An Analysis of the Necessity for 3D Cadastres with Reference to Trinidad and Tobago

Charisse GRIFFITH-CHARLES and Michael SUTHERLAND, Trinidad and Tobago

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SUMMARY

The theoretical methodology for the construction of a 3D cadastre can be an interesting academic exercise that is worthy of investigation. For individual countries or jurisdictions, however, the practical possibility of implementation must be supported by a discussion of the situational need and a cost-benefit analysis of the concept. This exercise to determine the need for a 3D cadastre in Trinidad and Tobago is conducted to determine the instances where the existence of a 3D cadastre would improve the activities that are now performed using the 2D cadastre. For this analysis therefore, an assessment is made of the percentage of the area of the country where 3D rights exist, and are acknowledged and supported, and where 3D restrictions and responsibilities exist and are actively enforced. This is balanced with the increases in costs that would naturally come from aspects of introduction of the 3D cadastre.

For many countries, such as Trinidad and Tobago, where the 2D cadastre is not yet comprehensive and current, it is difficult to argue the case for introducing a 3D cadastre as another unattainable ideal. A cost benefit analysis was conducted to determine the feasibility of introducing a 3D cadastre into the country.

This paper finds that there is a need for a 3D cadastre in Trinidad and Tobago but that this need is isolated to the urban, densely populated areas and the oil mining areas. The cost/benefit analysis finds a positive benefit/cost ratio. Beyond the economically advisable outcome, the non quantifiable benefits of introducing a 3D cadastre are many and therefore the introduction of a 3D cadastre in selected areas only is recommended.

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1. INTRODUCTION

The benefits of a 3D cadastre include the ability to support the rights of individuals in strata occupation, the ability to store attribute information that is directly linked to intricately inter-related parcels in three dimensions, and the ability to differentiate between and transact on surface as opposed to subsurface rights. Despite the benefits, developing countries must be wary of embarking on programmes to implement comprehensive 3D cadastres over their entire jurisdiction without a thorough cost-benefit analysis of such implementation. For Trinidad and Tobago, such an assessment must be done if the country is to consider the introduction of a 3D cadastre in an environment where there is not yet a comprehensive 2D cadastre and where the economic conditions of the past few years require prioritising of the use of resources. This paper examines the broad factors that would need to be taken into account in a cost benefit analysis for the purpose of establishing a 3D cadastre. The examination is applied to the particular context of Trinidad and Tobago to conclude whether and how the project to establish the 3D cadastre should be implemented.

2. COST-BENEFIT ANALYSIS

2.1 General CBA theory

Cost-benefit analysis (CBA) is a systematic approach to decision making that is generally based upon the presumption that a decision to support an action or set of actions should not be pursued unless perceived benefits outweigh perceived costs (Kelman 1981; Drèze and Stern 1987). In other words, CBA is undertaken to maximise net benefits. Heinzerling and Ackerman (2002), Vining and Weimer (2010) and others directly link CBA to government initiatives but it has been used for private initiatives. Benefits and costs can be tangible or intangible. Costs can include fixed costs, variable costs, direct and indirect costs, sunk costs, and opportunity costs. In CBA, costs and benefits are normally expressed in common scales or denominators for ease of comparison. Costs and benefits that flow into the future, once translated into monetary terms, are discounted to *present value* (Kelman 1981; Hanley and Spash 1993; Heinzerling and Ackerman 2002; Roman and Farrell 2002).

According to DiLorenzo (2002), CBA is associated with two principles. One principle treats CBA as a "standard" that leads to "proper decisions", and which in effect leads to the most efficient resource allocation. This principle has apparently been severely criticized by many experts. The other principle treats CBA as a tool in the decision making process, requiring the decision maker to deeply explore probable outcomes (costs/benefits) before choosing a line of action. In this latter principle benefits do not have to outweigh costs for an action to be

chosen; rather, costs and benefits have to be clear before an action is taken (Kelman 1981; DiLorenzo 2002).

