THE APPLICATION OF ENTITY-RELATIONSHIP MODEL IN THE DESIGN OF AN INTEGRATED DATA-DRIVEN LAND ADMINISTRATION SYSTEM

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ABSTRACT

The emerging open market philosophy, the decline in oil revenue, and the increasing environmental considerations have renewed the need to improve land administration systems, particularly in the developing countries. These countries cannot continue to treat land resources as a common good nor used colonial infrastructure which have proven inadequate and sometimes inappropriate in meeting modern land administration demands. Each country would need to design its land administration system to meet its present and future requirements using appropriate and affordable infrastructure. The paper proposes the use of Entity-Relationship Model (ERM) for the design of an Integrated Data-Driven Land Administration System (IDLAS). The use of entity-relationship model in business management and manufacturing industry as a design tool is well founded. The model presents the following advantages to land administration development:

- *It incorporates semantic information about the land;*
- *It can be used to achieve a high degree of data dependency;*
- *It facilitates the derivation of the database schema required in an automated land administration system;*
- *It provides a holistic view of data within a system.*

Using Trinidad and Tobago as a case study, the paper uses entity-relationship diagrams as tools in the design of land administration. The various design steps are presented at the corporate and domain levels.

1.0 LAND ADMINISTRATION: AN INFORMATION SYSTEM PERSPECTIVE

Land administration can be defined as *the planning, organisation, coordination, and control of land resources towards the development of a society* (Opadeyi, 1995). These characteristics of land administration can be appreciated from a system perspective. A *system* is a group of elements, either physical or non-physical in nature, that exhibits a set of interrelations among themselves and interact together toward one or more goals (Alexander, 1974). A system resides within its boundaries and operates in a defined environment. The environment consists of those things that have impacts on the operations of the system. Land administration is a system because it has four main functional components: *land policy, land tenure administration, land use management, and land (property) taxation* which act as a whole to perform the common goals of land administration. Each of these components may itself be perceived as sub-systems with their own domain, for example, the cadastre sub-system (Dale, 1979).

Land administration systems operate within an environment of a known fixed quantity of land with its accompanied social and economic variables, e.g., land-squatting, housing development, agricultural and infrastructural development. The magnitudes of these variables affect the four components. **Figure 1** provides a system view of land administration. The system boundary is depicted by the square-edged box while the round-edged box contains elements of the system environment. Land administration is a large system comprising of subsystems and other related systems, e.g., planning system, property valuation system, estate

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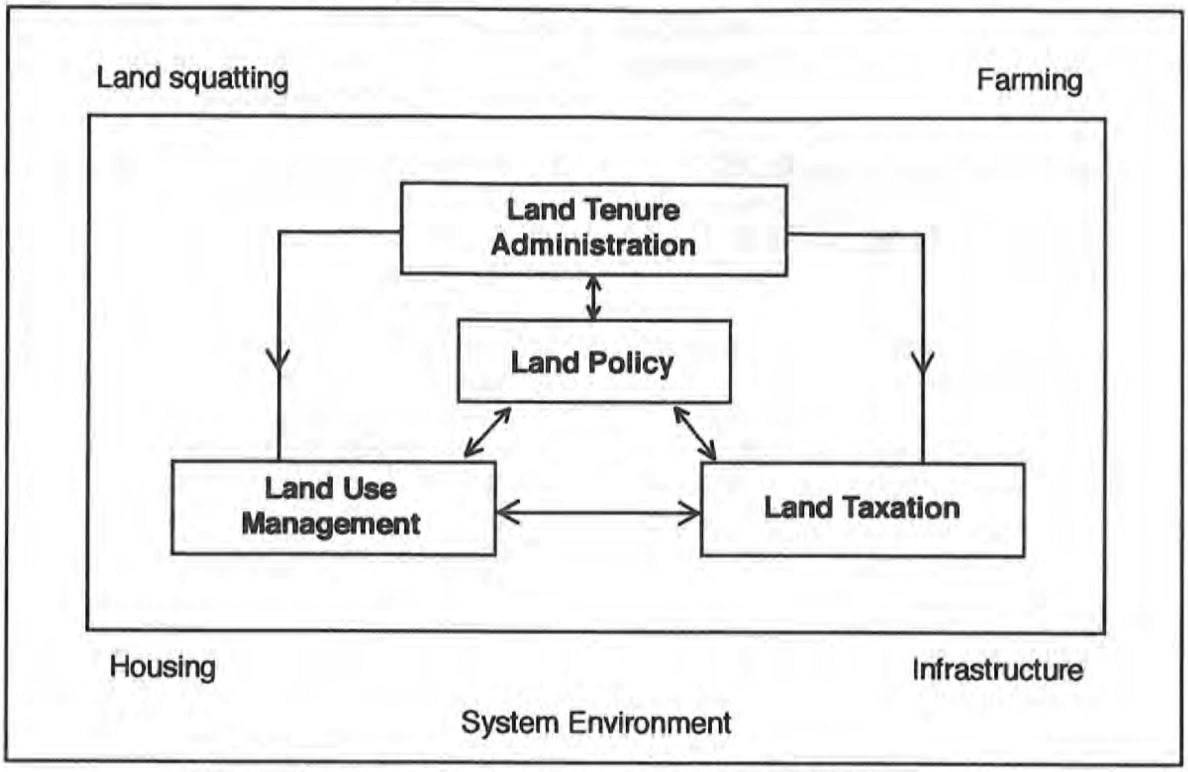

Figure 1: **A System View of Land Administration**

management system, and land registration system. These subsystems can be integrated into the larger land administration system in order to improve efficiency and performance.

