the statutory relationship of that digital map to existing land titles/rights that exist in document form. Digital cadastral database mapping & modern accurate imagery is accessible to more stakeholders but where mapping does not approximately match the apparent land occupied, uncertainties exist in the minds of the Title holders. This can undermine the goals of FFP.

Historically, cadastral surveyors have been trained with a local focus to define a land title by a plan or map of the parcel geometry. In most GIS databases, parcels are represented by a series of individual vectors defined by the coordinates of each end point, more commonly known as a "spaghetti" data model. The presentation will discuss the transition to a topological data model which provides considerably more capacity to spatially upgrade cadastral databases.

Digital topology outcomes support a strategic solution that require surveyors to understand that recording parcel relationships with adjoining land and spatial location are as important to cadastral database management as accurately measuring land title boundaries.

Good governance sets standard data formats and workflows. Across large jurisdictions like Indonesia, mobilising trained resources for digital data capture and to enforce those standards and governance is a challenge. To begin with, that can compromise data but good practice and training will overcome this in time.

Smarter data, smarter data models (topology) and basic quality control is the key to building capacity. Modern technology can shorten the 'Field to Finish' outcome but relies on the content quality at the early stage of field capture and data output. Data does not have to be of

the highest spatial integrity but it must contain attribution to digitally identify the level of spatial integrity. This is critical for higher levels of digital database management efficiencies.

This presentation is based on a review of some of the above issues encountered in the Indonesian "One Map Project" and how to progress implementing:

- Greater efficiencies in digitisation and automation
- options to spatially improve the existing FFP cadastral model using different applications and recently developed survey and spatial technologies (drones, etc.,)
- 3D cadastre – there is limited 3D data available but FFP solutions can be applied to populate data for powerful 3D visualisation technologies

The Indonesian project issues will also be compared with Digitisation Projects in Australia.

2. SUMMARY

The Indonesian Project to Accelerate Agrarian Reform (One Map Project) was an early implementation of the philosophy outlined in the Fit-For-Purpose Land Administration publication by FIG and World Bank.[1]

Collecting and collating millions of land titles into a database has challenged the available resources, quality control and governance. Fit-For-Purpose (FFP) meets the need of providing a high level of productivity in database creation for Land Administration efficiencies but Indonesia is now looking at a higher level of spatial integrity and management, particularly in urban areas which was the focus of this review.

Overcoming spatially poor FFP data becomes an exercise in looking at the detail of the spatial integrity, the structure and the data intelligence (attribution) of the database. The problems are usually not consistent so AI or application solutions are not going to be a complete solution.

The One Map Project has recognised that it needs to consider the detail that will resolve those spatial inconsistencies so it can apply better solutions and take advantage of newer applications and data collection technologies (drones, etc) to manage the spatial component of the Land Administration database more efficiently. The future for One Map is managing smarter digital data in a database, facilitating spatial upgrading and 3D cadastre.

3. INTRODUCTION – THE ONE MAP PROJECT

The One Map Project is a five year project, beginning in November 2018 and ending on 31 October 2023. The project components include Participatory Mapping, Agrarian Reform, Geospatial Data Infrastructure for Environmental and Natural Resources, Project Management, Institutional Development and Monitoring.

One Map Project will provide better survey and spatial infrastructure across Indonesia and clarity on actual land rights and land use at the village level in the target areas. Increased clarity over land rights and land land use will enhance agrarian reform, sustainable landscape management, land governance, social stability, access to land for investment, inclusive growth, conflict resolution, enviromental protection and conservation including positive co-benefits to climate change adaptation and mitigation and women's awareness and access to legal land rights individually or through joint ownership.

This project was implemented in seven (7) priority fire-prone provinces in Sumatra (South Sumatera, Riau, Jambi) and Kalimantan (Central, East, West and South). First component of One Map Project is Participatory Mapping and Agrarian Reform that will produce a comprehensive map of tenure rights (ownership, occupancy, concessions, permits, leases, etc.), land use, indicative area boundaries. forest and other agreed boundaries.