As often happens, difficulties are encountered in quantifying some costs or benefits at chosen scales/denominators when those costs or benefits are not traded in markets. Economic feasibility (because CBA requires the assignment of monetary values) may not always be easily demonstrated as the appropriate measure of the rightness of an action (Heinzerling and Ackerman 2002). In many instances ethical, legal and scientific grounds may be more appropriate bases for decisions (Sagoff 1988; Schokkaert 1995). However, since the 20th Century CBA has been used as a basis for decision making, even with regard to non-marketed items, or those things that cannot be easily priced, such as numbers of human lives saved etc. (Kelman 1981; Heinzerling and Ackerman 2002; DiLorenzo 2002). A common approach to CBA, when faced with qualitative benefits and costs, is to exclude these items from the analyses and to use qualitative information in other forms of decision making at the time of final analysis. Other difficulties associated with CBA include (among other things) (Kennedy, 1981; Schmid 1989; Schokkaert 1995; Ackerman and Heinzerling 2002; Vining and Weimer 2010):

- Making best guesses in relation to uncertain futures;
- Tradeoffs in relation to uncertain futures;
- Assuming that everything can be traded for something else;
- Distortions of perceptions of the future based upon the assumption that costs and benefits will occur simultaneously;
- Exaggerated costs or benefits;
- Subjective biases.

In some instances, benefits are assumed to be derived from certain actions, and are significant when realized. However, as stated by DiLorenzo (2002) while discussing CBA in relation to deregulated markets, some assumed benefits were in fact “modest or even non-existent”.

It has been suggested that, depending upon the situation, other forms of decision making may be more appropriate, including multi-criteria analyses and holistic evaluation of costs and benefits (among others) (Kelman 1981). For example, according to Joubert *et al* (1997), multi-criteria approaches are more appropriate for developing countries “where much of the population is outside of a market setting, where there is extreme inequality in the distribution of income, and the environment is a major factor of production”.

2.2 CBA in Developing Countries

The efficient allocation of limited economic resources to address social, economic, political and environmental objectives is a problem faced by all countries. This problem is more acute in developing countries that generally have less available economic resources to pursue economic efficiency, i.e. the difference between costs and benefits (Arrow et al 1997), when pursuing their objectives. When faced with actions in pursuit of objectives, the achievement of which depends upon economic expenditures, CBA appears to be a responsible exercise even in developing countries, at least as part of the decision making process. Lutz and Munasinge (1994) supported this position when they stated:

> A major need at present is not for more theory or techniques, but for application of existing methodology and approaches to concrete problems, particularly in developing countries. ... Cost-benefit analysis should be used to the extent possible. Alongside, one needs to consider and, to the extent possible, rigorously analyze consequences and risks that cannot be measured in monetary terms and use, for example, multi-criteria analysis where possible. This, together with sound judgement, are at present the best inputs into decision-making.

On the other hand, Davies (1997) cautions the use of CBA in "Third World" countries that have histories of socioeconomic distortions and failures. Davies (1997) however concedes that the balanced approach may work in developing countries where governments are constrained by the political process to acknowledge the values of the "poor", and therefore their values are part of the analyses.

Another major constraint in developing countries is the high cost of performing a highly data driven and therefore more reliable and precise CBA exercise (Boardman et al 2001). Economies with scarce resources can seldom afford the data capture and pilot exercises that are necessary to underpin a CBA in which the decision makers can have confidence. The cost of the exercise can also contribute to larger sunk costs for the project which may bias the decision to implement the project.

2.3 CBA in Cadastres and 3D Cadastres

There have already been extensive discussions on the benefits of 2D cadastres. These benefits when extrapolated to their logical conclusion are akin to the benefits attributed to land administration systems (LAS) and spatial data infrastructures (SDI) since cadastral systems are a foundational dataset of the LAS and SDI. The benefits of a functioning cadastre are broadly grouped as social, environmental and economic which accrue through the security of tenure and the access to information that the cadastre provides (Feder and Nishio 1999; Deininger et al 2003; World Bank 2000; World Bank 1997; Agency for International Development 1974; Agency for International Development 1985). Many programmes have therefore been put in place in developing countries to accelerate the pace of attaining these benefits from a comprehensive cadastre. There are just as many studies that posit and illustrate that these benefits do not accrue or do not continue to flow without additional costs of continued system maintenance and supportive market structures (Coles, 1989; Carter and Olinto, 1996; Jansen and Roquas, 1998; Zoomers and van der Haar, 2001; Deininger et al, 2003; Gould et al, 2006; Griffith-Charles 2004, Barnes and Griffith-Charles 2007). This would mean that any CBA undertaken will have to be computed on a specific future period by which time the major benefits and costs would be achieved.

