

A Web-Based Object-Relational Cadastral Model for Kenya: The Case for Spatially Enabled Land Governance.

Prof. Gordon Wayumba¹, Benard Odhiambo², Dr. Samson Ayugi³, Martin Ondiwa⁴, Boaz Nyakongo⁵

¹ Lecturer in Geospatial Engineering and Land Administration, The Technical University of Kenya, Nairobi. Tel: +254722775168, Email: gowayumba@gmail.com.

² Geospatial Engineer and Developer at Serian Geospatial Limited. Nairobi. Tel: +254717374902, Email: odhiambb@gmail.com.

³ Lecturer in Geospatial Engineering and Geoinformatics, The Technical University of Kenya, Nairobi. Tel: +254722276544, Email: okothayugi@gmail.com.

⁴ Geospatial Engineer, The Technical University of Kenya, Nairobi. Tel: +254798095529, Email: surekondiwa@gmail.com.

⁵ Geospatial Engineer, The Technical University of Kenya, Nairobi. Tel: +254797073761, Email: boaznyakongo99@gmail.com.

1 The Technical University of Kenya, Nairobi

2 Private Consultant in Geospatial Engineering

ABSTRACT

Harmonizing data into comprehensive cadastral models, such as Land Information Management Systems, is a mandatory requirement in developed countries, where such systems support the implementation of sustainable development needs. For example, Europe already has the Land Administration Domain Model [Lemmen, 2012] and Infrastructure for Spatial Information in the European Community (INSPIRE, 2007). Both models were developed to facilitate efficient spatial data access and sharing between the European nations and for ease of doing business. Accessible information on tenure systems is crucial for various needs; it supports sustainable economic and infrastructural development and interrelated spatial planning needs. It also supports resource and environment management for climate change and the associated disaster risk reduction.

Contrastingly, in most developing countries, several aspects of spatial data management are still missing. In most cases, land parcels are not registered, recorded, or spatially referenced to a specific geodetic datum. In the cases where spatial/and attribute data exist, their quality is poor and incomplete, and the land records kept in the registries are not up-to-date and do not represent the actual situation on the ground. Most spatial data are analog format, and the few computerized data are often improperly maintained.

A research project was initiated between the Technical University of Kenya and a Cooperative Society in Nairobi to develop a prototype Web-Based cadastral model for Kenya based on the Object-Relational model to solve this problem. The prototype used a web-centric solution, with data stored and managed centrally from an Object-Relational database (PostgreSQL/PostGIS) through implementing the Django framework as a back-end framework. Further interactive pages

Walympa Gordon, Oghiambo Bernard, Martin Zure Ondiwa, Nyakongoro Boss and Samson Ayugi (Kenya)

(15453)

A Web-Based Object-Relational Cadastre Model for Kenya: The Case for Spatially Enabled Land Governance

in the front end were developed using bootstrap4, HTML, JavaScript, and CSS. Consequently, it enabled users to view the land data in the system through their web browsers. The research, therefore, developed a Web-Based Application for Land Information Management where different users can log in and interact with the different land information attributes and spatial data for different needs.

Keywords.

Web_based Cadastre, Object-Relational database, Land Information Management, spatial data.

Walter Ochieng, Odhiambo Bernard, Martin Zure Ondiwa, Nyakong'o Boss and Zamboni Abugi (Kenya)
(2024)

A Web-Based Object-Relational Cadastral Model for Kenya: The Case for Spatially Enabled Land Governance

1. INTRODUCTION

The National Land Policy (NLP) [MoL, 2009] observed that the Kenya government currently lacks an up-to-date and comprehensive National Land Information System (NLIMS), and this compromises the efficient land administration processes in the country. The available land information system is currently held primarily in paper format and is managed manually. This is inefficient, time-consuming and does not support timely decision-making on land matters. Additionally, the current system is centralized in Nairobi; it is slow and involves cumbersome and bureaucratic procedures. De Soto [2000] observed that the bureaucratic Land Administration processes and lack of adequate documentation of resources in developing countries is why capitalism thrives best in the developed world but fails everywhere else.

The Ministry of Lands in Kenya, in its Strategic Plan (2008-2012) and performance contract (2010/2011), already identified that to ensure effective and efficient service delivery to the clients, processes, procedures and practices of handling land information need to be redesigned. It further noted that such redesign should include Business Process Re-Engineering and targeted four bench-marking activities towards achieving these objectives. These four bench-mark activities included reviewing and documenting current processes, procedures and practices; redesigning procedures and processes of land administration; making recommendations for quick-win projects; and implementing a digital National Land Information System [MoL, 2011: 17].

After promulgating the Kenya Constitution 2010 and establishing the National Land Commission (NLC), the government mandated the newly formed NLC to develop NIMS for the country. However, up-to-date, the NLC has not developed the NLIMS and Kenya still operates the manual LIMS. Kuria et al. [2016] attempted to develop a web-based workflow system for better Land Administration, but no web-based operational NLIMS exists. To solve this problem, the School of Surveying and Spatial Science of the Technical University of Kenya initiated a research project to develop and test a prototype Web-Based Object-Relational Cadastral Model for Kenya.

2. METHODOLOGY

2.1 System Analysis, Data Collection, and User Requirements.

The methodology adopted for the research is summarized in Figure 1.1 and consisted of the following approaches: literature review and research, systems analysis, data collection and user need assessment, systems design, coding and implementation, testing, deployment and maintenance. To elaborate on the methodology in more detail, it consisted first of (i) transformation of the coordinates of the cadastral map of the study area from Cassini-Soldner projection to the UTM (1960 Arc Datum) through a four-parameter affine transformation and further transformation from the UTM projection (1960 Arc Datum) to the WGS84 projection through the PROJ4 Software (Codes 21037 and 4326 for the UTM 1960 Arc Datum and WGS84 respectively). The transformed coordinates were used to digitize the cadastral maps into the WGS84 coordinates system for compatibility with the World Wide Web

Finally, appropriate classes representing the main components of the Kenyan Cadastre were developed with the UML Diagrams (Fig.1.4). The various selected classes are presented below for more details and a better understanding of the Kenyan Cadastre.