Project activities carried out since the Fiscal Year (FY) 2019 until the FY 2021 have produced a parcels map of 2,067,146 parcels. In the FY 2021 the procurement process had a target of 1,620,000 parcels. For further details contact Co-Author Virgo Eresta JAYA.

4. REVIEW PROJECT - ITEMS FOR EXAMINATION

2.2 Plot Anomalies

Plot Anomalies are where existing registered parcels overlap or "collide" with new parcels or they do not reasonably represent the location of the land. One of the prime objectives for the review is to investigate the options with respect to managing these parcels.

Historically, manually produced title documents, plans, maps, etc of individual parcels were adequate to define the amount (area) and shape of land and managed in a local registry. Digital outcomes now require equal consideration of spatial relationships (topology) and location so ongoing training and quality control is educating surveyors and data collectors to provide better and smarter data. Plot Anomalies could be caused by several reasons:

- Poor data capture measurement or data representation
- Poor location data
- Poor topology
  - Gaps and overlaps are not resolved
  - No consideration of boundaries that may intersect with the subject parcel.

The spatial integrity of Plot Anomalies varies considerably and as Plot Anomalies are uploaded directly to head office by the surveyor indicates that there could be better QA at the data capture source or they may not have the capacity to check their data locally.

The Review project completed a Pilot Project which focused on urban areas where good imagery was available and considered varied datasets suitable to apply adjustment options including Least Squares. Various examples of Plot Anomalies are shown in the diagrams below with some context. Some rare examples of parcels being 50-100km into the ocean have not been included!

Diagram 1 below highlights parcels that are obviously incorrectly located in the database. The remainder of the database indicates that there are many topology issues to overcome.

Diagram 1

Diagram 2 below identifies a cleaner topology and whilst there are some location issues the database generally gives a clear connection between the database parcel and the apparent physical extents.

Diagram 2

Diagram 3 below shows the cadastral database in a lower socio-economic area. The parcel shapes may be reasonable but the location is randomly out by up to 8m. Topology is uncertain and the physical extents of land are not obvious from the imagery due to the high population density.

Diagram 3

The Review Project showed it was possible to adjust the parcel database using Least Square Adjustments as shown in Diagram 4 below. This was a basic desktop exercise and could continue to rectify lesser irregularities as needs and budgets dictate. This process could also benefit from field survey but the nature of access and density of buildings would probably indicate through a cost/benefit analysis that it was not economically sustainable.

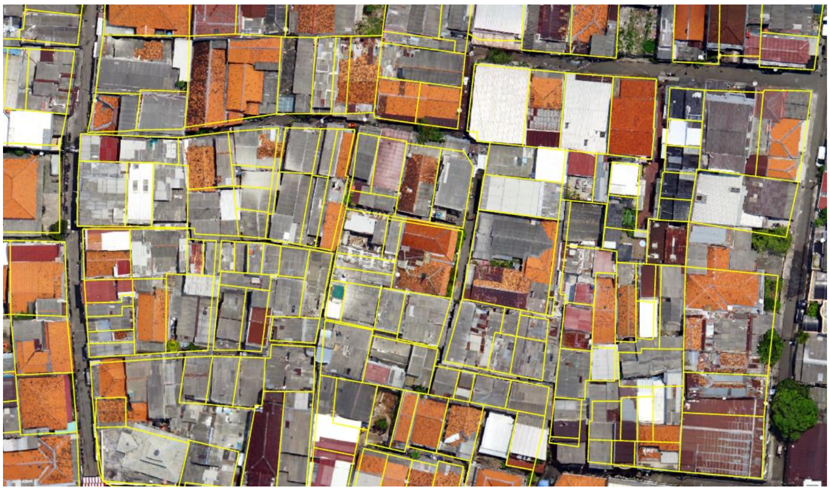

Diagram 4

As outlined in the Summary there is no standard method to resolve plot anomalies, so the process requires an initial review of the database from an experienced parcel database operator or surveyor.

See more detail in Adjustment Options Section below.