The benefits of the cadastre to a state or society that are quantifiable in monetary terms, albeit in some instances with difficulty, can be listed as:

1. Economic

- The increase in tenure security leads to increases in land transactions which is reflected in and can be quantified by the change in GDP
- Increases in transactions provide increases in transaction taxes to the state
- The system provides for increased ability to recover outstanding land taxes

- The system provides for increases in land values and therefore the opportunity for increases in income from raised levels of land taxation

2. Social
- Lowered levels of land conflict provide savings to court costs
- Increase in security of tenure encourages entrepreneurial activity
- Increased ability to access credit for development results in lowered levels of poverty and lowered social support bills

3. Environmental
- Decreased costly environmental impacts such as flooding, degradation, and deforestation caused by informal occupation

The benefits of the cadastre to a state or society that are not quantifiable in monetary terms include:

1. Economic
- Establishment or improvement of a land market

2. Social
- Increase in level of well being of citizens as a result of security of tenure and lowered conflict
- Improved decision making and planning made possible by the presence of the database
- Establishment of legislation to regulate and revise land policy

3. Environmental
- Preservation of habitats that were vulnerable to informal occupation, degradation

It can be argued that 3D cadastres should provide similar benefits but would especially be required in situations of intensive overlapping and interlinking of property rights. A good description can speed up transactions, resolve ambiguity about the land object described and can be used to reproduce the land object if it is destroyed. These benefits would be available to all the land objects that are able to be graphically described on a 2D cadastre.

The costs of establishment of the cadastre to a state or society both quantifiable and non quantifiable in monetary terms can be stated to be:

1. Economic
- Data acquisition for initial population of the databases
- Data acquisition on a continuous basis for maintenance of the databases
- Establishment of legislation to regulate procedures for management of the cadastre
- Capacity building for institutions required to establish and maintain the database

2. Social
- Loss of access to land by persons who have no evidence to support their claim and are ejected
- Loss of land and reduction to poverty by persons who exercise the newfound ability to monetise their registered tenure

3. Environmental
- Increase in costly environmental impacts such as flooding, degradation and deforestation caused by development

Again, 3D cadastres would result in similar costs. These costs may be intensified since such cadastres would incur greater costs for the establishment of systems, acquisition of additional data and maintenance of a greater volume of records.

The benefits and costs of the 3D cadastre are also dependent on how it is constructed. There can be partial coverage in 3D in areas that would benefit from the implementation (Stoter and Salzmann, 2003). There can also be different precisions required for the data used in the visualisation of the parcel object.

3. 3D CADASTRES: INTERNATIONAL STATUS

The need for a 3D cadastre in contrast with what technology can provide has been addressed in research projects. Stoter and Salzmann (2003) investigate the technical possibilities available to create a 3D cadastre for the Netherlands. They conclude that because of the current technical difficulties of introducing a fully 3D cadastre, a 2D cadastre with visualisation of the 3D situation should be adopted as this would satisfy the need. Kim et al (2010), however, posit and demonstrate that the acquisition of data has benefitted from advances in technology to such an extent that high precision geospatial data can be quickly achieved at a positive benefit/cost ratio with LiDAR, and photogrammetry.

4. CADASTRE IN TRINIDAD AND TOBAGO

4.1 Status

Trinidad and Tobago is a small developing country in the southernmost part of the Caribbean. The population of approximately 1.3 million persons shares a land space of 5,100 sq km. Land space is therefore at a premium. It is an archipelagic state with responsibility for managing a large expanse of ocean space from which is derived the oil and gas that form the core of its economy.

The cadastral system of Trinidad and Tobago is comprised of a set of cadastral index maps that have been partially transferred to a digital system that to date is incomplete and of low spatial precision. This graphic component is not linked to the registration documents evidencing title to an estimated 70% of existing parcels (Stanfield and Singer, 1993).

Cost benefit analyses have been performed for Trinidad and Tobago to support the implementation of a programme of systematic land adjudication and registration (Williams and Bloch 2005). These analyses have estimated that an improvement in the security of tenure of properties would result in an increase in investment and construction expenditure, which, as a result of its impact on the GDP of the country, would improve the overall economic outlook of the country.

Prior to the 1980s it was recognised that condominium complexes were proliferating leading to problems attached to representing ownership of elevated spaces (Wylie 1986). Condominium legislation was drafted in the 1980s to address the issue but was never

promulgated. More recent attempts were made to conclude the legislation with little success. Establishment of a 3D cadastre will therefore require comprehensive legislation to address the issues of registration, conveyance, management, and control of the rights in these and other 3D situations. Many countries have already established a history of treating with this type of legislation (Aien et al 2011), so adapting these versions to Trinidad and Tobago will be theoretically simple but practically difficult as professional stakeholders and the public would need to have confidence in the changes.