The system view may be extended to an *information system* view. An information system has the objective of *collecting, processing, storing, retrieving, manipulating, and disseminating information in support of a set of required tasks.* An information system perspective of land administration can be conceptualised if the relationships between the components are perceived as mainly the exchange of information about the different land-related issues. The components require an adequate supply of data from the other components so that they can perform at optimal level. Any break in communication between any of the components could lead to a collapse of the system. In an information system environment, therefore, the objective would be to collect, process, manipulate, store, retrieve and distribute information in support of land administration activities.

2.0 DESIGN ENVIRONMENT FOR AN IDLAS IN DEVELOPING COUNTRIES

The system environment can be viewed through the economic, institutional, and technological conditions of a typical developing country (Dunkerley, 1986; Holstein, 1990). The environment is characterised by:

- (a) Weak and declining economy;
- (b) Existence of old, sometimes unreliable but valued land records;
- (c) Growing dependency on land resources;
- (d) Influence of social and cultural factors in respect to land use and land tenure;
- (e) Inappropriate legislation and regulations governing land administration; and
- (f) Lack of technical support for technological repairs and maintenance.

Against this background, the system should be designed to accommodate the weaknesses and to expand the potentials of the user. The selective and systematic introduction of new ideas and new technology is needed to ensure the non-disruption of the existing system.

2.1 Design Objectives of an IDLAS

An integrated data-driven land administration system (IDLAS) shall be designed with the following set of objectives. It should:

(a) Promote effective data acquisition support for land administration;

(b) Provide for efficient coordination in the demand, use, processing, and dissemination of land-related data among land administration agencies;

(c) Ensure that land administration components are adequately provided with relevant and current data in support of their respective functions.

2.2 Design Criteria of an IDLAS

Five design criteria shall be considered in the design and implementation of an IDLAS. These are:

- Appropriateness
- Flexibility
- Expandability
- Affordability, and
- Compatibility

2.3 Need for an Integrated Approach

One of the problems of land administration in general is the inability of its components to operate as a whole. Possible reasons for this include the introduction of the components at different times in the life of a country, their establishment in different agencies or at different levels of government, and unequal support being provided either financially or politically. An integrated approach requires the identification of all the components and the inclusion of these components in the design process. Integration provides a holistic approach to the design and operation of the components. Integration demands that resources are equitably shared among the components. In an integrated environment, it is possible to assess the contributions of the component.

2.4 Need for a Data-Driven Approach

Most of the existing land administration systems are process-driven. Process-driven approaches first describe the dynamics of the system, i.e., functions or activities, and then the information requirements of the system are derived for each of the functions. This approach anticipates user transactions or activities and derives data semantics which would fit those transactions. Unlike the process-driven approach, the data-driven approach first examines the data structure on the basis of the general information semantics of the system. This allows the users to be flexible in their business functions.

The data-driven approach assumes that land data is the main resource of all land-related agencies. Data holds the key to all the administrative activities on land. Once information that reflects the historic and current conditions of a land parcel is available, land administration functions become a decision-making process by breaking down the barrier of "data exclusiveness" typically found in the land administration systems of most developing countries. A data-driven approach is one in which the input of data initiates processes that transform the input data from one state into another (Shelly et al., 1991). Planche (1992) advanced the following benefits of a data-driven approach. It:

(a) Yields a more efficient development process and system which are easier to operate and to maintain;

(b) Promotes a comprehensive view of the system and, hence, enables investigation into the system;

(c) Provides an orderly and consistent framework throughout the system's development life cycle;

(d) Promotes the modularity of system components thereby minimising interaction required to develop each component;

(e) Provides consistency in the architecture of the components by providing that data be collected and stored independent of a particular requirement of a single component but consistent with the general requirements;

(f) Provides a basis for the development of a corporate strategy to meet the data needs of all the components of the system.

An example of a data-driven system is illustrated in **Figure 2**. Given as input data: the names of owner(s) of a land parcel, the nature of the tenure rights existing on the land, and the location of the parcel; land adjudication and land registration processes would transform these input data into information: the land title. These processes, however, are driven by the availability of appropriate sets of data failing which, the land adjudication and land registration processes shall be rendered ineffective or inefficient.

3.0 LOGICAL DESIGN OF AN IDLAS USING ENTITY-RELATIONSHIP MODEL

The use of modelling techniques in the development of land administration components is gaining popularity. Gillis (1993) used data modelling techniques (entity-relationship model and object-oriented model) to design a relational database for data generated from global positioning systems. Williamson and Hunter (1990) argued for the use of conceptual modelling in the design of land information systems because of the ability of the models to provide a framework for organising, simplifying, and predicting the systems. Object-oriented logical models were developed for cadastral information by Kjerne and Dueker (1986). Zhang and Robinson (1990) and Von Meyer (1989) used entity-relationship diagrams to develop the conceptual models of cadastral databases. Dangermond and Freedman (1989) also applied the conceptual model in the design of a municipal geographic information system database. In support of modelling techniques, Planche (1992, p. 23) concluded that *"modelling techniques ensure that the conceptual model satisfactorily captures the essence of a domain, and that subsequent logical and physical models suitably utilise the wealth of information present in the conceptual model."*

Information system development concepts and modelling techniques can be used in the design of an integrated data-driven land administration system (IDLAS). The entity-relationship models have the capacity to depict the components of logical models of a system. It also provides a consistent approach towards any future modification of the system without any disruption of the original design (Planche, 1992). The basic principles of this diagrammatic modelling technique and the actual entity-relationship diagram of an IDLAS are provided below.