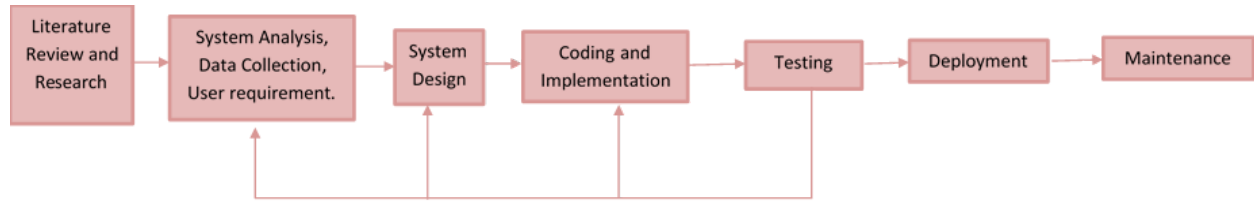


Fig 1. Flow-chart Diagram for the Research Methodology

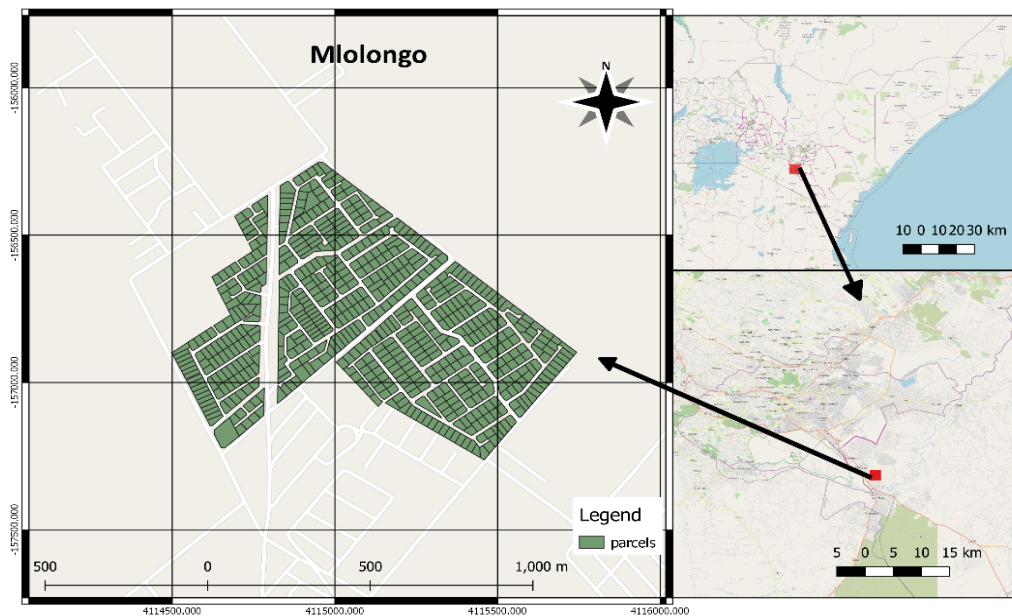


Fig. 2. Map showing the location of the study area.

2.2 The UML Classes used in this study were adopted from Nyadimo [2006] and Wayumba [2013]

2.2.1 Parcel Class

The scenario in the diagram below depicts the relationship between the Land Object, RightfulClaimant, and RightsOrRestrictions as required in the Cadastral Core Model. The LandObject can be modeled as a polygon feature (in most cases with coordinates) and presented in a class diagram, the ParcelClass, including its attributes and the operations that can be performed over the LandClass. The RightfulClaimant, in this case, is identified as the land owner, modeled in the OwnerClass.

Landowners can be further identified as individual owners, Company and Cooperatives organizations, and Savings and Cooperative Companies (SACCO). The ParcelOwner class defines the relationship between the land parcel and the landowner. The diagram above shows a multiplicity situation where many people can own a parcel, many people can own a parcel, and many can own one parcel. This is a many-to-many relationship.

The unique identifier for the ParcelClass is the ParcelID. Land parcels in the study area were registered under the Registration of Titles Act (RTA), which uses the Land Registry Number (LR. Nos.) as the land parcel identifier. In Kenya, the LR Nos are kept and maintained by the Department of Survey (Survey of Kenya) as unique parcel identifiers in the RTA system. The LR Nos was, therefore, chosen as the Primary Key for the ParcelClass.

2.2.2 Buildings Class

While conducting a user needs assessment, most clients wanted to know which plots had been developed into housing and which were still vacant. This was particularly appealing to clients who were interested in selecting properties for purchase. It was therefore decided to include the Building Class to fulfill the needs of the property market. Figure 1.1 The Building class is directly related to the Registration class. In contrast, the water and electricity on the buildings are related to the Registration class through the building class and related to the Owner Class.

The status of a building in the urban centers in Kenya is of significant concern regarding the property market. This is particularly critical in informal settlements where the owner of the land and the building are different. In a better-planned environment, property buyers would typically like to know whether the building has been constructed according to the City Zoning plan or if the building is likely to be demolished due to wrong sitting.

2.2.3 Encumbrances Class

Encumbrances are defined as the limitations on the rights and use of land. Examples of encumbrances are easements, wayleaves, caveats, cautions or covenants. While easements and wayleaves are topographical features demarcated on the land, the other encumbrances are cautionary measures registered against the property in the land registry. In the Land Administration Model, Lemmen [2012] refers to encumbrances as restrictions. Encumbrances are essential information in the property market to punchers and banks that lend funds against registered land parcels being used as collateral.

In Kenya, easements are precisely surveyed and depicted on deed plans with bearings and distances, while wayleaves are shown as topographical features.

2.2.4 Boundary Beacon Class

Boundary beacons define rights limits under the precise cadastral survey system in Kenya. The Survey Act Part VI defines survey marks, boundary beacons and boundaries established under a precise

Wangari Maathai Foundation, Ministry of Lands and Physical Planning (Kenya) (Kenya) taxation) such as rates, rent, and the ability to purchase a property. During the user assessment needs survey, all the respondents indicated the need to know the property's value. Valuation is also necessary for stamp duty before registering properties in Kenya.

2.2.7 Survey Class

Data from the survey class is the source of information for all other classes in the cadastral model. The primary data required in this class are the name of the surveyor who carried out the survey, the date of submission of the survey to the Director of the survey and the date of authentication, the name of the authenticating officer, computations number, survey plan number and the Part Development Plan (PDP) Number. All this information is contained in the Folio Registry map, which is kept at the Department of Survey in the Ministry of Lands in Nairobi.

In this model, the ParcelID is the Primary Key that links the SurveyClass to the ParcelClass. The attribute Comps No. Identifies the number usually given to the computations submitted by a surveyor to the Director of Survey. This number helps to identify other parameters of the survey plan, such as the Folio Registry Number (FR. No.), in case the plans cannot be located in the records. SurveyorsName is necessary in case of queries on the survey. At the same time, TypeOfSurvey defines the type of survey carried out, e.g., an extension of a lease, a new grant, a subdivision

and many more.

The date identified when the survey was entered into the Survey Records Register in the Office of the Director of Survey. This is important in case of disputes on the date of issuance of deed plans and the authentication dates. In many cases, two clients claim ownership of the same plot, and the date of entry into the register would determine the first person to be allocated the plot, hence the first owner.

The PDPRefNo gives the number of the approved PDP, the date of approval and the persons who approved. In Kenya, all new grants must be accompanied by approved PDP; hence, this reference helps check whether the survey is valid. Under the new Physical Planning Act, only the Director of Physical Planning and the Minister for Lands are allowed to sign the PDPs for new grants. A Registered Physical Planner and the parcel owner are the only persons authorized to sign a subdivision scheme plan or the subdivision PDP for subdivisions.

2.2.8 Registration of Persons Class

The PersonsClass represents the organization that issues Kenya's personal identity cards and passports. These two documents are the official identification documents required for any land transactions. However, currently, there are no maps locating the position of the registered persons, and the registration officials have to depend on the provincial administration personnel or the information from the local authorities or tenants to locate the clients.