3.2 Spatial Upgrading of The Cadastral Database – Adjustment Options

Where a Fit-For-Purpose (FFP) cadastral database is in place The Indonesian National Land Agency (BPN) is now looking at methods to increase the spatial integrity.

Better imagery now highlights inconsistencies between the image occupations (buildings, fencing, etc,) and the current database as well as other topology (gaps and overlaps) issues. There are now many more public stakeholders able to view and access that data and unfortunately they may have concerns when they witness boundaries not matching the physical extents of their land on a government web site. Informed users understand there are spatial inconsistencies in either the cadastral data or the image.

In building or managing these databases, field surveying or GNSS data collection has advantages in accuracy and ground truthing of boundaries but it can require considerable human and economic resources. Limited resources will always challenge the expansive intent of the One Map Project so further FFP efficiencies are considered in the Review Project with the use of high resolution imagery. Drone and Lidar technology are now an additional source to supplement high resolution satellite and aerial imagery for location and height data.

There are many parcel adjustment options being considered from open source and Custom Off The Shelf (COTS) solutions to spatially improve parcel location. These range from basic ”rubber sheeting” to weighted Least Squares Adjustment (LSA). The Review Project was directed to consider utilisation of an LSA to pursue the highest spatial outcomes and efficiencies for the future. The LSA requires smarter data but that can be incorporated in future project data collection guidelines.

Cadastral surveyors have always been trained with a local focus to provide a land title represented by a plan or map of the parcel geometry that creates an entity or ”object” with a taxable area. In most GIS databases, parcels are represented by a series of individual vectors defined by the coordinates of each end point, more commonly known as a “spaghetti” data model. This is a mapping solution that does not fit the logic of survey and cadastral data.

The One Map Project now recognises there is a need to transition to a topological data model which defines the relationship between parcels and whether they are contiguous or not. Providing there are no gaps or overlaps, survey or vector connectivity allows more capacity to spatially upgrade cadastral databases. As the object or parcel is a defined entity, it can be linked to attributes that provide data relating to cadastral intelligence and the spatial integrity of individual parcel measurements.

In existing cadastral databases improving location relies on better survey and spatial data. Some translation and adjustment can be done with better data but rectifying topology is the key to improving location integrity as it can minimise the reliance on expensive survey or other spatial resources in the field.

In the Parcel Fabric topology, original field measurements can be stored as parcel attributes with survey integrity indicators that are used as weighting in the Least Square Adjustment. All data will be adjusted to maintain the topology but boundary dimensions defined by modern accurate measurements will retain those measurements and the shape/geometry of the parcel as much as possible while less accurate data will be adjusted to fit the better data. Of greatest importance is that modern accurate data will not be corrupted by the adjustment and when a query on the parcel is undertaken the original survey measurements and area as defined on the Title are reported rather than the adjusted ones.

If adjustments are being made to a parcel database with no measurement integrity attribution, there is no benefit to transition to the Parcel Fabric data structure but as newer more accurate data is added to an area, an adjustment within a Parcel Fabric is more productive.

In the Review the ESRI ArcGIS PRO using the Dynadjust LSA engine and the GeoCadastre™ (GC) stand alone cadastral survey management and adjustment system were considered. The LSA adjustment processes vary but produce similar outcomes. The ESRI solution offers considerable capacity to manage state or national databases or work with smaller datasets.

The GeoCadastre LSA is more focussed on a local solution, working with datasets of 2,000 - 3,000 parcels, adjusting smaller sections of those datasets (<500 parcels) to troubleshoot problems. Both COTS solutions set up an environment where little knowledge of the complexity of a LSA is required but adjustment reports can provide basic indicators of adjustment outcomes or have the capacity to analyse spatial integrity in depth by virtue of redundant observations.

As reinforced in the conclusion, different adjustment solutions can be more effective with different levels of initial spatial integrity, but the highest outcomes require smart data and a clean topology in a Parcel Fabric data structure.