Currently 3D cadastral information is represented only on some condominium plans by including vertical sections on the cadastral plan. No provision has been made for including 3D graphic visualisation of the cadastre for the proposed Land Adjudication and Registration Programme (LARP). Establishment of a 3D cadastre will therefore require the acquisition of data on the boundary locations beyond the 2D aspects normally acquired by cadastral surveyors.

4.2 3D cadastre-related issues

4.2.1 Strata titles

The population density of Trinidad and Tobago stands at 261 persons per square kilometre. While this figure is lower than the densities of many of the countries of the Caribbean except for Jamaica, the figure is larger than the 254 per km for the UK and 32 per km for the US. This density indicates that a significant amount of the housing is now or must in future trend towards multi strata development. Currently, low income state provided multi-storied housing and very high income multi-storied condominium housing is prevalent. Middle income housing is trending towards intricately interwoven townhouses. High density development is, however, especially concentrated in the major cities, towns and peri-urban areas. The management of rights in these areas would require visualisation in three dimensions.

4.2.2 Mineral rights

Oil and gas exploration and extraction both on land and at sea provide the foundation of the economy of Trinidad and Tobago. The oil companies manage their sub-surface leases, licences and freehold interests on a parcel by parcel level leading to inefficient management. The lack of a cadastre that would indicate the areas where the state retains the mineral rights of privately owned parcels stymies the planning of exploration programmes (Lewis and Baptiste 2011). Conflicts occur between surface owner and sub-surface mineral rights owners as a result of the inadequate management and description of the relationship between the rights.

4.2.3 Issues

Difficulties may arise in determining the referent group as has occurred in many land registration and cadastre establishment projects. Projects targeted at higher income groups can generate wealth in the society that can improve the economy generally and benefit lower income groups. The morality of this approach may be questioned however. Projects targeted at lower income groups can improve their living standard and well being leading to a lowered tax burden requirement on the higher income groups. In instances of scarce resources it may be difficult to determine where the priority should be placed to the exclusion of others in the society.

5. METHODOLOGY FOR THE CBA

The methodology to be used here would be a hybrid method utilising standard CBA procedures to cost the financially quantifiable costs and benefits and discussion of the non-financially quantifiable and the intangible costs and benefits. The procedure follows a typical CBA sequence (Boardman et al 2001)

- Determine the alternatives that will be focused on in the analysis
- Determine from whose perspectives the costs and benefit will be defined
- List the benefits, costs and the units to be used to quantify them
- Determine the relevant quantities
- Monetise the costs and benefits using specified computations
- Reduce benefits and costs to present values for comparison
- Test the result with a sensitivity analysis
- Recommend based on the results and an understanding of the issue

5.1 Alternatives

In theory there may be several options to choose from leading to a range of scenarios on which to perform the CBA as shown in Figure 1. For example the 3D cadastre may be implemented in a comprehensive fashion over the entire country or its installation may be limited to densely populated urban areas where multiple level parcel units are more prevalent.