To begin with, a model of land administration system must be built. A model of a system is built to provide a representation which will give an insight into some aspects of the system. The level of insight required dictates the level of abstraction of the model. There are three levels of abstraction: the physical model, the logical model, and the conceptual model. The *physical model* describes the system in terms of data requirement, data processing, and data processing resources. It involves the detailed specification of hardware and software required by the system. It is also called the implementation model. The *logical model* focuses on the components of the system and the connections between these components. It addresses the data requirement of the system. It is independent of the data processing resources, whether manual or automated. It depends, however, on the

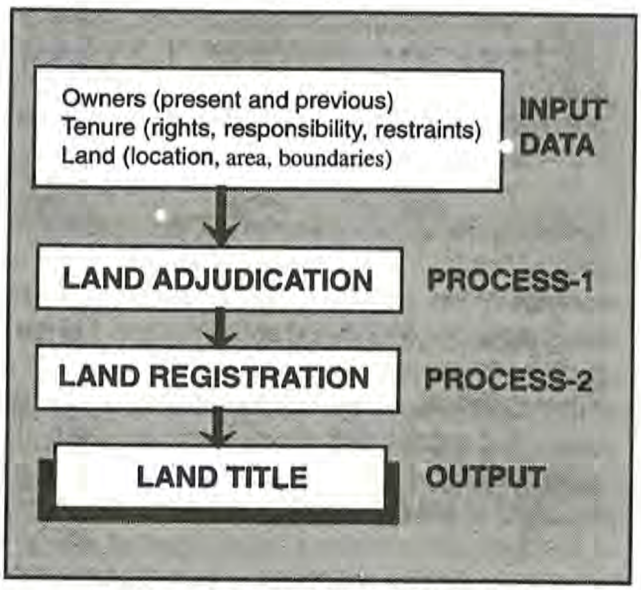

Figure 2: **A Typical Data-Driven Land Titling System**

institutional structure, i.e., the system environment within which it operates. It is also referred to as the data modelling phase for it provides a knowledge of the data required. Its results are used to design the databases and files of the system. The *conceptual model* provides insight into the flow of data among the components of the system, as well as describes the data processing requirements of the components. It is not affected by the institutional structure of the system (Rock-Evans, 1992).

4.0 PRINCIPLES OF THE ENTITY-RELATIONSHIP DIAGRAM

The entity-relationship model was introduced by Chen (1976), and it has since been enhanced by Smith and Smith (1977) and Codd (1979) in particular. The entity-relationship model has four main advantages which makes it consistent as a logical design tool (Chen, 1976). It:

(a) Incorporates semantic information about the real world;

(b) Can achieve a high degree of data independence;

(c) Facilitates the derivation of the database schema; and

(d) Provides a holistic view of data within a system.

Its use in the design of a land administration system is influenced by two main objectives:

(a) To provide an accurate model of the information needs of the organisation which will act as a framework for development of new or enhanced systems;

(b) To provide a model which is independent of any data storage and access method, so that objective decisions can be made about the implementation techniques and coexistence with existing systems.

The use of the sentity-relationship diagram (ERD) to illustrate the entity-relationship model is widely recognised. ERD was defined by Planche (1992, p. 27) as *"a symbolic representation of a real-world domain which allows the structuring of information about categories of 'things' in the domain."* The use of ERD in the design and modelling of a system is based on the assumption that the real world can be described in terms of entities and entity types, relationships and relationship types, and attributes.

An *entity* is a collection of things which are identifiable and are important to the information system of the organisation. Examples of entities in the land administration domain are land, land-owner, and land tenure. These are real and identifiable features in a land administration system. Entities can be grouped into *entity types* so as to allow for the factoring out of common characteristics. Veryard (1992) provides four conditions that a collection of things must fulfill to be classified as an entity type with a model:

(a) There must be a clear boundary between the occurrences of the entity type and the rest of the system domain;

(b) The properties of the entities of interest to the system must be similar in the system domain;

(c) Entity occurrences must be identifiable in a standardised manner, and must be distinguishable as an individual;

(d) The occurrences of the entity must play similar roles in the system domain.

For instance, *State land* is an entity of type *land tenures*. An entity must have occurrences. These are individual members of the collection represented by the entity which distinguishes one from the other. The total number of occurrences is called the population of an entity. Hence, the total number of state lease land parcels in a country will correspond to the population of the entity type state leased land. An entity type is represented by a rectangular box, relationship type is represented by an oval-shaped circle, and relationships are represented by solid lines connecting the entity types. A diagrammatic model of the relationship type between entity types *land* and *person* is shown in **Figure 3**.

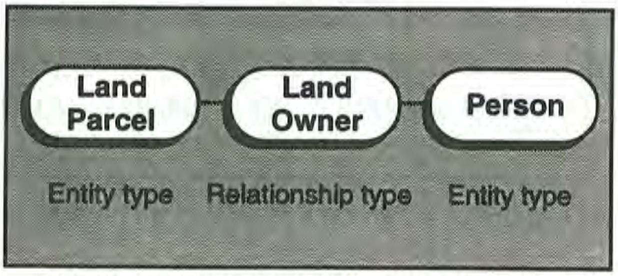

Figure 3: **Diagrammatic Representation of an Entity-Relationship Model**

A *relationship* is a collection of similar interactions which exist between entities. For instance, "land-owner" has a relationship between two entity types - *land* and *persons*. Chen (1976) provides five important characteristics about relationships between entities:

(a) A relationship can connect two or more entity types as shown in **Figure 4**: a *person registers* the land title in the land registry; the *Bank registers* the Bill of Mortgage in the *land registry*.