4.2 3D Cadastre

Digitisation of the existing 3D Cadastral legislation is now being implemented by BPN. That existing legislation provides individual identification of multi storey properties. It requires a basic 2D representation but has no database location attributes or height deliniation that would allow digital representation of 3D ownership extents or modelling in a dynamic 3D environment. The first goal for BPN is to replace the floor/unit plan in a Strata Title with a 3D room/unit model embedded in a digital Strata Title certificate

Pilot Projects have been undertaken by BPN on buildings of various complexity. Examples of those and some context for each building is included below and some general comments follow.

A significant field survey of a recently constructed urban Metro Station is shown in Diagrams 5 & 6. Dynamic 3D modelling is available and from the compiled data a leasable area is identified with attributes supporting the highest level of land administration data.

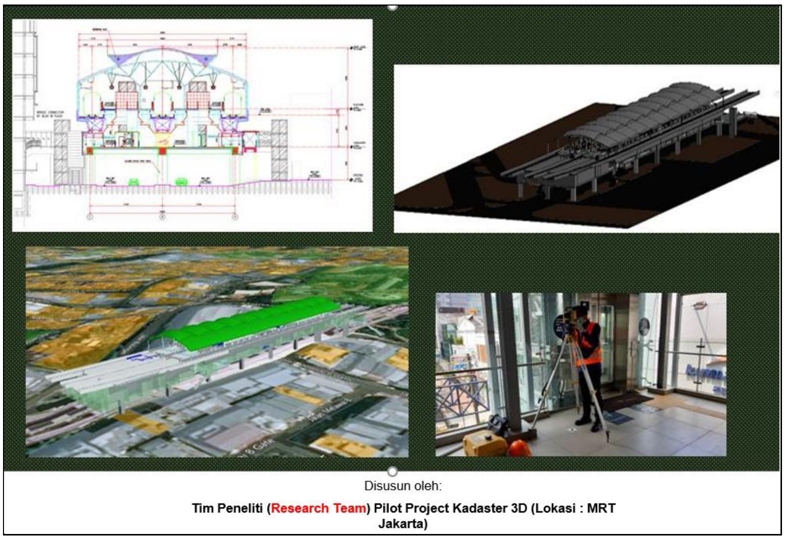

Diagram 5

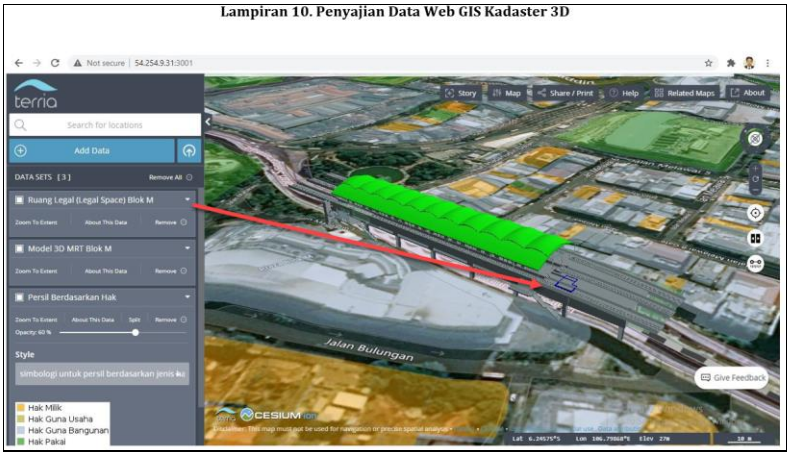

Diagram 6

Another project was to undertake a field survey of several office buildings. The aim was to take a minimum of measurements so critical elements of the 3D cadastral components were able to be accurately represented. Floor levels can be extruded to approximate the space up to the underside of the floor of the next level. There are many components of the building that could be considered under shared ownership and responsibility such as structural walls and floors, internal shared areas for access, services (water, electricity, etc,) and surrounding land within the Title. These types of RRRs can be referenced in formal managemenent statements/by laws or measured and mapped so privately owned spaces would be better represented in the model.

As shown in Diagram 7 the survey components included:

- the location of the buildings
- the heights of the respective floors to identify them as separate entities
- the surrounding ground to generate a DTM

Diagram 7

Diagram 8 below shows the variety of survey tools utilised.