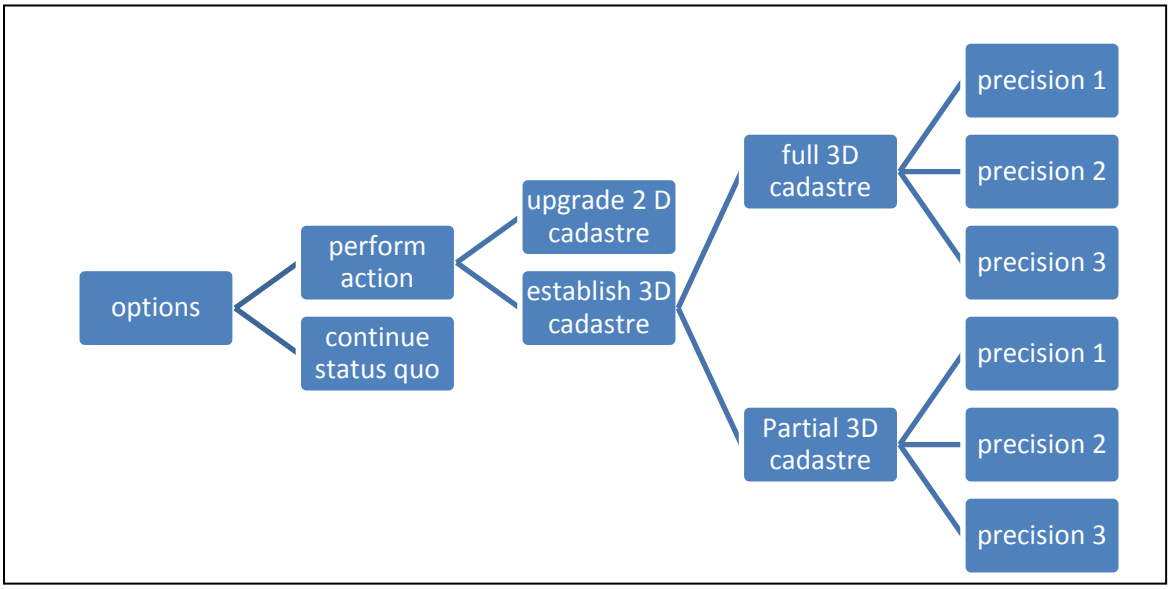

Figure 1. Alternatives for the project to establish a cadastre

The method chosen would have implications for the cost, time, labour and system requirements. The precision of the data may vary over a range from centimetre level to graphic illustration by extrusion of buildings on the 2D layer. The data acquisition method may vary from laser mapping to, leading to very variable costs. There are uncertainties in predicting how technology will advance over the duration of the project implementation leading to changes in methodology, speed and cost. The decision tree may look like the diagram at Figure 1 or may be more complex. For practical simplicity at this point, the CBA

here will be done assuming that the options are either introducing a 3D cadastre over the necessary areas only or maintaining the current incomplete 2D cadastre. The spatial precision will be ±0.05 m in relative position with a focus on the cadastral use only. Relative precision is therefore of greater importance than absolute positions.

5.2 Cost perspective

Since this is of necessity a public project, the capital outlay will be borne by the state, however, the state would need to hold a broader view of the costs and benefits to the society at large and more particularly to the disadvantaged poor and landless groups in the society.

5.3 Defining the variables

From examination of and extension of some of the typical costs and benefits of 2D cadastres, the variables to be discussed and taken into consideration in the CBA for establishing a 3D cadastre are as set out in Table 1.

Table 1. Variables for CBA/multi criteria analysis

		Impact Type	Variable
Financially quantifiable	Costs	Economic	Acquisition of boundary data, maintenance costs, capacity building for institutions, creation of legislation
		Social	Social welfare benefits for loss of access to land
		Environmental	Increases in costs of flooding etc due to development.
	Benefits	Economic	Increase in GDP real estate, transaction taxes, recovered and increased land taxes
		Social	Decrease in court costs, increases in small businesses
		Environmental	Decreases in costs of flooding, degradation, deforestation
Non-Financially quantifiable and intangible	Costs	Economic	Loss of opportunities to engage in informal land market activity
		Social	Dispossession from land
		Environmental	Increases in development and loss of habitats,
	Benefits	Economic	Improvement in land market
		Social	Increase in well being, perceptions of tenure security
		Environmental	Improved decision making

For the establishment of the system, each parcel or land object in the relevant areas will have to be surveyed to determine a boundary location for each vertex of the parcel object. The number of parcels or land objects to be surveyed must be determined. Resurveying will be necessary as development occurs to build to the existing database. A number of persons in the state institutions responsible for maintaining the database will have to be trained to establish and maintain the system. Legislation will have to be revised or developed to accept the changes in defining and graphically representing boundaries. Some persons will experience loss of land or loss of access to land as the system more clearly determines and supports rights to many more land objects. These persons will then turn to the state for shelter. The enabling

environment will support development and construction leading to the negative impacts of flooding and other environmental damage.

There will be positive impacts of the 3D cadastre as it is supportive of the land market for a larger number of land objects and so increases in the real estate GDP are anticipated. Increases in recovery and the potential to increase taxes are available. Benefits of lowered conflict and litigation build on the same argument for 2D cadastres.

5.4 Data Acquisition

The data is acquired for the CBA using a combination of inference, extrapolation and surrogate use to obtain the measurements in the units required since many of these data are not available or unavailable in the form required for the analysis.

5.5 Monetisation

Figure 2 shows the more highly fragmented parcels in the cadastral system as determined from those areas where larger scaled maps have been prepared by the state cadastral institution to show the complex subdivisions. These areas are also those urban areas where population density is greatest and most of the strata parcels exist.