Υπουργείο Οικονομικών, Μεταφορών, Υποδομών, Μεταφορών, Ενέργειας και Περιβάλλοντος (Κεφάλαιο 1)

The WaterBillClass was modeled as an aggregate of the BuildingClass as one building may have many Water Bills and is connected to the RegistrationClass through the Building Class. The association is many-to-many, meaning one parcel can have many buildings with different water bills. The ElectricityBillClass is therefore modeled as an aggregate of the BuildingClass as a Building may have many units and hence many power bills to pay. The classclass provides all the necessary attributes for location and efficient readings of the meters. The main attributes include the name of the bill's owner, the owner's address, the bill amount, the meter number, the date of the last payment, and the location by coordinates. The association is many-to-many, and Figure 1.1 shows that the ElectricityClass is related to the RegistrationClass through the BuildingClass.

Therefore, It was necessary to include PersonsClass in the cadastral database to provide the registered persons' location and profile. This way, it would be possible for the government to have adequate data for locating the clients and be able to relate the identity cards with other social attributes. In the UML Diagrams in Fig. 3. The PersonsClass is connected to the parcel RegistrationClass through the OwnershipClass. The PhysicalPlanningClass is directly related to the LandAdministrationClass, the SurveyClass, where the Parcel Number is allocated to the planned and surveyed land parcel. The classclass is then further related to the RegistrationClass through the parcel class. Land Admin.

The Land Administration Class is first related to SurveyClass, the ParcelsClass and then to the RegistrationClass, where land titles are prepared. During the user needs assessment, it was observed that the demand for information in this classclass was the highest. Including the LandAdjudicationClass in the UML diagram gives the government an overview of the attributes and how the system can be modernized. The classclass is directly related to SurveyClass, then to the ParcelsClass and RegistrationClass. The ParkingClass is connected directly to the ParcelsClass and indirectly to the RegistrationClass, as the parking spaces are usually created out of the parcels to be registered and are allocated the Land Registry Number as any other parcels.

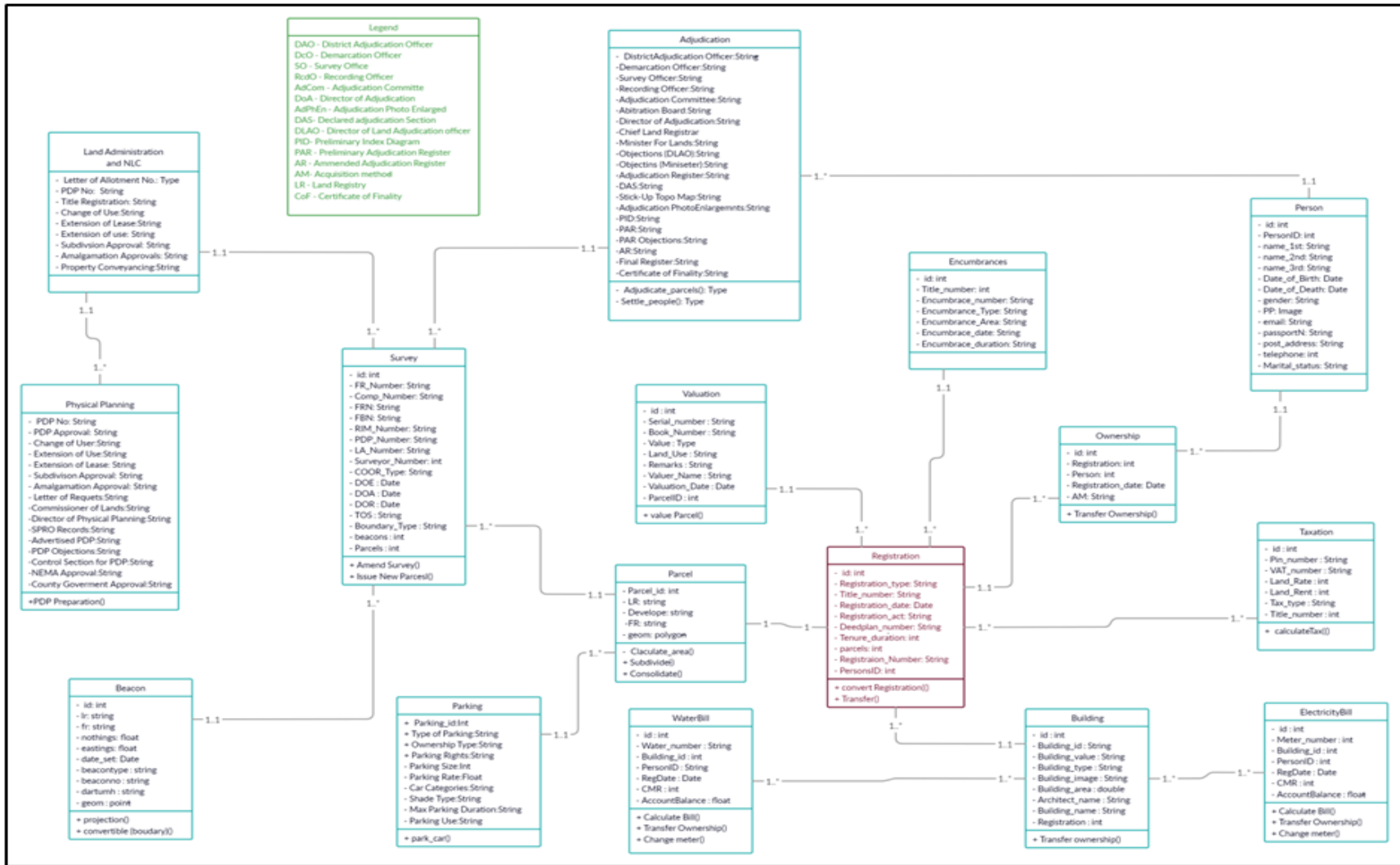


Fig. 3. UML Diagrams for the cadastral classes in Kenya

2.4 Use case diagrams

For the system development, only four users were considered: the visitor, the land owner, the land administration staff/officer, the land professionals, and the land administrators. Fig. 4 shows one of the use case diagrams for landowners. The use case diagrams assist the systems design team identify users and their needs. In this research, the users of the system and their needs were carried out with structured questionnaires implemented by Wayumba (2013). The primary users identified consisted of the visitors to the Land Registry who are interested in various aspects of the Cadastre, land owners who usually want to assess the status of their property, the land administrators involved in the operations of the Cadastre in the land registry, and the land professionals. The use case diagrams were coded in **views.py**, while the user privileges were coded in the decorators, as discussed later in this paper. Flow chart Diagrams were prepared for a few selected use case diagrams to demonstrate the directions of the database operation.

After designing the appropriate UML diagrams and the Use Case Diagrams, the authors designed an empty PostgreSQL (PostGIS) database as it is an Open-Source system capable of handling spatial data better than other available database systems. The Django (Geodjango) was selected as the best back-end framework for data interaction locally and in the Web interface, while the bootstrap4 was selected for the front-end operations.