(a) (b) (c)

Field Work Image : (a) GNSS CORS, (b) Total Station Reflectorless, (c) UAV Lidar

Diagram 8

The data collected is presented in Diagrams 9 and 10 as part of a dynamic database showing each level as a separate cubic space. The imagery shown is adjusted to the ground Digital Terrain Model (DTM) defining the local geoid as measured by LIDAR and 3D objects are seen above and below that DTM.

Diagram 9

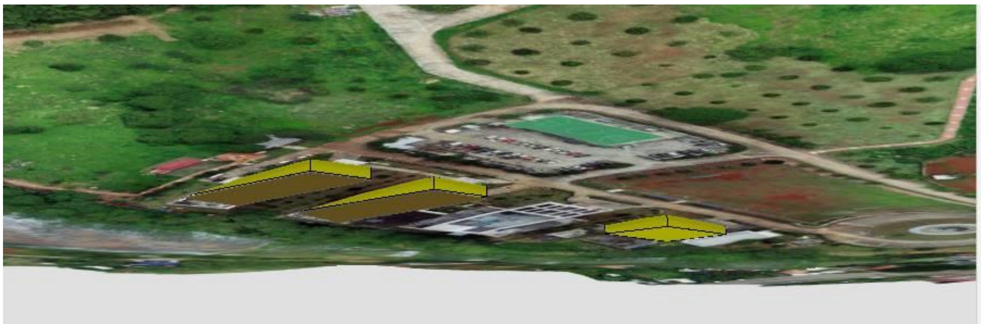

Diagram 10 – From below

The third 3D project (see Diagram 11 below) involves a basic building with a degree of compexity that was surveyed in a similar fashion to the previous examples that produced an accurate 3D representation of the structure. Whilst this is a Pilot Project, any cost benefit analysis for such a building could not be justified when a FFP solution is achievable at considerably reduced cost as outlined in the next section.

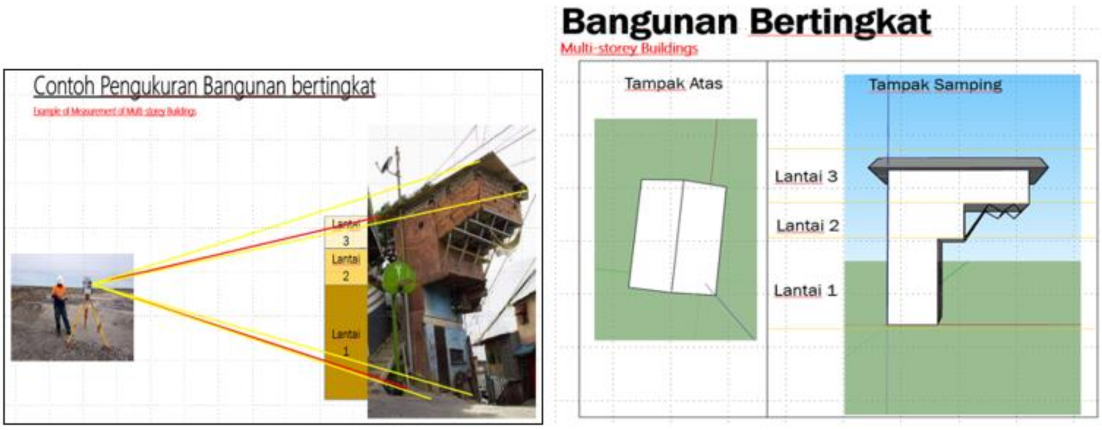

Diagram 11

2.1.1 Fit-For-Purpose 3D Cadastre and Digital Twin

The 3 previous surveyed examples can be replicated with desk top solutions which meet the Fit-For-Purpose agenda of maximising the output of 3D titles across areas where digital Land Administration is being implemented. Desktop solutions will not have the survey rigour and precision of surveyed data but where 3D data approximates real world legal ownership extents it can become a cost effective foundation for wider digital 3D Land Administration. Underpinning this process is an understanding that the database does not define boundary extents, they are defined by the title survey documents.