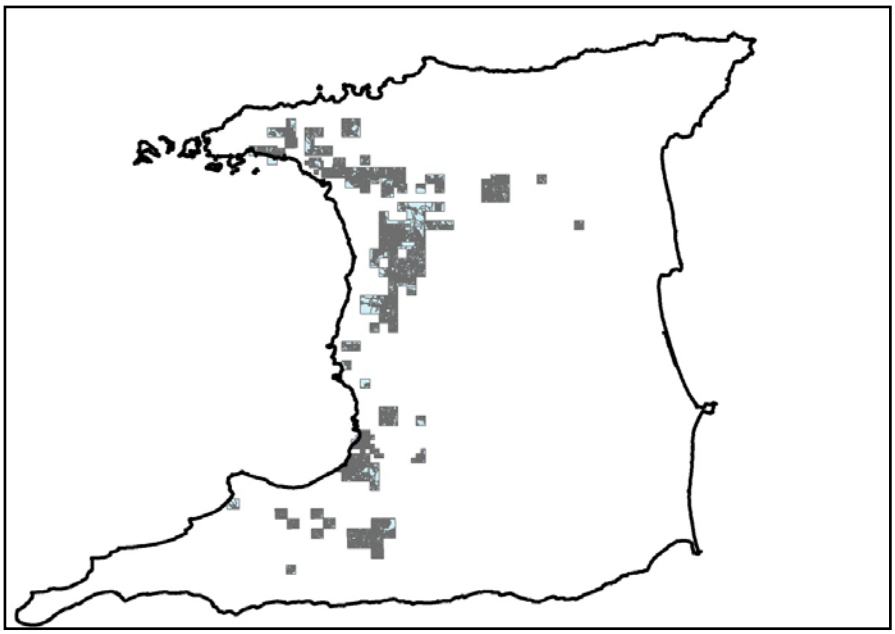

Figure 2. Densely populated/highly fragmented areas of Trinidad

The total area to be covered in the 3D cadastre therefore is calculated at approximately 300 sq. km which, when reduced to the number of surface parcels at 500 sq. m per parcel gives some 600,000 residential sized parcels. Estimating half of this area to be deployed for infrastructure leaves some 300,000 possible surface parcels but this can be doubled to account for strata levels of different heights. Currently buildings, both commercial and residential, range in height from a majority at 1 or 2 floors to a few with 25 floors. Therefore an estimated 600,000 land objects are projected to be potentially included in the database.

Figures 3 and 4 illustrate sub-surface parcels used for oil extraction where the surface parcels are differently configured. In most cases illustrated here the surface parcel configuration is overlaid on the subsurface rights situation. Another 100,000 parcels may be added to the total of 3D land objects here resulting in 700,000 parcels to be put onto the database after some adjudication.

This computation indicates that some 400,000 land objects will be added to the land market to result in a benefit to the state of increased taxes on land transactions, and land taxes. The computations for the CBA were therefore based on adding 400,000 land objects to the existing database as opposed to maintaining the status quo of the existing 2D parcels.

Johnson (2008) gives typical survey costs per parcel for registration. The figure of US$1190 in 2006 dollars per parcel was used to calculate the cost of survey for the 400,000 additional parcels. The cost of survey is the largest of the costs.