Web-Based Cadastral Model for Kenya: The Case for Spatially Enabled Land Governance

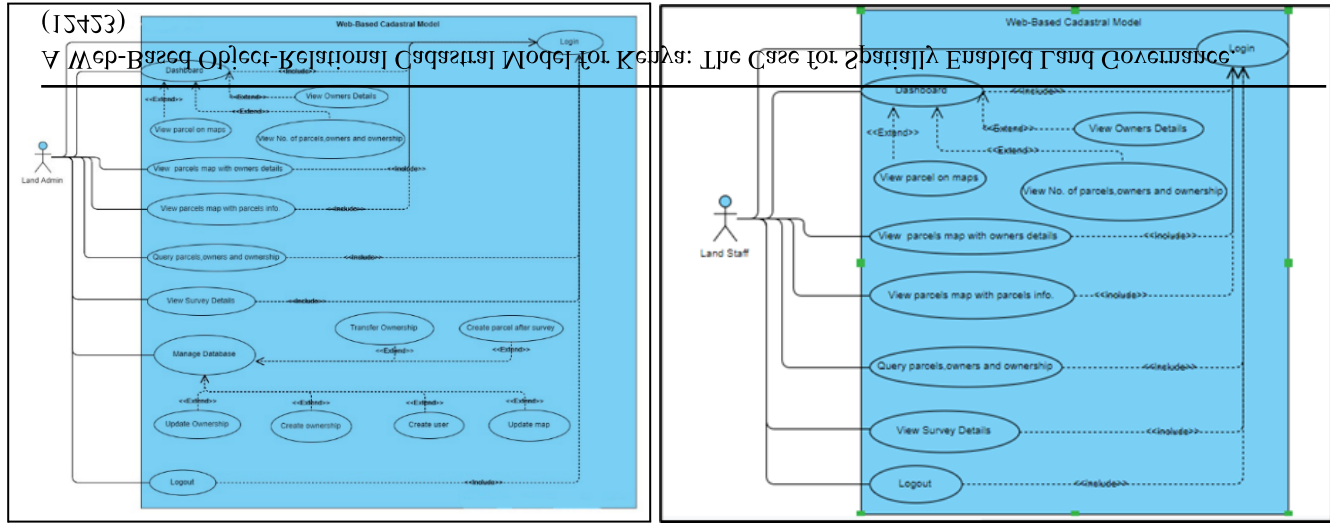


Figure 4: Use case diagram for Land admin super-admin. Figure 5: Use Case diagram for Land administration staff

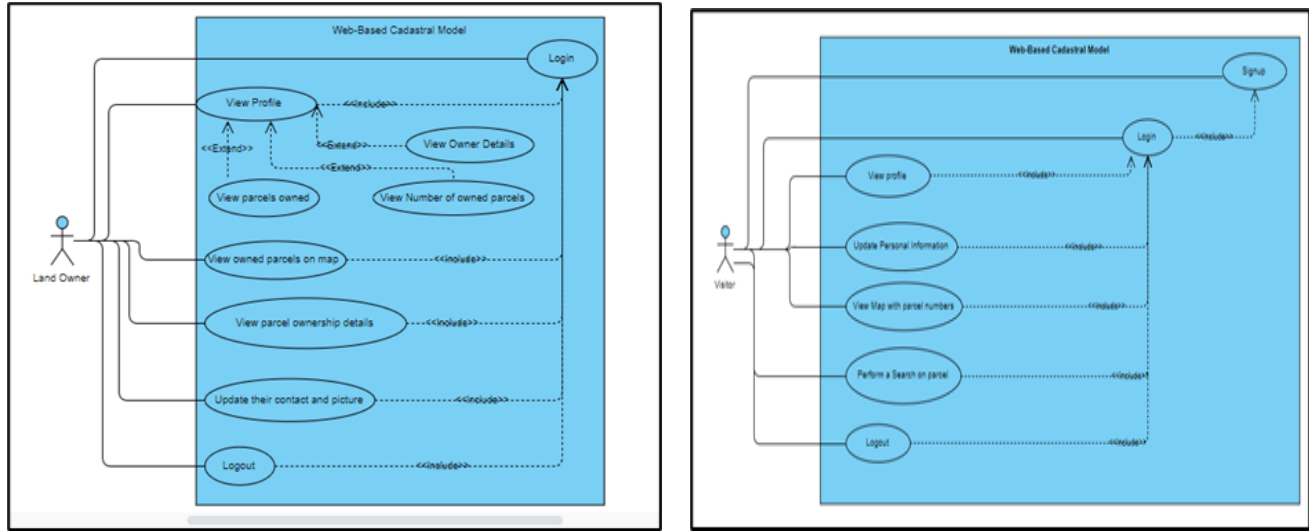


Fig 6: Use Case diagram for land owners. Fig 7: Use case diagram for visitors.

2.5 Coding and Implementation.

In order to convert the UML classes into computer models, a Geodjango application was created to handle the coding processes and import the spatial data into the already-created PostgreSQL/PostGIS database. The spatial data was prepared from survey plans through coordinate transformation and digitization. Consequently, the resulting shape files are populated in QGIS software as fields identified as id, FR, LR, and Development status. After completion of the process, the final data was saved as Esri shapefiles (.shp). To code spatial class data in Django, the GDAL libraries (ogrinfo or inspect) were used to inspect and confirm that the coded data corresponded with the class attributes in the UML diagrams. The Ogrinfo in the GDAL library is generally used to inspect spatial data formats like shapefiles (.shp) or .kml before they can be coded into the Django model.

Μεταφράστηκε από το OpenOffice Writer 3.6.0.1 (Κωδικός: 1034)

```
class Survey(models.Model):
    FR_Number = models.IntegerField(verbose_name='Folio Registry Number',
    null=True)
    Comp_Number = models.IntegerField(verbose_name='computation Number',
    null=True)
    Deedplan_Number = models.IntegerField(null=True, blank=True)
    RIM_Number = models.IntegerField(verbose_name='Registry Index Number',
    null=True, blank=True)
    PDP_Number = models.IntegerField(verbose_name='Part Development Plan
    Number', null=True, blank=True)
    LA_Number = models.IntegerField(verbose_name='Letter of Allotment Number',
    null=True)
    Surveyor_Name = models.CharField(max_length=50, null=True)
    DOE = models.DateField(verbose_name='Date of Entry', null=True)
    DOA = models.DateField(verbose_name='Date of Authentication', null=True)
    TOS = models.CharField(verbose_name='Type of Survey', max_length=50,
    null=True)
    Boundary_Type = models.CharField(max_length=50, null=True)
    beacons = models.ForeignKey('Beacons', on_delete=models.CASCADE)
    Parcels = models.ForeignKey('Parcels', on_delete=models.CASCADE)

    def __str__(self):
        return self.Surveyor_Name
```