It should be noted that the above surveys all had the capacity to record the local geoid as the height datum but if we move to creating a 3D cadastre across wider areas and populate a Digital Twin as BPN seeks, a standard height datum becomes an essential. Defining local ground geoid heights may start to involve resources that would not fit with a FFP wider solution, so the business case for this becomes a management decision and a determinant of what would be required in a Digital Twin and datums.

Diagram 12 is a 3D model using the simplest mathematical approximation of 2 or 3 rectangular prisms that would enclose the building at ground level and the overhanging section. The upper and lower limitation of heights recognises that the title does not include the public road underneath the building overhang and the 3D model effectively represents that.

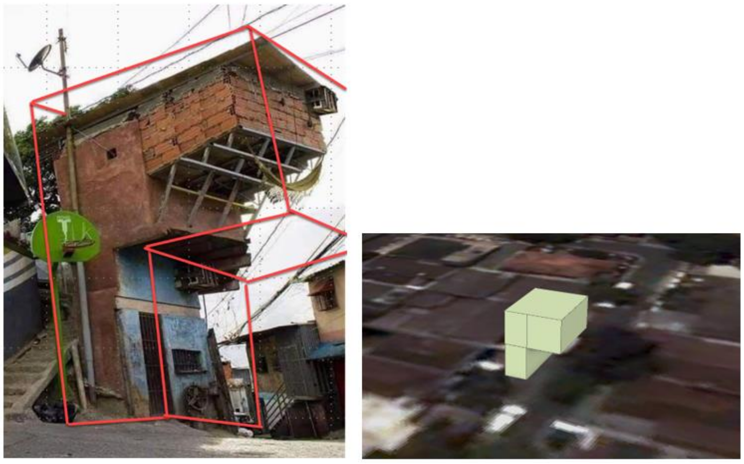

Diagram 12

Diagrams 12,13 and 14 are variations of two of the previuosly mentioned 3D datasets but heights are set to a zero datum on the ground at the local level so imagery can be set at a horizontal plane and all data can be modelled relative to that plane. This means that any 3D data can be collected in the field or estimated and modelled as shown and the Land Administration data Model could allow both ground and geoid heights to be stored and automatically accessed as required.

Diagram 13

Diagram 14

In the future all data could be adjusted to any geoid or other standard datum that may be adopted as a known point on each building is measured. Diagrams 13 and 14 gives an indication of the extent that 3D ground related data could be modelled without field survey.

2.1.2 Building Information Models - BIM

BIM databases have been mandated by BPN for all future multi-titled building developments but the big challenge for BPN is extracting 3D cadastral objects from an architectural model intended for construction. The underlying information is available but not readily accessible in its architectural format so one option is that BPN needs to also mandate that a 3D dataset of only the cadastral objects are provided to BPN in a standard format as part of the final consent for a completion of a building.

BPN's role should be to set the standards/governance of digital cadastral data content (including designated RRRs), format, attribution and standards to feed quality data into the Land Administration component of the national SDI

BIM models are usually generated on site datums and coordinate systems and often there is usually only approximate connectivity to cadastral boundaries. This is OK for design and construction as the BIM model is a self-contained entity and can be built on that basis. For best practice, surveyors should complete an as-built survey to validate the construction or if that is not economically feasible the representative title spaces could be considered FFP.

If a title space is complex, the applications for 3D cadastral modelling must have similar visualisation capacity to BIM across a national database. This may not always be possible so consideration should be given to what level of complexity is acceptable to the 3D database.

Demonstrations of one-off Indonesian 3D cadastre projects prove technology can provide the mechanisms to digitally manage and model 3D cadastre in a Digital Twin but the capacity of current data and resources does not provide a pragmatic national solution. Regulations must be flexible to achieve the greatest production of 3D representation across Indonesia. Lesser standards could be applied in certain areas but the data structure must be easily scalable to allow data to be upgradable to higher levels of content and 3D modeling capacity.