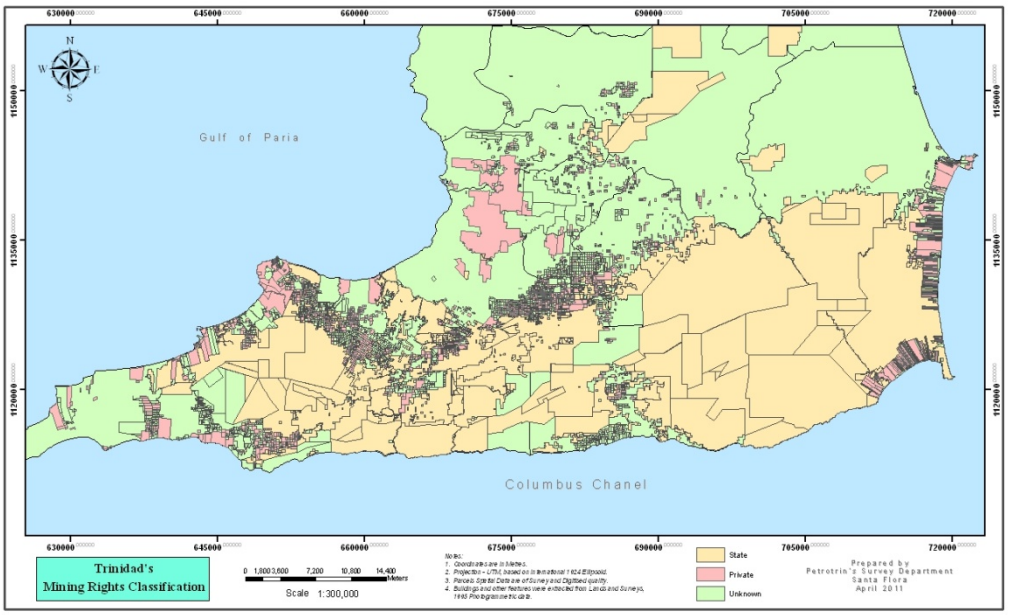

Figure 3. Subsurface cadastral situation (Lewis and Baptiste 2011)

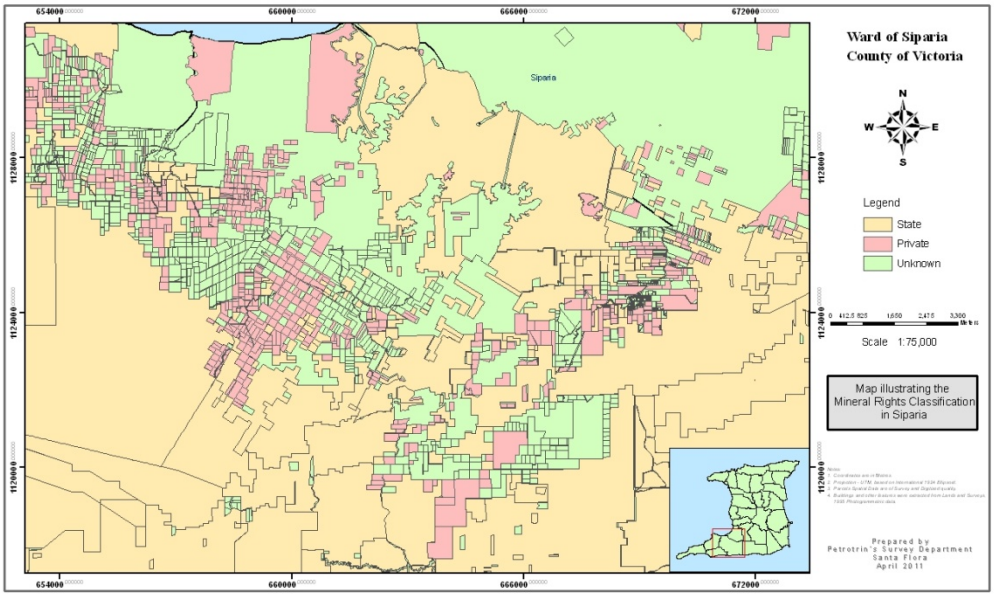

Figure 4. Cadastral map of subsurface rights used for oil mining purposes (Lewis and Baptiste 2011)

Cost of maintenance of the database was predicated on the cost of 5 persons hired to perform this function at TT$8,000 per month for 5 years. Training costs for the maintenance was estimated at TT$50,000 for a single training course.

Amendment to the legislation was given as an estimated single cost of $500,000. This cost is difficult to quantify as so much of the passage of legislation requires political and social support for efficient completion. For example the Land Adjudication Act 2000 was introduced as a bill in 1999 and has not yet been promulgated some 12 years afterward while Anti-Gang Act, 2011 was introduced in 2010 and promulgated in 2011. Rules for defining and describing land parcels, however, fall under the purview of the Land Survey Board (Land Surveyors Regulations 1998) and so should be simpler and less costly to amend. The Conveyancing and Law of Property Act also devolves responsibility of the plan presentation to the registered land surveyor (Conveyancing and Law of Property Act 56:01 1999)

The figure of TT$2,310,000,000 was used as the value of 18000 mortgages on properties over the country in 2004 (CSO 2006). It was estimated that 25% of this value would occur on the area selected for 3D implementation given an invigoration in the market as a result of the cadastre, and that this number would continue over five years. The NPV was calculated from this total.

Trinidad's estimated damage from flood events in 2006 was given as US$ 2,500,000 (Brakenridge et al 2007).

Transaction fees were estimated based on the total of 18000 transactions occurring in 2001. Estimating one tenth of this number of transactions occurring in 2011 and an additional 1800 per year for 5 years gives 9000 transactions at a cost of TT$ 400 per transaction.