Fig. An example of a SurveyClass Spatial Attributes Django Model Class

```
class person(models.Model):
    GENDER = [
        ('M', 'Male'),
        ('F', 'Female'),
        ('O', 'Other'),
    ]
    MS = [
        ('S', 'Single'),
        ('M', 'Married'),
        ('D', 'Divorced'),
        ('SE', 'Separated'),
        ('W', 'Widowed'),
    ]
    PersonID = models.IntegerField(null=True)
    name_1st = models.CharField(max_length=20, null=True, verbose_name='First
    Name:')
    name_2nd = models.CharField(max_length=20, null=True, verbose_name='Second
    Name:', blank=True)
    name_3rd = models.CharField(max_length=20, null=True, verbose_name='Third
    Name:', blank=True)
    Date_of_Birth = models.DateField(null=True, blank=True)
    Date_of_Death = models.DateField(null=True, blank=True)
    gender = models.CharField(max_length=1, choices=GENDER, null=True, blank=True)
    PP = models.ImageField(verbose_name='Upload your Passport Image', null=True,
    upload_to='images/%Y/%m/%d/', blank=True)
    email = models.CharField(max_length=200, null=True, blank=True)
    passportN = models.CharField(max_length=200, null=True, blank=True)
    post_address = models.CharField(max_length=200, null=True, blank=True)
    telephone = models.CharField(max_length=200, null=True, blank=True)
    Marital_status = models.CharField(max_length=2, null=True, choices=MS,
    blank=True)

    def __str__(self):
        return '%d: %s %s %s' %(self.PersonID, self.name_1st, self.name_2nd,
    self.telephone)
```

Fig. An example of a PersonClass a Non-Spatial Attributes Django Model Class
A Web-Based Object-Relational Database Model for Kenya: The Case for Spatially Enabled Land Governance

```
class Ownership(models.Model):
    Method= [
        ('A', 'Allotement'),
        ('I', 'Inheritance'),
        ('P', 'Purchase'),
        ('G', 'Gift'),
    ]
    Registration = models.ForeignKey('Registration', on_delete=models.CASCADE,
null=True )
    Person = models.ForeignKey('Person', on_delete=models.CASCADE, null=True )
    Registration_date = models.DateField( max_length=50, null=True, blank=True )
    AM = models.CharField(verbose_name='Acquisition Method',max_length=1,
null=True, choices=Method, blank=True)
    def __unicode__(self):
        return self.AM
```

Fig. An example of a PersonClass Non-Spatial Attributes Django Model Class

```
68 class Registration(models.Model):
69     Registration_type = models.CharField( max_length=50, null=True )
70     Title_number = models.IntegerField( null=True, blank=True )
71     Title_deed = models.ImageField(verbose_name='Upload title deed image', null=True, blank=True)
72     Deedplan = models.ImageField(verbose_name='Upload Deedplan image', null=True, blank=True)
73     Registration_date = models.DateField( null=True, blank=True )
74     Registration_act = models.CharField( max_length=50, null=True )
75     Tenure_type = models.CharField( max_length=50, null=True )
76     Deedplan_number = models.IntegerField( null=True, blank=True )
77     Tenure_duration = models.IntegerField( null=True )
78     parcels = models.OneToOneField('Parcels',on_delete=models.CASCADE,null=True , related_name='parco')
79     Registraion_Number = models.IntegerField( null=True, blank=True )
80     PersonsID = models.ManyToManyField('Person',
81         through='Ownership',
82         through_fields=('Registration','Person'),
83         related_name='Person')
84
85     def __str__(self):
86         return '%d: %s %s' %( self.Deedplan_number,self.Registration_act, self.Tenure_type)
```

Fig An example of an OwnershipClass Non-Spatial Attributes Django Model Class

```
class Encumbrances(models.Model):
    title_number = models.ManyToManyField('Registration')
    Encumbrace_number = models.IntegerField(null=True)
    Encumbrance_Type = models.CharField(max_length=50, null=True)
    Encumbrance_Area = models.DecimalField(max_digits=50, decimal_places=3,
null=True)
    Encumbrace_date = models.DateTimeField(auto_now=True)
    Encumbrace_duration = models.IntegerField(null=True)

    def __str__(self):
        return self.Encumbrance_Type
```

Fig An example of an EncumbranceClass Non-Spatial Attributes Django Model Class

2.5.1 Migration Between Django Models and Database Tables.

Django, with its object-relational-mapping (ORM) capability and using Python makemigration and migrate commands (Greenfield & Greenfield, 2021), through psycopg2 creates table schemers in the PostgreSQL database from the Django models/classes. The ORM maps model classes into tables in the PostgreSQL (PostGIS) database through the psycopg2 python library. Django uses this library to communicate with PostgreSQL/ (PostGIS) (Fig. 7.). Psycopg2 is only used with the PostgreSQL database. In the case of the other databases, such as Oracle, Spatialite, or MySQL, use Django LayerMapping dictionary or Geojson to read the spatial data and load them into the relevant database tables.

The LayerMapping dictionary provides a way to map the contents of vector spatial data files (e.g., shapefiles, kml files) onto the database. Through Django-admin.py, the remaining non-spatial attribute data in the Django model classes were imported from the Excel sheets and loaded into the PostgreSQL database. This makemigration operation marked the end of creating schemas of all the spatial and non-spatial models into the database as tables, ready for operations in the views.

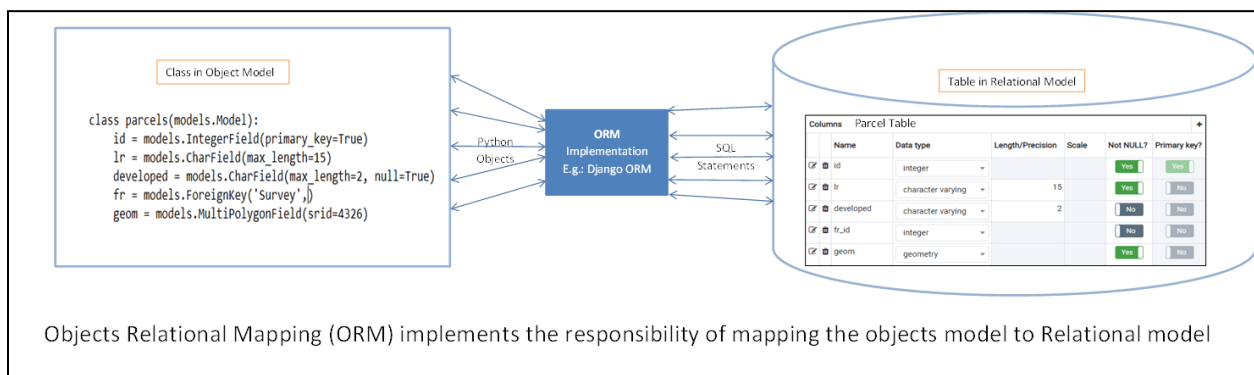


Fig. 7.3 Diagram of Object Relational Mapping of Django generated classes into the PostgreSQL database.
A Web-Based Object-Relational Cadastral Model for Kenya: The Case for Spatially Enabled Land Governance

2.5.2 Display of Cadastral Data from the Database.

The data stored in the PostgreSQL database is retrieved through Django views to retrieve cadastral data from the database and display them on a webpage as maps.API. The Django Views.API enables one to retrieve or query data from the database and keep them ready for any other use in the format chosen by the researcher; under views.py or views.API functions are written to retrieve the data required for the function (e.g., object, filtered object, or all objects) and convert them into a useable ready format, i.e., GeoJayson for cadastral data since these data will be loaded on a web page as maps.