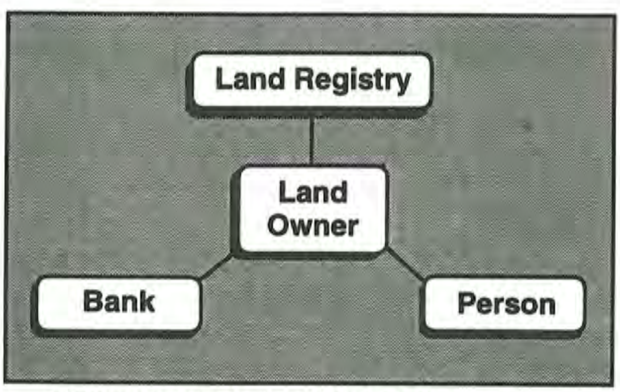

Figure 4: **A Relationship between Two or More Entity Types**

(b) A relationship set may be defined on only one entity type as shown in **Figure 5**.

(c) There may be more than one relationship type defined on a given entity set. In **Figure 6**, a land occupier may be different from the land owner.

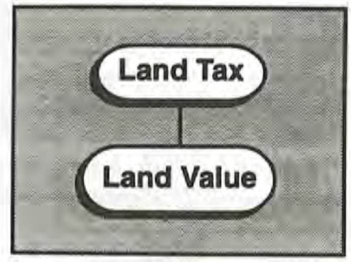

Figure 5: **A Relationship Set on a Single Entity Type**

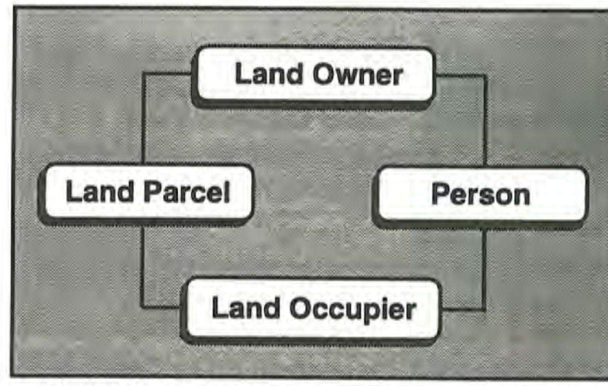

Figure 6: **More than One Relationship on a Given Entity Type**

(d) A relationship type can have three types of cardinalities: one-to-one (1:1), one-to-many (1:m), and many-to-many (m:m). The cardinality rule provides the degree of occurrences permitted for a given occurrence of an entity type in a relationship type as shown in **Figure 7**:

Cardinality	*Examples*
1:1	One land registry and one land valuation office.
1:m	One land registry registers many land parcels.
m:n	Several land parcels may be owned by more than one person.

(e) The diagram can express the existing dependency of one entity type on another. The existence of an entity in the entity type *Bank* depends on the corresponding entity of the entity type *land owner*. When the land owner

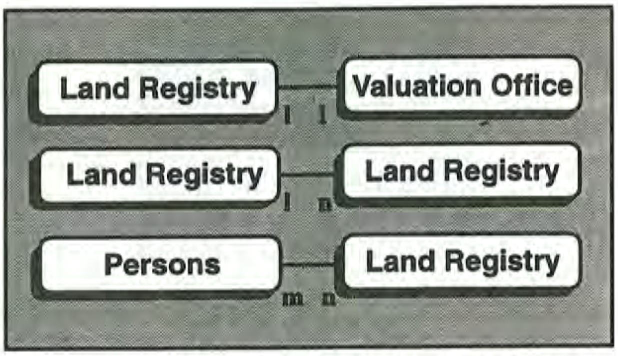

Figure 7: **Cardinalities of Relationships**

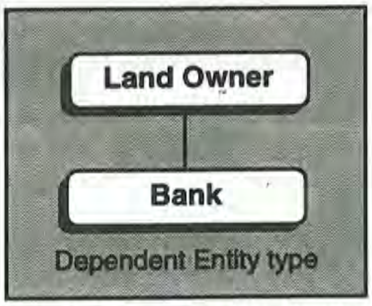

Figure 8: **Dependent Entity Type**

has fulfilled the required financial obligations, the entity type *Bank* will be dropped off the system; as shown in **Figure 8**.

An *attribute* is an item of information which describes an entity or a relationship. For example, the entity type *land* may have the following attributes associated with it: parcel number, area, location, owner. An attribute should have a domain, i.e., a set of possible or permissible values. **Figure 9** shows the attributes of the entity types *land* and *person*. The four stages in the design of a system using the ERM are (Chen, 1976):

(a) Identification of the entity types and the relationship types between them;

(b) Identification of the cardinalities between the relationship types and the entity types;

(c) Definition of the attributes and values set for each entity type; and

(d) Development of the ERD and decision on primary keys.