Property taxes were estimated from published data from the Central Statistical Office (CSO 2011). An estimate of one tenth of this tax was used and computed over five years.

6. DATA

The CBA data results in the following tabular information at Table 2.

Table 2. CBA estimation

Items	Costs (Actual)(TT$)*	Costs (NPV) (TT$)	Benefits (Actual) (TT$)	Benefits (NPV) (TT$)
acquisition of boundary data	2,998,800,000	2,998,800,000		
maintenance over 5 years (NPV)	2,400,000	1,880,462		
training (2011)	50,000	50,000		
amendments to legislation	500,000	500,000		
Mortgages/credit access			3,869,526,160	3,031,874,998
increase in real estate transaction taxes			3,600,000	3,600,000
increase in real estate property taxes x 5 years			162,500,000	127,323,002
Total	3,001,750,000	2,999,350,000	4,035,626,160	3,162,798,000
benefit			1,033,876,160	163,448,000

*Current exchange rate is US$ 1 ≈ TT$ 6.30

The results show a net benefit in 2011 dollars of TT$163,448,000. A sensitivity analysis must take into account that this positive result is based on an invigoration of the land market leading to development as a result of the possibility of mortgages and credit access. The result is also based on the ability of the beneficiaries of the increased security of title to pay land taxes and the ability of the state to recover those taxes. An unpredictable decline in the market can significantly affect these outcomes.

7. ANALYSIS

The quantitative analysis of economic costs and benefits indicates that benefits outweigh costs. However, this is only part of the picture as the non-quantifiable costs and benefits listed in Table 1 did not enter into the computation. The non-quantifiable costs and benefits also have to be taken into consideration qualitatively. The social value of installing a 3D cadastre is great and supports the introduction even if the economically quantifiable costs outweigh the benefits. The fact that the introduction of the system would provide shelter and support the rights of a significant number of landless persons is justification for implementing the programme as a social one.

8. CONCLUSION

To perform a CBA, a determination first has to be made regarding the options that would be considered in the analysis. Several options can be analysed and compared, however, for decision making, it is best to consider only a few options to ensure that the brain can comprehend the complexities inherent in any one situation.

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BIOGRAPHICAL NOTES

Charisse Griffith-Charles is currently lecturer in Cadastral Systems, Land Administration and Surveying in the Department of Geomatics Engineering and Land Management at the University of the West Indies, St. Augustine, Trinidad and Tobago where her research interests are in land registration systems and communal tenure. She is a member of the Royal Institution of Chartered Surveyors and a registered and licensed land surveyor in Trinidad and Tobago and has worked on, inter alia, projects to revise land survey legislation in Trinidad and Tobago, assess the impact and sustainability of land titling in St. Lucia, address tenure issues in regularizing informal occupants of land, and to assess the socio-economic impact of land adjudication and registration in Trinidad and Tobago. She is currently President of the Institute of Surveyors of Trinidad and Tobago (ISTT) and President of the Commonwealth Association of Surveying and Land Economy (CASLE) Atlantic Region.

Michael Sutherland is currently Lecturer in Land Management in the Department of Geomatics Engineering and Land Management, University of the West Indies, St. Augustine, Trinidad and Tobago with more than 20 years' international experience in land and marine tenure systems and administration. Michael is a member of the Canadian Institute of Geomatics and the Institute of Surveyors of Trinidad and Tobago, and is an elected member of the Royal Institution of Chartered Surveyors. He is currently Chair of Commission 4, International Federation of Surveyors.

CONTACTS

Charisse Griffith-Charles
The University of the West Indies, St. Augustine
St. Augustine
TRINIDAD AND TOBAGO
Phone: +1 868 662 2002 ext. 82520
Fax: +1 868 662 2002 ext 83700
E-mail: Charisse.Griffith-Charles@sta.uwi.edu
Website: http://www.eng.uwi.tt/depts/survey/staff/cgriffith-charles/cgriffith-charles.htm

Dr. Michael Sutherland
Department of Geomatics Engineering and Land Management
The University of the West Indies, St. Augustine
TRINIDAD AND TOBAGO
Phone: +1 868 662 2002 ext. 82564
Fax: +1 868 662 2002 ext 83700
E-mail: michael.d.sutherland@unb.ca and michael.sutherland@sta.uwi.edu
Website: http://www.eng.uwi.tt/depts/survey/staff/msutherland/msutherland.htm