To load cadastral data onto the web page, write a function in Django Views. API is the app for retrieving all data from the PostgreSQL database and presenting them as Geojson. The Geojson cadastral data are kept in virtual storage, ready to be used with any map-loading Library. For example, Leaflet.Js can load Geojson cadastral data onto the web page. Leaflet.Js provides ways to view and interact with maps on a web page for any spatial data to be displayed and /or interacted with in the form of web maps. JavaScript library, e.g.leaflet.js, is used. In this case, the OpenStreetMap (OSM) data is utilized as a base map to show the location of the cadastral information. The Leaflet.Js library can generate attribute information in a parcel as **pop-up views**. Fig. 14. shows the pop-up information in a specific parcel in the study site. This tool can, therefore, be used to display many-to-many relations or any special tenure information in the parcel, such as customary/indigenous/or special rights in a parcel. Currently, there has not been any study showing how other special tenure types can be incorporated into the formal land administration system. This facility provides a means of mapping and displaying these special tenure rights as pop-ups.

After the display of spatial data on the webpage, the users may perform queries. **Django views.API** is used to perform queries from the database. For example, Leaflet.Json is a front-end operator that helps to display spatial data onto the database. Other front-end languages include HTML, CSS, and JavaScript. The Django **views.API** is responsible for retrieving both spatial and non-spatial data from the database and keeping them in a virtual format.

For images, **Django Views.API** does not keep any image in the database but keeps only the location information of the image columns files in the static folders in the database. The folder can then be secured in a Dropbox or Google Drive. **Django Views API** picks the image url and stores it in the database. When there is a need to retrieve the image from the database, Django Views.API calls the image url from the database by following the URL path and retrieving the image.

2.5.3 Serializing the Database Data.


```
(135) def owners(request):  
    queryset = parcels.objects.all()  
    queryset1 = queryset.exclude(parcel__isnull=True)  
    parcel = ParcelSerializer(data=queryset1, many=True)  
    parcel.is_valid()  
    parcel.data  
    return JsonResponse(parcel.data, content_type='json', safe=False)
```

Fig. 9. Using the Serializer in Views.py

```
urlpatterns = [  
    path('owner/', views.owners, name='owner')  
]
```

Fig. 10. The Url.py

2.5.4 Decorators.

The decorators are used to obstruct access to different views and web pages to display data from the database for non-authorized persons. Generally, access to the database data and specific web pages used to display then requires authorization, and the user privileges are coded in the decorators and used to decorate view functions. For example, from the Use Case Diagrams, the people authorized to access the database and what they should access are known. The users who want to access information on parcel ownership have to be authorized as either owners of the parcels or land-administrator. Those who are not authorized are redirected to where to log in and shown empty ownership information through decorator functions.

```
@login_required(login_url='login')  
@allowed_users(allowed_roles=['Admin'])  
def survey(request):  
    survey1 = Survey.objects.all()  
    context = {'survey':survey1}  
    return render(request,'Cadastre/survey.html', context)
```

Fig. 11. Using the Decorators

Μεγιστοποίηση Οφελισμο Βεβαιότητα Μεταπο Ζητήματα Μετακίνηση Βάσης και Ζωνών Αλιείας (Κεφάλαιο 12)

```
(13453) def unauthenticated_user(view_func):  
    def wrapper_func(request, *args, **kwargs):  
        if request.user.is_authenticated:  
            return redirect('home')  
        else:  
            return view_func(request, *args, **kwargs)  
    return wrapper_func  
  
def allowed_users(allowed_roles=[]):  
    def decorator(view_func):  
        def wrapper_func(request, *args, **kwargs):  
            group = None  
            if request.user.groups.exists():  
                group = request.user.groups.all()[0].name  
            if group in allowed_roles:  
                return view_func(request, *args, **kwargs)  
            else:  
                return HttpResponse('You are not authorized to view this page')  
        return wrapper_func  
    return decorator  
  
def admin_only(view_func):  
    def wrapper_function(request, *args, **kwargs):  
        group = None  
        if request.user.groups.exists():  
            group = request.user.groups.all()[0].name  
        if group == 'owners':  
            return redirect('user-page')  
        if group == 'Admin':  
            return view_func(request, *args, **kwargs)  
    return wrapper_function
```

Fig. 12. The Decorators

2.5.5 Testing the Database.

After the development of the system and all operations made available for use, a small section of every user of the system was selected to perform the test on the system and submit their comment for consideration before the full deployment for use. The system was then tailored again based on the user views and comments that were necessary. The result of the system is discussed in the result section with figures.

2.5.6 deployment and maintenance.

This is the final stage of every system development. Our system was then deployed on a cloud server at Heroku (Amondi). The database was managed locally and backed up in Amazon web services so the system can be easily accessed anywhere.

3. RESULTS

Preliminary results show that (i) it is possible to query all the attributes in the classes, including multiple property ownership, encumbrances, taxes due for each parcel, and water and electricity meter readings, just to mention (ii) the Object-Relational models developed in the python Django software can function as a Multi-Purpose Cadastre and a Land Information Management in Kenya. The code presented in Fig. 9. retrieves parcels and ownership data from the relational database, which is then used in the leaflet to display ownership as a pop-up when a parcel is clicked, as shown in the map in

Μαρίνα Τσιφούρη Οδηγήτρια Βεβαιωμένης Μάθησης Ομάδας Μεταπτυχιακών Βοσών και Δασμών Αγρίνης (Κεφάλαιο 17)

Leaflets use the geom in the code to draw the map and the attribute data to display as a pop-up, for example, the information displayed in the pop-up below. The results of these operations are displayed in HTML for visualization. A pop-up can present several property owners in a parcel, displaying many-to-many relationships. It can also display multi-tenure systems or any other multi-user in the Land Administration Systems.

3.1 Dashboard View

Parcels, owners, ownership and survey data were all queried from the database through views in Django. Parcel data were serialized using Django inbuilt gejson serializer since all the properties we used to label the parcels, i.e., LR, were already among the parcels attribute. Retrieved and serialized data were then passed to a template. In the template, the data layout was then designed. A table was used to display the parcels and their respective attributes, and a leaflet was used to display the parcel data on a map.

Μαγιστράς Γεωργίου Οδhiάμβο Βενιαμίν Ματίνι Ζυρε Ουσιγιάς, Γλαβκούχο Βόσκα και Ζαμζου Άλιγι (Κενυά)

(15453)
 V Map-Based Oracle-Βασισμένης Εφαρμογής Μοδελιού για Κενυά: Επεξεργασία Γεωγραφικών Επιστημονικών Δεδομένων

Dashboard Parcels Survey Ownerships Hello, odhiambo Logout

Total Parcels

624

Populations

5

Total Owners

8

Dep No: Developed: FR: Gender: Encumbrances:
 Lease: Owner ID: Owner Name: Age: Marital Status:
 Telephone: Search