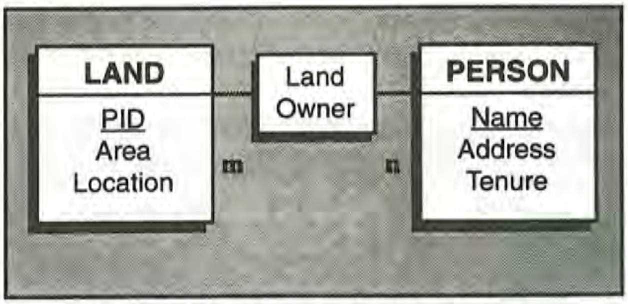

Figure 9: **A Typical ERD of Entity Types: Land and Person**

5.0 ENTITY-RELATIONSHIP MODEL OF AN IDLAS AT CORPORATE LEVEL

The functional components of land administration in Trinidad and Tobago are: land tenure administration, land use management, land policy, land taxation, land inventory and land evaluation (Opadeyi, 1995). In this design, two levels of designs shall be developed: a corporate level and a domain level. The corporate level, according to Planche (1992, p.6), *"provides high level overviews of the systems and are the basis for developing long range systems plans."* The domain level is an expansion of the corporate level for specific functional domains. The two provide the domain architecture which is required for the physical design. **Table 1** and **Figure 10** show the matrix of these entity types and their ERD respectively at the corporate level.

The cardinalities of the relationships are represented using the letters n and m, both of which indicate *many* relationships, and the number 1 which indicates *one*. The attributes of the entity types are presented as A1, A2, ..., and A6 while their representative values are shown in **Table 2**. The primary keys of the entity types are the underlined attributes. The relationships are represented as R1, R2, ..., and R11 while their definitions are given in **Table 3**. *Land inventory* (LInv.) collects baseline data on the natural and physical state of the land, collates the data, and distributes them to the other entities in the system (LUM, LEva, and LPy). *Land evaluation* (LEva) monitors the state of the land resources and evaluates it against current or proposed use, as well as its capability for other uses. It proposes land management mechanisms that will sustain the land based on its evaluation. It also distributes its outputs to the various other entity types (LUM and LPy).

ENTITIES	LPy	LTA	LUM	LTx	LInv.	LEva.
Land policy (LPy)	-	R4	R5	R11	R2	R3
Land tenure administration (LTA)	-	-	R8	R7	-	-
Land use management (LUM)	-	-	-	R6	R9	R10
Land taxation admin. (LTx)	-	-	-	-	-	-
Land inventory (LInv.)	-	-	-	-	-	-
Land evaluation (LEva.)	-	-	-	-	-	-

Table 1: **Matrix of Relationships between the Entity Types: IDLAS**

ENTITY TYPE	ATTRIBUTES
A1	Land use, land taxes, land tenures, admin. boundary
A2	Parcel ID, area, owners, tenure type
A3	Parcel ID, owner, approved use, current use
A4	Parcel ID, property value, property tax
A5	Rivers, swamps, coastlines, vegetation, admin. boundary
A6	Wetlands, watersheds, erosion, deforestation, admin. boundary

Table 2: **Attributes of Entity Types in Figure 10**

R1	Provide inventory data.
R2	Provide inventory data.
R3	Provide evaluation data.
R4	Provide land tenure policy requirements.
R5	Provide land use policy requirements.
R6	Share land use and land value data.
R7	Share land tenure and land value data.
R8	Share land use and land tenure data.
R9	Provide land inventory data.
R10	Provide land evaluation data.
R11	Prescribe land taxation requirements.

Table 3: **Definitions of the Relationship Types in Figure 10**

Land policy (LPy) provides the business rules for the land use management, land tenure administration and the land taxation entity type using some prescribed sets of guidelines. *Land Use Management* (LUM) ensures that the land resources are utilised to meet the national development plans and for some other economic, productive, or sustainable purposes. Land Tenure Administration (LTA) is responsible for the provision and protection of tenurial rights recognised by the system. *Land Taxation* (LTx) is the economic driving force of the system, which depending on the land policy objectives encourages or discourages land use activities within the system.

The entity-relationship diagram of two domain levels: the land tenure administration and the land use management shall be illustrated. These two are considered to be the most dynamic components in a land administration system. On a time scale, they may be considered to be active while the others are passive.

6.0 ENTITY-RELATIONSHIP MODEL FOR LAND TENURE ADMINISTRATION: DOMAIN LEVEL

The ERD for the land tenure administration at the domain level is shown in **Figure 11**. The entity types identified are the following: *previous owner, conveyancer, owner, land registry, land tax office, land surveyor,* and *land*. The domain level design, however, is connected to corporate level entity types *land policy* (LPy), *land inventory* (LInv.), and *land evaluation*