5. DIGITAL DATA TRANSFER STRUCTURE

The One Map Project has previously introduced a digital file format (GeoJSON) to transfer parcel details surveyed and collected in the field.

Further investigation of the capacity of BPN applications to integrate digital files should be considered. GeoJSON could be preferred as it is currently in use and is a flexible machine readable, logical format.

That investigation would include the:

- Capacity of data procurement applications
- Capacity of integrated 2d & 3D parcel database management solutions to read digital files & incorporate cadastral intelligence.

6. GOVERNANCE OF FIT-FOR-PURPOSE PROCESSES AND STRATEGIC MANAGEMENT INITIATIVES

After reviewing issues associated with problem parcels in the BPN cadastral database, we believe a move towards more regional responsibility in the management and quality analysis of survey data could be of benefit, particularly in a jurisdiction the size of Indonesia.

The underlying reason is that a local office has more chance of understanding the data, where there are problems and what the local needs of the system are.

This would result in regional BPN Offices administering national BPN directions and standards but taking a more active role in the survey data and Title creation and management processes involving:

- Disseminating existing BPN database and reviewing content and quality
- Collection of digital data by local surveyors
- Identifying and rectifying plot anomalies
- Local adjustment
- Return to BPN a spatially accurate parcel and survey control if provided

Whilst the focus of this initiative is on data integrity other benefits include:

- Decentralisation of BPN resources
- Upskilling of local resources
- Regional ‘ownership’ of data and roles providing greater incentives for better outcomes.
- Better solution for BPN national office to resolve Plot Anomalies or other problems

7. AUSTRALIAN CADASTRAL DIGITISATION PROJECT REVIEW

A recent review by one of this paper’s authors of a cadastral digitisation project in Australia produced findings similar to the Indonesian Review even though the existing Australian Torrens Title survey system and data would be considered good and the project processes more technical. The scope of the jurisdiction is also considerably smaller in every way in comparison to Indonesia.

Existing survey plan measurement data was back-captured into machine readable text files and high levels of automation were developed to compile and adjust the cadastral database. The processes were highly effective with reasonable survey data, particularly in urban areas but survey information in rural areas was often of poor spatial quality and combined with uncertain topology the main processes were not as effective. A variation of methods was added to the process so a more FFP solution was adopted.

Importantly, the data structure across the Australian jurisdiction is being put in place so future upgrading with better survey and spatial data can be done more efficiently.

8. CONCLUSIONS

In reviewing aspects of the One Map Project there are various types of data and levels of data integrity across a wide range of urban, rural and remote areas. Experience identifies that in such a scenario, to build capacity requires some diversity in the approach to data collection and management, computer applications and governance.

BPN seeks to introduce higher levels of spatial integrity and functionality (3D, etc,). Applications have the capacity to achieve this but require smarter data and emerging technologies provide new options.

As learnt from the Australian project review, there will not be one solution. The challenge is understanding what solution or solutions can be applied to provide higher levels of automated processes where data integrity is reliable or consider FFP solutions where data is not reliable.

A usable Fit-For-Purpose solution is achievable across large areas of Indonesia but in major urban areas higher levels of spatial integrity, functionality and efficiencies are necessary. The business case requires wider cost/benefit analysis by government and understanding that investment in data capture and data integrity is the key to better systems.

REFERENCES

1 – ***Fit-For-Purpose for Land Administration. - 2014***
Authors - Stig Enemark, Keith Clifford Bell, Christiaan Lemmen, Robin McLaren
The pulication is the result of cooperation between the World Bank and the International Federation of Surveyors (FIG) over recent years to address the issue of building and sustaining land administration systems that are basically fit-for-purpose rather than blindly complying with top-end technological solutions and rigid regulations for accuracy.

CONTACTS

Ian HARPER – Survey and Cadastral Database Consultant
Geodata Australia Pty Ltd
harper@geodata.com.au

Virgo Eresta JAYA - Senior Information Technology Advisor to The Minister at Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (BPN)
Jakarta
erestajaya@gmail.com

Sofyan Khairul ANWAR
Jakarta
sofyan.geospatial@gmail.com