Map View

Parcel Information
Hover over a Parcel

Powered by Geosolar | © OpenStreetMap contributors

Parcels

Map View

FR No.	LR No.	Title No.	Deedplan No.	Tenure Type	Owner ID	Owner Name	Owner Address	Owner Tell.
339/32	26699/751	75421839	29996684	Leasehold (99)	30807475	Benard Odhiambo Odhiambo	P.o.box 53567 NRB	0734563157
339/32	26699/753	1254367	4523670	Leasehold (99)	2143158	Janet Moraa Makori	P.o.box 1565 Nairobi	0734565271
339/32	26699/752	865432	3648127	Leasehold (99)	2143158	Janet Moraa Makori	P.o.box 1565 Nairobi	0734565271
339/29	26699/494	3642574	7132645	Leasehold (99)	2143158	Janet Moraa Makori	P.o.box 1565 Nairobi	0734565271
339/32	26699/752	865432	3648127	Leasehold (99)	30807475	Benard Odhiambo Odhiambo	P.o.box 53567 NRB	0734563157
None	26699/828	1425874	8754868	Leasehold (99)	7845712	Patrick ochiang wando	p.o.box 14284 kisumu	0748512785
None	26699/550	7540967	365407	Leasehold (99)	33487526	Ornyangu Geoffrey Wendolo	P.O.Box 24315-14502	0714578962
None	26699/575	111000	1110001	Leasehold (99)	7845712	Patrick ochiang wando	p.o.box 14284 kisumu	0748512785

Fig. 13. Presents various Dashboard views containing:

3.2 Ownership Map View

A Web-Based Object-Relational Database Model for Kenya: The Case for Spatially Enabled Land Governance

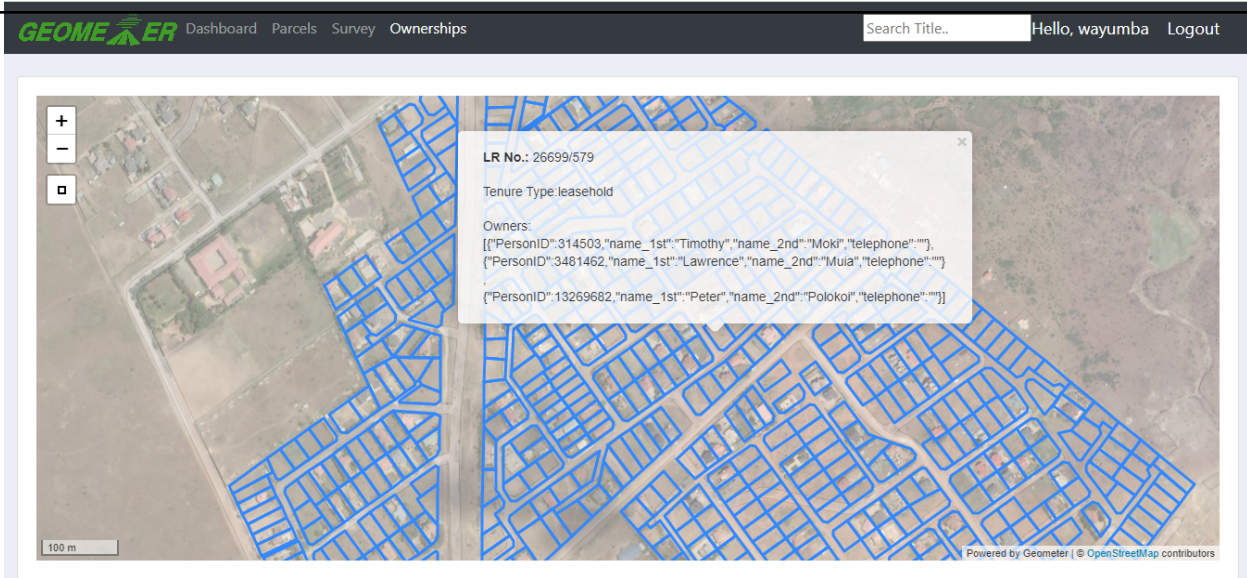


Fig. 14. shows the retrieval of ownership from the parcels class in the database as ManyToMany ownerships in a pop-up fashion.

The Pop-Up shows the Parcel L.R.No. Under reference, the names of the multiple owners, the tenure of the property, and their Identification card numbers. The method involved in querying the ownership view involves the following steps: (i) A nested-serializer was used to pass the parcel ownership details to the parcel class so that the parcels could be viewed on the digital map of the study site. The map was already loaded onto the PostGIS database through the leaflet operation. (ii) the parcel data was queried from the database and serialized using the developed serializer to display the multiple ownership details. (iii) the data was then served as geojson to the template, (iv) Leaflet was then used to display the geojson data and pop-up ownership details on the click of an open street map (OSM) and satellite image.

3.3 Survey view

Survey data was queried from the database and passed to the survey template for viewing and interaction. In the template, the data were displayed in a table format showing different attributes of the survey. A button was provided for viewing the survey map as an image in a different template, as shown in Fig. 16.

Wangari Gichuru Ombiano Bwana Makori Zina Ombiwa Mwakombo Bosa na Zinao Achi (Kwara)

A Web-Based Object-Based Cadastre Model for Kenya: The Case for Digitally Enabled Land Governance

Surveys


FR_Number	Comp_Number	File Reference Number	Field Book Number	Licence Suveyor No.	Coordinate Type	Date of Authentication	Date of Registration	Type of Survey	Boundary Type	FR Map
339/29	54146 VOL I-IV	CT/221/71/77	13301/VOL I -II	143	UTM	Nov. 8, 2006	Sept. 18, 2006	Subdivision	None	FR Map
339/32	54/46 VOL I-III	CT/221/71/77	13301 VOL I -IV	143	UTM	Nov. 8, 2006	Sept. 18, 2006	Subdivision	Fixed	FR Map
339/33	54/46 VOL I-III	CT/221/71/77	13301 VOL I -IV	143	UTM	Nov. 8, 2006	Sept. 18, 2006	Subdivision	None	FR Map
339/28	54146 VOL I-IV	CT/221/71/77	13301/VOL I -II	143	UTM	Nov. 8, 2006	Sept. 18, 2006	Subdivision	None	FR Map

Fig. 15. shows a survey details views in the admin account.

3.4 Owner views

Profile view

GEOME ER Profile View Map Settings Hello, janet Logout



Contact Information

ID No: 2143158
 Name: Janet Moraa Makori
 Address: P.o.box 1565 Nairobi

Total Parcels

3

Parcel Number	Deedplan Number	Title Number	Tenure Type	Tenure Duration	More Information
26699/494	7132645	3642574	Leasehold	99	More Info
26699/752	3648127	865432	Leasehold	99	More Info
26699/753	4523678	1254367	Leasehold	99	More Info

Fig. 17. Land owner profile page with the plots owned and their attributes.

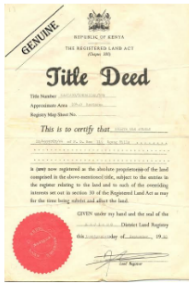
Ownership data was retrieved from the database using a query based on the logged-in user's primary key to get only data specific to the user. Owner data were also retrieved from the database. Counting is done on owned properties. Data was passed to the profile template, whose layout was designed as shown in Fig. 17. above with the help of bootstrap4, HTML, CSS and JavaScript. A button is provided for each owned property to display more details of the specific property on a different template, as shown in Fig. 18.