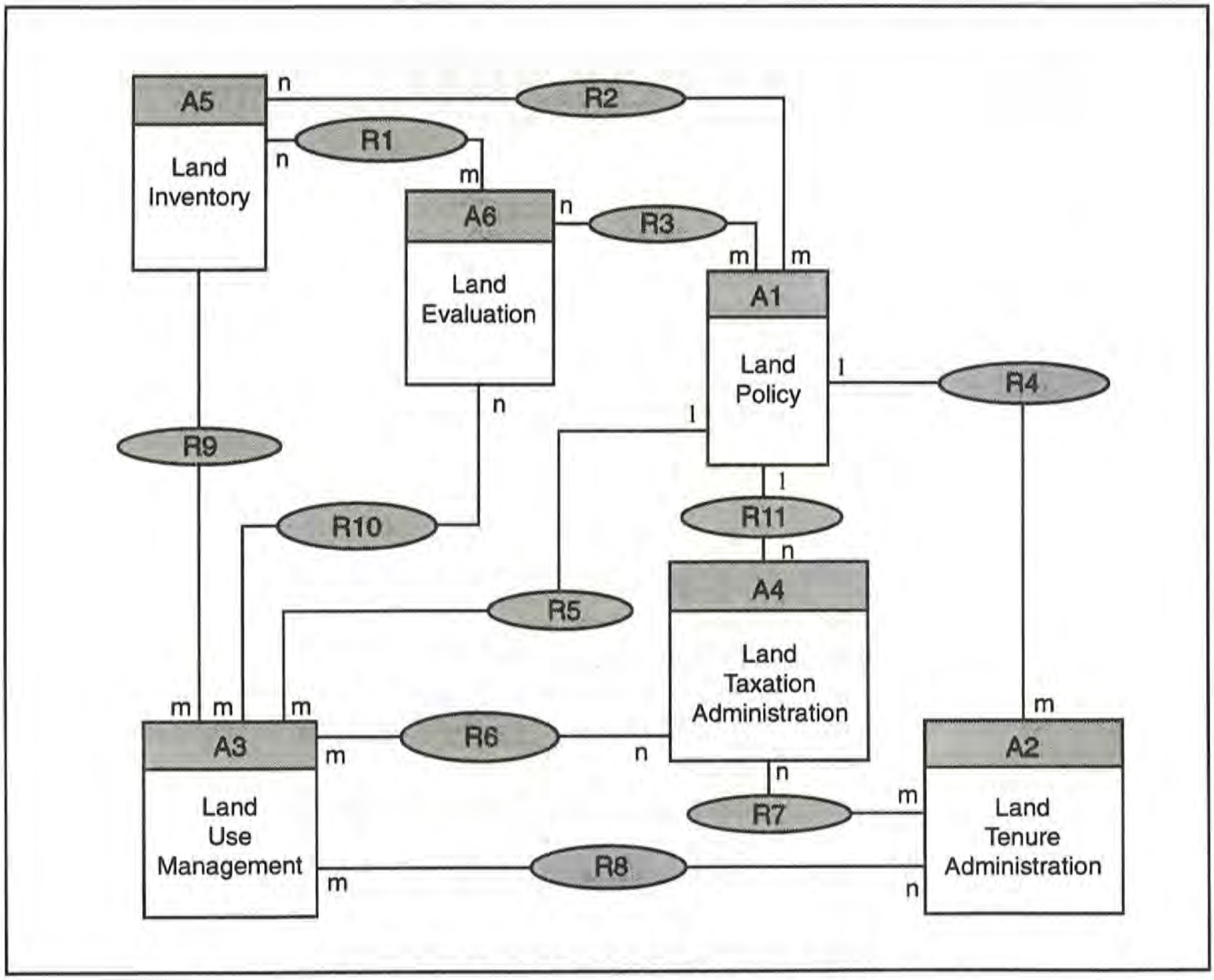

Figure 10: **ERD of an IDLAS: Corporate Level**

(LEva.). The matrix of the entity types and relationship types is shown in **Table 4**. The description of the relationship types is given in **Table 5**, while **Table 6** contains the list of sample attributes of the entity types. The attributes underlined are the primary keys of each entity type.

7.0 ENTITY-RELATIONSHIP MODEL FOR LAND USE MANAGEMENT: DOMAIN LEVEL

This subsystem would have the entity types and relationship types shown in **Tables 7** and **8**, respectively. Land registry, land policy, land inventory,