Αναμενόμενα Αποτελέσματα: Μετά την ολοκλήρωση της εφαρμογής, οι χρήστες θα μπορούν να παρακολουθούν και να ελέγχουν τα αποτελέσματα της διαδικασίας (Κεφάλαιο 13)

GEOMEER Profile View Map Settings Hello, Janet Logout

Αναμενόμενα Αποτελέσματα: Μετά την ολοκλήρωση της εφαρμογής, οι χρήστες θα μπορούν να παρακολουθούν και να ελέγχουν τα αποτελέσματα της διαδικασίας (Κεφάλαιο 13)

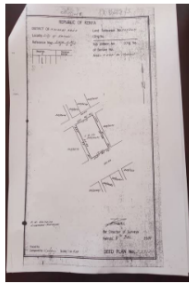
Title Deed Image



Parcel Information

Fr No: 339/29
 Deedplan NO.: 7132645
 LR No: 26699/494
 Title No.: 3642574
 Reg date: Feb. 15, 2012

Deedplan Image

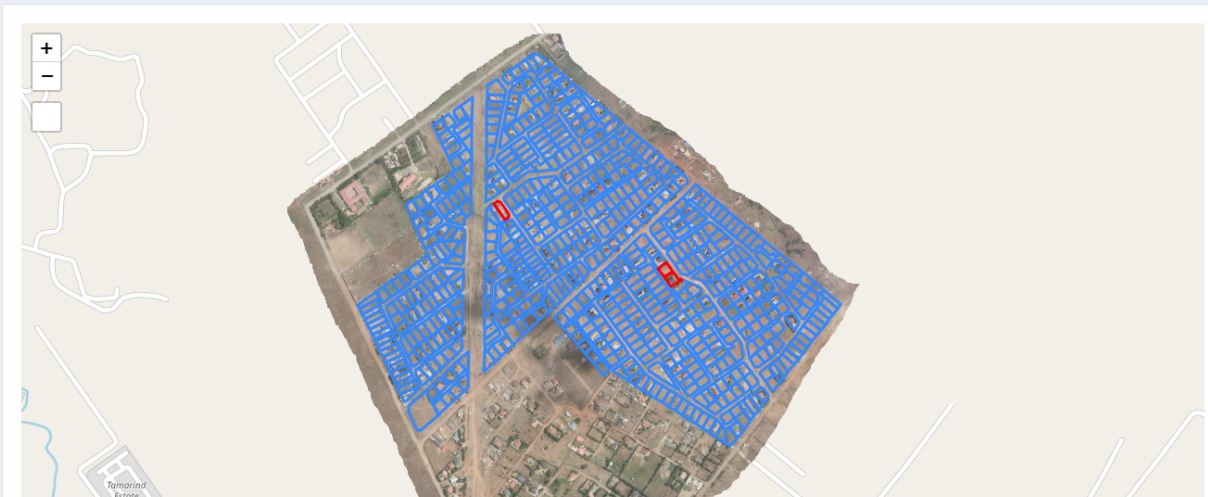


ID No.	Name	Address	Telephone	Ownership Duration
--------	------	---------	-----------	--------------------

Fig. 18. Land parcel registration details views.

Owned parcel map view.

GEOMEER Profile View Map Settings Hello, Janet Logout



The image shows a satellite map of a residential area. A large portion of the map is overlaid with a blue grid representing land parcels. Two specific parcels within this grid are highlighted with red outlines, indicating they are owned properties. The map includes standard navigation controls like zoom in (+) and zoom out (-) buttons in the top left corner.

Fig. 19. Map showing owned parcels highlighted in red overlaid on a satellite image.

All parcel objects were queried and serialized as geojson and passed to the owner-map template using a leaflet. The geojson were displayed on a map, and owned parcels were highlighted based on their LR number from the owned properties list.

4. CONCLUSIONS

~~A Web-Based Object-Relational Cadastral Model for Kenya: The Case for Spatially Enabled Land Governance~~
Kenyan LADM country profile has been extended and used to develop a Web-based Object-Relational Cadastral model prototype that supports access to cadastral information through the Web anywhere in the world. This system can be adapted to other developing countries facing similar constraints to Kenya and, through this, enhances the transparency of land information to the world, increasing security. This system can be extended to a 3D cadastral system to complete it. The authors believe that the Ministry of Lands in Kenya can adopt and implement this prototype database at the government's National and County levels.

5. ACKNOWLEDGMENT

The authors acknowledge the Technical University of Kenya for availing some of the laboratory facilities to prepare the paper.

6. FUNDING

The paper was prepared purely from the funds contributed by the authors themselves.

7. AUTHOR CONTRIBUTIONS:

Benard O. Odhiambo investigator, field task, web-application development (60% of the paper)

Gordon O. Wayumba, reviewer, consultant, and document (40% of the paper)

8. REFERENCES

- ISO 19152 (2012).** Geographic information - Land Administration Domain Model (LADM), version 1 December 2012.
- Lemmen, C. (2012).** A Domain Model for Land Administration. PhD Thesis. DelftUniversity of Technology, Delft, the Netherlands.
- De Soto, H., (2000).** The Mystery of Capital. Why Capitalism Triumphs in the West and Fails Everywhere Else, Basic Books, New York, USA.
- Greenfield, D. R., & Audrey Roy G(2021).** Two Scoops of Django 3. x: Best Practices of Django Web Framework. Two scoops press, 2021.
- Kuria, D.N., Moses, M.N., Caroline, G., Charles N. M., (2016).** A Web-Based Pilot Implementation of the Africanized Land Administration Domain Model for Kenya. A Case Study of Nyeri County. Journal of Geographic Information Systems, 2016, pp. 8, 171–183. <http://www.scirp.org/journal/jgis>
<http://dx.doi.org/10.4236/jgis.2016.82016> (Accessed on 10th June 2021).
- Ministry of Lands, 2009:** Sessional Paper on National Land Policy, August, 2009. Government Printer, Nairobi, Kenya.
- Ministry of Lands, 2011:** A Report on Re-Engineering of the Ministry's Business Processes. Ministry of Lands, Nairobi.
- Nyadimo, E., (2006).** Cadastral Data and Process Modelling Using the Unified Modelling Language A

Wayumba, G. O. (2013). An evaluation of the cadastral system in Kenya and a strategy for its modernization. PhD Thesis, 08 2013. UoN Digital Repository, University of Nairobi, <http://erepository.uonbi.ac.ke/handle/11295/56366?show=full>.

Westra, E. (2016). Python Geospatial Development. Third Edition ed., Birmingham, packt publishing, 2016.

Amondi, Grace (2019). "Deploy GeoDjango application to Heroku." Medium, 2019. <https://medium.com/the-geospatials/deploy-geodjango-application-to-heroku-in-2019-part-2-f553812d7b4c/>. Accessed 5th october 2021.

Django Documentation 3.2 (2021). Geodjango Retrieved from [GeoDjango](https://docs.djangoproject.com/en/3.2/ref/contrib/gis/). 23rd September 2021

9. ADDITIONAL READING

In this section, please provide a list of 3-6 additional readings (e.g. journal articles, book chapters, case studies, etc.). As the contributing author(s), you are the best source for suggestions on additional readings in your field.

10. KEY TERMS AND DEFINITIONS

Equity: A system of jurisdictions ensuring the quality of fairness within a society or a territory.

Web-Based: System which can be assessed through a web browser.

Object Relational: Relational database, but with an object-oriented database model: objects, classes and inheritance are directly supported in database schemas and the query language.

Land parcel: The land parcel is identified as the building block of each land administration system.