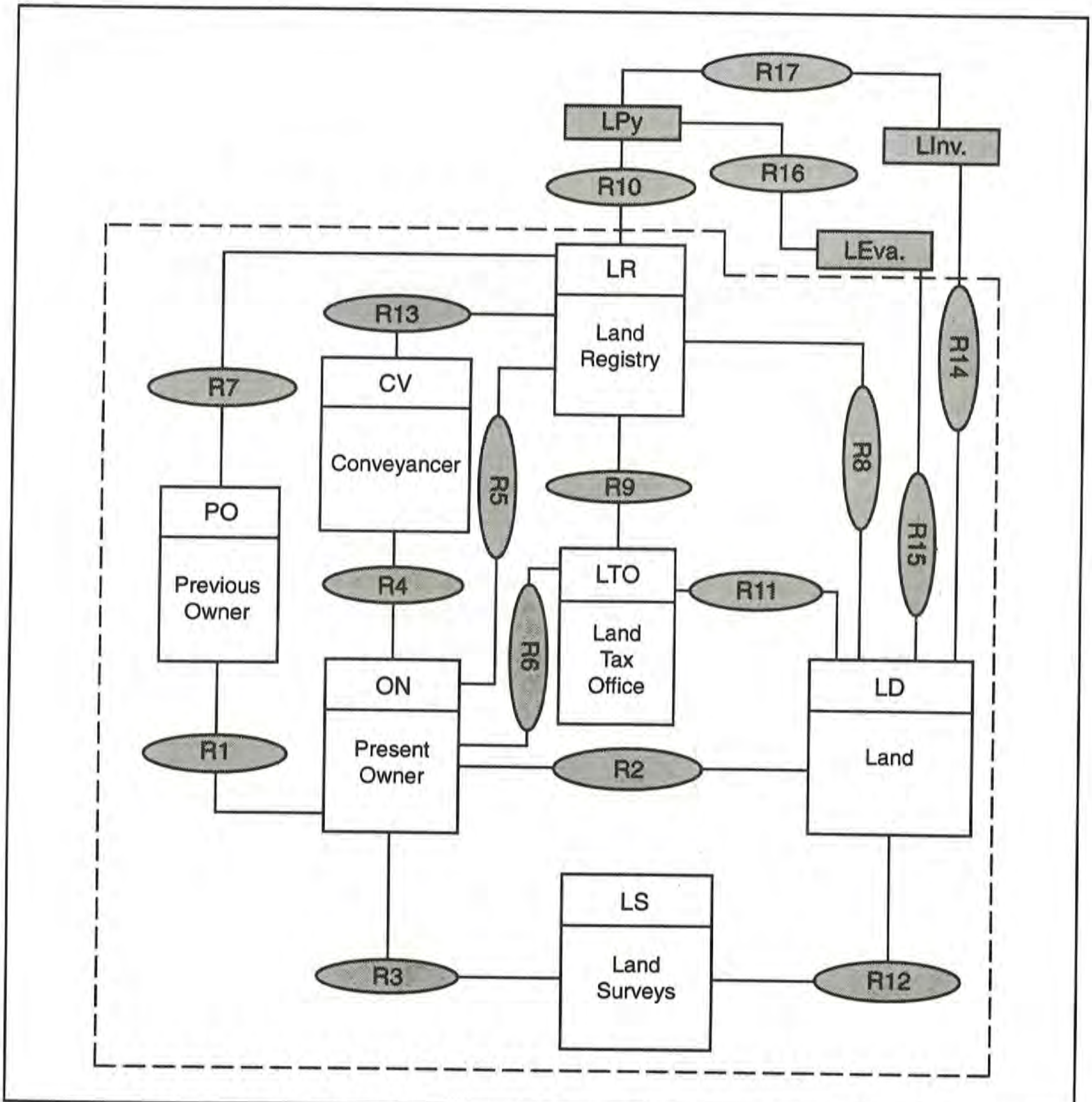

Figure 11: **ERD of Land Tenure Administration: Domain Level**

ENTITY TYPES	PO	ON	LR	LTO	LD	LS	CV	LPy	LInv.	LEva.
Previous Owner (PO)	-	R1	R7	-	-	-	-	-	-	-
Owner (ON)	-	-	R5	R6	R2	R3	R4	-	-	-
Land Registry (LR)	-	-	-	R9	R8	-	-	R10	-	-
Land Tax Office (LTO)	-	-	-	-	R11	-	-	-	-	-
Land (LD)	-	-	-	-	-	R12	R13	-	R14	R15
Land Surveyor (LS)	-	-	-	-	-	-	-	-	-	-
Conveyancer (CV)	-	-	-	-	-	-	-	-	-	-
Land Policy (LPy)	-	-	-	-	-	-	-	-	R14	R15
Land Inventory (LInv.)	-	-	-	-	-	-	-	-	-	-
Land Evaluation (LEva.)	-	-	-	-	-	-	--	-	-	-

Table 4: **Matrix of Relationships between the Entity Types: LTA**

ENTITY TYPES	ATTRIBUTES
Previous owner	Name, Address, Parcel ID, Dates
Owner	Name, Address, Parcel ID, Dates, Tenure type
Land registry	Parcel ID, Grantee/Grantor, Certificate #
Land tax office	Parcel ID, Assessment #, Value, Tax due
Land	Parcel ID, Location, Owner, Land Use, Area
Land surveys	Parcel ID, Plan #, Client Name, Date
Conveyance	Parcel ID, Deed Certificate #, Grantee, Grantor
Land policy	Admin. Bd., Land tenure rights
Land inventory	Admin. Bd., Rivers, Vegetation, Soils
Land evaluation	Admin. Bd., Wetlands, Floor plains, Erosion

Table 5: **Attributes of the Entity Types in Figure 11**

R1	Transfer tenure rights.	R2	Owns land parcel.
R3	Request survey plan.	R4	Request deed documents.
R5	Seek registration.	R6	Pay property tax.
R7	Transfer tenure rights.	R8	Maintain records.
R9	Share data.	R10	Provide guidelines.
R11	Maintain records.	R12	Conduct surveys.
R13	Conduct title search.	R14	Collect data.
R15	Maintain records.	R16	Provide data.
R17	Provide data.		

Table 6: **Definitions of Relationship Types in Figure 11**

and land evaluation are external but necessary entity types to the subsystem. The internal structure of the subsystem is shown by the dashed lines in **Figure 12**. This figure depicts the fully designed ERD of the subsystem. **Table 9** contains samples of the attributes of the entity types. The primary keys are the underlined attributes.

8.0 CONCLUSIONS

Entity-relationship model is a model of the information needs of land administration agencies. This information is fundamental to the development of new systems and the enhancement of existing ones. Since the model is independent of any data storage and access method, an objective decision can be made about its

ENTITY TYPES	LUO	LD	LDP	OA	LPy	LInv.	LEva.	LR
Land Use Office (LUO)	-	R3	R1	R4	R5	-	-	R10
Land (LD)	-	-	R2	-	-	R7	R6	-
Land Developer (LDP)	-	-	-	-	-	-	-	-
Other Agencies (OA)	-	-	-	-	-	-	-	-
Land Policy (LPy)	-	-	-	-	-	R9	R8	-
Land Inventory (LInv)	-	-	-	-	-	-	-	-
Land Evaluation (LEva)	-	-	-	-	-	-	-	-
Land Registry (LR)	-	-	-	-	-	-	-	-

Table 7: **Matrix of the Relationships between the Entity Types: LUM**

R1	Seek use approval.	R2	Develop land.
R3	Maintain records.	R4	Sought comments.
R5	Prescribe guidelines.	R6	Evaluation land use.
R7	Map land use.	R8	Report on land quality.
R9	Report on land quantity.	R10	Verify data.

Table 8: **Definitions of Relationship Types in Figure 12**

ENTITY TYPES	ATTRIBUTES
Land Use Office	Parcel ID, Location, Propose Use, Approved Use
Land	Parcel ID, Location, Owner, Land Use, Area
Land Developer	Parcel ID, Location, Propose Use
Infrastructure Control	Parcel ID, Location, Propose Use, Approval
Land Policy	Admin. Bd. Land Tenure, Rights, Land Use Rights
Land Inventory	Admin. Bd., Rivers, Vegetation, Soils
Land Evaluation	Admin. Bd., Wetlands, Floodplains, Erosion
Land Registry	Parcel ID, Grantee/Grantor, Certificate #, Owner

Table 9: **Attributes of the Entity Types in Figure 12**

implementation. The logical designs of an integrated data-driven land administration system and two of its components: land tenure administration and land use management have been undertaken using entity-relationship model as shown in **Figures 10, 11,** and **12**. These represent the corporate and domain levels of the design. These results can now be used in the physical model design for a given institutional and technological environment. The entity types, attributes, and relationships were also specified.

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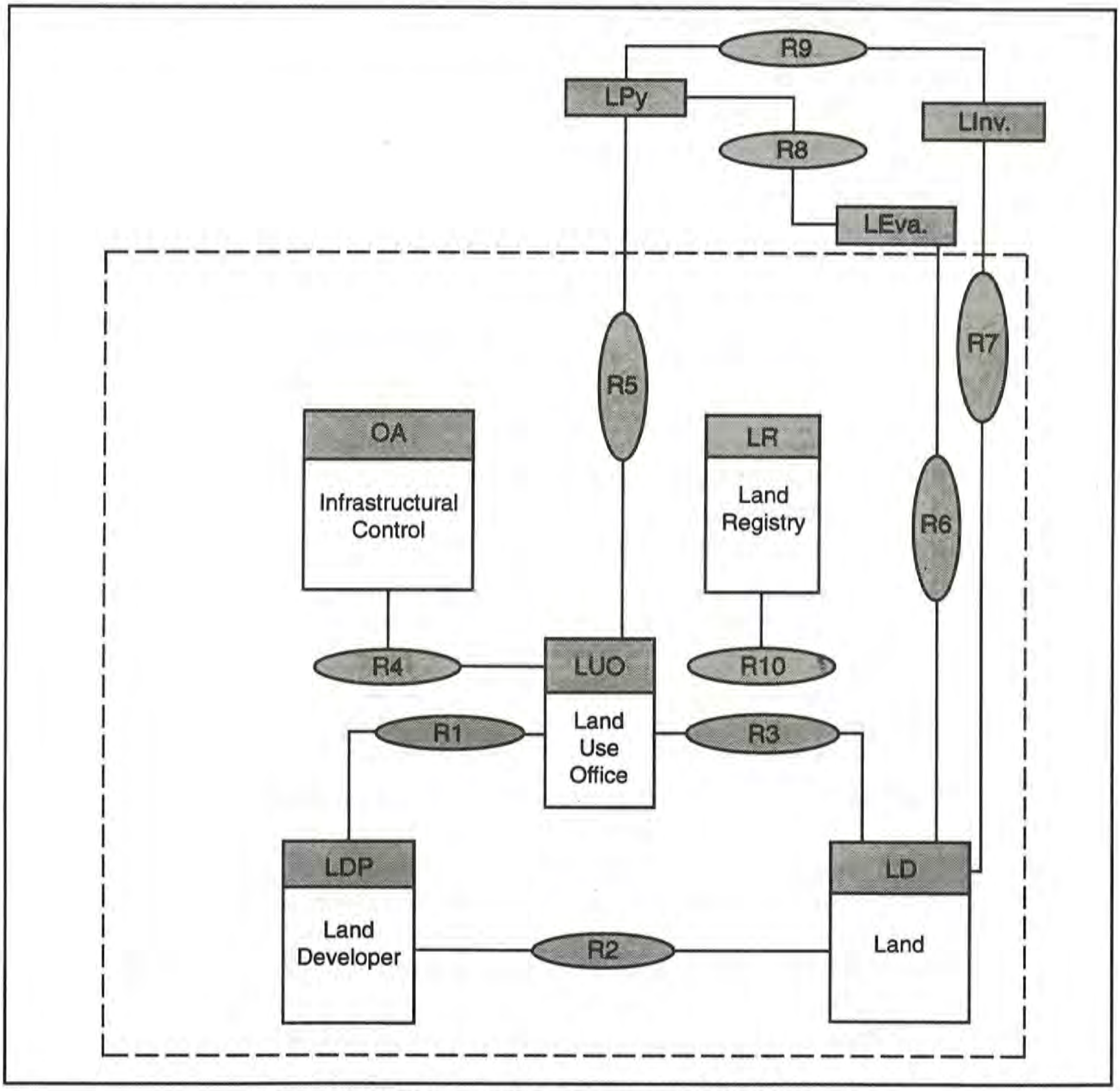

Figure 12: **ERD of Land Use Management: Domain Level.**

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